Back in control : the episodic retrieval of executive control

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Back In Control

The episodic retrieval of executive control

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CHAPTER 1: BACK IN CONTROL

Philosophers, theologians and psychologists have long wondered how, in a world full of temptation and distraction, humans are able to attain their various, often difficult, goals. Many religions place great importance on self-control: Christianity, for example, associates temptation with evil and Buddha supposedly reached enlightenment through self-restraint. Yet, although religion may help in promoting control in its followers (e.g. McCullough & Willoughby, 2008), it tells us little about the mechanics by which we are supposed to achieve this.

Early psychologists also sought to explain the mystery of the *will* in terms of two sides of the same coin: the intention-, or goal-related, head and the distraction, or automaticity-related tail. William James (1890) painted a vivid scenario in which the problem of intention truly becomes clear: "We know what it is to get out of bed on a freezing morning in a room without a fire, and how the very vital principle within us protests against the ordeal." Inspired by Lotze (1852), he hypothesized that we are able to do this due to a mechanism that associates outcomes to actions, and that the mere thinking about this outcome can then produce the action. Thus, thinking about all the things one can do outside of bed should prompt abandoning the warmth of the bed. As for the distraction, an early example may be found in Sigmund Freud (1923), who, noting that our subconscious is driven by erotic and violent urges, installed a more rational agent in his model of psychoanalysis, which could suppress the secret desires from fully coming to the fore.

Both ideas, and many of the proposed mechanisms, are surprisingly alive in modern thinking about how we exercise *control*. To empirically test James' ideomotor model, Elsner & Hommel (2001) designed a task in which, first, participants' free-choice actions produced audible consequences. In the second stage of this experiment, the 'action-effects' were used as the imperative stimuli. Thus, if action 1 would first produce effect A and action 2 would produce effect B,

they were now presented with effects A and B and asked to perform action 1 or 2. Proving that, apparently, bi-directional links had been established between the actions and their associated effects, participants took longer to produce actions that previously were not *followed* by the effect (such as performing action 2 after hearing effect A).

The other side, related to temptation and distraction, has never ceased its hold over the public, and psychological, imagination. In the wider psychological literature, the concept of temporal discounting refers to the ability to delay short term gratification in favour of reaching long-term goals (cf. Mischel, Shoda & Rodriguez, 1989). Recent research in that area suggests that there is a limited capacity for self-control and that after exercising it, a state of fatigue that Baumeister, Vohs & Tice (2007) term 'ego-depletion' sets in. Apparently, although we are able to restrain ourselves from acting upon temptations, there is an ironic limit to freedom: will-power.

Several effects in experimental psychology also illustrate how distraction affects behaviour. Research has shown that it is hard to name the colours in which words are printed if they do not match the word themselves (Stroop, 1935), to respond left to stimuli appearing right (Simon & Rudell, 1967) or to ignore the flankers of a central stimulus (Eriksen & Eriksen, 1974). Similar to ideas of temptation and distraction, such effects have often been taken to involve an *automatic* dimension to stimuli – automatic reading of words in the Stroop task, responding towards the source in the Simon effect, and processing the peripheral stimuli in the flanker task. And, similar to the urge-suppressing qualities of the ego, the eventual (after some 20 to 80 ms) success in *not* being tricked by this automatic route was implemented by means of an *inhibiting* agent, commonly referred to as *executive control*.

In this dissertation, I will attempt to re-integrate the study of volition with new insights in executive control by describing several studies that are related to

both, as well as to their interaction. The key to this will be the concept of *episodic retrieval*, the mechanism by which earlier memories, or *episodic traces*, can be brought back by being reminded of them, and that may help or hinder present processing. Our bed-stricken William James, for example, was reminded of his many tasks of the day, and only then came to action. It may be that he brought back such ideas by pure volition, but more in line with present thinking on this subject that take a more mechanistic stance towards the will (c.f. Libet, Gleason, Wright & Pearl, 1983; Haggard, 2008), merely looking at the window next to his bed may have *reminded him*; the idea that a world is out there, in essence, retrieved.

Chapter 2 introduces the experimental paradigm of which several variations are used throughout this dissertation. An arrow pointing left or right cues an initial left or right response (R) to two words that follow immediately after, and that, together, comprise the first stimulus (S1). After a blank inter-stimulus interval (ISI), again two words appear (S2), one of which is underlined. Now, the participant is to respond with a left key-press if the *underlined* word describes an animated object or life-form, and else respond right (though vice versa in half the subjects).

According to the Theory of Event Coding (Hommel, Müsseler, Aschersleben & Prinz, 2001), the co-occurrence of S1 with a response should result in a mental representation that effectively integrates the stimuli and response. The episodic traces thus *bind* the number of visual and motor components of this event into one coherent whole, which is retrieved if parts of it are encountered again. As a result, if the subsequent event is exactly the same (i.e. if the two words of S2 are the same as the two words of S1 *and* the required response of S2 is the same as the cued response of S1), the retrieved event may help responding correctly to S2. If, on the other hand, the second stimulus is only *partly* the same, for example, if the words

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of S2 were the same as S1, but the required response would be different, the retrieved event should hinder the new response (Hommel, 1998).

In Chapter 3, this framework of feature-integration and retrieval is expanded to include adaptive processes. Suppose, for example, we see a cup of coffee. This would normally involve integrating its features; it is warm, located about thirty centimetres from my hand, has a cylinder shape and white outer colour with black substance inside, and would maybe come with a strong grasp affordance. Consider, however, if we would see a similar cup at a different location. How does the brain bind the features of cup A without confusing it with cup B? Or, is it actually the same cup, but *moved* to the new location?

A series of three experiments show that bindings are not only retrieved, but can also be adapted. As in Chapter 2, participants were cued to respond to an initial display (S1), this time comprising a circle or star in one of two boxes on a screen. After a short ISI, another circle or star was shown in one of the two boxes, but now (during S2), a key-press response was to be made on the basis of the shape. As location-repetition, shape-repetition and response-repetition was fully randomised, the three bindings, and the cost of repeating one, but not the other, could be studied separately (as in Hommel, 1998). Of crucial importance to our purposes, however, during the ISI, the boxes – in which the shape had previously been presented – gradually rotated around their axis. According to Kahneman, Treisman & Gibbs (1992), this should effectively result in representations that has the shapes localised in the box (e.g. if the shape first appeared up, then rotated 180°, it would be represented down). Going beyond that prediction, we showed that not only the location-shape binding is updated, but also the location-response binding, whereas the only feature-pair that does not include location (shape-response bindings) remains untouched. Also, we found evidence that although the episodic traces are adapted due to the gradual shifts in location, the event-files continue to have information regarding their history.

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In Chapter 4, the issues of conflict and control are again picked up. As stated before, akin to the Freudian idea of the ego suppressing unwanted actions, experimental psychological models of executive control typically argue for the existence of inhibiting processes that resolve conflict. Data from sequential conflict studies are often taken to support such views. Gratton, Coles & Donchin (1992), for instance, observed that after an initial conflict effect (e.g. responding right to <<><<), participants are better in resolving further conflict (<<><<). Likewise, Stürmer, Leuthold, Soetens, Schröter & Sommer (2002) found better performance with incompatible Simon-tasks (responding left to a stimulus right) if they followed incompatible stimulus-response conditions than if they followed compatible trials. This effect, that is usually called conflict-adaptation or the 'Gratton-effect', can be seen as evidence for the conflict-monitoring model (Botvinick, Nystrom, Fissell, Carter & Cohen, 1999). The anterior-cingulate cortex (ACC) continuously monitors for the occurrence of stimulus-response conflict and, when found, adjusts attention either by inhibiting the location-to-response route (Stürmer et al., 2002) or by changing decision-making strategies in order to avoid the re-occurrence of conflict (Botvinick, 2007). Thus, in marked contrast to the ego-depletion mentioned before, after experiencing distraction once, it becomes easier to resist it the second time.

Despite the elegance of this model, testing it with sequential conflict paradigms has some caveats. Mayr, Awh & Laurey (2003), for instance, noted that it is well-known (e.g. Bertelson, 1963; Meyer & Schvaneveldt, 1971) that repeating stimuli or responses typically lead to enhanced performance, and that, therefore, response-priming could account for the performance benefits of some conflict-conflict sequences (such as when a '>><>>'-trial is followed by a '>><>>'-trial) without referring to any higher-order mechanisms. Even if no feature is repeated, Hommel, Proctor & Vu (2004) illustrated by means of a sequential Simon effect study that the Gratton-effect is entirely confounded with feature-integration effects. That is, as also shown in this dissertation's Chapter 2 and 3, completely

alternating events (such as '>><>>' → '<<><<') are expected to have faster reaction times, not due to their conflict being repeated, but due to their bindings not overlapping. In Chapter 5, the hypothesis that sequential effects basically boils down to overlapping features rather than repeating conflict is referred to as our *radical position*.

As a consequence, various studies sought to disentangle response-priming, feature-integration and conflict-adaptation using complex designs or clever statistical techniques. Kerns et al. (2004), for example, kept feature-repetitions constant, while Wühr & Ansorge (2005) used four-alternatives Simon effects and included repetitions as independent factors in their design, whereas Notebaert & Verguts (2007) used multiple regression to find the source of sequential effects. Although such approaches are not without problems (see introduction to Chapter 5), the evidence they brought forth suggests both conflict-monitoring and feature-integration account for part of the variance in sequential conflict studies.

Another possibility that is largely unexplored, however, may be that the two accounts are not so mutually exclusive or even independent as portrayed. Studies showing the boundaries of conflict-adaptation indicated this possibility initially. Conflict adaptation seems to be absent, for example, if no similarities exist between the current and previous task (Notebaert & Verguts, 2008; Akçay & Hazeltine, 2008). As task-parameters may be bound in event files (Waszak, Hommel & Allport, 2003), an interesting third option may exist: control-related parameters might be integrated as parts of event-files, retrieved if a current event shares features with a previous one. In Chapter 5, this hypothesis is tentatively named the *less radical position*.

Chapter 4 tested this hypothesis using a sequential Stroop effect. In a task in which participants were to respond "high" and "low" to high and low tones respectively, voices saying "low" or "high" were used as distracters. Importantly, the voice sometimes switched between two trials. If this was the case, for example if a participant first responded "high" to a high tone with a female voice saying "high", and then "low" to a low tone with a *male* voice saying "high", no conflict-adaptation occurred. It thus appeared that due to the change in voice – an entirely irrelevant change of features – the retrieval of the previous event was disrupted, and therefore also its control.

In Chapter 5, this investigation, but using a sequential Simon paradigm, is continued. With the adaptive feature-integration information obtained from Chapter 3, similar conclusions as in Chapter 4 were predicted. In one scenario, for example, participants were first to respond left to a stimulus left, then left to a stimulus right (i.e. a compatible-incompatible scenario, typically leading to the slowest reaction times). In another, *exactly the same* compatibility and feature-repetition conditions were used, except that during the ISI, the box in which the stimulus initially appeared rotated from left to right. Closely replicating the findings of Chapter 3, this greatly reduced partial repetition costs, but, more importantly, it likewise reduced conflict-adaptation effects to near-zero (similar to the findings of Chapter 4). It was thus suggested that the transition from trial to trial changed episodic retrieval, and because of this, also conflict-adaptation.

Finally, in Chapter 6, a similar sequential Simon experiment is conducted in an EEG setting to investigate the influence of the rotation on psychophysiological markers of conflict. As Stürmer et al. (2002) found, conflicting location information may activate the response in the erroneous hemisphere (i.e. the one ipsilateral to the correct hand), as shown in the lateralised readiness potential (LRP). This erroneous activation is greater if the preceding trial was non-conflicting (see also Gratton, Coles & Donchin, 1992). It was hypothesised that the rotation

manipulation of Chapter 5 should modulate this interaction, as well as an evoked response potential commonly referred to as the N2. Supporting our claim of episodic retrieval induced conflict-adaptation, rather than proactive interference, all effects showed up as a result of S2 presentation, rather than during S1's rotation.

In light of the evidence presented in this dissertation, it seems quite possible that William James got out of bed, exercising control, because he was reminded of his duties. Rather than seeing 'conflict' as somehow an intrinsic part of a stimulus in a psychological laboratory, we should also remember how much of conflict and control are only there because of retrieval processes. Conflict, in a Stroop task, depends on the instruction – which presumably by reading triggers the correct stimulus-response associations. For example, the word green in black ink only becomes conflicting because we have learnt to read very fast, rather than naming colours of everything we see. One may even say that, in essence, we are *primed* to read words and, in models on language we retrieve their (lexical, semantic, phonetic) features from memory as a result. Similarly, in a Simon task, the stimuli can be conflicting only because our goal is to respond left and right (Hommel, 1993), not merely because they happen to be left and right. Therefore, priming or episodic retrieval should not be seen as the common, "low" mechanism that is independent from conflict, but as having a pivotal role as to *why* we need executive control in the first place, and *how* we use it to get to where we want.

CHAPTER 2: THE CONTROL OF EVENT-FILE RETRIEVAL

Single co-occurrences of stimulus events and actions are integrated and encoded into episodic "event files". If later presented with one or more of the constituent features of such a file, the other previously bound features are retrieved, which creates conflict if these do not match the current episode (partial-repetition costs). Partial-repetition costs depend on the task relevance of the repeated features: task-relevant features create higher costs, suggesting that the handling of event files is under contextual control. To disentangle whether control affects the creation or the retrieval of event files, we employed a task that prevented the control of creating stimulus-response bindings. Participants were precued to carry out a manual response to the onset of two irrelevant words, before categorizing one of two words (the target) by means of a manual binary choice response while ignoring the other word (the foil). Repeating the target word interacted with response repetition, showing the standard partial-repetition cost, while repeating the foil had no effect. This does not necessarily rule out that event-file creation is under contextual control, but it demonstrates that event-file retrieval is.

Introduction

Just like that of other primates, the human brain is highly modular and processes the different features of an event, and of the action it possibly requires, in various cortical areas. Though this division of labour lends many useful qualities to the brain, it also raises the question how all the processes devoted to coding a given event are coordinated. Impressed by the considerable number of visual areas, researchers assume that visual features belonging to a given event are somehow bound into what Kahneman, Treisman, and Gibbs (1992) have called an object file. Research on feature integration has indeed provided evidence that the features of an object are spontaneously bound, so that repeating one of these features is particularly beneficial for performance if the other features also repeated (for an overview, see Hommel, 2004).

Modularity and parallel processing is not restricted to the visual system, suggesting that binding processes cross borders between sensory modalities and perception and action. Indeed, if participants carry out two actions in a row (R1 and R2) in response to two stimuli (S1 and S2), stimulus repetition effects and response repetition effects interact: performance is better if either both stimulus and response are repeated or if they both change than if the stimulus is repeated and the response alternates or vice versa (Hommel, 1998). In other words, there are *partial-repetition costs* (as compared to complete repetitions or alternations), suggesting that a single co-occurrence of a stimulus and a response is sufficient to integrate the two into a kind of event file (Hommel, 1998, 2004). This file is retrieved automatically if it matches at least one feature of the present stimulus or response, which creates conflict if this entails the retrieval of a stimulus or response feature code that is actually not present or necessary. For instance, having carried out a left-hand response to the letter X leaves behind a trace connecting that letter with that response; processing the same letter and/or the

same response a second later retrieves this trace, which creates conflict if either another response is required more the present letter is different from X.

Further research has revealed that stimulus-response binding is not comprehensive, in the sense that a whole object is bound to an action, but feature based. For instance, if people attend to shape information, they show strong evidence of shape-response binding but not of color-response binding; if they attend to color information, this pattern reverses to show strong color-response binding (e.g., Hommel, 1998). This means that feature binding is spontaneous, in the sense that it takes place even in tasks that do not require the integration of features, but controlled through the current attentional set to particular feature dimensions. The main question of the present study was which aspect of the handling of event files is being controlled. On the one hand, it may be that the creation of bindings is under attentional control. Features from dimensions that are task relevant may be primed or selected for integration, and thus be more likely to enter the object or event files being created. On the other hand, it may be that the retrieval of bindings is under attentional control. The creation of bindings may (or may not) be entirely nonselective, but bindings that include task-relevance features may be more likely to be retrieved when a stimulus and/or a response related to the given binding is encountered (cf., Logan, Taylor & Etherton, 1996). The standard paradigms to investigate repetition effects and their interactions are not suitable for distinguishing between these two possibilities: A binding effect can only be present if a given binding was both created and retrieved, and its absence does not tell us anything about which of the two preconditions failed to operate.

The present study was designed to overcome this limitation and to modify the standard paradigms accordingly (see Fig. 1). S1, the prime display, consisted of two words, both being nominally irrelevant to the task but taken from the same pool as the relevant words presented on S2. As in the standard paradigm (e.g., Hommel, 1998), participants were cued to prepare a left or right keypressing

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response (R1) that was to be carried out as soon as S1 was presented. That is, the content of S1 was entirely uninformative but its presence had to be noticed to trigger the prepared R1. A second later, S2 appeared, again two different words. One word was underlined, indicating that this word was to be categorized as referring to an animate or a non-animate object (requiring a left vs. right keypressing response). This set up required the selection of a target word from the S2 display, which appeared at a position that was not known when S1 was presented. Accordingly, control processes could affect S2 processing but not S1 processing. The main question was whether the repetition of the (later) target (the word that was underlined and to be responded to upon S2 presentation) would interact with response repetition to show the standard partial-repetition costs (i.e., worse performance if the target is repeated but the response alternates, or vice versa), and whether this pattern would also be obtained for the (later) nontarget or foil (i.e., for the word that was not underlined and to be ignored).

If it would be the retrieval of event files that is controlled, one would expect partial-repetition costs for the target word but not (or significantly less) for the foil. In contrast, if it would be the creation of event files that is controlled, one would expect equivalent partial-repetition costs for the target word and the foil. As neither the location nor the identity of the later target could be known upon S1 presentation, any S1 word should be equally bound to the respective R1. If retrieval would be purely automatic (i.e., unaffected by task relevance), word-response bindings should be retrieved irrespective of whether the target or the foil word is repeated. Hence, both target repetition and foil repetition should interact with response repetition. If, however, retrieval is controlled by task relevance, only the word-response binding matching the current target word would be retrieved. Hence, target repetition should matter while foil repetition should not.

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Method

Participants

Thirty students from Leiden University voluntarily participated in this experiment for a small fee or course credits. Data from one participant did not enter analysis due to an error rate of more than 50%.

Apparatus and stimuli

Stimuli were presented on a 17" monitor in 800 x 600 pixels resolution and a refresh-rate of 100 Hz. A Pentium-III 450 MHz PC running E-Prime (1.1, SP3) on Windows 98 SE controlled stimulus-presentation and recorded reactions. The 120 words of animate and 120 words of inanimate referents consisted of 3-10 18-point-sized characters and varied in width accordingly. For presentation of S1 and S2 two horizontally centered words appeared, one 23 mm above the vertical screen center and the other 23 mm below the center. Letters were presented in black, bold-printed, "New Courier" font on a grey (RGB values 192, 192, 192) background.
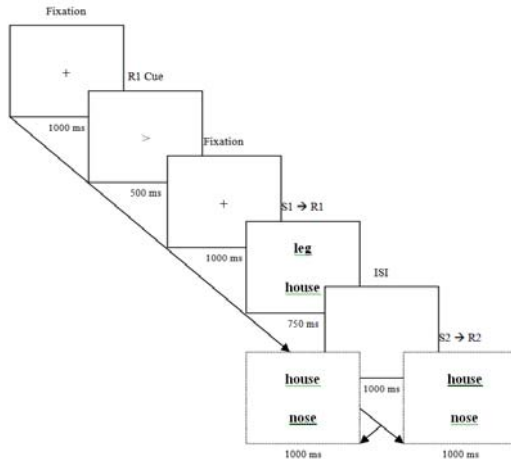
Procedure

Figure 1: Sequence of events in a single trial. From top-left to bottom-left: foil repeated, target alternated; from top-left to bottom-right: foil alternated, target repeated.

As outlined in Fig. 2, a fixation cross was presented for 1000 ms, followed by a small arrow (the R1 cue). The arrow stayed for 750 ms and was replaced by the fixation cross for another 1000 ms, so that participants had ample time to prepare the cued R1. This response was to be executed on display of S1, two uninformative words. One word was animate and the other non-animate, with the locations (top or bottom) varying randomly. Participants were not required to attend the words or respond to them in any other way than pressing the pre-cued key: <Q> for the left −, <P> for the right-pointing arrow. After 750 ms, a blank screen was displayed for 1000 ms, creating a stimulus-onset asynchrony of 1750 ms. Then S2 was shown for 1000 ms, consisting of one word from the animate list and one from the inanimate list, one of them underlined. Half of the participants were to press <Q> if the underlined word was animate or <P> if it was not, and the other half had the opposite response mapping.

After each S1-S2 pair of trials, a 1500-ms blank inter-trial-interval (ITI) ensued if R1 and R2 were both correct, otherwise the ITI lasted 4500 ms, the extra

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3000 ms showing a warning message. The ITI was also used every eighth trial to give participants feedback regarding their average number of correct responses and average reaction time. The experimented lasted about 30 minutes.

Design

The experiment used a three-factor (response-repetition x target-repetition x foil-repetition) repeated measures design: The response to S2 was either repeating or not repeating the response to S1; the underlined word of S2 (i.e., the target) was either repeating or not repeating one of the two words making up S1; and the not-underlined word (i.e., the foil) was either repeating or not repeating one of the words making up S1 (see fig. 2). Each of the eight combinations of these factors was presented 40 times, and the word locations of animate and non-animate words, the location of the target words, and the two responses were distributed evenly across design cells.

Results

From the 29 participants, correct R2 responses from trials with both responses being correct were analyzed Few errors were made overall (M = 11.8%, SD = 8.6%), although their pattern was largely consistent with the pattern of reaction times.

In a repeated measures analysis of variance with target-repetition, foil-repetition, and response-repetition as factors, responses were found to be significantly faster if the target word was repeated, $F(1, 28) = 94.45$, MSe = 1088.72, $p < .001$, and if the foil word was repeated, $F(1, 28) = 31.76$, MSe = 449.73, $p < .001$. Responses were slower if the response was repeated, $F(1, 28) = 21.55$, MSe = 326.03, $p < .001$—indicating an alternation bias. More important for present purposes, response repetition interacted significantly with target-repetition, $F(1, 28) = 6.34$, MSe = 316.24, $p < .02$: as Figure 3 shows, the target-repetition benefit was more pronounced with response repetition than alternation. Interestingly, no

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such interaction was obtained between foil repetition and response repetition, $F(1, 28) = .04$, MSe = 353.59, $p > .8$.

Error-data showed no significant effect of target-repetition, $F(1, 28) = 1.77$, MSe = 83.58, $p > .19$ or foil-repetition, $F(1, 28) = 2.30$, MSe = 66.54, $p > .14$. Responses were less accurate when the response was repeated, $F(1, 28) = 15.53$, MSe = 1071.27, $p < .001$. Repeating the response showed a trend towards a significant interaction with repeating the target, $F(1, 28) = 2.95$, MSe = 97.96, $p < .1$, but not with repeating the foil, $F(1, 28) = 1.72$, MSe = 38.29, $p > .1$.

To allow for direct comparisons of the interactions between target and response repetition on the one hand and foil and response repetition on the other, we computed the two corresponding interaction terms, which can be taken to represent feature-overlap-costs (see Hommel, 1998). Target-related reaction time and error overlap costs (OC_{target}) were calculated as follows: OC_{target} = (target repeated | response alternated + target alternated | response repeated)/2 − (target repeated | response repeated + target alternated | response alternated)/2. Correspondingly, foil-related overlap costs (OC_{foil}) were calculated: OC_{foil} = (foil repeated | response alternated + foil alternated | response repeated)/2 − (foil repeated | response repeated + foil alternated | response alternated)/2. As predicted by the retrieval-control account, OC_{target} was significantly larger than OC_{foil}; both in reaction time, $t(28) = 1.78$, $p < .05$, and error rates, $t(28) = 1.84$, $p < .04$.

Table 1. *Effects of repeating target, foil and response on mean and SE (italicized) of RTs, demonstrating calculus of overlap-costs.*

Target			
Response	Alternated	Repeated	Priming effect
Alternated	677 (*13*)	641 (*13*)	36
Repeated	694 (*14*)	646 (*15*)	48
		Partial-repetition cost:	12
Foil			
Response	Alternated	Repeated	Priming effect
Alternated	667 (*14*)	652 (*14*)	15
Repeated	678 (*13*)	662 (*15*)	16
		Partial-repetition cost:	1

Discussion

Our findings provide direct evidence for the contextual control of event file retrieval. The way our experiment was set up did not allow for selective integration of one of the two words presented as S1—and yet, partial-repetition costs were only obtained for words that were marked as targets in S2. Apparently, then, focusing on the target word selectively retrieved the matching word-response binding created for the previous S1-R1 episode (in trials where the word was repeated), whereas bindings matching the unmarked word were not retrieved. This does not exclude the possibility that the creation of event files can be affected by the task context if the experimental set up allows for it, but given that the present design prevented such an impact our observations must reflect retrieval control. Another implication of our findings is that the two words forming S1 were apparently bound to the corresponding R1 independently from each other— otherwise repeating the target would have been sufficient to also retrieve the foil. This supports the idea that event files do not bind actions to un-interpreted visual snapshots but, rather, to feature-based descriptions of the respective visual event.

CHAPTER 3: ACTIONS TRAVEL WITH THEIR OBJECTS: EVIDENCE FOR DYNAMIC EVENT FILES

Moving a visual object is known to lead to an update of its cognitive representation. Given that object representations have also been shown to include codes describing the actions they were accompanied by, we investigated whether these action codes "move" along with their object. We replicated earlier findings that repeating stimulus and action features enhances performance if other features are repeated, but attenuates performance if they alternate. However, moving the objects in which the stimuli appeared in between two stimulus presentations had a strong impact on the feature bindings that involved location. Taken together, our findings provide evidence that changing the location of an object leaves two memory traces, one referring to its original location (an episodic record) and another referring to the new location (a working-memory trace).

Introduction

Due to the modular, distributed organization of the primate brain, human perception relies on the integration of features coded in various cortical areas of the brain (cf. Treisman, 1996). Consider, for example, the neural correlate of perceiving a red cup placed on a green saucer. The two objects activate several brain regions, including those associated with processing locations and colours – red and green, top and bottom – creating a confusing situation where the features are easily mixed up into green cups and red saucers. To solve problems of that sort, integration processes have been postulated that bind features of the same object into episodic traces or object files (Kahneman, Treisman & Gibbs, 1992).

Evidence for object files has been provided by studies looking into the after-effects of feature binding. Kahneman et al. (1992), for example, showed that a visual target letter can be identified faster if it appears as part of the same object in a task-irrelevant preview display. That is, if the preview display consisted of a number of letters appearing inside of boxes, repeating one of those letters yielded particularly good performance if it also appeared in the same box. This was the case even if all the boxes moved between the presentation of the preview letters and the eventual target, suggesting that the letters remained represented as part of the boxes and thus, in a sense, moved with them. Kahneman et al. suggested that letters and boxes were bound into common object files, which were updated when the boxes moved and retrieved as a unit when a letter reappeared.

The assumption that moving an object leads to the updating of its cognitive representation is consistent with the outcome of multiple-object tracking (MOT) studies. Pylyshyn and Storm (1988) showed that even if objects move rapidly and randomly, their constituent features, such as their identities as being either targets or distracters, remain bound to them. This triggered a debate as to whether attention is primarily object- (Yantis, 1992) or space-based (Pylyshyn, 1989). As it appeared that these two positions are not mutually exclusive – since space may not

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be the *only* pointer towards different objects that are tracked in parallel, but is most certainly particularly important for object based attention (Blaser, Pylyshyn & Holcombe, 2000) – later studies refocused research interests onto what exactly constitutes an object and how objects are selected and kept within attention or working memory (Mitroff & Alvarez, in press; Pylyshyn & Annan, 2006; Scholl, Pylyshyn & Feldman, 2001).

At present, it is not clear how – or even whether – the ability to track multiple objects across time and space relies on the maintenance of object-files. Pylyshyn and Storm (1988) argued that MOT is enabled by means of an early system that attaches indices to visual features in a display. Analogous to "sticky fingers", these indices ("fingers of instantiation", or FINSTs) remain bound to the objects in a MOT task, limited by their number (around four or five, according to Pylyshyn and Storm) and visual task demands such as the velocity of the objects. Kahneman et al. in turn suggested that these indices might be closely related to object files, hypothesising that they may even be the initial phase of object files. Further research, however, brought evidence that although object files are related to (cf. Oksama & Hyönä, 2004; Carey & Xu, 2001), they can be experimentally differentiated from (Horowitz et al., 2007), FINSTs.

Object files have been claimed to contain perceptual information about an object but may also include memory-derived knowledge about the object's identity and meaning (Kahneman et al., 1992; Horowitz et al., 2007). Indeed, increasing evidence suggests that object representations comprise pragmatic information about action affordances (Barsalou, 1999; Gibson, 1979; Hommel, Müsseler, Aschersleben & Prinz, 2001). Along these lines, Hommel (1998) provided evidence that action features are integrated and kept bound within object representations, resulting in what may be more appropriately labelled "event files". To demonstrate the existence of stimulus-response bindings, he cued participants to respond with a left or right button-press (R1) to the mere onset of a visual stimulus (S1) presented

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above or below a central fixation. Shortly after that, another stimulus (S2) was presented to signal a binary choice response (R2) to its shape or colour. When one perceptual feature (such as the shape) was repeated between the two displays (S1 and S2), but another (such as the location) was not, participants responded slower than when both perceptual features were either repeated or alternated—thus replicating the observation of Kahneman et al. (1992). However, the same pattern emerged *across* perception and action: when a shape was first reacted to with one button-press, performance benefits only ensued if participants responded to the same shape in the same way or to a different shape in a different way. In other words, repeating a stimulus feature and alternating the response, or vice versa, created partial-repetition costs. Apparently, experiencing the co-occurrence of a stimulus and a response created an event file that was retrieved upon S2/R2 processing if at least one ingredient was repeated—thus inducing conflict between stimulus or response features if other ingredients did not match with the present features.

In the present study, we asked whether object files as investigated in object-tracking studies are comparable to event files as investigated along the lines of Hommel (1998; for an overview see Hommel, 2004). The Theory of Event Coding (TEC; Hommel et al., 2001) suggests that they are. Even though the resulting representation may well be complex, highly structured, and multilayered, this account claims that perceptual and action-related information is integrated into a network that acts like a functional unit. Hence, if perceptual features travel with the object they are a part of, actions should do so as well. We tested this prediction by combining the original previewing design (S1→S2/R2) introduced by Kahneman et al. (1992) with Hommel's (1998) S1/R1→S2/R2 extension.

Experiment 1

In Experiment 1, participants were pre-cued to carry out a particular key press (R1) in response to the onset of a visual stimulus (S1), assuming that this would create a binding between the corresponding stimulus features in the response (see figure 1). Then, the second target stimulus (S2) appeared to signal a binary choice response (R2) to its shape. The location of the two stimuli varied randomly and could thus repeat or alternate. The crucial manipulation was that each target stimulus appeared in one of two boxes, which did or did not rotate by 180 degree in between S1 and S2 presentation. If stimulus features and/or responses would travel with their object, rotation should have a distinct effect: If S2 appears in the same physical location as S1, this should amount to a repetition of stimulus location with a static display but to an alternation with a rotating display. This might affect two types of interactions. First, the interaction between the repetitions versus alternations of the two varying stimulus features, shape and location. According to the object-file literature and object-tracking studies, the shape of S1 should be integrated with the box in which it appears and thus move with it. If so, rotation of the boxes should render alternations of the physical locations of the stimuli (S1 top $\rightarrow$ S2 bottom, or vice versa) location repetitions, so that performance should be better if shape repetitions come with changes of physical location and shape alternations with repetitions of physical location. The crucial question was whether a comparable effect would be obtained for interactions between location repetition and response repetition. If the response information would travel with the moving box, rotation should result in better performance is if response repetitions are combined with changes of physical location and response alternations with repetitions of physical location. In other words, we predicted that partial-repetition costs for stimulus-location and stimulus-shape combinations and for stimulus-location and response combinations would reverse in sign in the box-rotation condition.

Method

Eight male and five female students from Leiden University voluntarily participated. Stimuli were presented on a 14.1" TFT monitor in 800 x 600 pixels resolution and a refresh-rate of 60 Hz. A Dell dual-core 1.66 GHz laptop PC running E-Prime 1.2 on Windows XP SP2 was used to control stimulus-presentation and record reactions. Cues, targets and boxes were presented in black against a silver (RGB 192, 192, 192) background. Cues consisted of three greater-than or lesser-than signs, and were centrally presented. Targets were presented in one of two black-lined, gray-filled (RGB 128, 128, 128) boxes of 60 x 60 pixels, presented 60 pixels above or below the centre of the screen. Rotation consisted of 45 frames, with each of these rotating 4 degrees and lasting for approximately 27 ms. Targets were either black (RGB 0, 0, 0) circles or four-pointed stars.
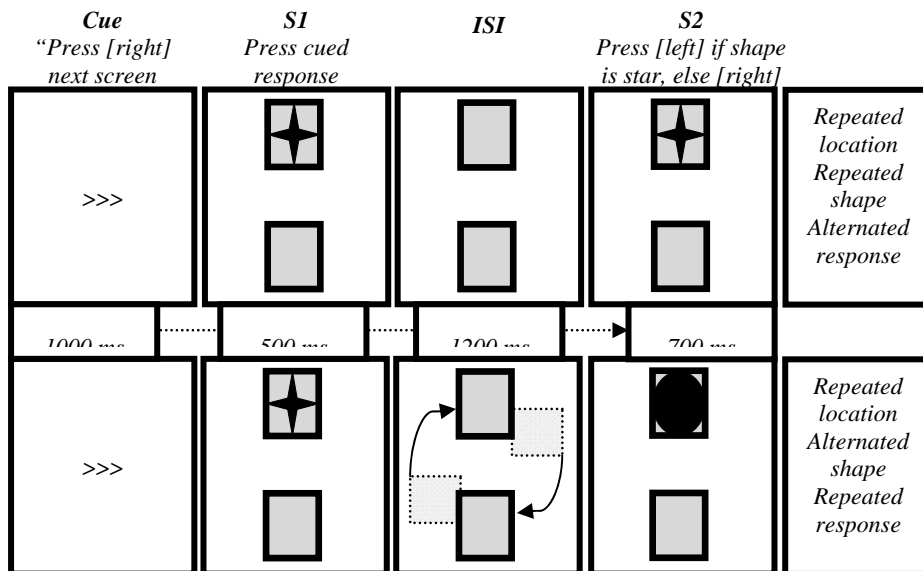

Figure 1. Sequence of events of two trials in experiment 1.

As outlined in Fig. 1, a response-cue (<<< or >>>) was presented for 1000 ms, during which the participant was asked to prepare the cued response and to press the corresponding key ('Q' for <<<, 'P' for >>>) upon the onset of the next screen. This next screen (S1) showed two vertically placed boxes, one of them containing a circle or star. Participants were asked and trained to ignore the shape and to merely respond according to the previously shown cue. Following this, the shape inside one of the boxes disappeared and the boxes either rotated (in the rotation condition), or remained still (the static condition) for another 1200 ms. Then, during S2, a target was presented for 700 ms in one of the boxes, and now participants were required to respond (R2) within this time interval to the shape with either a left ('Q') or a right ('P') key-press (Q, for circles, P for stars, for example), with the stimulus-response mapping being counter-balanced across participants. This was followed by an inter-trial interval of 1100 ms with feedback in terms of a score that reflected both accuracy (1 point was given for each correct reaction) and speed (2 point were given for each accurate and fast reaction). This system of feedback was explained during training, which consisted of the first twenty trials of the experiment. The experiment took approximately half an hour.

The experiment used a four-factor repeated measures design with the factors stimulus-shape, stimulus-location, and response repetition versus alternations, and rotation (static versus rotated boxes). Each of the 16 combinations of these factors was presented 24 times, and the direction of the rotation (clock- or counter-clockwise) was balanced across design cells.

Results

S2 reaction times were analyzed only if both reactions were correct and fast (< 700 ms). Overall, few errors were made for S1 (M = 3.8%, SD = 4.2%) compared to S2 (M = 15.7%, SD = 9.6%). In a repeated measures four-way ANOVA, reaction times were found to be faster in rotation than in static conditions, $F(1, 12)$ = 13.49, MSe = 7300.36, *p* < .005, if the response alternated than repeated, $F(1, 12)$

= 8.55, MSe = 6246.15, $p < .02$; and if location alternated, $F(1, 12) = 6.18$, MSe = 2276.20, $p < .03$. Rotation significantly interacted with location repetition, $F(1, 12) = 6.51$, MSe = 3790.65, $p < .03$, such that the alternation bias during static trials (15 ms) disappeared during rotation trials (-2 ms). The opposite pattern was observed with response-repetition, which yielded a significant interaction between rotation and response-repetition, $F(1, 12) = 23.00$, MSe = 2433.78, $p < .001$, the response-alternation benefit being smaller in static trials (4 ms) than in rotation trials (18 ms).

Replicating the pattern reported by Hommel (1998), partial-repetition costs were found (see Figure 2): between location repetition and response repetition, $F(1, 12) = 10.22$, MSe = 5452.28, $p < .01$; and between shape repetition and response repetition, $F(1, 12) = 45.84$, MSe = 19743.78, $p < .001$; whereas the interaction between shape and location repetition only approached significance, $F(1, 12) = 3.53$, MSe = 892.75, $p < .09$. Finally, the three-way interaction between all three repetition effects was significant, $F(1, 12) = 5.77$, MSe = 1482.21, $p < .04$.

More important for the present study, the two two-way interactions that involved stimulus-location repetition were modulated by rotation: location-by-shape, $F(1, 12) = 10.73$, MSe = 2821.06, $p < .01$, and location-by-response, $F(1, 12) = 25.95$, MSe = 4459.38, $p < .001$. In contrast, neither the shape-by-response interaction nor the three-way interaction were further modified by rotation, $F(1, 12) = .49$, MSe = 214.47, $p > .4$, and $F(1, 12) = .32$, MSe = 117.79, $p > .5$, respectively. Table 1 shows the emerging pattern: While quite substantial partial-repetition costs[1] were obtained for all three combinations of stimulus features and

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[1] Partial repetition costs were computed as the difference in priming effects for one feature (F1) as a function of repeating (rep) versus alternating (alt) another feature (F2); Partial Repetition-Cost = $(F1_{rep}F2_{alt} - F1_{rep}F2_{rep}) - (F1_{alt}F2_{alt} - F1_{alt}F2_{rep})$. For example, partial repetition costs in the

response, rotating the boxes eliminated the costs for the two combinations involving location repetitions and alternations.

Table 1. *Experiment 1: Mean reaction times and error percentages (in parentheses) as a function of rotation and repetitions versus alternations of shape, stimulus location and response. For each combination of two features, the partial-repetition costs are shown. These were calculated as the interaction term between two features and show the cost in reaction time resulting from changing either the one feature or the other, as opposed to changing both or neither one of the two features[1].*

Shape	Location repeated		Location alternated		Partial repetition costs
	repeated	alternated	repeated	alternated	
Static	426 (12)	428 (6.4)	422 (7.4)	401 (9.2)	23 (-7.4)
Rotating	411 (9.8)	403 (10.7)	410 (8.9)	408 (9.2)	-6 (0.6)
Response	Location repeated		Location alternated		
	repeated	alternated	repeated	alternated	
Static	419 (5.8)	435 (12.6)	424 (12.4)	400 (4.2)	39 (15.0)
Rotating	415 (13.8)	398 (6.7)	418 (11.2)	399 (0)	2 (-2.7)
Shape	Response repeated		Response alternated		
	repeated	alternated	repeated	alternated	
Static	416 (4.7)	428 (13.6)	433 (14.8)	402 (2.0)	43 (21.8)
Rotating	410 (9.1)	423 (15.9)	410 (9.5)	387 (4.0)	35 (12.3)

The analysis of errors was based on proportions and reflected only data from the trials were S1 was correct and sufficiently fast (< 700 ms). In general, the error patterns followed those of the reaction times. The only reliable main effect indicated that repeating a response yielded more errors than alternating it, $F(1, 12) = 5.60$, MSe = .05, $p < .04$. Rotation significantly interacted with response repetition, $F(1, 12) = 5.33$, MSe = .03, $p < .04$, and with shape repetition, $F(1, 12) = 5.96$, MSe = .01, $p < .04$. Significant interactions were obtained for shape and

shape x response domain were calculated as the response priming-effect with shape alternated subtracted from the response priming-effect with shape repeated.

response repetition, F(1, 12) = 55.84, MSe = .38, *p* < .001, location and response repetition, F(1, 12) = 8.25, MSe = .05, *p* < .02, and shape and location repetition, F(1, 12) = 4.85, MSe = .02, *p* < .05. All three interactions were further modified by rotation: F(1, 12) = 5.97, MSe = .01, *p* < .04, F(1, 12) = 10.76, MSe = .10, *p* < .01, and F(1, 12) = 5.08, MSe = .02, *p* < .05, respectively.
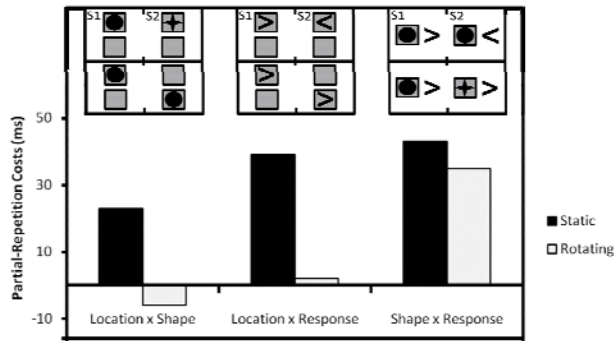

Figure 2. Partial-repetition costs in Experiment 1 of location-by-shape, location-by-response and shape-by-response as a function of rotation. The upper part of the figure shows two conditions in which alternation of one of two features between S2 and S2 results in partial-repetition costs.

Discussion

The outcome of Experiment 1 can be considered mixed. On the one hand, it is clear that rotation had a strong effect in the expected direction. Whereas standard partial-repetition costs were obtained for location and response repetitions as well as for shape and location repetitions, rotating the empty boxes in between S1 and S2 presentation eliminated these costs. Also as expected, rotation only affected partial-repetition costs related to location repetitions but not with respect to the interaction of shape and response. On the other hand, however, the location-related partial-repetition costs were only eliminated but they did not reverse in sign—as we would have expected if rotation led to an

update of the respective object or event files. There are at least two interpretations of this observation.

First, it is possible that moving the boxes induced the creation of a new event file without overwriting the previous one. If, say, a circle appeared in the bottom box before the boxes were rotated, this could have left two shape-location bindings: one linking circle with bottom and another linking circle with top, the new location. If the circle would appear again then, it would retrieve two bindings with contradicting spatial information that may cancel out one another. The same logic can be applied to location-response bindings. Whereas this scenario would be consistent with our main hypothesis, there is a second, theoretically less interesting possibility however. For various reasons, moving the empty boxes may flush any sort of visual working memory and thus delete any available binding. True, this possibility is ad hoc and does not seem to fit with the results from previewing studies using moving stimuli (Kahneman et al., 1992) and multiple-object tracking studies (Pylyshyn & Storm, 1988). However, it would be consistent with assumptions from leading theories on the limitations of working memory capacity and executive control (Gilbert & Shallice, 2002; Logan & Gordon, 2001) and with studies on event segregation (Zacks, Speer, Swallow, Braver & Reynolds, 2007). Accordingly, we considered it important to replicate our findings and to seek for independent evidence supporting the multiple-binding interpretation.

Experiment 2

We attributed the disappearance of partial-repetition costs in the rotation condition of Experiment 1 to the existence of two types of event files: one linking shape and response information to the physical location of S1 and another linking this information to the updated location, that is, to the post-rotation location of the box in which S1 had appeared. The idea underlying Experiment 2 was to try making the transition between the two represented states—S1 appearing in the box and the empty box rotating—visually smoother by softly fading out S1 rather

than letting it abruptly disappear. Zacks et al. (2007) have claimed, and provided evidence, that unpredicted visual changes are more likely to lead to the closing of the current event representation and the opening of a new one, whereas predicted changes merely induce an update of the currently open representation. Smoothing the transition between S1 and S2 may thus help linking these two events to one another or, more precisely, the event files representing them. If so, chances are that only one updated file would be maintained at least in some trials or that the updated file would dominate the previous one more strongly. This should drive the result pattern in the rotation condition more in the expected direction, that is, partial-repetition costs for location-related interactions should no longer be zero but go negative. We thus replicated Experiment 1 but added a further condition in which S1 gradually faded out.

Method

Six male and 10 female students from Leiden University voluntarily participated. The method was as in Experiment 1, except that in fading conditions, the opacity of the stimulus shown in S1 decreased with each of the 45 frames by approximately 2.2% during the inter-stimulus interval. Thus, it appeared to gradually fade out, while its position remained anchored to the box of its prior appearance.

Results

Overall, few errors were made for S1 (M = 4.2%, SD = 3.5%) compared to S2 (M = 17.8%, SD = 7.4%). In a repeated measures five-way ANOVA with fading, rotation, shape-, location- and response-repetition as factors, responses were found to be slightly (8 ms) slower in fading conditions than in abrupt conditions, $F(1, 15) = 11.05$, MSe = 8959.92, $p < .005$, in static conditions than in rotating conditions, $F(1, 15) = 24.26$, MSe = 43348.93, $p < .001$, and if the response repeated

than alternated, $F(1, 15) = 6.68$, MSe = 2918.48, p < .02. Neither repeating the location, p > .1 nor repeating the shape, p > .7, affected reaction time.

The partial-repetition costs of Experiment 1 were replicated (see Figure 2): reliable interactions were obtained between location repetition and response repetition, $F(1, 15) = 17.35$, MSe = 12475.48, p < .001; and between shape repetition and response repetition, $F(1, 15) = 68.66$, MSe = 72317.37, p < .0001; but not between shape and location repetition, p > .8. The three-way interaction involving all three repetition effects was far from significant, $F(1, 15) = .11$, MSe = 68.50, p > .7.

Replicating the main findings from Experiment 1, partial-repetition costs involving location repetitions were modulated by rotation: location-by-shape, $F(1, 15) = 8.04$, MSe = 4192.07, p < .02, and location-by-response, $F(1, 15) = 25.52$, MSe = 17819.65, p < .001. Again, neither the shape-by-response interaction, $F(1, 15) = .24$, MSe = 99.77, p > .6, nor the three-way interaction, $F(1, 15) = .03$, MSe = 16.06, p > .8, was affected by rotation.

Table 2. *Experiment 2: Mean reaction times and error percentages (in parentheses) as a function of stimulus fading, rotation, repetitions versus alternations of shape, stimulus location and response.*

	Shape	Location repeated		Location alternated		Partial rep. costs
		repeated	alternated	repeated	alternated	
Abrupt	Static	430 (12.2)	444 (10.2)	433 (8.8)	425 (9.2)	23 (-2.4)
	Rotating	414 (12.5)	416 (10.0)	412 (8.8)	420 (11.5)	-7 (-5.2)
Fading	Static	444 (13.0)	442 (10.0)	442 (10.0)	441 (12.0)	-1 (-5.0)
	Rotating	431 (13.9)	419 (13.9)	418 (11.4)	424 (13.2)	-17 (-1.7)
	Response	Location repeated		Location alternated		
		repeated	alternated	repeated	alternated	
Abrupt	Static	426 (7.7)	449 (14.8)	438 (11.4)	420 (6.6)	41 (12.0)
	Rotating	416 (12.4)	414 (10.1)	421 (10.3)	424 (13.2)	8 (-2.0)
Fading	Static	437 (8.4)	449 (14.7)	458 (15.1)	425 (7.0)	45 (14.4)
	Rotating	432 (16.3)	419 (11.6)	420 (14.5)	422 (10.1)	-16 (-0.1)
	Shape	Response repeated		Response alternated		
		repeated	alternated	repeated	alternated	
Abrupt	Static	419 (5.5)	445 (13.6)	444 (15.5)	424 (5.8)	46 (17.7)
	Rotating	407 (7.0)	430 (15.7)	419 (14.2)	406 (5.9)	35 (17)
Fading	Static	435 (4.5)	460 (18.9)	451 (18.5)	424 (3.1)	52 (29.8)
	Rotating	413 (8.0)	438 (22.8)	436 (17.4)	405 (4.3)	57 (27.9)

The fading condition affected this pattern in two significant ways. First, it modulated the interaction between response repetition and rotation that was observed in Experiment 1, $F(1, 15) = 5.48$, MSe = 1354.86, $p < .04$: In the fading condition, the response alternation bias no longer changed after rotation. Secondly, it modulated the interaction between location and shape, $F(1, 15) = 9.07$, MSe = 2321.87, $p < .01$: Whereas partial-overlap costs were positive with abruptly disappearing stimuli, these costs were negative with fading stimuli (see Table 2).

As summarized in Figure 3, the resulting partial-repetition costs in abrupt conditions were very similar to those found in Experiment 1, and they were similarly affected by rotating the boxes. In contrast, fading conditions produced significant *negative* partial-repetition costs in reaction times with rotating boxes for

location x shape, *t*(15) = -2.41, p < .02, and marginally significant costs for location x response, t(15) = -1.61, p = .06; no effects were reliable in the error data, p's > .3.
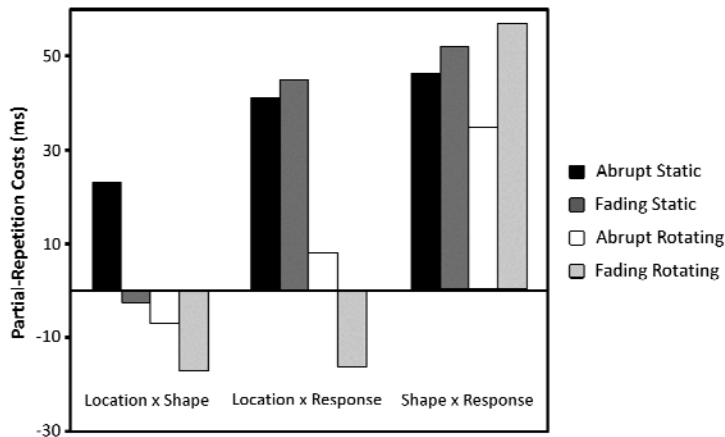

Figure 3. Partial-repetition costs in Experiment 2 of location-by-shape, location-by-response and shape-by-response as a function of rotation and fading.

Error patterns followed the reaction times. Fading stimuli increased the error rate, F(1, 15) = 5.24, MSe = .04, p < .04. Location interacted significantly with response, F(1, 15) = 21.11, MSe = .117, p < .0005, as did shape, *F*(1, 15) = 73.15, MSe = 1.71, p < .0001. The interaction between location and response was modulated by rotation, F(1, 15) = 18.33, MSe = .16, p < .001. Fading did not interact with any factor or interaction other than the shape x response interaction, F(1, 15) = 11.85, MSe = .107, p < .005, with a greater effect of partial repetition in fading trials (see Figure 3).

Discussion

The outcome is clear-cut. We were able to replicate the main findings of Experiment 1 with abruptly disappearing stimuli: Substantial partial-repetition costs were obtained for all three combinations of stimulus features and responses with static boxes, while these costs were eliminated for location-related interactions by having the boxes rotate. With fading stimuli, static boxes yielded a

similar outcome as in the abrupt condition but rotating the boxes produced a very different pattern. As expected, the partial-repetition costs including location were no longer close to zero but significantly inverted. Hence, there is evidence that the fading manipulation had the expected effect of increasing the contribution from the updated (i.e., post-rotation) event files, which supports the suggestion of Zacks et al. (2007) that smoother and thus more predictable changes between two events facilitate their integration.

Even though it seems clear that improving the visual link between S1 and S2 led to the integration of the corresponding event representations and that this integration was apparently prevented in Experiment 1, there are still two possible interpretations of how that may have produced the findings we obtained there. According to one scenario, separate event representations for S1 and S2 were created and maintained in Experiment 1 because the abrupt visual change worked against their integration. The absence of reliable effects in the rotation condition would thus reflect the common impact from two event files that effectively cancel each other out. According to the other scenario, the more abrupt visual change in Experiment 1 may have simply flushed visual working memory and deleted the representation of S1. Hence, even though Experiment 2 demonstrated that event-file updating does take place under conditions that favour event integration, it does not provide sufficient evidence to determine what happens under less favourable conditions. Experiment 3 was conducted to fix that.

Experiment 3

In Experiment 3, we investigated whether an abrupt visual change between S1 and S2 (as in Experiment 1) only prevents the integration of these events (and, thus, the updating of the S1 representation towards S2) or whether it leads to the deletion of any S1-related bindings. We did so by replicating Experiment 1 but letting the stimulus configuration rotate only 90 degrees, so that the previous 'non-updated' location of S1 would no longer interfere with the new location of S2 (or

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the corresponding representation). Under these conditions, we had different predictions for the two scenarios we considered. If the abrupt visual change would lead to the deletion of any S1-related binding, no interactions between repetition effects should occur, that is, no evidence for feature integration should be obtained. In contrast, if the null effects obtained in Experiment 1 were due to bindings that cancelled each other out, using different spatial dimensions for S1 and S2 should prevent cancellation, so that reliable evidence for integration should be obtained.

Method

Four male and 11 female students from Leiden University voluntarily participated. The method was as in Experiment 1, except that S1 varied on the vertical and S2 on the horizontal dimension, with clock- or counter-clockwise rotations of 90 degrees in between (the static condition was dropped). To avoid confusion with use of the term "location repetition" in the previous experiments (which in Experiment 3 no longer applied), we will use the term 'rotation towards' for a "rotation into S2" (e.g., S1 presented at the top → top box rotated to the right → S2 presented to the right) and 'rotating away' for the opposite case (e.g., S1 presented at the top → top box rotated to the left → S1 presented to the right).

Results

Overall, fewer errors were made for S1 (M = 3.0%, SD = 2.3%) than for S2 (M = 19.1%, SD = 8.2%). One subject was omitted from further analysis due to disproportionally low accuracies (M = 33.0%, SD = 7.0%). In a repeated measures ANOVA with fading (fading vs. abrupt), rotated location (towards vs. away), shape- and response-repetition as factors, responses were found to be less (2%) accurate if they were repeated, $F(1, 13) = 9.79$, MSe = 774.80, p < .01, but not slower, p > .3. Repeating the shape likewise increased (2%) error rates, $F(1, 13) = 6.23$, MSe = 213.72, p < .03, but did not affect RTs, p > .9. The fading condition did not affect

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error rates, p > .7, and only marginally yielded (3 ms) slower responses in fading conditions than in abrupt conditions, F(1, 13) = 4.07, MSe = 549.69, p < .07. Rotated location had no significant effect on RT, p > .5, or error rates, p > .1.
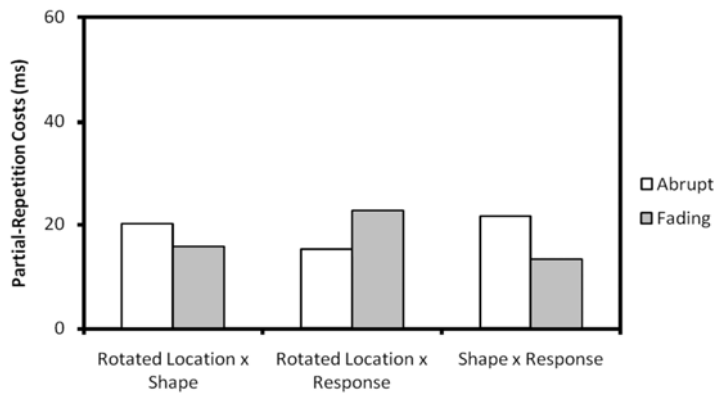

Figure 4. Partial-repetition costs in Experiment 3 of rotated location-by-shape, rotated location-by-response and shape-by-response as a function of fading. Note that partial-repetition costs based on rotated location can only be understood as repetitions by virtue of their integration with their object – i.e., locations were never repeated between two stimulus-displays.

Even though the location was never repeated as was the case in Experiment 1 and 2 (since the first stimulus-display was vertical and the second horizontal), rotated location had similar effects to location-repetition in the former experiments[2]. Significant interactions were obtained between rotated location and

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[2] 2. Presenting S2 to the left and right created spatially compatible and incompatible relations with the left and right responses, a condition that is known to lead to the Simon effect (Simon & Rudell, 1967), i.e., better performance if stimulus and response spatially correspond. In another repeated measures ANOVA with S2-response compatibility, rotated location, response-repetition and shape-repetition as factors, the Simon-effect was found to be significant in RTs, F(1, 13) = 122.44, MSe = 83252.72, p < .001, and error rates, F(1, 13) = 29.90, MSe = 8015.66, p < .001, indicating that in spatially incompatible stimulus-response conditions, participants were 31 ms slower and made 11% more errors. Importantly, however, the Simon effect did not interact with any other factor.

shape repetition on RTs, F(1, 13) = 24.89, MSe = 4475.90, p < .001, though only marginally on error rates, F(1, 13) = 3.56, MSe = 57.21, p < .09 and between rotated location and response repetition on RTs, F(1, 13) = 22.02, MSe = 5033.50, p < .001, but not on errors, p > .2. Again, shape x response repetitions interacted significantly on RTs, F(1, 13) = 25.58, MSe = 4240.38, p < .001, and errors, F(1, 13) = 40.70, MSe = 3186.10, p < .001.

Table 3. *Experiment 3: Mean reaction times and errors (in parentheses) as a function of stimulus fading, rotated location and repetitions versus alternations of shape and response.*

Shape	Rotated towards		Rotated away		Partial repetition costs
	repeated	alternated	repeated	alternated	
Abrupt	391 (12.5)	398 (7.4)	399 (13.5)	390 (8.3)	15 (0.1)
Fading	393 (9.9)	399 (10.0)	408 (13.7)	390 (9.0)	23 (4.8)
Response	Rotated towards		Rotated away		
	repeated	alternated	repeated	alternated	
Abrupt	387 (9)	401 (10.9)	398 (9.0)	392 (12.8)	20 (-1.8)
Fading	390 (10)	401 (10.0)	401 (10.2)	397 (12.4)	16 (-2.2)
Shape	Response repeated		Response alternated		
	repeated	alternated	repeated	alternated	
Abrupt	387 (8.9)	402 (9.2)	397 (17.1)	391 (6.5)	22 (11.0)
Fading	395 (6.4)	405 (13.8)	396 (17.2)	393 (5.3)	13 (19.2)

Discussion

The outcome of Experiment 3 is consistent with our interpretation of the null effects obtained in Experiment 1 in terms of multiple bindings and mutual cancellation but inconsistent with an account in terms of flushing. The latter would have predicted no integration-related effects, which is the opposite of what the data show.

Conclusions

The present study allows for three conclusions of theoretical relevance. First, moving an object leads to an update of the respective event file, including the response. In other words, response information does not only become integrated with object information but it seems to behave just like perceptual ingredients of object or event files. This bolsters the claim that object representations can include more than just perceptual codes (Kahneman et al., 1992) and, more specifically, that stimulus and action codes are bound into sensorimotor event representations (Hommel et al., 2001).

Second, whether particular events are coded into one or more event files seems to be determined by perceptual factors, possibly among others, such as the smoothness of the transition between perceptual states. According to Zacks et al. (2007), short-term event representations are used to predict future perceptual states on a continuous basis. As long as these predictions are successful, incoming information is considered to belong to the same event and, put into our theoretical terminology, integrated into the same event file. As soon as the predictions fail, a new event file is opened and the prediction-integration cycle goes on. Applying this logic to the present study implies that abrupt disappearance of a stimulus might be more likely to violate perceptual expectations and trigger the opening of a new event file than a stimulus that is softly fading out.

Third, it is interesting to note that both the rotation and the fading manipulation affected location-related bindings only—but no impact was observed on shape-response bindings. This is consistent with a number of other dissociations between different types of bindings (e.g., Colzato, Fagioli, Erasmus & Hommel, 2005; Colzato, Warrens & Hommel, 2006; Hommel, 1998, 2007). Apparently, event files are not created by putting all the available evidence about a given incident on one pile. Rather, they seem to consist of multilayered structures of separable (and separately accessible and alterable) but nevertheless connected associations between feature codes (Hommel, 2004).

All in all, this study provides insight into our ability to track objects in the wider scope of perception for action. Tracking an object through time and space must come in handy in the perceptual arsenal of many an animal, yet the use of tracking remains limited for prey or predator if it could not bind various actions to an object that was tracked. A prowling cat may passively store the location of various objects, but without binding the act of hunting to some of them it could easily mistake a sleeping sparrow for a muddy rock on the bank of the river. This is not what cats want.

CHAPTER 4: HE SAID, SHE SAID: EPISODIC RETRIEVAL INDUCES CONFLICT ADAPTATION

People respond more slowly if an irrelevant feature of a target stimulus is incompatible with the relevant feature or the correct response. Such compatibility effects are often reduced in trials following an incompatible trial, which has been taken to reflect increased cognitive control. This pattern only holds if two trials share some similarities, however, suggesting it may be modulated by the episodic context. To look into this possibility, we had participants respond to high or low-pitched tones by saying "high" or "low", respectively, and ignore the simultaneously presented auditory word "high" or "low". As expected, performance was impaired if the heard word was incompatible with the required response, and this Stroop-like effect was reduced after incompatible trials. This sequential modulation was only observed, however, if the voice in the two successive trials was the same, while no modulation was obtained when the speaker changed. The results suggest that sequential modulations are due to the automatic retrieval of episodic event representations that integrate stimuli, actions, situational, and task-specific control information, so that later reactivation of some elements of a given representation tends to retrieve the other elements as well.

Human performance is very sensitive to conflict between stimuli and the responses they activate. Reactions are slower and less accurate if the features or elements of a stimulus point to different actions, as indicated by the Stroop effect (Stroop, 1935), the Simon effect (Simon & Rudell, 1967), and the flanker effect (Eriksen & Eriksen, 1974). Recent studies have shown, however, that people can adapt to conflict-inducing circumstances, perhaps by using the occurrence and degree of conflict between cognitive representations to fine-tune control processes so as to reduce or even eliminate conflict in the future (Botvinick, Nystrom, Fissell, Carter & Cohen, 1999). Consistent with this suggestion are the observations of systematic sequential changes of conflict-induced effects: the Stroop effect (Kerns et al., 2004), the Simon effect (Stürmer, Leuthold, Soetens, Schröter & Sommer, 2002), and the flanker effect (Gratton, Coles & Donchin, 1992) are all smaller, absent, or negative after a conflict trial and larger after a non-conflict trial. Thus, registering conflict in a given trial seems to increase the amount of cognitive control exerted, so that conflict can be prevented in the subsequent trial.

Even though this cognitive control account fits much of the obtained data patterns, recent observations show that sequence modulations reflect more than the workings of executive control. Several authors have pointed out that repetitions and alternations of conflict trials are commonly confounded with repetitions and alternations of relevant and irrelevant stimulus and response features and, most critically, of the relations amongst them (e.g., Hommel, Proctor & Vu, 2004; Mayr, Awh & Laurey, 2003; Nieuwenhuis et al., 2006; Wendt, Kluwe & Peters, 2006). In fact, repeating the type of conflict (i.e. non-conflict followed by non-conflict, or conflict followed by conflict) commonly implies that all or none of the stimulus and response features are repeated, conditions that even in non-conflict tasks allow for better performance as compared to trials in which feature repetitions and alternations are mixed—presumably due to the episodic retrieval of stimulus and response bindings (Hommel, 1998, 2004; Hommel, Müsseler,

Aschersleben & Prinz, 2004). Thus, both the reduced conflict effects following a conflict trial and the inflated conflict effects after a non-conflict trial may be due to episodic retrieval of stimulus-response bindings, a conflict monitoring system in action, or both[3].

Recent studies sought to disentangle episodic and control effects and provided evidence that sequential modulations may indeed reflect both episodic retrieval (e.g., Hommel et al., 2004; Wendt et al., 2006) and conflict-induced effects (e.g., Akçay & Hazeltine, 2007; Wühr, 2005). Proponents of episodic and control approaches have tended to interpret these exhibitions as kind of existence proofs to justify further investigation of the respective effects in isolation. However, here we would like to argue that episodic processes and control operations may not just happen to co-occur in the mentioned conflict tasks but may be intrinsically related in a theoretically interesting way. In particular, it may be that episodic representation of events—event files in the sense of Hommel (1998, 2004)—do not only integrate stimulus and response codes but task and control parameters as well, including the weights of associations between stimulus and response features that control theorists assume to produce the control-related part of sequential modulations (e.g., Botvinick et al., 1999).

Some evidence for this possibility has been obtained in task-switching studies: Processing a stimulus that was previously encountered in another task interferes with switching to a new task, suggesting that the stimulus induced the

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[3] Note that the same argument holds for manipulations of the frequency of congruent and incongruent trials (e.g., Logan & Zbrodoff, 1979; Tzelgov, Henik & Berger, 1992)—manipulations that have often been taken to induce adaptive control (Botvinick et al., 1999; Logan, 1980). Making incongruent trials more frequent, say, produces more memory traces for incongruent stimulus-response episodes, which is likely to facilitate responding in such trials for reasons that are unrelated to control processes.

automatic retrieval of a representation of the task it accompanied (Waszak, Hommel & Allport, 2003). If we assume that a stored task representation is comprised of stimulus-response associations, it makes sense to assume that the strengths of these associations can be stored with them—which implies that the outcomes of the hypothesized control operations may be encoded in episodic event representations and later retrieved with them. This consideration is consistent with recent observations from sequential studies. Some authors reported that conflict-adaptation after a task-switch is only observed if there is at least some overlap in terms of stimulus or response-features between the two tasks (Kiesel, Kunde & Hoffmann, 2006; Notebaert & Verguts, 2006). In the absence of a certain degree of similarity between tasks, Notebaert and Verguts (2008) found no remaining effect of one conflicting trial on the next, prompting them to state that conflict-monitoring acts *locally* (see also Blais, Robidoux, Risko & Besner, 2007). Indeed, this is what an episodic integration approach would suggest: stimulus-response episodes belonging to the same or a similar task overlap with respect to the contextual and task information they contain, so that they are more likely to be retrieved in the same context.

A related interpretation may be derived from ideas as expressed in the Event Segmentation Theory proposed by Zacks and colleagues (Zacks & Tversky, 2001; Zacks & Swallow, 2007). It assumes that people continuously predict future perceptions based on the flow of current perceptions, but will segment the stream into a new event if the error between prediction and perception becomes too large, that is, if critical features change. In other words, if two events occurrences are too different from one another to fit comfortably into one event, a new event boundary is created to make sense of ongoing activity. Although what exactly constitutes "too large" remains fuzzy, there is some evidence that people are likely to create a new event boundary during changes in time, space and causal contingency, e.g. if the protagonist in a story changes (Kurby & Zacks, in press). This

may suggest that encountering a significant change in a context variable (such as the task) resets the system, thereby eliminating the after-effects of conflict-induced adjustments—a line of thought that would fit the idea that task switching involves the inhibition of the previous task (Mayr & Keele, 2000) or the flushing of control systems (Logan & Gordon, 2001).

To explore the possibility that conflict-induced effects are more likely in situations where two successive events are similar, we manipulated a feature that has no obvious relation to action control operations and does not call for a task switch but nevertheless constitutes a salient change in the episodic context. We presented participants with a vocal Stroop-like task where they were to ignore a distracting word ("high" or "low") and respond to a high or low pitched tone. The episodic manipulation of interest related to the voice speaking the word, which either changed or remained the same from one trial to another. Voice can be discriminated very rapidly and induces the automatic classification of a speaker, which has been found to channel the integration of information from the spoken message (Van Berkum, Van den Brink, Tesink, Kos & Hagoort, 2008). If so, voice changes should be particularly suited to signal event boundaries and signal the closing of open event files and the opening of a new file. In other words, changing the voice (even though entirely irrelevant for the task) can be expected to alter the context and/or trigger event segmentation processes, rendering a sequence of trials with a voice change less similar than a sequence with a voice repetition. If so, conflict-induced sequential effects may be smaller or even absent after a voice change.

Chapter 4: He said, she said: Episodic retrieval induces conflict adaptation

Method

Seven female and seven male students from Leiden University voluntarily participated in this experiment for a small fee or course credits. Data from one more female participant did not enter analysis due to an error rate of more than 50%.

Participants responded to sinusoidal tones of 550 or 1050 Hz by vocally responding "low" and "high" (in Dutch), respectively. The irrelevant stimulus was the word "low" or "high" (in Dutch), spoken by a male voice, a female voice, or by the voice of the participant him- or herself (recorded and edited before the experiment started)[4]. Voices were recorded and later presented using a Samson microphone attached to the Behringer BCA2000 audio-interface. To present the samples at similar psychoacoustic levels, they were normalized to maximum level, trimmed to 350 ms, compressed at a rate of 2:1 above -15 dB, and then again normalized to -6 dB level using Syntrillium CoolEdit. A sinusoidal tone of 550 or 1050 Hz of -9 dB was generated and digitally mixed into the samples. Finally, the tone and voice were reshaped with a linear slope on the first and final ten milliseconds respectively to compensate for onset- and offset clicking sounds, after which the samples were normalized again to maximum level.

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4 The inclusion of the own-voice condition was motivated by the observation that different neural networks seem to be implicated in tasks inducing conflict per se, such as the Stroop task, and tasks that create conflict between self-generated and externally triggered motor representations, such as when finger movements are signaled by visual displays showing movements of an incongruent finger (Brass, Derrfuss & von Cramon, 2005). We thought that presenting irrelevant information in the participant's own voice may be similar to the latter condition and were interested to see whether it might increase or otherwise affect conflict-related effects. Given that the voice variable did not yield any significant effect, and was not involved in any interaction, we will neglect it in the following and focus on the repetition and alternation of voice only.

Stimuli were presented with AKG K-55 headphones and timed using E-Prime 1.1.3, under Windows XP SP2, running on a 1.8 GHz Dell Latitude laptop. A Psychology Software Tools voice-key setup recorded vocal reactions, which were displayed on a computer screen that was monitored for accuracy and false alarms by two independent observers. White noise was played during the entire experiment to mask external and extra-experimental sound.

Each trial started by playing white noise for 150 ms, a preparation signal that was followed by 1000 ms of silence. The first stimulus (S1) was then played for 350 ms. Participants were required to respond to the high- or low-pitched tone by saying "high" or "low" into the microphone, ignoring the voice they heard along with the tone. After they responded, another 400 ms followed before the onset of the second stimulus (S2), which was also played for 350 ms. The trial was concluded with a 1000 ms blank inter-trial interval, unless the participant had reacted incorrectly, in which case verbal feedback was given. The first 20 trials were considered training, during which the participant received extra feedback concerning speed and accuracy of performance and after 144 trials (resulting from the combinations of 3 voices, 2 relevant pitches, and 2 irrelevant words for both S1 and S2) a five-minute break was introduced, followed by another 144 trials.

Results

In repeated measures ANOVAs of responses to S1 (reaction times, RTs, and error rates, ERs) with the factors of word ("high" or "low"), response (to a high or low-pitched tone), and voice, responding with the word "high" was found to be significantly faster than responding with the word "low", $F(1, 13) = 14.87$, $p < .003$, $\eta^2 = .53$, although not significantly more accurate, $p > .2$. The distracting word had no significant effect on RT, $p > .4$, or ER, $p > .1$. A congruency effect was revealed by interactions between word and response on both RTs, $F(1, 13) = 25.59$, $p < .0003$, $\eta^2 = .66$, and ERs, $F(1, 13) = 7.89$, $p < .02$, $\eta^2 = .38$, with incongruent words resulting in reactions that were 65 ms slower and had 6.0% more errors. However, this effect

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was not modulated by voice, p's > .2, nor did voice interact with other variables, p's > .1.

Further ANOVAs looked into responses to S2, with S1 congruency, S2 congruency, and voice repetition or alternation as factors (see figure 1). While S1 congruency had no effect, p's > .1, S2 congruency affected RTs, $F(1, 13) = 21.70$, $p < .0005$, $\eta^2 = 63$, and ERs, $F(1, 13) = 14.41$, $p < .003$, $\eta^2 = .53$, : Responses were 54 ms slower and 6% less accurate errors in incongruent than congruent conditions. Repeating the voice showed a trend towards significance in RT, $F(1, 13) = 3.16$, $p = .099$, $\eta^2 = .20$, with a repeating voice giving a small 13-ms benefit.
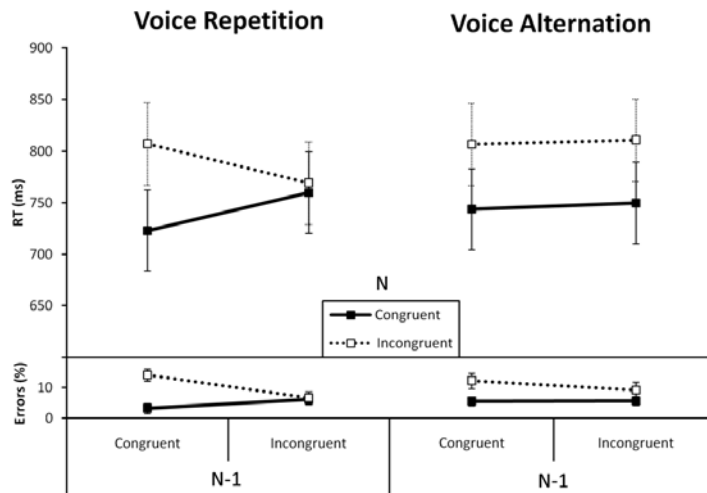

Figure 1. Reaction times (RT) and errors of the current trial (N) as a function of its congruency condition, the congruency of the previous trial (N-1) and the type of voice-repetition between the two trials.

More important were the interactions. As expected, the two-way interaction of trial N-1 and trial N congruency affected RTs, $F(1, 13) = 9.30$, $p < .01$, $\eta^2 = .42$, and ERs, $F(1, 13) = 7.94$, $p < .02$, $\eta^2 = .38$, with the congruency effect in trial N being 38 ms smaller after an incongruent trial than after a congruent trial. This conflict-adaptation effect was significantly modulated by a three-way interaction involving voice repetition in RTs, $F(1, 13) = 16.36$, $p < .002$, $\eta^2 = .56$, and nearly so in ERs, $F(1, 13) = 4.66$, $p < .06$, $\eta^2 = .26$ (see Table 1). If the voice was repeated, the congruency effect was strongly dependent on N-1 congruency, the congruency effect decreasing by 76 ms (or 10.5% ER) after incongruent N-1's: $F(1, 13) = 21.30$, $p < .0005$, $\eta^2 = .62$; ER: $F(1, 13) = 14.56$, $p < .003$, $\eta^2 = .53$, while no such a modulation was observed for voice alternations, RT: the congruency effect decreasing only 4 ms (or 3.4% ER) after incongruent N-1's, $F(1, 13) < 1$; ER: $F(1, 13) = 1.11$, $p > .3$, $\eta^2 = .08$.

Table 1. *Reaction times and error rates (in parentheses) of the current trial (N) as a function of stimulus-response congruency in trial N, congruency in trial N-1, and voice repetition or alternation. Effect sizes show the congruency effect (Conflict) and how it is affected by congruency in N-1.*

| | | N | | Effects | |
Voice	N-1	Congruent	Incongruent	Conflict	Conflict adaptation
Repeated	Congruent	723 (3.2)	807 (14.2)	85 (11.0)	
	Incongruent	760 (6.2)	769 (6.7)	9 (0.5)	76 (10.5)
Alternated	Congruent	744 (5.1)	807 (12.1)	64 (7.0)	
	Incongruent	750 (5.3)	811 (9.0)	60 (3.7)	4 (3.4)

Conclusions

Hearing a stimulus- and response-incongruent, irrelevant word impaired performance, very similar to the standard Stroop effect. In keeping with previous findings, this Stroop effect was considerably reduced after conflict trials, thus replicating Gratton et al.'s (1992) observation in the flanker paradigm and comparable findings of Kerns et al. (2004) and others using Stroop-type tasks. However, the previous trial affected the degree of conflict *only* if the distractor information was presented in the same voice. In contrast, no sequential effect was obtained if the voice changed. This observation goes beyond previous findings that sequential effects are affected by task switches or the similarity between sequential tasks by showing that sequential effects can be eliminated even within the same task and even with an entirely task-irrelevant similarity manipulation. We take that as a clear-cut demonstration that the impact of conflict-induced operations is mediated by the episodic context and consider this contextual modulation to be the reason why conflict-induced control acts "locally" (Blais et al., 2007; Notebaert & Verguts, 2008).

As we have pointed out, there are at least two possibilities of how the episodic context may interact with control processes or their after-effects. First, it may be that each single stimulus-response episode is integrated with the task context, including the just-modified weights of stimulus-response associations, and only retrieved in a sufficiently similar context—be it the task to be carried out (as with Notebaert & Verguts, 2006) or the source of the information (as in the present study). Second, it may be that significant changes of the context induce event segmentation, which may lead to the inhibition of the representation of the previous event. Even though both interpretations would fit with our present observations, other findings seem to favour the first over the second. As noted earlier, bindings between stimuli and task representations impair switching to another task. Given that they do so even if the acquisition of the binding and the

task switch are separated by more than 100 trials (Waszak et al., 2003), this is unlikely to reflect transient inhibition but, rather, the retrieval of episodic traces. Along the same lines, conflict adaptation has been observed to operate across intervening trials. For instance, Wendt et al. (2006) had participants alternate between two different conflict tasks and found that the size of the conflict effect in the present trial (n) was considerably affected by the amount of conflict in the previous trial of the *same task* (trial n-2, that is). This is inconsistent with the idea that context change or task switch would lead to or even require the inhibition of task representations. Accordingly, we attribute context effects to episodic retrieval. In particular, we suggest that episodic event representations integrate stimuli, actions, situational, and task-specific information, so that later reactivation of some elements of a given representation will tend to retrieve the other elements as well (Hommel, 2004). Even though more research is necessary to determine exactly what characteristics of an episode count as context, which aspects of context and task are considered for event integration, and how exactly the similarity between event codes is computed, it seems clear that event representations contain control parameters that are automatically retrieved under suitable conditions. This suggests that cognitive control and episodic retrieval are more intimately related than previously assumed.

CHAPTER 5: SEQUENTIAL MODULATIONS OF THE SIMON EFFECT DEPEND ON EPISODIC RETRIEVAL

Sequential modulations of conflict effects, like the reduction of the Simon effect after incompatible trials, have been taken to reflect the operation of adaptive control mechanisms. However, recent findings suggest that such modulations are often contaminated by prospective episodic effects like priming and stimulus-response feature integration. Here we replicate previous observations that the Simon effect is strongly reduced after incompatible trials. More importantly, however, we demonstrate that this sequential modulation is eliminated entirely under conditions that are likely to change the memory representation of stimuli between two trials without affecting the degree or likelihood of conflict. This suggests that control-relevant information is integrated into episodic structures or event files that are retrieved only if the current situation is sufficiently similar to the situation in which the files were created.

Introduction

The time it takes to act is strongly affected by the compatibility between the stimulus and response (Fitts & Seeger, 1953). Simon and Rudell (1967), for example, showed that processing the location of a stimulus automatically triggers a response towards the source of the stimulus, such that even though the location of a stimulus may be irrelevant to the task, having to respond with a left button-press to something appearing right wreaks havoc in terms of error and reaction latency. This effect later became known as the *Simon effect* (coined by Hedge & Marsh, 1975), and is one of the more popular effects amongst the range of stimulus-response compatibility phenomena (see Alluisi & Warm, 1990, for an overview). Like similar phenomena such as the Stroop effect (Stroop, 1935) or the flanker-compatibility effect (Eriksen & Eriksen, 1974), the Simon effect follows a more general rule: if a task-irrelevant dimension of a stimulus suggests a different response than the relevant dimension, this leads to a robust impairment of performance.

Conflict Control

Whether a location attracts a response in its direction, a flanker triggers an associated key-press, or a color word suggests reading it, people experience response conflict. How are they able to resolve this conflict and eventually carry out the correct action? According to some researchers, detecting conflict enhances the amount of cognitive control exerted by increasing the support for the correct response (e.g., Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999; Egner & Hirsch, 2005). Others have suggested that incorrectly triggered response alternatives are actively suppressed, thus eliminating the response competition (e.g. Band, Ridderinkhof, & Van der Molen, 2003; Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004). Thus, both approaches assume that the cognitive system continuously monitors for output conflict and enhances cognitive control if conflict is detected.

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The main empirical basis for conflict-control approaches is provided by the observation of sequential effects in conflict-inducing tasks. Using the flanker-compatibility task (Eriksen & Eriksen, 1974), Gratton, Coles, and Donchin (1992) showed that the impact of response-compatible and incompatible flankers on performance is reduced in trials that follow trials with incompatible flankers as compared to trials with compatible flankers. Comparable observations have been made with the Stroop task (e.g., Kerns et al., 2004) and the Simon task (e.g., Praamstra, Kleine, & Schnitzler, 1999), demonstrating that the Stroop effect and the Simon effect are reduced and sometimes even eliminated after incompatible trials. These observations have been taken to suggest that facing a conflict trial challenges and leads to an increase of cognitive control, which then facilitates the handling of conflict in the next trial. Given that flanker, Stroop, and Simon effects can be taken to reflect response conflict, reducing conflict necessarily reduces their size.

Event Files

Recent considerations and findings have, however, raised some doubts in the interpretation of sequential effects in flanker, Stroop, and Simon tasks in terms of conflict monitoring and resolution. As pointed out by Mayr, Awh, and Laurey (2003) and Hommel, Proctor, and Vu (2004), sequential relationships between compatibility and incompatibility are entirely confounded with particular patterns of stimulus and response repetitions and alternations. Decades of research (since Meyer & Schvaneveldt, 1971) on priming have shown that repeating (parts of) a stimulus affects reacting upon this stimulus, and during sequence modulations, such effects are always present. The same goes for response repetitions, which since research in the 1960s are known to affect performance (e.g., Bertelson, 1963). Interestingly, the combination of stimulus and response repetition has been reported to facilitate performance in a overadditive fashion, which has been attributed to a tendency to bypass response selection if everything repeats

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(Bertelson, 1963). Given that the combinations of stimulus and response repetitions are not equally distributed across the possible transitions between compatibility conditions, it is possible that at least a part of sequential modulations goes back to repetition priming (Mayr et al., 2003).

But things are more complicated. Sequences of stimulus-response combinations do not only invite simple priming effects. Treisman and colleagues have claimed that processing the features of an object leads to a binding of the corresponding feature codes, that is, of the neural representations of these features (e.g., Treisman, 1996). Indeed, the priming effect obtained by repeating an object is strongly enhanced if this object also appears in the same location, suggesting that object features get bound to location codes (Kahneman, Treisman, & Gibbs, 1992). Hommel and colleagues have extended this approach to include action and suggested that object features and action features may be spontaneously integrated into what they call *event files* (Hommel, 1998; Hommel, Müsseler, Aschersleben & Prinz, 2001). If, for instance, a stimulus like a cup of coffee is accompanied by an action like grasping or drinking, the codes of the sensory features (BROWN, WARM, ROUND, etc.) become integrated with action features like moving the dominant hand towards an object, touching it with thumb and index finger, etc., resulting in an event file referring to the "grasping of a brown, warm cup of coffee". If one or more features are encountered again the whole event file, or at least parts of it, is retrieved automatically (cf., Logan, 1988) in a kind of pattern-completion process. This can lead to benefits and costs— depending on the circumstances. It can lead to benefits if the retrieved feature components are useful by further specifying the repeated features (e.g., if recognition is hampered by suboptimal visibility). And it can lead to costs if some but not all features are repeated but now combined with other features. For instance, repeating the mentioned cup-grasping action may lead to the prediction of tasting coffee and thus trigger surprise if what one is drinking is actually tea.

Costs induced by partial feature overlap between two successive stimulus-response conjunctions have been demonstrated under various circumstances. For instance, performance is as good if both the shape of a stimulus and the location of a corresponding action are repeated than if both are alternated, whereas worse performance is obtained if the shape repeats a response alternates, or vice versa (Hommel, 1998, 2004; Hommel & Colzato, 2004; Keizer, Colzato, & Hommel, 2008). Importantly for present purposes, Hommel, Proctor, and Vu (2004) pointed out that partial-overlap costs are commonly confounded with the sequence of compatible and incompatible trials in the Simon task (and other conflict tasks). For instance, if a participant responds with a *left* button-press to a stimulus appearing on the *right*, this implies stimulus-response incompatibility (IC), whereas responding with the same key to a *left* stimulus, this would imply compatibility (C). Consider the case that these trials are followed by a compatible trial, such as a right button-press to a right stimulus. In the IC-C case (left|right → right|right), the right location is repeated. According to event file logic, this should reactivate the left response, which creates response competition. In the C-C case (left|left → right|right), on the other hand, both features alternate and no retrieval takes place. Comparing these two conditions, C-C should yield better performance than IC-C for reasons that are entirely unrelated to executive control issues—episodic retrieval in the IC-C condition simply induces more selection conflict than in the C-C condition.

Given that conflict tasks rely on the interrelationship of stimulus and response features, the confound between feature repetitions and the repetitions of compatibility conditions is to some degree unavoidable—at least if the original tasks are left more or less intact. Recent workaround solutions have improved the situation by introducing relatively more complex design versions. For instance, some studies have considered only those conditions where no stimulus or response feature is repeated (e.g. Akçay & Hazeltine, 2007) and, given that sequential effects

were still obtained, been taken to demonstrate purely executive effects. Even though this approach seems straightforward, it creates two somewhat related problems.

One problem is that excluding any feature overlap between two successive stimuli or stimulus-response episodes does not exclude proactive effects of episodic integration and retrieval (Dutzi & Hommel, in press). Consider stimuli that vary on two dimensions, such as the visual letters "X" and "O" appearing in red or green. According to available models of feature integration (e.g., Duncan & Humphreys, 1989; Treisman, 1988; Wolfe, 1992), processing a green "X", for instance, would lead to the competition between codes of the colors GREEN and RED and between codes of the shapes X and O. Collecting sufficient visual evidence should provide sufficient support for GREEN and X, which helps them to outcompete the possible alternatives. Now consider that you process the green X after having seen a red O. If having processed the red O led to the integration of the codes RED and O (Kahneman et al., 1992), they can be assumed to act as a unit and engage in what Duncan and colleagues have called "integrated competition" (Duncan, 1996; Duncan, Humphreys & Ward, 1997). This has advantages for the integrated unit if the stimulus it encodes is repeated but a competitive disadvantage if the stimulus changes: having integrated RED and O makes it easier to reject them as a unit (Duncan & Humphreys, 1989). Any loss of RED in the competition with GREEN will propagate to and thus weaken O as well, and losses of O in the competition with X will propagate to and weaken RED. Empirical evidence for this mechanism has been obtained in search tasks, where nontargets can be more easily rejected if they share features that do not overlap with the target, so that they can be grouped together and rejected as a group (Duncan & Humphreys, 1989). Also in line with expectations from an integrated competition approach is the observation that alternating all features and aspects of a stimulus or stimulus-response episode leads to performance that is as good as (e.g., Hommel, 1998) and

sometimes even better than performance with complete repetitions (e.g., Colzato, Fagioli, Erasmus & Hommel, 2005; Colzato, van Wouwe & Hommel, 2007a; Hommel & Colzato, 2004). In any case, it seems clear that avoiding feature overlap between successive trials does not allow one to exclude contributions from feature integration and episodic retrieval.

Another problem one runs into by restricting analyses to alternation trials is that this amounts to the selection of just one data point from what can be considered a least two-by-two interaction (repetition versus alternation of one feature and another). This implies the loss of statistical control over possible interactions between control processes and episodic effects. That this is a real problem is suggested by recent observations by Spapé and Hommel (2008). They had participants respond to high or low-pitched tones by saying "high" or "low", respectively, and ignore the simultaneously presented auditory word "high" or "low". Not surprisingly, this created a Stroop-like effect showing worse performance if the heard word was incompatible with the required response. The standard sequential modulation was also obtained, showing that the Stroop effect was reduced after incompatible trials. Importantly, however, this sequential modulation was only observed if the voice in the two successive trials was the same but not if the voice changed. This does not necessarily rule out that conflict control took place and affected successive trials if the speaker remained the same. Apparently, however, control information was integrated with the episodic context, of which the voice was a part of. If this episodic context was the same in the next trial, the previous event file including all the control adaptations was retrieved and could thus affect performance. If the context changed, however, episodic retrieval was prevented and so was the impact of previous adaptations on current control. Task-switching studies provide support for this interpretation. While switching to a new task is difficult in general (Allport, Styles & Hsieh, 1994), switching costs are particularly pronounced if the current stimulus was previously encountered in a

competing task (Waszak, Hommel & Allport, 2003). This suggests that stimuli and task information are integrated into episodic bindings that are retrieved if the stimulus is encountered another time—which is beneficial if the task has remained the same (as is usual in everyday life) but problematic if the task is different. Further converging evidence is provided by observations from sequential studies. Some authors have obtained conflict-adaptation-like result patterns after a task-switch only if the tasks had at least some overlap in terms of stimuli and responses (e.g., Kiesel, Kunde & Hoffmann, 2006). In the absence of any similarity between tasks, Notebaert and Verguts (2008) found no sequential effects, suggesting to them that conflict-monitoring acts *locally* (see also Blais, Robidoux, Risko & Besner, 2007).

To summarize, there are reasons to assume that at least some of the effects that are commonly taken to reflect adaptive control actually reflect stimulus-response integration and that these effects cannot be avoided entirely by restricting one's analyses to alternation trials. Moreover, even if adaptive control does take place, its proactive impact on subsequent behavior seems to depend on episodic retrieval, suggesting that control information is being integrated into episodic, context-sensitive event representations.

Aim of Study and Rationale

The aim of the present study was to investigate the relationship between adaptive control processes and episodic retrieval in producing sequential modulations in a conflict task, and to test the hypothesis that the former may depend on the latter. Instead of trying to get rid of episodic effects and see whether something is left to explain, the present study was based on the opposite logic. We used the standard Simon task, leaving its basic design and structure intact, and did not exclude conditions that may or may not be crucial for episodic retrieval. However, we did introduce a manipulation that arguably affects episodic retrieval without having any impact on control processes. If sequential effects

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would reflect adaptive control only, they should not be affected by these manipulations at all. If sequential effects would be due to a mixture of independently operating control and episodic processes, they should be weakened by our manipulation but still present. If, however, sequential effects would be entirely controlled by, or at least be contingent on episodic retrieval, we should be able to eliminate sequential modulations by manipulating retrieval. This is what we tried to do in the following two experiments, but let us first introduce our episodic manipulation.

In their classical study on feature integration, Kahneman et al. (1992) provided evidence that feature bindings can "move" with the object they represent. They presented participants with preview displays consisting of a number of letters appearing inside boxes and found that, as mentioned already, repeating one of those letters yielded particularly good performance if it also appeared in the same box. Interestingly for our purposes, this was the case even if all the boxes moved between the presentation of the preview letters and the eventual target, suggesting that the letters remained represented as part of the boxes and thus, cognitively speaking, moved with them. Letters and boxes were apparently bound into enduring object representations that were updated when the boxes moved, even if the letters were currently not visible, and retrieved as a unit when a letter reappeared. That object representations survive movements of the objects they represent is also suggested by the observation that multiple objects can be concurrently tracked (e.g., Blaser, Pylyshyn, & Holcombe, 2000). For instance, when a subset of a larger number of squares is briefly flashed to indicate their role as targets, participants are well able to track up to four of them through their rather complex movements across a display.
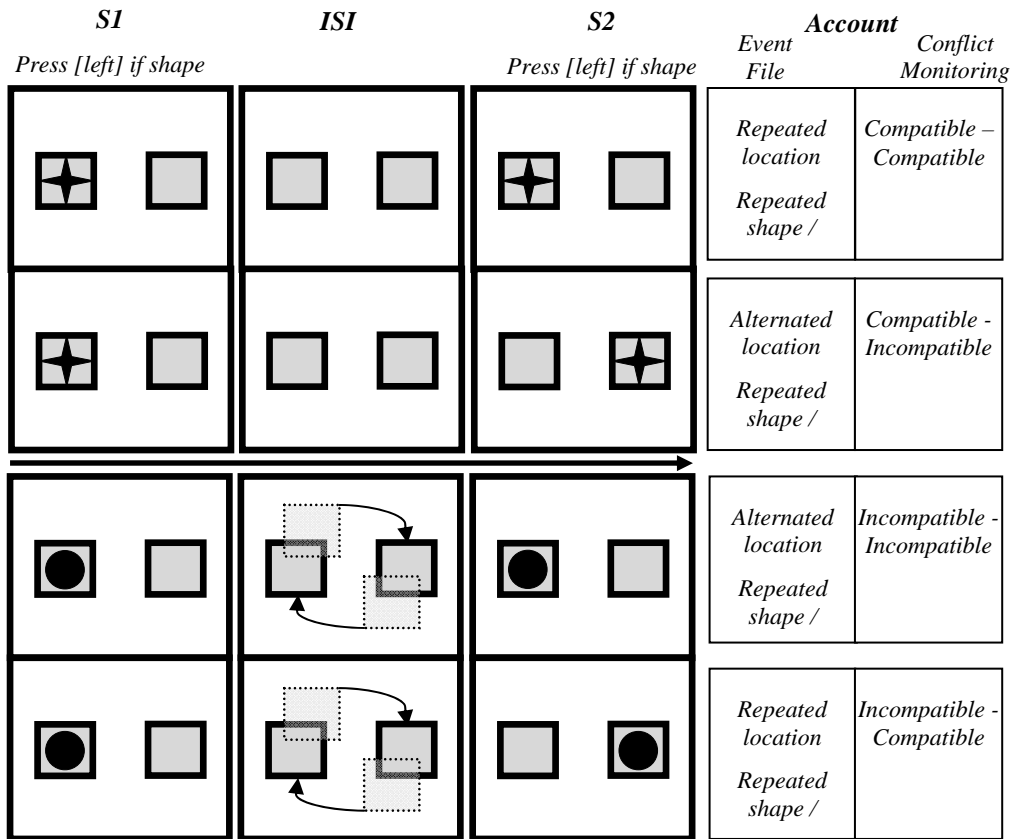
S1	ISI	S2	Account	
			Event File	*Conflict Monitoring*
Press [left] if shape		*Press [left] if shape*		
			Repeated location *Repeated shape /*	*Compatible – Compatible*
			Alternated location *Repeated shape /*	*Compatible - Incompatible*
			Alternated location *Repeated shape /*	*Incompatible - Incompatible*
			Repeated location *Repeated shape /*	*Incompatible - Compatible*

Figure 1: Sequence of events in a single trial and coding in terms of event files and conflict-monitoring.

In the present study, we made use of people's ability and spontaneous tendency to track objects across space and to update object-related feature bindings accordingly. Consider the situation depicted in the first row of Figure 1. In the first of a pair of trials the participant is presented with a star to signal a left-hand keypress. The star appears in the left of the two boxes displayed, which makes this a stimulus-response compatible trial. In the following trial, the star appears again to signal a left-hand keypress and it again appears in the left box. As this is also a compatible trial, the sequence of these two stimuli and responses (S1-

R1 and S2-R2) falls into the C-C category. In the next row, S1 and R1 are the same but they are followed by the star (still signaling a left-hand keypress) appearing in the right box. This makes the second member of the trial pair incompatible and the sequence falls into the C-I category. Other conditions can be easily constructed along the same lines (see rows 3 and 4 for more examples) and we in fact investigated all four types of sequences of compatible and incompatible trials. In all these conditions, predictions from control approaches and an event file approach are just as indistinguishable as in many other preceding studies. Accordingly, we would expect to find the standard pattern of a smaller Simon effect after incompatible than after compatible trials, but would not be certain whether this is due to adaptive control or episodic retrieval or both.

More interesting is the manipulation that is sketched in the two lower rows of Figure 1 (which again applied to all four types of sequences of compatible and incompatible trials). Stimulus presentation and response requirements were unchanged but the two boxes on the screen were rotated by 180° around the screen center in the inter-trial interval. There is no reason to assume that this would affect control processes: if registering conflict upon R1 selection suppresses or prevents the processing of stimulus location on S2 presentation, this should not be affected by the presence or absence of a rotation of actually task-irrelevant boxes in between two trials. From an episodic approach, one would expect rotation to have a strong impact on sequential effects. Let us consider the example depicted in the third row. In both parts of the double trial, a circle signals a right-hand key-press but appears in the left box, which makes both trials incompatible. From a control view, this implies that the sequence falls into the category I-I, which leads us to predict a smaller Simon effect on R2 in this condition as compared to the sequence C-I as shown in the second row.

From an episodic view, one of two alternative predictions can be derived. Following Kahneman et al. (1992), one may assume that rotating the boxes leads to

an update of the object representation that codes S1 from {CIRCLE↔LEFT} to {CIRCLE↔RIGHT}—given that the box in which the circle appeared on S1 presentation is now moved to the right. If so, seeing the circle to fall into the left box on S2 presentation would amount to a partial feature mismatch: the shape repeats but the location alternates. This would turn the relative benefit obtained without rotating boxes (which produces a complete repetition) into a partial-overlap cost. In contrast, sequences that without the moving boxes would result in partial feature overlap, as the one depicted in the lowest row, would be turned into complete repetitions or "complete" alternations (e.g., if a left circle is followed by a left star, or vice versa). In a recent paper (Spapé & Hommel, in press), we showed that moving an object does not only move all of its features with it (in the sense that even currently invisible features are spatially updated) but also the actions linked to that object.

In other words, episodic traces of previous actions are apparently accessed via representations of the object they operated on, so that the action in a sense moves with the representation of the object. This would imply that all the effects observed under static conditions should reverse in sign. Note that this prediction presupposes that moving the boxes consistently induces a complete update of all aspects of object representations or event files, so that the content of the original file created upon R1 execution is entirely overwritten. However, recent observations suggest that this may not be what happens in tasks such as those investigated here. Rather, people seem to maintain the original file representing the stimulus-response relationship before the rotation and create a second, updated file after the rotation, so that the effects of reversals of features (such as if left is turned into right) tend to cancel each other out (Spapé & Hommel, in press). If so, one would expect rotations to eliminate sequential effects rather than to reverse their signs. In any case, however, the event file approach would predict a substantial effect of box rotation whereas the control approach would not.

To summarize, the rationale underlying this study was that bridging the gap between research on object tracking and on event coding would help to better understand the relationship and possible contingencies between conflict control and episodic retrieval. In the following, we will introduce and test the basic paradigm in Experiment 1 and show that conflict-adaptation patterns drastically change when a conflicting stimulus is "mentally" repositioned.

Experiment 1

In a Simon task, participants respond to a non-spatial stimulus feature by carrying out a left or right response, whilst ignoring the irrelevant location of the stimulus. In our version, participants responded to circles and stars by pressing a left or right key. The stimuli appeared in the left or right of two constantly visible boxes. Trials were presented in pairs, so that one circle or star was presented (S1) and responded to (R1) before a second circle or star (S2) appeared to signal a second response (R2). The boxes remained visible in between the two trials of a pair and they were rotated by 180° in 50% of the trials. Based on Kahneman et al. (1992), we assumed that the target stimuli would integrate with the box they appear in and thus be "mentally rotated" with it—turning left stimuli into right stimuli, and vice versa. We further assumed that actions would also be integrated with the boxes and the features having appeared therein (Spapé & Hommel, in press). Hence, carrying out a left-hand action to a left stimulus would create an event file linking a LEFT stimulus code ($LEFT_s$) to a LEFT response code ($LEFT_r$). If then rotating the boxes would turn the $LEFT_s$ code into a $RIGHT_s$ code, this would result in a representation that links a RIGHT stimulus code to a LEFT response code $\{RIGHT_s \leftrightarrow LEFT_r\}$. If so, responding with a left-hand response to a stimulus on the right would now imply a complete match, whereas repeating the physical stimulus and response locations would imply a partial mismatch.

Given the presence of two approaches that differ with respect to the factors they consider relevant, we analyzed our data in two ways. In the first

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analysis, which we in the following will call the Conflict-Control analysis, we analyzed the data in terms of the sequence of compatibility conditions, testing whether the effect of compatibility on S2-R2 would be modulated by the compatibility of S1 and R1. In view of the available evidence, we expected that such a modulations would exist, showing a reduced or even eliminated S2-R2 compatibility effect after incompatible S1-R1 trials. The main question here was whether rotation, a factor that should be meaningless from a conflict-control point of view, would affect the interaction between S2-R2 compatibility and S1-R1 compatibility.

The second analysis, which we will call the Event-File analysis, concerned the data from a feature integration point of view and tested whether the effects of response repetition (which was confounded with shape repetition) and stimulus-location repetition would interact. Here we expected the standard partial-repetition cost pattern: complete repetitions and alternations should produce better performance than repeating the response but not the stimulus location, or vice versa (Hommel et al., 2004). Of particular theoretical interest was whether rotation would tend to eliminate these effects (as the two-event-files account of Spapé and Hommel, in press, would suggest) or even reverse their sign (as a one-file extension of the approach of Kahneman et al., 1992, might imply).

Table 1*: Summary of predicted effects under the paradigms of conflict-adaptation and feature integration. Conflict-adaptation is based on the compatibility (C) or incompatibility (I) of the first stimulus (S1) and its pro-active effect on the second stimulus (S2). A compatible stimulus followed by an incompatible stimulus (i.e. C-I) is predicted to result in slow reaction times. Effects of feature integration are related to the repetition (R) or alternation (A) between the stimuli's location- and response characteristics. If the location alternates (L:A) between two stimuli whilst the response is repeated (R:R), reaction times are predicted to be slow – unless the stimulus-display rotates in between S1 and S2 (as with trial types 5–8)*.

	S1		ISI	S2		Effects	
Type	*Location*	*Response*	*Rotation*	*Location*	*Response*	*Conflict-Adaptation*	*Feature integration*
1	*Left*	*Left*	*Static*	*Left*	*Left*	*C-C: fast*	*L:R-R:R: fast*
2	*Left*	*Right*	*Static*	*Right*	*Left*	*I-I: fast*	*L:A-R:A: fast*
3	*Left*	*Left*	*Static*	*Right*	*Left*	*C-I: slow*	*L:A-R:R: slow*
4	*Left*	*Right*	*Static*	*Left*	*Left*	*I-C: slow*	*L:R-R:A: slow*
5	*Left*	*Left*	*Rotating*	*Left*	*Left*	*C-C: fast*	*L:R-R:R: slow*
6	*Left*	*Right*	*Rotating*	*Right*	*Left*	*I-I: fast*	*L:A-R:A: slow*
7	*Left*	*Left*	*Rotating*	*Right*	*Left*	*C-I: slow*	*L:A-R:R: fast*
8	*Left*	*Right*	*Rotating*	*Left*	*Left*	*I-C: slow*	*L:R-R:A: fast*

Method

Participants

Eighteen students from Leiden University voluntarily participated in this experiment for a small fee or course credits.

Apparatus and stimuli

Stimuli were presented on a flat-screen 17" CRT monitor in 800 x 600 pixels resolution and a refresh-rate of 120 Hz. A Pentium-IV dual 1.67 GHz PC running E-Prime (1.1, SP3) on Windows XP SP2 controlled stimulus-presentation and recorded reactions via the USB connected keyboard. Target-containing boxes were gray (RGB value of 128, 128, 128), black-lined squares of 60 x 60 pixels or approximately 32 x

32 mm presented against a silver (RGB value of 191, 191, 191) background. The target itself was also 60 x 60 and was either a circle or a four-pointed star. Boxes were presented 180 pixels (approximately 96 mm) left and right from the centre of the screen and also kept at this distance during the gradual shifts in location.

Procedure

As outlined in Fig. 2, a fixation cross was presented for 500 ms, after which the two boxes were presented in the left and right of the screen, one of them containing the target shape (S1) to which participants were required to respond. After 500 ms, the targets were no longer shown on the screen. In the "static" condition, the boxes stood still, without targets, for 800 ms, whereas in the rotating condition, they rotated around their axis at a speed of approximately 4 degrees with each 44 ms. After the 800 ms, both in the static condition and the rotating condition, the boxes were presented for another 200 ms before the second target (S2) was presented. S2 was shown for 700 ms before a screen with feedback informed the participant of the performance. This last screen also comprised the inter-trial interval and was shown for 1100 ms.
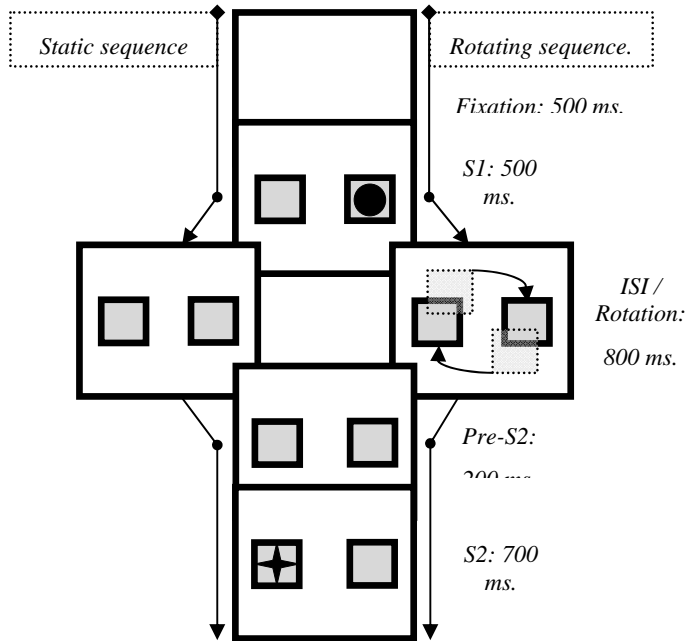
Figure 2: Schematic depiction of the trial-sequence of two example trials. After presenting a fixation crosshair, two boxes were presented for 500 ms in the left and right of the screen, one containing the shape (S1) to which participants were required to respond. In the "static" condition (left), an inter-stimulus interval (ISI) followed in which the boxes stood still for 800 ms, whereas in the rotating condition, they rotated around their axis during this ISI. In both conditions, the boxes were statically presented for another 200 ms before the second target (S2) was shown. S2 was shown for 700 ms before an inter-trial interval of 1100 ms ended the trial.

Following the instruction, the first 20 trials of the experiment were considered practice of acquiring the mapping between circles or stars with a <Q> or <P> keypress. Half of the participants were to press <Q> for stars and <P> for circles, the other half received the opposite stimulus-response mapping. They were required to respond as quickly and accurately as possible and were shown a personal score next to a high score which they were encouraged to break. Getting

points could only be done by responding both fast (1 point for each reaction below 600 ms) and accurately (1 point for each accurate reaction) and although breaking the high score was not reinforced with any kind of monetary or other incentive; most participants did indicate being positively motivated to aim for a (fictional, computed as 3 × number of trials) high score. The experimented lasted about 30 minutes.

Design

Results were coded so as to analyze them with two different three-factor repeated measures designs. First, predictions from the conflict adaptation approach were tested by considering rotation (static versus rotating), compatibility of the first stimulus and response, and compatibility of the second stimulus and response. Second, predictions from the event coding approach were tested by considering rotation, shape/response repetition, and stimulus-location repetition. For both types of analyses, the eight design cells resulting from crossing these factors were replicated an even 32 times. The four blocks consisted of the 64 possible, randomly presented, combinations of rotation (versus non-rotation), direction of rotation (clockwise versus counter-clockwise), target shapes (in S1 and S2) and the location of the targets (in S1 and S2).

Results

Responses with latencies longer than 1000 ms were not considered, and all incorrect reactions to S1 or S2 were excluded from RT analyses. Few errors were made during S1 (M = 6.7%, SD = 5.7%) and S2|S1 (M = 4.3%, SD = 2.7% of the remaining correct responses).

Conflict-Control analysis

In a repeated measures analysis of variance on the RT to S2 with rotation, S1 compatibility and S2 compatibility as factors, reactions were some 30 ms faster after seeing the boxes rotate, $F(1, 17) = 52.09$, MSe = 31661.46, $p < .001$, while error rates were not affected, $F(1, 17) = 2.03$, MSe = .01, p > .1. Compatibility on S1 had no effect on RT, $F(1, 17) = .08$, MSe = 34.73, p > .7, but increased accuracy, $F(1, 17) = 4.54$, MSe = .01, p < .05. Participants were 30 ms slower if S2 and R2 were incompatible, $F(1,17) = 73.05$, MSe = 32753.76, $p < .001$, and made 4% more errors, $F(1, 17) = 24.784$, MSe = .06, p < .001. The conflict-adaptation-type effect was replicated, as evidenced by a significant interaction between S1 compatibility and S2 compatibility on RT, $F(1,17) = 25.49$, MSe = 16578.71, $p < .001$, and errors, $F(1, 17) = 21.11$, MSe = .02, p < .001: The compatibility effect was larger after compatible than incompatible trials. Indeed, on static trials, the Simon effect was significantly *inverted* after incompatible trials, $t(17) = 2.27$, p < .04, although not for errors, $t(17) = .29$, p > .7. However, this effect was modulated by rotation in both RTs, $F(1,17) = 40.93$, MSe = 14174.49, $p < .001$, and errors, $F(1, 17) = 12.63$, MSe = .02, p < .005. To test the effect of conflict-adaptation under static and rotating conditions, two t-tests of the interactions between S1 and S2 compatibility were computed. Whereas the interaction between S1 compatibility and S2 compatibility was very pronounced and reliable with static boxes, RTs: $t(17) = 6.17$, p < .001), errors: $t(17) = 4.72$, p < .001), it entirely disappeared with rotating boxes, RTs: $t(17) = .50$, p > .6, errors: $t(17) = .59$, p > .5, see Table 2a.

Table 2a. *Experiment 1, compatibility and conflict-adaptation results. Reaction times, error rates and standard errors (in parentheses) for S2 (the probe or "current trial") as a function of S1 compatibility, S2 compatibility, and rotation. Effect sizes to the right show the compatibility (Simon) effect and how it is affected by preceding (S1) compatibility. The conflict-adaptation effect is measured as the degree to which the compatibility-effect of S2 is attenuated after incompatible S1s.*

	S1	Compatible (C)		Incompatible (IC)		*Compatibility effect* after C	after I	*Conflict* Adaptation
	S2	C	I	C	I	CI - CC	II - IC	(CI - CC) - (II - IC)
			Reaction times					
Static		448 (9)	515 (15)	489 (13)	473 (11)	66	-16	83
Rotating		432 (10)	469 (12)	436 (12)	470 (11)	37	34	3
			Error rates					
Static		2 (1)	11 (2)	4 (1)	3 (1)	9	0	10
Rotating		2 (1)	6 (1)	2 (1)	5 (1)	4	3	1

Event-File analysis

Rotation had a comparable effects here, both on RTs, $F(1, 17) = 52.39$, MSe $= 32831.63$, *p* $< .001$, and errors, $F(1, 17) = 2.23$, MSe $= .01$, p $> .2$. The only other main effect indicated that responses were faster if the shape/response was repeated, $F(1, 17) = 18.77$, MSe $= 15887.34$, p $< .001$. As expected (Hommel et al., 2004), stimulus-location repetition interacted significantly with shape/response repetition in RTs, $F(1, 17) = 25.34$, MSe $= 17916.27$, p $< .001$, and errors, $F(1, 17) = 23.84$, MSe $= .03$, p $< .001$. The standard cross-over interaction indicated that performance was better with complete repetitions and alternations than with partial-repetitions (see Table 2b). In other words, performance was good if stimulus shape, stimulus location, and the response was repeated or if all three features changed, but comparatively bad if shape and response were repeated while stimulus location alternated or if shape and response alternated while stimulus location repeated. This interaction was further modified by rotation in both RTs,

F(1, 17) = 43.47, MSe = 14077.43, p < .001, and errors, F(1, 17) = 12.83, MSe = .02, p < .005. As shown in Table 2b, partial-repetition costs and, thus, the interaction of location and shape/response repetition) were restricted to static boxes and disappeared with rotating boxes. Interestingly, overlap costs were not negative in the rotation condition.

Table 2b. *Reaction times, error rates and standard errors (in parentheses) for responses to S2 (the probe or "current trial") as a function of rotation, S1-S2 location- and response-repetition. Effect sizes to the right show response-priming effects and how they are modulated by location-repetition. Partial Overlap-costs (the effect of repeating only the location or response between S1 and S2) were measured as the difference between response-priming effects of location-repetitions (Loc. R) and location-alternations (Loc. A).*

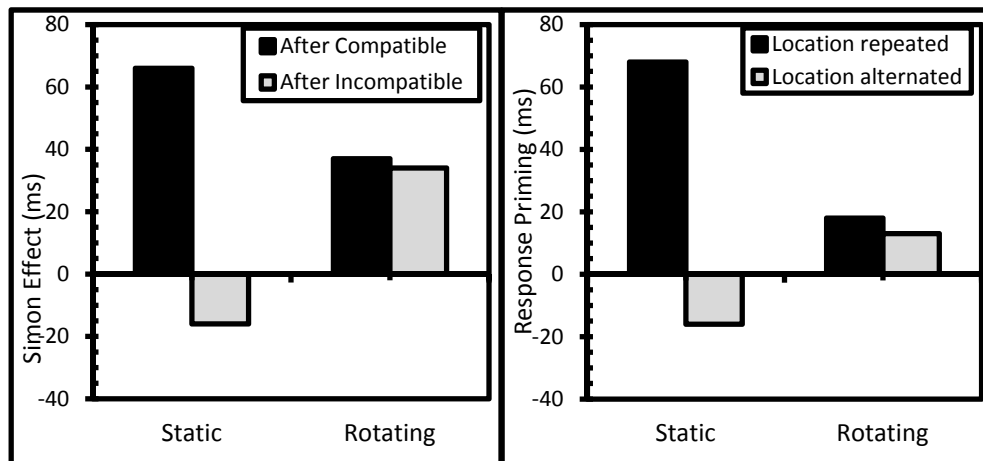| | Location | | | | Response Priming | | Partial |
	Repeated (R)		Alternated (A)		Loc. R	Loc. A	Overlap-costs
Response	R	A	R	A	RA - RR	AA - AR	(RA-RR) - (AA-AR)
	Reaction times						
Static	451 (9)	519 (15)	487 (14)	470 (12)	68	-16	84
Rotating	441 (7)	460 (13)	446 (10)	459 (13)	18	13	5
	Error rates						
Static	2 (1)	8 (2)	7 (2)	3 (1)	5	-5	10
Rotating	3 (1)	4 (1)	4 (1)	4 (1)	1	0	0

Fig. 3: Results experiment 1: Effects of rotation on sequential Simon effects (left) and event-coding (right). Conflict-adaptation was measured as the reduction in Simon effect after incompatibility. Event-coding effects were measured as the decrease in response-priming benefits if the location did not repeat along with the required response.

Discussion

The outcome of Experiment 1 is rather clear-cut. With static boxes, we replicated the earlier finding that the Simon effect is larger after compatible than incompatible trials (Stürmer, Leuthold, Soetens, Schröter & Sommer, 2002). From a conflict-monitoring perspective, it has often been suggested (cf. Stürmer et al., 2002) that Simon stimuli are processed via two pathways from perception to action: an automatic route, based on an automatic triggering of the response by the location of the stimulus (Simon, 1969) and a voluntary route, based on the task requirements (Kornblum, Hasbroucq & Osman, 1990). Detecting a conflict may trigger the gating or blocking of the automatic route (Botvinick et al., 1999), which would predict less or no Simon effect after incompatible trials. This account fails to account for the *reverse* Simon effect after incompatible trials that was encountered in the present and other previous studies. Alternatively, the automatic route may be actively suppressed, as suggested by Ridderinkhof (2002), which could account for reverse Simon effects after incompatible trials. In any case, our findings for

static conditions are consistent with at least some versions of the conflict-control approach.

The rotation conditions, however, during which the sequential effects disappeared altogether, are harder to fit in such models. Since the boxes themselves are unlikely to cause any conflict, and as they do not even contain any targets while being rotated, there is no reason why moving the boxes should have any effect on conflict-adaptation. Accordingly, we see no way how conflict-monitoring theories can account for our observations. Would the sequential effects have been only smaller (but not absent) in the rotation condition, one could have argued that they consist of an adaptation component and an independently operating episodic component—with the latter being eliminated and the former being constant. Given the total elimination of the effect, however, this does not seem to be an option.

From an event-file perspective (Hommel, 2004; Hommel et al., 2001) the outcome pattern makes more sense. As predicted, rotating the boxes strongly affected the interactions between stimulus- and response-repetition effects. To the degree that these interactions reflect the creation and later retrieval of feature bindings, this suggests that rotation at least co-determined how the features were coded. In the introduction to Experiment 1, we considered two possible scenarios of how that might work. The first extended Kahneman et al.'s (1992) logic to event files that contain response information and holds that R2 performance is affected by the retrieval of one event file only. In particular, it assumes that rotating the boxes leads to an update of the event file that had just been formed to represent the S1-R1 episode: left stimulus codes are turned into right and right stimulus codes into left codes. If so, the event-file analysis should show positive partial-overlap costs under static conditions and negative costs under rotation conditions. This was clearly not the case, supporting the claim of Spapé and Hommel (in press) that updating is only part of the story.

The second scenario assumed that two events files are affecting R2 performance under rotation conditions: one that codes the original S1-R1 episode and another that represents the post-rotation state of affairs. Given that the spatial stimulus codes in these two files are always inconsistent their effects will tend to cancel each other out. If so, one would expect positive partial-overlap costs under static conditions costs around zero with rotation. This is exactly the pattern we have obtained, suggesting that the two-file account is more realistic.

To summarize, Experiment 1 provides evidence that, at least under the conditions tested here, sequential modulations of Simon effects are entirely due to episodic binding and retrieval. There is one fly in the ointment however: Although the null effect of event coding in the rotation condition may result from the counteracting effects from two event files, we have no direct evidence that it does. Rather than creating a second, updated file when the boxes move, the cognitive system may simply erase the previous (or any) file whenever a movement or any other dramatic change of the visual display is encountered (Zacks, Speer, Swallow, Braver & Reynolds, 2007). What is therefore needed is positive evidence that event files are actually updated and that the updated files actually affect performance—evidence that we attempted to provide in Experiment 2.

Experiment 2

In Experiment 2 we also rotated the boxes in which stimuli appeared in between S1 and S2 presentation. Two of the three rotation conditions conceptually replicated Experiment 1: A 0-degree rotation condition corresponded to the static condition of Experiment 1, in which the boxes were not moving, and a 180-degree rotation condition corresponded to the rotation condition of Experiment 1. The outcomes of these two conditions were expected to replicate the basic finding that conflict-adaptation-type effect should be restricted to the 0-degree condition and be eliminated in the 180-degree rotation condition. The more important manipulation, however, was the introduction of a third rotation condition. Here, the boxes were rotated only 90 degrees, so that boxes did not overlap between S1 and S2 displays. S2 could still appear either in the same box (e.g., in the location towards which the box where S1 appeared was rotated) or in the other box (i.e., in the location opposite to the box where S1 appeared was rotated). However, given that the 90-degree rotation always moved the boxes to locations that were not occupied by the boxes in the S1 display, old and new event files could no longer cancel each other out. Accordingly, their effects should be reliable and more pronounced than in the 180-degree condition.

Method

Twenty-two students from Leiden University between the age of 19 and 25 volunteered for a small fee or course credits. The procedure was the same as in Experiment 1, except that S1 and S2 could also appear above and below the screen center, that the boxes could be rotated by 0, 90, or 180 degrees, and that the rotation could take 800 or 1200 ms (a factor that was introduced for reasons unrelated to the present study and that therefore was not considered further in the analyses). The two boxes could thus be either horizontally or vertically oriented in both the S1 and S2 displays, which created four types of transition: horizontal-to-horizontal (H-H) and vertical-to-vertical (V-V), the two 180-degree conditions, and

horizontal-to-vertical (H-V) and vertical-to-horizontal (V-H), the two 90-degree conditions. The experiment lasted about forty minutes.

Results

Trials with incorrect responses to S1 (11.6%) were excluded from the error analyses, and trials with incorrect responses to S1 or S2 (another 11.6%) were excluded from RT analyses.

Conflict-Control analysis

The factors were again rotation (rotated vs. static) and compatibility of S1 and S2 (compatible vs. neutral vs. incompatible), where the compatible and incompatible conditions were taken from the horizontal displays and the neutral conditions from the vertical displays. In repeated measures ANOVAs, S1 compatibility approached significance in RTs, $F(2, 42) = 3.01$, MSe = 575.99, $p < .07$, but not in error proportions, $F(2, 42) = .79$, MSe = .002, $p > .7$; while S2 compatibility had a significant effect on both RTs, $F(2, 42) = 42.82$, MSe = 20235.00, $p < .001$, and errors, $F(2, 42) = 48.85$, MSe = .21, $p < .001$. Participants were 15 ms faster with rotating trials, $F(1, 21) = 26.19$, MSe = 13974.68, $p < .001$, but not more often correct, $F(1, 21) = 1.75$, MSe = .01, $p > .2$. Rotation modulated the effect of S1 compatibility, $F(2, 42) = 4.55$, MSe = 626.31, $p < .02$, for RTs, but not errors, $F(2, 42) = .46$, MSe = .001, $p > .6$. The standard conflict-adaptation pattern was found for RTs, $F(4, 84) = 10.54$, MSe = 2521.80, $p < .001$, and errors, $F(4, 84) = 8.60$, MSe = .03, $p < .001$, with larger S2 compatibility effects after compatible than incompatible S1 (effect sizes: 39 ms and 13% as opposed to 12 ms and 2% respectively). Adaptation-type patterns after a neutral S1 were in between (24 ms, 7%). The three-way interaction was also significant in RTs, $F(4, 72) = 14.65$, MSe = 3527.93, $p < .001$, again showing that rotation eliminated all adaptation-type effects: strong conflict-adaptation was found under static conditions, RTs: $t(21) =$

5.57, p < .001, errors: t(21) = 4.59, p < .001, but insignificant under rotating conditions, RTs: t(21) = -1.10, p > .1, errors: t(21) = .15, p > .8.

Table 3a: *Experiment 2, compatibility and conflict-adaptation results. Reaction times, error rates and standard errors (in parentheses) for responses to S2 as a function of S2 compatibility, S1 compatibility, and rotation. Effect sizes to the right show how the compatibility effect is affected by preceding (S1) compatibility (see table 2a). Note that Neutral S1s indicate trials in which the stimuli were vertically aligned.*

		S2			Conflict	Conflict Adaptation
Rotation	S1	Compatible	Incompatible	Neutral	C - I	(CI-CC) − (II-IC)
		Reaction times				
	Compatible	378 (4)	428 (9)	410 (6)	51	
Static	Incompatible	415 (9)	405 (7)	418 (8)	-10	61
	Neutral	402 (6)	428 (7)	406 (6)	26	
	Compatible	386 (5)	413 (6)	396 (6)	27	
Rotating	Incompatible	379 (5)	412 (6)	398 (6)	33	-6
	Neutral	389 (5)	411 (6)	399 (6)	22	
		Error rates				
	Compatible	2 (1)	19 (3)	6 (2)	17	
Static	Incompatible	10 (2)	6 (2)	5 (1)	-4	21
	Neutral	3 (1)	11 (2)	8 (1)	7	
	Compatible	3 (1)	12 (2)	6 (1)	9	
Rotating	Incompatible	4 (1)	12 (2)	5 (1)	8	0
	Neutral	4 (1)	11 (1)	5 (1)	8	

Event-File analysis

To establish whether we were able to replicate our findings of experiment 1, we conducted repeated measures ANOVAs with rotation (rotated vs. static), location-repetition and response-repetition on the conditions where the displays were horizontally aligned and rotated either 180 degrees or not at all. Rotation had a significant effect on RTs, $F(1, 21) = 19.65$, MSe = 7459.94, $p < .001$, and a marginally significant effect on errors, $F(1, 21) = 4.19$, MSe = .03, $p < .06$, with rotated conditions being 13 ms faster and 2.7% more often correct. Location repetitions were slightly (7 ms) slower, $F(1, 21) = 12.33$, MSe = 2404.12, $p < .005$, but not less often accurate, $p > .6$, than location alternations, whereas response repetitions were significantly faster (10 ms), $F(1, 21) = 5.81$, MSe = 4536.24, $p < .03$, but not more often accurate, $p > .2$, than response alternations. In a similar fashion to experiment 1, response-repetition interacted significantly with location-repetition for both RTs, $F(1, 21) = 42.02$, MSe = 13192.65, $p < .001$, and errors, $F(1, 21) = 24.17$, MSe = .24, $p < .001$, the effect of which itself was modulated by rotation for RTs, $F(1, 21) = 29.89$, MSe = 13046.56, $p < 001$, and errors, $F(1, 21) = 16.23$, MSe = .16, $p < .001$. These findings replicate our observations in Experiment 1 and confirm that they represent a robust pattern.

The next analysis compared the two rotation conditions, which required us to recode the data. We compared trials where S1 location (i.e., the box that contained S1) was *rotated towards* the location of the upcoming S2 (e.g., if S1 appeared in the top box, this box was rotated to the right, and S2 appeared in the right box) with trials where the box holding S1 was *rotated away* from the location where S2 would appear (e.g., if S1 appeared in the top box, this box was rotated to the right, and S2 appeared in the left box). ANOVAs were run with the factors shape/response repetition (repetition vs. alternation), direction of rotation (towards vs. away the location of S2), and degree of rotation (0 degree vs. 90 degree—taken from V-H and H-V transitions –vs. 180 degree—taken from V-V and

H-H transitions). Repeated responses were faster, $F(1, 21) = 7.28$, MSe = 3347.00, p < .02, but not more accurate, $F(1, 21) = .001$, MSe = .00, p > .9. Direction of rotation had no effect on RT, $F(1, 21) = .09$, MSe = 9.83, p > .7 or errors, $F(1, 21) = .01$, MSe = .00, p > .9. Degrees of rotation had no effect on RT, $F(1, 21) = .10$, MSe = 9.09, p > .7, but had a small effect on errors, $F(1, 21) = 6.32$, MSe = .00, p < .03, with 90-degree rotations eliciting 1.0% more errors than rotations of 180 degrees. More importantly, shape/response repetition significantly interacted with direction of rotation in RTs, $F(1, 21) = 6.76$, MSe = 752.28, p < .02, and marginally in errors, $F(1, 21) = 3.13$, MSe = .00, p < .09. While rotations towards the target location generally resulted in (4 ms) faster, more (0.7%) accurate reactions than with rotations away with repeated shapes/responses, rotations away yielded (5 ms) faster, more (0.6%) accurate responses than rotations towards with alternated shapes/responses. This effect itself, however, was modulated by the degrees of rotation, for both RTs, $F(1, 21) = 7.82$, MSe = 436.06, p < .02, and errors, $F(1, 21) = 8.57$, MSe = .01, p < .01. Post-hoc tests comparing the partial-repetition costs (see table 3b for calculus) for the 90 and 180 degrees revealed that partial-repetition costs were larger for both RTs, $t(21) = 2.80$, p < .02, and errors, $t(21) = 2.93$, p < .01, with rotations of 90 degrees than with rotations of 180 degrees (see table 3b).

Table 3b. *Experiment 2, response-priming and Event-file results. Reaction times, error rates and standard errors (in parentheses) for S2 as a function of degrees of rotation ($0°$ degrees indicating static conditions), response-repetition and (rotated) location. Note that, different from table 2b, rotating is either "towards" – as with conditions where the box containing the stimulus in S1 gradually rotated towards the location in which S2 was presented – or "away" – under conditions in which the box containing S1 rotated away from the location in which S2 was presented. Thus, with rotations of $0°$, rotating towards and away are tantamount to location-repetitions and alternations respectively.*

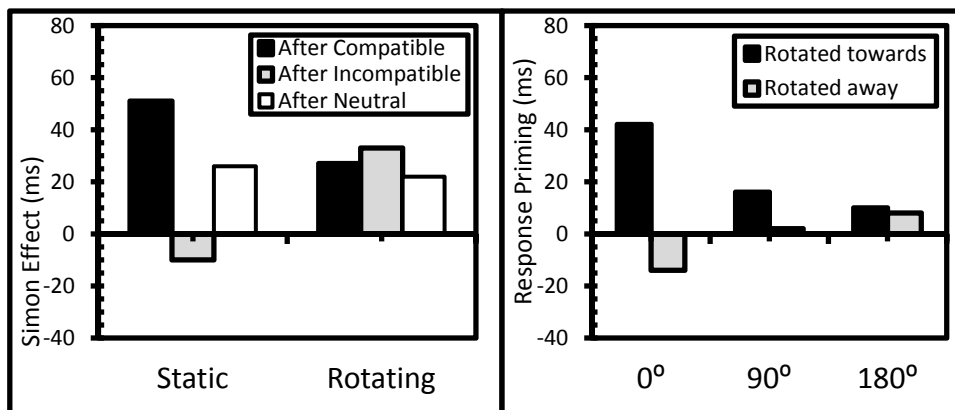| | | Location / Rotation | | | Response Priming | | Partial Repetition Costs |
		Towards (R)		Away (A)	Loc. R	Loc. A	
Response	R	A	R	A	RA - RR	AA – AR	(RA-RR) - (AA-AR)
Degrees		Reaction times (ms)					
0°	385 (5)	427 (8)	403 (7)	389 (8)	42	-14	56
90°	391 (5)	407 (7)	398 (6)	399 (6)	16	2	15
180°	394 (5)	403 (6)	394 (5)	402 (7)	10	8	2
Degrees		Error rates (%)					
0°	2 (1)	20 (3)	10 (2)	4 (1)	18	-6	24
90°	5 (1)	8 (1)	7 (1)	6 (1)	3	-1	4
180°	7 (1)	5 (1)	6 (1)	5 (1)	-2	0	-2

Figure 4: Results experiment 2: Effects of rotation on sequential Simon effects (left) and event-coding (right).

Discussion

The findings of Experiment 2 demonstrate that the degree of rotation matters and that, as expected, the 90-degree rotation condition produces stronger binding effects. The results of Experiment 1 showed that after rotating the stimulus display for 180 degrees, both conflict-adaptation and partial-repetition costs were reduced to numbers around zero. Following Spapé & Hommel (in press), we employed a design in Experiment 2 in which the boxes rotated for 90 degrees, yielding two conditions in which presentations either rotated from neutral *to* conflicting or vice versa. Although the conflict-control analysis essentially had no clear predictions for these conditions, we predicted partial-repetition costs due to the rotated position of the stimuli being not repeated in a lower-level manner.

One might argue, however, that the results of Experiment 2, merely show that rotation in and of itself reduces feature-integration, and/or conflict-adaptation. The results of experiments 1 and 2 suggested that this may be so, since partial-repetition costs were found to be smaller with each 'extra degree of rotation': from a sizable 80 ms in 0° (i.e. static) conditions, via a smaller but significant 15 ms in 90° conditions to insignificant near-zero in 180° conditions. Thus, one could argue that the more the boxes rotate, the lesser be the binding. Likewise, rotation itself could have disrupted conflict adaptation, as after rotating the boxes, no conflict-adaptation was found. If rotation in and of itself eliminates both conflict-adaptation and feature-integration, however, this would predict that partial-repetition costs, nor conflict-adaptation should occur after rotating the boxes 360°. In our third experiment, we sought to test this hypothesis.

Experiment 3

In Experiment 3, the boxes in which stimuli appeared were rotated in similar fashion to Experiment 1, thereby again conceptually replicating two of the three rotation conditions: in one third of the trials, the boxes did not move at all

(the static condition of Experiment 1 or the 0-degree condition of Experiment 2) and in another third of the trials, they rotated 180-degrees. Crucially for this experiment, however, was the new 360-degrees condition in which the boxes rotated fully around their axis. Thus, if a conflict-inducing stimulus first appeared left, it would rotate to its original location. If rotating itself eliminates conflict-control, no conflict-adaptation was predicted after a 360-degrees rotation. However, if conflict-adaptation would depend on episodic retrieval, significant conflict-adaptation should still be present.

Method

Twenty students from Leiden University between the age of 18 and 27 volunteered in exchange for course credits or money. As in Experiment 1, S1 and S2 could only appear to the left and right of the screen. Also similar to Experiment 1, the boxes in which S1 initially appeared either kept their fixed positions or gradually rotated around their axis during the ISI. Unlike the previous experiments, however, the ISI was either 800 or 1600 ms to cancel out the confounding effect of rotation (in degrees) on rotation-speed (which should be important for tracking, cf. Pylyshyn & Storm, 1988). Two thirds of the trials replicated the static and rotating conditions of Experiment 1 – the boxes rotating 0 or 180 degrees – whereas in the other third, the boxes rotated 360 degrees. The experiment lasted for approximately 50 minutes.

Results and Discussion

Trials with incorrect responses to S1 (10.9%) were excluded from the error analyses, and trials with incorrect responses to S1 or S2 (another 9.6%) were excluded from RT analyses.

Conflict-Control analysis

In repeated measures ANOVAs with rotation (static vs. 180 degrees vs. 360 degrees), ISI (800 vs. 1600 ms) and compatibility of S1 and S2, S1 compatibility had a significant effect on error proportions, $F (1, 19) = 4.50$, MSe = .005, $p < .05$, but not on RTs, $F(1, 19) = 1.42$, MSe = 323.01, $p > .2$ whereas S2 compatibility affected both RTs, $F(1, 19) = 165.86$, MSe = 125054.10, $p < .001$, and errors, $F(1, 19) = 35.42$, MSe = .57, $p < .001$. Rotation had no significant effect on RTs, $F(2, 38) = 1.91$, MSe = 1578.36, $p > .1$ and only approached significance on errors, $F(2, 38) = 2.65$, MSe = .02, $p < .09$. ISI significantly affected RTs, $F(1, 19) = 18.24$, MSe = 10520.22, $p < .001$, and errors, $F(1, 19) = 29.28$, MSe = .09, $p < .001$, with longer ISIs being 9 ms faster, but 2.7% more often incorrect. Furthermore, ISI interacted with S2 compatibility on RTs, $F(1, 19) = 6.48$, MSe = 1719.27, $p < .02$, and errors, $F(1, 19) = 5.26$, MSe = .04, $p < .04$. The effect of S2 compatibility was greater after longer ISIs (36 ms, 8.8%) than after shorter ISIs (28 ms, 5.1%). Rotation interacted with ISI on RTs, $F(2, 38) = 4.48$, MSe = 1578.84, $p < .02$, but not on errors, $F(2, 38) = .61$, MSe = .004, $p > .5$. Also, rotation interacted with S1 compatibility on errors, $F(2, 38) = 4.07$, MSe = .01, $p < .03$, but not on RTs, $F(2, 38) = .85$, MSe = 92.33, $p > .4$, and with S2 on RTs, $F(2, 38) = 12.60$, MSe = 3525.34, $p < .001$, but not on errors, $F(2, 38) = 2.65$, MSe = .01, $p > .08$.

S1 and S2 compatibility significantly interacted on RTs, $F(1, 19) = 147.53$, MSe = 32287.75, $p < .001$ and errors, $F(1, 19) = 91.36$, MSe = .39, $p < .001$. Larger S2 compatibility effects were found after compatible than incompatible S1s (50 ms and 12.6% as opposed to 16 ms and 1.2% respectively). The three-way interaction between rotation, S1 compatibility and S2 compatibility was again significant on RTs, $F(2, 38) = 69.07$, MSe = 19484.08, $p < .001$ and errors, $F(2, 38) = 35.69$, MSe = .19, $p < .001$, showing rotating had a great effect on conflict-adaption.

To further analyze the effects of rotation on conflict-adaptation, separate ANOVAs testing the degree to which S1 and S2 compatibility significantly interacted

were conducted for each type of rotation. This interaction proved significant for static trials on RTs, $F(1, 19) = 188.91$, MSe = 68587.80, p < .001, and errors, $F(1, 19) = 81.08$, MSe = .74, p < .001. Although the interaction was smaller, it was still significant for trials in which the boxes rotated 360 degrees for both RTs, $F(1, 19) = 12.57$, MSe = 2662.96, p < .003, and errors, $F(1, 19) = 11.82$, MSe = .03, p < .003. However, the conflict adaptation pattern was completely eliminated after rotating the boxes 180 degrees for RTs, $F(1, 19) = .03$, MSe = 5.14, p > .8, and errors, $F(1, 19) = .43$, MSe = .001, p > .5.

Table 4a: *Experiment 3, compatibility and conflict-adaptation results. Reaction times, error rates and standard errors (in parentheses) for responses to S2 as a function of S2 compatibility, S1 compatibility, and rotation. Effect sizes to the right show how the compatibility effect is affected by preceding (S1) compatibility (see table 2a).*

| | S1 | Compatible (C) | | Incompatible (IC) | | Compatibility effect | | Conflict |
| | | | | | | After C | After I | Adaptation |
	S2	C	I	C	I	CI - CC	II - IC	(CI - CC) - (II - IC)
				Reaction times				
Static		375 (7)	438 (7)	413 (8)	393 (6)	63	-20	83
180°		381 (9)	416 (7)	381 (9)	417 (8)	35	36	-1
360°		377 (9)	424 (8)	383 (8)	415 (9)	48	32	16
				Error rates				
Static		2 (1)	21 (2)	12 (2)	4 (1)	19	-8	27
180°		3 (1)	12 (2)	4 (1)	12 (2)	9	8	1
360°		3 (1)	13 (1)	5 (1)	9 (1)	10	4	6

Event-File analysis

In repeated measures ANOVAs with rotation (static vs. 180 degrees vs. 360 degrees), ISI (800 vs. 1600 ms), location-repetition and response-repetition, rotation had marginally significant effect on RTs, $F(2, 38) = 2.62$, MSe = 2226.78, p <

.09 and error proportions, $F(2, 38) = 3.11$, MSe = .02, $p < .06$. Longer ISIs were significantly faster, $F(1, 19) = 22.53$, MSe = 12788.14, $p < .001$, but also more often incorrect, $F(1, 19) = 29.68$, MSe = .09, $p < .001$. Location repetition was significant for RTs, $F(1, 19) = 9.35$, MSe = 1650.65, $p < .01$, but not for errors, $F(1, 19) = 2.85$, MSe = .01, $p > .1$. Response repetition was significant for RTs, $F(1, 19) = 5.53$, MSe = 9163.96, $p < .03$, but only marginally for errors, $F(1, 19) = 4.10$, MSe = .02, $p < .06$. Repeating the response significantly interacted with ISI on RTs, $F(1, 19) = 12.89$, MSe = 3474.06, $p < .002$, but not errors, $F(1, 19) = .34$, MSe = .0004, $p > .5$. ISI interacted significantly with rotation on RTs, $F(1, 19) = 4.69$, MSe = 1623.81, $p < .02$, but not on errors, $F(1, 19) = .62$, MSe = .004, $p > .5$.

More interestingly, we replicated the overall pattern Experiment 1 and 2: location-repetition significantly interacted with response-repetition for RTs, $F(1, 19) = 178.94$, MSe = 38853.61, $p < .001$ and errors, $F(1, 19) = 80.07$, MSe = .46, $p < .001$. This interaction was modulated significantly by rotation for RTs, $F(1, 19) = 65.14$, MSe = 18809.87, $p < .001$, and errors, $F(1, 19) = 34.41$, MSe = .20, $p < .001$.

To evaluate whether the cost of partially repeating location or response was dependant on rotation, separate ANOVAs were conducted for each type of rotation (or lack thereof). For static trials, the interaction between repeating location and response was significant for RTs, $F(1, 19) = 191.64$, MSe = 72363.01, $p < .001$ and errors, $F(1, 19) = 75.10$, MSe = .80, $p < .001$, with partial-repetition costs of approximately 85 ms or 28.3%. With rotations of 360 degrees, these costs were smaller (20 ms or 6.5%), but still significantly present for both RTs, $F(1, 19) = 19.72$, MSe = 4030.82, $p < .001$, and errors, $F(1, 19) = 14.24$, MSe = 04, $p < .002$. However, with rotations of 180 degrees, the costs were almost non-existent (2 ms or 2.3%) for RTs, $F(1, 19) = .37$, MSe = 79.52, $p > .5$, or errors, $F(1, 19) = 1.55$, MSe = .005, $p > .2$.

Table 4b: *Experiment 3, response-priming and Event-file results. Reaction times, error rates and standard errors (in parentheses) for responses to S2 as a function of rotation, S1-S2 location- and response-repetition. Effect sizes to the right show response-priming effects and partial-repetition costs.*

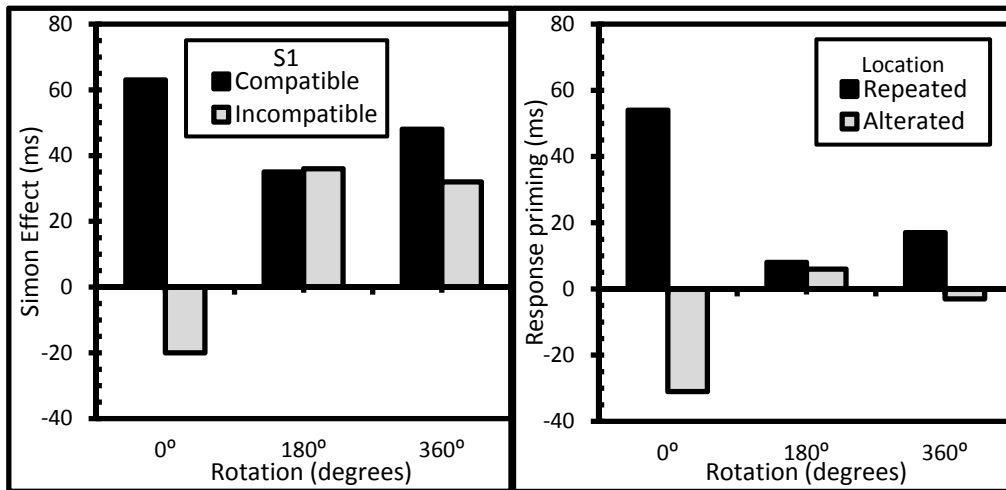| | Location | | | | Response Priming | | Partial |
| | Repeated (R) | | Alternated (A) | | Loc. R | Loc. A | Repetition costs |
Response	R	A	R	A	RA - RR	AA - AR	(RA-RR) - (AA-AR)
	Reaction times						
Static	381 (8)	436 (7)	416 (8)	386 (7)	54	-31	85
180°	395 (8)	404 (9)	393 (8)	398 (9)	8	6	3
360°	390 (9)	407 (9)	400 (7)	398 (9)	17	-3	20
	Error rates						
Static	1 (1)	19 (2)	14 (1)	4 (1)	18	-10	28
180°	8 (1)	10 (1)	7 (1)	6 (1)	2	-1	3
360°	6 (1)	8 (1)	10 (1)	6 (1)	2	-4	7

Figure 5: Results experiment 3: Effects of rotation on sequential Simon effects (left) and event-coding (right).

Discussion

The event-file analysis shows us that rotation in and of itself does not reduce binding cost. In Experiment 2, more degrees of rotation resulted in less partial-repetition costs, leading to the hypothesis that rotation itself might reduce binding. Experiment 3 falsified this hypothesis: only in the 180 degrees condition, the partial-repetition costs were completely eliminated, whereas in the 360 degrees, they were again present.

More importantly, the conflict-control analysis provides evidence that rotation itself does not eliminate conflict-control. If conflict-inducing stimuli rotated back to their original location, a normal – albeit smaller – conflict adaptation pattern emerged. The previous experiments show that there is ample reason for them to be smaller. For one, if the previous location of a stimulus leaves an episodic trace of both where the box *is* and where it *had been* (as suggested by Spapé & Hommel, in press), instances of the objects could have formed all around their axis. Since the object travelled via the opposite (180 degree) location to its former (360 or 0 degree) place, an instance of its 180 degree position may well have been created. Second, if a participant "lost track" halfway during the rotation – i.e. paying more attention to the fact that the boxes moved as such than where they actually landed – similar patterns as during the 180 degrees conditions would be found.

General discussion

Trial-to-trial modulations in response-conflict inducing tasks are commonly taken to reflect adaptive control processes. According to this idea, conflict is registered by conflict-monitoring control process, which then signal the enhancement of the amount of control exerted (Botvinick et al., 2001; Botvinick, 2007). If so, control processes would be more efficient in trials following conflict-inducing trials, a result pattern that has been reported for various sorts of conflict

tasks. In keeping with these predictions and previous observations, we were able to replicate the finding that the Simon effect is strongly reduced after incompatible trials (cf. Stürmer et al., 2002; Wühr & Ansorge, 2005). However, this sequential modulation was eliminated altogether by rather simple manipulations of the visual display in between two stimulus presentations. From a control-theoretic view this is unexpected and difficult to explain without additional assumptions, whereas an episodic approach provides a straightforward interpretation of the obtained pattern.

We have suggested that carrying out a response to a stimulus leads to the integration of stimulus and response features (shape, stimulus location, and response location in our case) into an event file that is retrieved if at least one element of the file is repeated (Hommel, 1998, 2004). Following Kahneman et al. (1992) we have assumed that visual conditions that suggest that the object that contained a stimulus has moved to a different location induce the creation of a spatially updated file. The two present experiments provide evidence that this updated file also contains information about the response, so that the response in a sense travels with its object (Spapé & Hommel, in press). The experiments also provide evidence that the updated file does not flush or overwrite the previous file, and that both files can affect performance concurrently. In the 180-degree conditions of all three Experiments, the impact of the two files apparently canceled each other out but when assessed separately, as in the 90-degree condition of Experiment 2, both could be shown to have an effect.

What do our findings imply for the relationship between adaptive control mechanisms and episodic integration and retrieval effects? We think that two different answers to this question are possible and that it would be premature to decide between them at this point. The radical response would be to consider that all effects that have been assumed to reflect adaptive control mechanisms are artefacts of priming and integration processes. Indeed, there are more possible

effects of that sort than proponents of control approaches have considered, ranging from simple repetition priming (Mayr et al., 2003) over feature integration and the partial-repetition costs they produce (Hommel et al., 2004) to effects of integrated competition (Duncan, 1996; Dutzi & Hommel, in press). Even though the basic characteristics of these types of processes are reasonably well understood, it is entirely unclear how they affect performance in the standard conflict tasks and the often rather complicated task versions that have been designed to minimize episodic effects. With respect to the present study, it is fair to say that our event-coding analyses are much easier and straightforward to interpret than the conflict-control analyses, and the latter are actually not needed to understand the data pattern we obtained. If so, it would be defendable to consider the reasoning underlying the conflict-control analyses as unnecessary theoretical overhead.

An alternative, less radical response could consider that adaptive control does take place and can indeed affect subsequent performance, but that the adaptations achieved by the respective control processes are entirely integrated into episodic event files. For instance, a given file may not only contain pointers to, or associations with codes of stimulus and response features but also information about association weights, that is, about how strongly each given stimulus feature is associated with, or predicts successful responses. There are several observations that are consistent with this scenario. For instance, event files are relatively liberal with regard to the precise timing relation between the stimuli and the responses they integrate, as long as the stimuli appear close to response execution (Hommel, 2005, 2007). This might suggest that the integration takes place vis-à-vis an evaluation of the response's success and is informed by the outcome of this evaluation.

Consistent with that possibility is the observation that the partial-repetition costs that we attribute to event files are systematically affected by experimental manipulations impacting the current dopamine level: Partial-repetition costs are

positively correlated with the spontaneous eye-blink rate, a marker of dopaminergic activity (Colzato, Van Wouwe & Hommel, 2007b); they increase if stimulus-response pairings are followed by task-irrelevant pictures with positive affective content (Colzato et al., 2007a), stimuli that are suspected to induce a phasic increase of the individual dopamine level (Ashby, Isen & Turken, 1999; Cohen, Braver & Brown, 2002); and they decrease in the case of stress, a condition that is known to induce an overproduction of dopamine (Colzato, Kool & Hommel, 2008). Given the evidence that phasic changes in the dopamine level are essential for success-controlled learning and stimulus-response integration (Schultz, 2002), these findings fit with the idea that the creation of event files is regulated by success. If we further assume that success triggers the integration of information about all processing aspects that were responsible for it and consider that the cognitive states underlying the efficient handling of response conflicts belong to those aspects, it makes sense to think that event files include control-relevant information. If so, some part of trial-to-trial modulations in conflict tasks may well reflect adaptive control processes and finding that these modulations are in a sense controlled by episodic retrieval does not necessarily imply a contradiction. This idea fits well with recent revisions of the conflict-monitoring hypothesis (Botvinick, 2007) that consider conflict as aversive stimuli that operate as teaching signals to avoid using the same selection of associated tasks and strategies. Indeed, if cognitive control operations would really be smart they should make sure that control-relevant information is stored in such a way that it will affect future performance in comparable situations only —that is, in situations that trigger the retrieval of episodic memories related to that situation.

Although this interpretation would be in line with the present results, current theorizing seems to restrict itself to the boundaries of either conflict-control or event-files whilst their possible interdependency is left to be accounted for. In contrast to Spapé & Hommel (2008) or Akçay & Hazeltine (2008), who found

conflict-adaptation to be dependent on the context of the stimulus or the task, others (e.g. Notebaert & Soetens, 2003; Wendt, Kluwe & Peters, 2006) still found conflict-adaptation even when task-relevant features changed between trials, making the present state of affairs heterogeneous (or conflicting, if you will). Rather than arguing that the effects of sequential conflict effects are a by-product of stimulus/response-repetition or feature-integration as such, we feel that a framework that focuses on the interplay of control and episodic retrieval could provide the more adequate solution to this puzzle. One of the greater challenges, then, becomes to be able to predict which contextual discontinuities reduce episodic retrieval, thereby disrupting or preventing cognitive control and adaptation. By providing one example of this mechanism, future research must focus on re-integrating the fields of executive control with working memory.

To conclude, our findings suggest that sequential modulations of conflict effects, the bread-and-butter of adaptive-control approaches, are strongly dependent on episodic retrieval and disappear under conditions that make episodic retrieval unlikely. In any case, this suggests that sequential modulations cannot be taken to represent process-pure measures of adaptive control (cf., Hommel et al., 2004; Risko, Blais, Stolz & Besner, 2008). It is possible that they can be accounted for entirely in terms of proactive episodic effects but it may also be that control-relevant information is integrated into event files and retrieved only if the current situationis sufficiently similar to the situation in which the event file was originally created.

CHAPTER 6: SEQUENTIAL EFFECTS IN THE SIMON TASK REFLECT EPISODIC RETRIEVAL BUT NOT CONFLICT ADAPTATION: EVIDENCE FROM LRP AND N2.

Behavioral and psychophysiological studies on the Simon effect have demonstrated that stimuli automatically activate spatially corresponding responses, even if their location is irrelevant to the task. Interestingly, this Simon effect is attenuated after stimulus-response incompatible trials (Gratton effect), a pattern that has often been attributed to online conflict adaptation, even though an account in terms of episodic binding and retrieval is just as plausible. Here we show that the sequential pattern can be eliminated and partly reversed by rotating the boxes in which stimuli are presented in between two given trials, a manipulation that is likely to affect episodic representation but not online control. Sequential modulations of electrophysiological indicators of automatic response priming were also eliminated (N2) or even reversed in sign (LRP), suggesting that sequential effects are due to episodic retrieval of stimulus-response bindings but not, or to an only negligible degree, to online adaptation.

Chapter 6: Sequential effects in the Simon task reflect episodic retrieval but not conflict adaptation: Evidence from LRP and N2.

Psychologists and philosophers alike have long wondered how humans achieve their intended goals in the face of distractions and temptations. To study the conflict between will and distraction, numerous conflict-inducing tasks have been developed: Stroop (1935) found that it is difficult to ignore color words while naming incongruent colors; Simon and colleagues observed that it is difficult to ignore the location of stimuli when carrying out a spatially defined response (Simon & Rudell, 1967); and Eriksen discovered that irrelevant flankers are difficult to ignore when responding to a central stimulus (Eriksen & Eriksen, 1974). Such effects have often been taken to demonstrate an *automatic* impact of stimuli of action control: stimuli sometimes seem to be able to evoke unwanted and interfering action tendencies against an agent's will.

At the same time, however, in none of these or other experimental tasks participants are enslaved to what stimuli tell them: even though it may take them a few more milliseconds to respond in the face of incongruent or incompatible stimuli, they are commonly able to do so. This suggests that voluntary and involuntary action tendencies compete, which has prompted researchers to conceive of action-control models that comprise of at least two processing routes—an automatic route that translates stimuli into habitually acquired or otherwise associated response tendencies and a voluntary route that makes sure that the intended action comes out as planned eventually (for a review, see Hommel, 2000).

There is general agreement that automatic routes are not entirely independent of the current intention. Seeing a color word, processing a stimulus location, and confronting a flanker stimulus does not always evoke action tendencies in people but they do so because particular experimental tasks provide a context that promotes processing of color, location, and flanker information. So

in some sense, automaticity is enabled by intentions, thus creating what one may call a prepared reflex (Hommel, 2000; Woodworth, 1938).

However, recent research suggests that automaticity may be under much tighter voluntary control than suggested by this scenario. Gratton, Coles, and Donchin (1992) found that the effect of irrelevant flankers is mediated by the congruence of flankers and targets in the previous trial: the delay of responding with incongruent as compared to congruent flankers (i.e., the flanker effect) was significantly reduced after an incongruent as compared to a congruent trial. This reduction was visible in both behavioral and electrophysiological observations. It is well-known that response-incompatible flankers activate a lateralized readiness potential (LRP) reflecting the flanker-related response (Coles, Gratton, Bashore, Eriksen, & Donchin, 1985). This suggests that flankers indeed prime the response they are associated with. Most interestingly, however, Gratton et al. observed that these incorrect LRPs are also reduced after an incongruent trial.

Conditions with response conflict usually also induce an increase in the N2 component of the event-related potential (ERP) relative to conditions without conflict. This peak has a fronto-central scalp distribution, presumably a source in the anterior cingulate cortex (ACC), and a peak latency around 300-400 ms (Nieuwenhuis, Yeung, van den Wildenberg, Ridderinkhof, 2003; Sasaki, Gemba, Nambu, & Matsuzaki, 1993; Watanabe et al., 2002). It has been claimed to reflect a general process of inhibiting erroneous responses (Kok, Ramautar, de Ruiter, Band, & Ridderinkhof, 2004) or exerting cognitive control (Folstein & Van Petten, 2008). Based on such observations, Botvinick, Nystrom, Fissel, Carter, and Cohen (1999) have suggested a model in which the ACC is held responsible for continuously monitoring for the occurrence of response conflict. As soon as conflict is detected, an adaptive mechanism fine-tunes control processes, thus reducing the risk of running into conflict in the future. Later modifications of this conflict-monitoring

model describe conflict as an aversive stimulus (Botvinick, 2007) that triggers the avoidance of decision-making strategies that are likely to lead to its re-occurrence.

Stürmer, Leuthold, Soetens, Schröter, and Sommer (2001) have suggested that the presence of such an error-detection/resolution mechanism may explain trial-to-trial adaptation effects as observed by Gratton et al. (1992) and others. In their own study, Stürmer et al. (2001) demonstrated that the Simon effect, characterized by delayed responding to stimuli that spatially correspond to an alternative action (Simon & Rudell, 1967), is affected by manipulations of the probability of stimulus-response compatibility and by the compatibility of the previous trial. Similar to the observation of Gratton et al., Stürmer and colleagues found that, after incompatible trials, the Simon effect is smaller, absent, and sometimes (if compatible trials are more frequent) even reversed. These manipulations caused response-incompatible stimuli to induce an LRP for the incorrect response, resulting in an initial 'dip' in the LRP before peaking in the direction of the final response. Similar to the Simon effect, the amplitude of this 'dip' was reduced after incompatible trials and in blocks with a high probability of incompatible responses. Stürmer et al. suggest that these observations reflect a mechanism of error detection/resolution along the lines of Botvinick et al. (1999). Experiencing response conflict leads people to suppress the automatic processing route, so that information processed by this route impacts response selection to a lesser degree or not at all. As a consequence, response selection is driven by the intentional route only and irrelevant information no longer impairs (or facilitates) performance.

It should be noted that the findings of Stürmer et al. provide a more process-pure indication of the possibility that response conflict is online-controlled by intentions than flanker experiments do. Flanker effects are likely to have multiple causes: in part they seem to result from direct interactions between target

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and flanker representations (stimulus conflict) and in part from interactions between the responses that are mapped onto targets and flankers (response conflict; e.g., Fournier, Scheffers, Coles, Adamson, & Villa Abad, 1997; Hommel, 1997; Rösler & Finger, 1993). In contrast, stimulus conflict can be excluded in the case of the Simon task (where there is no contradiction between any stimulus location and the relevant non-spatial stimulus feature), which leaves response conflict as the most likely culprit.

Episodic retrieval

Recent behavioral results have shed doubt as to whether sequential conflict studies truly demonstrate a mechanism of conflict-adaptation, however. Mayr, Awh and Laurey (2003) showed that Gratton et al.'s (1992) findings can also be accounted for without referring to any higher-order mechanisms, such as conflict monitoring. Mayr et al. point to the fact that sorting trials into those following flanker-target congruence versus incongruence induces a confound with (stimulus- and/or response-) priming effects, and that excluding the conditions in which stimuli and responses are repeated eliminates the adaptation-like effect. Hommel, Proctor, and Vu (2004) have made a similar argument for the Simon effect. They point out that there is independent evidence suggesting that stimulus features and responses are spontaneously integrated and bound into episodic memory traces (Hommel, 1998, 2004). These bindings have been shown to impair performance in subsequent trials if some features and/or the response are repeated while others alternate (partial repetitions), suggesting that repeating components of a binding leads to the retrieval of the whole binding, thereby inducing code conflict if repetitions are only partial. Again, sorting trials into those following compatible versus incompatible trials leads to a confound with partial-

repetition costs[5], which may account for parts or all of what looks like adaptation effects (Hommel et al., 2004).

Two different strategies have been applied to disentangle whether sequential effects in conflict tasks reflect true adaptation through cognitive control, an effect of stimulus-response binding, or a mixture of the two. Most authors advocate the use of only those conditions that are unaffected by binding processes. For instance, Akçay & Hazeltine (2007) restricted their analyses of trial-to-trial effects in the Simon task to trial transitions where not a single stimulus or response feature is repeated, and argued that this would avoid any contribution from binding-related effects.

Unfortunately, there are reasons to assume that even non-repetitions may be affected by binding (Dutzi & Hommel, 2009). Assume, for instance, the combination of stimulus S_b and R_y is encountered right after having processed S_a and R_x, and assume that the representations of S_a and R_x were bound on this occasion. Discriminating between the two stimuli and the two possible responses requires the code of S_b to outcompete the code of S_a and the code of R_y to outcompete the code of R_x. This process can be assumed to benefit from the

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[5] 1. To see that, consider RT_{cC}, RT_{cI}, RT_{iC}, and RT_{iI} the means of reaction times in compatible trials after compatible trials, incompatible trials after compatible trials, compatible trials after incompatible trials, and incompatible trials after incompatible trials, respectively. The standard pattern that is interpreted to reflect adaptation is that the Simon effect after compatible trials (RT_{cI}-RT_{cC}) is larger than the Simon effect after incompatible trials (RT_{iI}-RT_{iC}). Now consider that partial repetitions of stimulus-response combinations (which are known to delay responding for reasons unrelated to control: Hommel, 1998) only occur in conditions where the compatibility in the present trials differs from the one in the previous trial. This would selectively increase RT_{cI} and RT_{iC}, and may thus mimic adaptation effects even in the absence of any control-related effects.

previously created binding between S_a and R_x: losses of S_a in its struggle against S_b would also weaken R_x in its struggle against R_y, and vice versa—a mechanism that Duncan (1996) has called integrated competition. In other words, the previous binding of stimulus and response components helps rejecting them in alternation trials. This means that binding and episodic retrieval can affect performance even if not a single stimulus or response feature is repeated, suggesting that confounds between binding effects and possible adaptation effects are impossible to avoid in principle.

Therefore, Spapé and Hommel (in press) suggested a different research strategy. Rather than trying to isolate possible contributions from binding and control, they sought for manipulations that strongly impact, and even eliminate trial-to-trial effects while being unlikely to have any bearing on control. In fact, Spapé and Hommel (in press) demonstrated that a seemingly minor modification of the visual background in between two trials is sufficient to eliminate adaptation-like sequential effects.

In the present study, we aimed to extend this observation to LRPs, that produced outcomes that hitherto were taken as particularly convincing support of control accounts. In a nutshell, we compared performance in what one may consider a standard Simon task with performance in an only slightly modified version of this task where the left and right box in which the targets appeared rotated in the intertrial interval. In the standard condition, we expected to replicate the observations of Stürmer et al. (2001): the Simon effect should be reduced in size or even disappear after incompatible trials in both RTs and LRPs.

Given that our minor manipulation is unlikely to affect any control process but, as we will argue, can be expected to affect binding processes, a control account is unable to explain any impact of this manipulation on sequential effects. However, merely showing some effect of any binding-related manipulation is not particularly revealing. Control researchers increasingly admit that binding does play

some role in attenuating conflict (e.g., Verguts & Notebaert, 2008) so that modulations of sequential effects may easily be attributed to the "binding portion" of these effects without invalidating the assumption of further "control portions". What would be more informative is the demonstration that sequential effects can be eliminated altogether or even reversed by means of exclusively binding-related manipulations. And this is what we aimed to achieve in the present study.

Aim of Present Study

To test whether sequential effects in the Simon task can be eliminated or even reversed in both reaction times and LRPs we combined the design of Spapé and Hommel (in press), who demonstrated such an effect in reaction times, with EEG recordings along the lines of Stürmer et al. (2001). Sequential effects were assessed by presenting pairs of trials of a rather standard Simon task. Participants responded to the shape of the visual stimuli by pressing a left versus right key, and the stimuli were presented randomly in the left or right of two boxes on a screen. For the sake of clarity, we will call the first stimulus of each pair S1 and the second stimulus S2. Not only did we expect the standard Simon effect—better performance if the location of the stimulus corresponds to the location of the response (i.e., with stimulus-response compatibility) than if it does not—but a sequential effect as well: the Simon effect should be reduced, absent, or even reversed after incompatible as compared to compatible trials. In our terminology, the Simon effect for S2 should be less pronounced after an incompatible as compared to a compatible S1 trial, and this was expected for both reaction times and LRPs (Stürmer et al., 2001).

Static sequence

Rotating sequence.

Fixation: 500 ms.

S1: 608 ms.

ISI / Rotation: 818 ms.

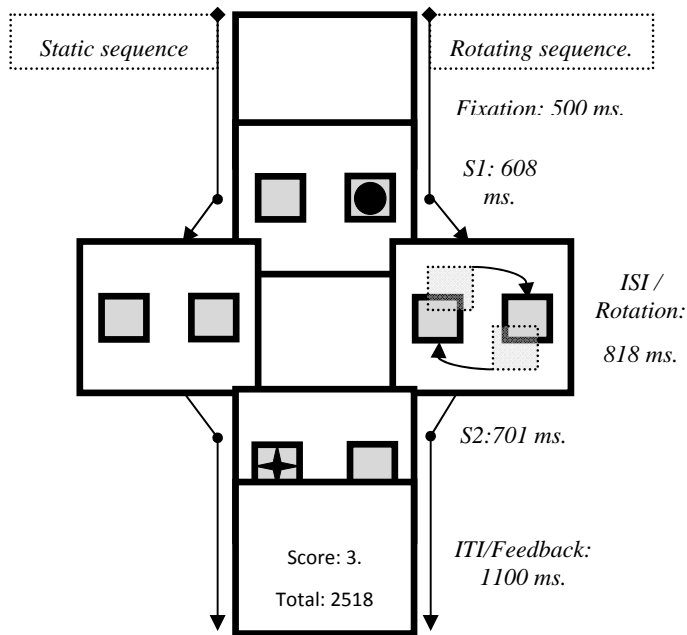*S2:701 ms.*

Score: 3.

Total: 2518

ITI/Feedback: 1100 ms.

Figure 1: Schematic depiction of the trial-sequence of two example trials. After presenting a fixation crosshair, two boxes were presented for 500 ms in the left and right of the screen, one containing the shape (S1) to which participants were required to respond. In the "static" condition (left), an inter-stimulus interval (ISI) followed in which the boxes stood still for 800 ms, whereas in the rotating condition, they rotated around their axis during this ISI. In both conditions, the boxes were statically presented for another 200 ms before the second target (S2) was shown. S2 was shown for 700 ms before an inter-trial interval of 1100 ms ended the trial.

This replication was expected for what we will call the *static* condition, where the two boxes in which the stimuli appeared stayed on the screen in the same positions throughout the whole experiment. However, in another condition, the *rotation* condition, the boxes were gradually rotated 180° around the screen center, as is schematically shown on the right branch of Figure 1, which led to the reversal of the two boxes. This rotation was taking place after the response to S1 was given and before S2 was presented, so that this manipulation should not have any effect on online conflict-monitoring in the sense of Botvinick et al. (1999) or

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Stürmer et al. (2001). In contrast, a binding approach would lead one to expect an impact on sequential effects.

Let us consider, for example, that a participant responds to circles and stars by pressing a right and a left key, respectively. In the scenario shown in Figure 1, he or she might encounter a compatible S1 (location: right, response: right) followed by an incompatible S2 (location: right, response: left), which typically results in long reaction times and many errors on S2—according to control theories the result of a lack of suppression of the automatic route (e.g., Stürmer et al., 2001). However, according to binding-theories of attention (Treisman, 2000), the rotation would cause the binding representing the right circle to be updated, so that at the timepoint of S2 presentation it would refer to a left circle (Kahneman, Treisman & Gibbs, 1992). If sequential effects reflect the benefits and costs of the repetition and alternation of feature bindings (Hommel et al., 2004), this should produce one of two outcome patterns. On the one hand, it might be that S2 processing is affected by the updated binding only. In this case, one would expect a complete reversal of the pattern obtained in the static condition, as turning left into right, and vice versa, should render compatible transitions incompatible, and vice versa. On the other hand, it may also be that updating a binding does not overwrite the original binding altogether, so that S2 processing should reflect a mixture of compatible and incompatible transitions. As this mixture should be the same for all conditions, one would expect that sequential effects are eliminated in this condition. Indeed, this is the pattern that was observed by Spapé and Hommel (in press), who therefore preferred the mixture hypothesis. They were also able to demonstrate independent contributions from original and updated bindings with rotations of 90⁰, which rules out the less theoretically interesting possibility that rotations simply erase existing bindings and/or the aftereffects of control processes.

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Even though the elimination of sequential effects by means of control-unrelated manipulations provides a strong challenge of the control account of sequential effects, converging evidence seems necessary to provide positive support for the binding account. Given that the prediction of a behavioral null effect remains somewhat unsatisfactory in principle, we sought for more insights by using EEG recordings, especially with regard to the temporal dynamics of rotation-induced effects on response tendencies as measured by LRPs. We thus computed LRPs for all compatibility sequences as a function of rotation. In line with previous findings (for an overview, see Praamstra, 2007), we predicted activation of the incorrect response as a result of incompatibility. Following Stürmer et al. (2001), this "invalid" activation was expected to be reduced after incompatible trials in the static condition. Similarly, the N2 component was predicted to be greater for incompatible following compatible trials as compared to incompatible following incompatible trials. However, both effects were expected to be reduced or even reversed in sign in the rotation condition. In order to determine whether this could be due to proactive conflict-monitoring mechanisms (cf. Botvinick, 2007), we also analyzed the S1 stimulus-locked LRPs. If the conflict-monitoring mechanism would adapt during the rotation, this was predicted to reduce amplitudes of the LRPs collected during this time-frame. On the other hand, if the LRPs of rotating trials would not differ from those of static trials up until the S2 was presented, binding-retrieval mechanisms that were prompted by the onset of S2 could be considered as the responsible mechanism.

Method

Participants

Sixteen students from Leiden University voluntarily participated in this experiment for a small fee or course credits. During the analysis of the LRPs over all conditions, four participants showed no negative LRP during responses, implying

that their LRP was not diagnostic of motor priming, so they were left out from further analysis.

Apparatus and stimuli

Stimuli were presented on a flat-screen 17" CRT monitor in 800 x 600 pixel resolution and a refresh-rate of 120 Hz. A Pentium-IV 2.60 GHz PC running E-Prime 1.2 on Windows XP SP2 controlled stimulus-presentation and recorded reactions via serial response boxes mounted on the armrests, left and right of the participant. The visual boxes that contained the targets were gray (RGB value of 128, 128, 128), black-edged squares of 60 x 60 pixels or an approximate visual angle of 2.4° presented against a silver (RGB value of 191, 191, 191) background. The target also measured 60 x 60 pixels and was either a circle or a four-pointed star. Boxes were presented 180 pixels (approximately 7.3°) left and right from the center of the screen and kept at this distance during the gradual shifts in location.

EEG was recorded at 512 Hz from seven Ag/AgCl scalp electrodes, positioned on the Fz, FCz, Cz, CPz, Pz, C3 and C4 locations, mounted in an elastic cap, using the Biosemi Active Two recording system. Common Mode Sense and Driven Right Leg electrodes (see www.biosemi.com/faq/cms&drl.htm) were used for online grounding and as initial reference, but the signal was re-referenced to the average mastoid signal off-line. Bipolar recording from approximately 1 cm above and below the left eye, and 1 cm lateral of the outer canthi of the eyes provided vertical and horizontal electrooculograms (EOGs), respectively. EEG and EOG were passed through a low-cut filter of 0.10 Hz and corrected for eye-movements using the Gratton, Coles, & Donchin (1983) algorithm, after which they were passed through high-cut filters of 8 Hz (for LRPs) or 16 Hz (for N2). Trials with EEG or EOG artifacts were excluded from the calculation of average ERPs.

Procedure

As outlined in Figure 1, a fixation cross was presented for 500 ms, after which the two boxes were presented in the left and right of the screen, one of them containing the target shape (S1) to which participants were required to respond. After approximately 606 ms, the targets disappeared. The empty boxes stayed on the screen for another 818 ms, either in the same position (the "static" condition) or being rotated around the screen center at a speed of approximately 4 degrees per 44 ms (the "rotated" condition). Then the second target (S2) was presented for 700 ms before a screen with feedback informed the participant about his or her performance. This last screen disappeared after 1100 ms and then the next trial started.

Participants were instructed to ignore the location of the stimuli but react to their shapes using their index fingers. Half of the participants were to press the left response key for stars and the right key for circles, whereas the other half received the opposite stimulus-response mapping. They were required to respond as quickly and accurately as possible and during the ITI they were shown a personal score next to a high score, which they were encouraged to break. Getting points could only be done by responding both fast (1 point for each reaction below 600 ms) and accurately (1 point for each accurate reaction) and although breaking the high score was not reinforced with any kind of monetary or other incentive, most participants did indicate being positively motivated to aim for a (fictional, computed as 3 × number of trial-pairs) high score. Participants received a break after about every quarter of the trials. The experimented lasted about 100 minutes in total.

Design

Results were coded for S1 and S2 compatibility (vs. incompatibility) and rotation (static versus rotated). The design was fully balanced, with 18 blocks of 64

trials, which resulted from the orthogonal combination within blocks of the two S1 and S2 locations and shapes, and the two types and directions of rotation.

LRPs were calculated by averaging the differences between contralateral and ipsilateral ERP for left and right responses to S2. Magnitudes of *Gratton-dips* (after Gratton, Coles, Sirevaag, Eriksen, & Donchin, 1988) –thought to reflect the stimulus-induced activation of incorrect hand responses–were measured as the maximally positive local voltage between 100 and 200 ms. Effects of rotation on S1 response encoding were investigated by calculating LRPs for S1 and the average difference between static and rotating conditions in the time-window rotation was tested (i.e. between 604 and 1426 ms after S1 onset).

N2 amplitude was measured as the difference in Cz amplitude between S2 compatible and incompatible conditions, the onset and offset of which was measured as the negative area of the FCz, Cz and CPz electrodes between 232 and 356 ms. This window corresponded with the period of a significant (>4 SD of baseline activity) difference between the grand average ERPs of compatible and incompatible conditions.

Results

Responses with latencies below 50 ms and above 1000 ms were not considered, and all incorrect reactions to S1 or S2 were excluded from RT and ERP analyses. Few errors were made during S1 (M = 6.9%, SD = 2.3%) and S2 given correct response to S1 (M = 5.5%, SD = 2.7% of the remaining correct responses).

Behavioral Results

In repeated measures analyses of variance (ANOVAs) on the reaction times (RTs) and error percentages (error %) of S2, with rotation (vs static), S1 compatibility (vs incompatibility), and S2 compatibility (vs incompatibility), rotation did not significantly affect RTs, p > .9, or error %, p > .08. Neither did S1 compatibility reach significance for RTs, p > .4, or error %, p > .09. S2 compatible trials were significantly faster than S2 incompatible trials, $F(1, 11) = 54.22$, $p < .001$, but only marginally more accurate, p = .05. A significant S1 compatibility-by-S2 compatibility interaction for both RTs, $F(1, 11) = 80.83$, $p < 001$, and error %, $F(1, 11) = 23.03$, $p < .001$, revealed a substantial conflict-adaptation effect. After compatible trials, participants were 52 ms slower and 4% more often incorrect with incompatible S2s, but after incompatible trials, a compatibility effect of only 9 ms and 0% errors was found. This conflict adaptation pattern was significantly modulated by rotation for both RTs, $F(1, 11) = 79.89$, $p < .001$, and error %, $F(1, 11) = 47.42$, $p < .001$. The conflict-adaptation pattern of some 89 ms / 8.3 % that was found under static conditions (see Table 1 for calculus), broke down after rotation to values of -4 ms / -0.4%. Two ANOVAs testing the static and rotating conditions separately revealed that the S1-by-S2 compatibility interaction was only significant for RTs, $F (1, 11) = 111.43$, $p < .001$ and for error % $F(1, 11) = 37.51$, $p < .001$, of static conditions, but not for RTs, p > .4 or error %, p > .7, of rotating conditions.

Chapter 6: Sequential effects in the Simon task reflect episodic retrieval but not conflict adaptation: Evidence from LRP and N2.

Table 1: *Behavioral results. Reaction times, error rates and standard errors (in parentheses) for the second Stimulus (S2) as a function of its compatibility, preceding (S1) compatibility and rotation. Effect sizes to the right show the Simon effect and how it is affected by preceding (S1) compatibility. The conflict-adaptation effect is measured as the degree to which the Simon effect of S2 is attenuated after incompatible S1s.*

Reaction Times (ms)

		S2 Compatible	S2 Incompatible	Simon Effect	Conflict Adaptation
Static	*S1 Compatible*	341 (9)	411 (11)	70	
	S1 Incompatible	381 (10)	362 (9)	-19	89
Rotating	*S1 Compatible*	356 (9)	390 (10)	34	
	S1 Incompatible	355 (9)	393 (10)	38	-4

Error rates (%)

		S2 Compatible	S2 Incompatible	Simon Effect	Conflict Adaptation
Static	*S1 Compatible*	9.3 (0.3)	12.3 (3.0)	4.0	
	S1 Incompatible	6.3 (0.9)	2.0 (1.0)	-4.3	8.3
Rotating	*S1 Compatible*	2.5 (0.5)	6.6 (1.7)	4.1	
	S1 Incompatible	2.0 (0.5)	5.7 (1.2)	3.7	-0.4

S2 EEG Results

In repeated measures ANOVAs on the LRP Gratton-dip magnitude with S1 compatibility, S2 compatibility and rotation as factors, neither rotation nor S1 compatibility produced a significant main effect, ps > .8. However, S2 compatibility strongly affected the Gratton-dip magnitude, $F(1, 11) = 39.78$, $p < .001$. Incompatible trials showed activations of the incorrect hand of ca. 1.4 µV compared to compatible trials. S1 compatibility did not interact significantly with S2 compatibility, $p > .9$. This appeared to be due to the interaction with the rotation factor, as evidenced by a significant three-way interaction with rotation, $F(1, 11) = 13.46$, $p < .004$. It indicated a change in sign for the static conflict adaptation (tested with a separate ANOVA as $F(1, 11) = 3.90$, $p = .08$) versus

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rotating conflict adaptation (separate ANOVA F(1, 11) = 11.40, p < .01). That is, in the static condition, the Gratton-dips were reduced after incompatible trials by 0.8 µV (compare the two upper panels in Figure 2), whereas in the rotated condition, the dips *increased* by 0.8 µV (compare the two lower panels in 2).
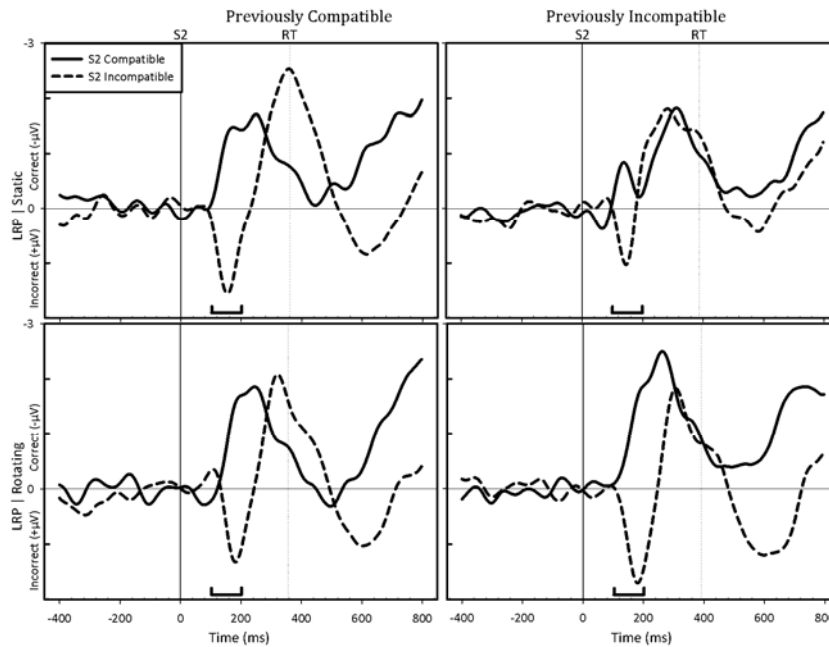

Fig. 2: Effect of current (S2) compatibility on the LRP as a function of preceding (S1) compatibility. Reaction times (RT) are averaged across the two conditions in each panel. Horizontal lines show latency where initial 'incorrect' activation – or, 'Gratton dip' – of the LRP was detected.

Further ANOVAs on the Cz mean amplitude of the N2 (computed as the difference between incompatible and compatible S2s) with S1 compatibility and rotation as factors showed that S1 compatibility decreased mean N2 activity, F(1, 11) = 34.48, p < .001. Rotation itself did not have a significant effect, p > .5, but did interact with S1 compatibility, F(1, 11) = 23.73, p < .001. We conducted two post-hoc tests to better understand this interaction. In post-hoc comparisons between

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the S1 compatible and incompatible conditions, the difference was shown to be strongly present in static conditions, t(11) = 5.61, p < .001, but not significantly in rotating conditions, t(11) = -1.10, p > .2. That is, in static trials, following incompatible S1s, the N2 difference changed sign (compatible showed larger N2 amplitudes than incompatible trials), whilst in rotating trials, no such change was present. Another set of post-hoc comparisons, now between the static and rotation conditions, revealed that there was no significant difference between the S1 compatible conditions, t(11) = -1.64, p > .1, but only between the S1 incompatible conditions, t(11) = 4.10, p < .005. Thus, the difference between static and rotation in N2 magnitude was only found after incompatible conditions. Table 2 shows that these results in the N2 component based on the Cz measurements were generally similar in the other midline (FCz, CPz) electrodes.
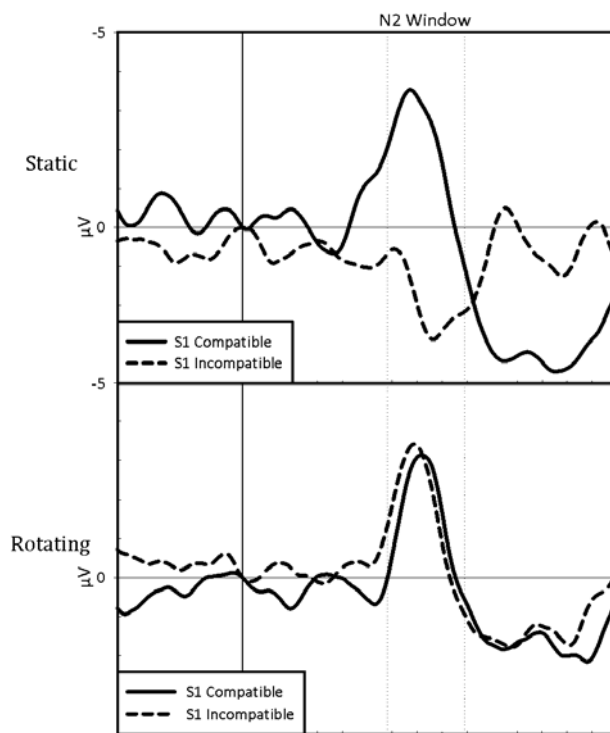
Fig. 3: Results experiment 1: N2 difference waves over Cz (subtraction of compatible from incompatible conditions) as a function of preceding compatibility and rotation.

Table 2: ERP results. *Average effect sizes for lateralized readiness potential (LRP) and the N2 effect for individual electrodes, stimulus-locked to the second stimulus (S2). Gratton Dip refers to the positive peak in the LRP at ca. 150 ms after stimulus, which is thought to be associated with the automatic (i.e. location-based) activation of the response. N2 voltages were calculated as the difference between compatible and incompatible conditions in mean amplitude of the FCz, Cz and CPz electrodes between 232 and 356 ms after S2 onset. Effect of conflict adaptation was measured as the difference in compatibility as a function of preceding compatibility for both rotating and static conditions. Difference shows the results of post-hoc comparisons between the static and rotation conditions, adjusted for the number of tests (Bonferroni), in terms of significance.*

| LRP | Rotation | Simon Effect (I - C) after | | Conflict Adaptation |
		Compatible	Incompatible	Conflict after C - I
Gratton Dip Magnitude	*Static*	1.7	0.9	0.8
(μV)	*Rotating*	1.1	1.9	-0.8
	Difference	*ns*	*	**
N2		**N2 (I - C) component after**		
		Compatible	Incompatible	N2 after C-I
Mean Amplitude FCz (μV)	*Static*	-1.2	1.7	-2.9
	Rotating	-0.8	-0.7	-0.1
	Difference	*ns*	*	**
Mean Amplitude Cz (μV)	*Static*	-2.6	1.4	-4.0
	Rotating	-1.0	-0.8	-0.2
	Difference	*ns*	**	**
Mean Amplitude CPz (μV)	*Static*	-2.8	1.1	-3.9
	Rotating	-1.9	-1.5	-0.4
	Difference	*ns*	**	**

*ns: not significant, *: p < .05, **: p< .01*

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S1 ERP Results

A repeated measures ANOVA on the averaged LRP waveform between 604 (rotation onset) and 1426 (rotation offset) with S1 compatibility and rotation as factors revealed that after incompatible S1s, the incorrect response became more activated, $F(1, 11) = 10.52$, $p < .01$, in a manner best described as an 'echo' of the Gratton-dip caused by S1. More importantly, rotation did not affect LRP, $p > .4$, nor did it interact with compatibility, $p > .4$.
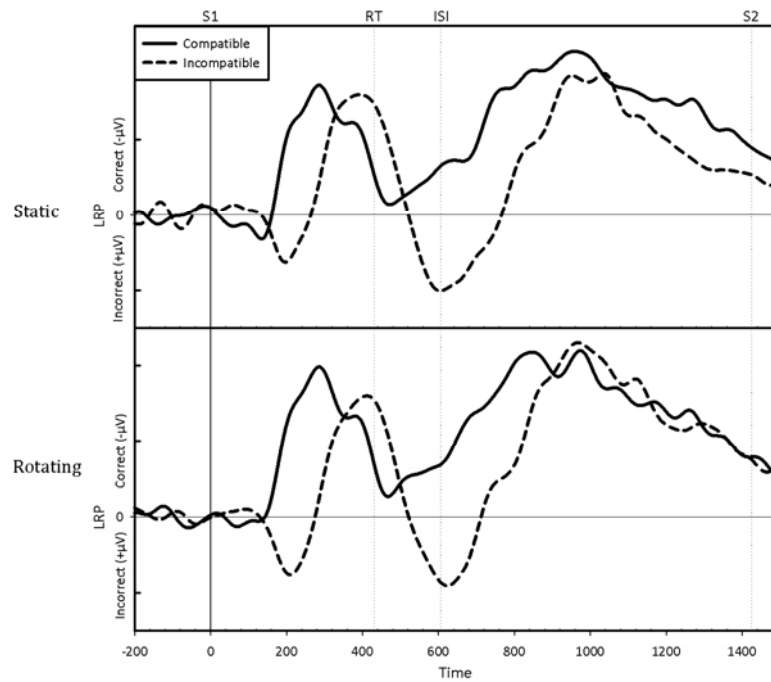

Fig. 4: Results experiment 2: Effects of rotation and compatibility on the LRP of the first stimulus (S1).

Discussion

The aim of this study was to test whether what looks like effects of control might be due to the impact of previously created stimulus-response bindings on present performance. We argued that if the sequential effects that are taken to diagnose the impact of control could be eliminated entirely, and perhaps even reversed in sign, by means of a manipulation that is arguably unrelated to any control process; this would provide strong evidence for a binding approach to sequential effects. We applied this logic to the Simon task that was previously demonstrated to produce particularly strong sequential effects in both reaction times and LRPs. We attempted to replicate these previous findings in our static condition and, indeed, the standard patterns were obtained: notably, the Simon effect was reduced after incompatible trials, as witnessed by reduced reaction time effects and less stimulus-induced activation of incorrect responses as indexed by LRPs (e.g., Stürmer et al., 2001).

Not so for rotating conditions however: Closely replicating the behavioral observations of Spapé and Hommel (in press), conflict-adaptation patterns disappeared in the rotation condition. As the electrophysiological findings demonstrate, this was not due to the overwriting of control effects or the flushing of control systems (Logan & Gordon, 2001). Rather than just disappearing in the rotation condition, the 'incorrect' parts of the LRP that are commonly taken to indicate the automatic, stimulus-induced activation of responses was strongly affected.

A control account would need to explain why a task-unrelated rotation would suddenly make nonconflicting stimuli to activate incorrect responses. As this seems rather difficult and counterintuitive, we suggest attributing the impact of trial transitions on LRPs to binding effects entirely. As pointed out by Hommel et al. (2004) and explained in footnote 1, what looks like adaptation effects may also

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result from a confound with sequential effects and the repetition versus alternation of stimulus and response aspects. In particular, stimulus and response features may be bound upon S1 processing and the resulting bindings be automatically retrieved upon S2 processing (Hommel, 2004). If the combination of stimulus and response features is the same in both trials, or if no feature overlaps, performance is unimpaired or even facilitated, but with partial overlap, code conflict occurs and performance suffers (Hommel, 1998).

In the rotation condition, bindings are updated to reflect the spatial change (Kahneman et al., 1992; Zacks et al., 2007), so that "left" codes become "right" codes, and vice versa. This change can account for the reversals we have seen in the LRP data. However, the overall pattern including the behavioral data does not look like a complete reversal, confirming the claim of Spapé and Hommel (in press) that overt performance on S2 is affected by both the original (not-updated) binding and the updated binding, resulting in a mixture of effects ranging from elimination to reversal. Whether and how the two bindings interact, how strong their relative contribution to present performance is, and whether this relative strength depends on context and task requirements, remains to be determined. As long as this is so, it seems logically impossible to exclude contributions from control in principle. More detailed and more quantitative predictions from both binding and control approaches would be necessary to conclusively decide on this issue. We do emphasize, however, that none of our findings is predicted by a control approach and that our outcome does not leave much space, if any, for contributions from control processes to sequential effects.

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CHAPTER 7: SYNOPSIS AND DISCUSSION

The question of how we are able to exercise voluntary action, or 'free will', in the face of automaticity, distraction and temptation, has long been debated. From an empirical point of view, the solution may be found by investigating simple psychological effects that show a robust behavioural effect of being distracted and understanding how and when participants are, in fact, *not*. Gratton, Coles & Donchin (1994) for example, showed that after people are tempted to react to the flankers of a visual stimulus, they tend to perform better if the incongruous stimulus is presented again. Likewise, in Stroop (1935) and Simon (Simon & Rudell, 1967) effects, repeating stimulus-response conflict typically leads to better performance (Kerns et al., Stürmer et al.). The influential conflict-monitoring model in neuroscience attempts to solve the problem by having a brain structure scan for response-conflict and, upon detection, change decision-making strategies to avoid repetition of such aversive conflict (Botvinick, 2007). Thus, the conflict-adaptation (or Gratton-) effect concerns the relative enhanced performance of conflict-conflict sequences to non-conflict-conflict sequences.

Despite the model's parsimony and effective prediction of many sequential conflict results, it is not without challenges. In marked contrast to conflict-adaptation, social psychologists found that after exerting self-control, resources for repeated self-control are typically *lower* (Baumeister, Vohs & Tice, 2007). Moreover, one may wonder how people are able to resist the temptation of acting upon distracters in the absence of previous, adaptation-incurring conflict. Logan (1980; 1988), for instance, would argue that the many instances in which we learned to read words, rather than naming their colours, are retrieved upon completing a Stroop-test, and interfere with the goal of naming the colours.

In this dissertation, the hypothesis is explored that memory – episodic retrieval – is a necessary condition for conflict-adaptation to occur. The radical variation of this hypothesis states that the repetition of the features constituting

conflict, rather than the attentional mechanism which supposedly 'solves' the conflict, account for all the variation in sequential modulation studies, therefore not requiring 'conflict-monitoring'. The less radical variation of the hypothesis involves the mostly unexplored option that episodic retrieval is required for conflict-adaptation to occur. After experiencing conflict in one task, this option states that the conflict-control that is required to defeat the temptation (for example: 'narrow your attention' after seeing conflicting flankers) is integrated in the episodic trace. If a subsequent event then reminds of the previous event, such control-parameters are retrieved and may help controlling current conflict.

Of course, most models based on conflict-monitoring are implicitly or explicitly reliant on memory or working memory, yet their accounts more indirectly link memory to cognitive control. For one, in the original Botvinick et al. (1999) model, detecting conflict leads to enhanced activation of working memory, so that subsequent stimulus-response incompatibility can be better dealt with. In Stürmer et al.'s (2002) dual route model, after a mismatching Simon trial, the automatic stimulus-response route will be suppressed if it is detected as being disadvantageous. Presumably, in order to inhibit this route in such a way that it affects the processing of the subsequent trial, working memory is required. Finally, in a recent review by Verguts & Notebaert (2009), a noteworthy attempt is made to bridge the gap between binding and conflict-monitoring, by suggesting that detection of conflict leads to arousal, which in turn facilitates binding.

These accounts differ from the hypothesis in this dissertation on two grounds. Firstly, binding is approached mainly from a retrieval perspective, as suggested by Hommel (1998), rather than as a forward process such as priming (Bertelson, 1963; Meyer & Schvaneveldt, 1971; Mayr et al. 2003) in which alternations of stimuli or responses are detrimental to performance. One may see binding as similar to these processes: on a given trial, stimulus and response features are temporarily associated with one another, such that stimulus A is

associated with response 1 into A1. This binding may be kept activated, for example in working memory. If a later stimulus-response episode requires either A or 1 for a new binding, a problem occurs because they are already bound to the previous stimulus. Although some authors (e.g. Notebaert, Gevers, Verbruggen & Liefooghe, 2006) are not exactly clear whether they interpret the binding process like this, it should be stressed that the account put forward here does not. Instead, my line of reasoning is based on the logic underlying Kahneman, Treisman & Gibbs' (1992) *reviewing* effects (c.f. chapter 3) and Hommel's (2004) event file retrieval. An encounter with episode A2 will *retrieve* episode A1 merely due to the overlapping feature A. If the retrieval reactivates stimulus and/or response features that conflict with features of the current stimulus and/or response, performance is hampered. This more or less passive retrieval process entails that there is no active maintenance of a binding per se.

Secondly, the claim here is that cognitive control *depends* on such retrieval processes. Either because all sequential modulation effects boil down to episodic retrieval – the radical approach – or because episodic traces also contain information regarding executive control – the less-radical approach – the claim is made that without episodic retrieval, there is no control. Thus, unlike in the *pro-active* conflict monitoring accounts, even if some allow a role for feature integration, the hypothesis is that cognitive control is possible *if and only if* episodic retrieval allows it to be.

Chapters 2 and 3 illustrate the basic mechanism of episodic retrieval without reference to conflict. In Chapter 2, the basic sequential paradigm, or typical Event Coding task, is explained. Perceiving and acting upon a set of features are assumed to result in a representation combining these as single "Event file", such that encountering one of the features again brings back the whole former event, which in turn may help (if every other feature is also repeated) or hinder (if other features are alternated, resulting in 'partial-repetition costs') subsequent

performance (Hommel, 1998; Zmigrod, Spapé & Hommel, in press). Importantly, partial-repetition costs were found to be related to retrieval, rather than encoding, as the cue that indicated the relevance was shown only in the second part of the task. Chapter 3 uses a similar task, but shows that event-files can be adapted if their features gradually change over time. However, it is also shown that the history of its previous location is not wiped out, or flushed, but is stored separately, as part of the same event-file.

With that information at hand, Chapters 4, 5 and 6 went back to the issue of voluntary action, adding feature-integration related manipulations to disentangle priming, feature-integration and conflict-monitoring sources of variance from the conflict-adaptation effect. In an attempt to find out how imitation mechanisms work, Chapter 4 described an experiment in which participants were asked to ignore distracting voices and instead respond to high or low tones. Though finding no effect whatsoever of being required to imitate ones' own voice, changes in voices, although entirely irrelevant to the task, were found to strongly affect the conflict-adaptation effect. This result prompted the less radical hypothesis regarding conflict-adaptation: control-related parameters (such as 'ignore the voice') might have been encoded into episodic traces or instances (i.e. 'ignore *this* voice'), such that after hearing the same voice, the parameters were retrieved, helping to resolve current conflict and resulting in a fully fledged conflict-adaptation, but not after hearing a different voice.

Chapter 5 used the manipulation of Chapter 3 to adapt a Simon effect *feature-integration style*: after rotating a stimulus-display (say, a stimulus left that was responded to with a right key-press) for 180 degrees, results closely mimicking those of Chapter 3 were obtained. Analysing both partial-repetition costs and conflict-adaptation, both were near-zero after rotation, thus supporting both radical and less radical position. For the radical position, the answer would be simple: indeed, the results look so similar to the non-conflict effects of Chapter 3

because feature-integration is enough to account for the conflict adaptation. Alternatively, the rotation might have rotated the response along with the stimulus and control-related effects continued playing a part, though not quite as obviously. Chapter 6, apart from showing robust, psychophysiological correlates to these effects, favours the radical position, as all effects were found to be incurred by presenting the second part of the task (S2), instead of affecting S1-locked LRP.

Yet, the difference between the radical (all conflict-adaptation *is* feature-integration) and less radical (conflict-adaptation depends on feature-integration) hypothesis may not be so great as is often assumed. If we leave the whole sequential effects aside, for example, why are people distracted by the word, if required to name the colour? What is the nature of the temptation? In essence, we assume that the features of the world retrieve their lexical, semantic and production features, and it is likely that due to our learning history, this retrieval is faster and more automatic than executing the task-set goals in psychological experiments (cf. Logan, 1988). Similarly, in Simon effects, not the location itself produces the conflict, but its partial repetition with our goal to respond in locations (Hommel, 1993). Episodic retrieval should therefore not be seen as an annoying, confounding variable in 'executive control' type of experiments, but as both the reason why distraction exists in the first place and how it can ultimately be overcome.

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Samenvatting

Filosofen hebben zich sinds de oudheid verbaasd over hoe het kan dat de mens in staat blijkt om soms een vrije keuze te maken en soms de keuze bijna reflexmatig veroorzaakt wordt. Ook psychologen, zoals William James (1842-1910), en neurologen, zoals Sigmund Freud (1856-1939) vroegen zich af hoe het kan dat we ondanks allerlei verleidingen ertoe in staat kunnen zijn om rationele, beschaafde beslissingen te maken. De paradox, van verleiding, veroorzaking en automatisme aan de ene kant en vrije wil, intentie en controle aan de andere, blijft echter aan de orde in de moderne cognitieve wetenschappen.

Een bekende illustratie waarbij verleiding en controle een meetbare rol spelen is het Stroop-effect. John Ridley Stroop beschreef in 1935 een experiment waarbij hij een aantal individuen vroeg de kleuren te benoemen op een kaart met verschillende gekleurde woorden, waarbij de woorden zelf de namen van kleuren waren. Hij merkte op dat wanneer de namen van de woorden niet overeen kwamen met de kleur van de inkt men veel langer deed om een kaart te voltooien dan wanneer dit wel het geval was. Hoewel de meningen na 74 jaar nog steeds verdeeld zijn over de precieze verklaring van het effect, lijkt het in ieder geval te betekenen dat men wordt afgeleid doordat men automatisch het woord leest, wat dan conflicteert met het benoemen van de kleur.

Nu vindt men het dus moeilijk om in tijden van conflict snel en rationeel te reageren, maar als men genoeg tijd heeft, is men toch in staat om een Stroop kleurenkaart, of welke variant van een dergelijke conflicttaak dan ook, te voltooien, of anders gezegd, te reageren au contraire de verleiding. Deze executieve controle blijft ook een fascinerend onderwerp voor de cognitieve- en neuro-psychologie, waaruit een populair model is voortgekomen dat het menselijke gedrag in conflictsituaties verklaart.

Ten eerste is er een systeem dat conflict tracht te detecteren. Gegeven een Stroop-taak, bijvoorbeeld, bestaat er een conflict wanneer de inktkleur een andere reactie vergt dan de woordnaam. Aangezien men meestal niet in staat is twee woorden tegelijk te zeggen detecteert deze 'conflict-monitoring module' een geval respons-conflict. Dit wordt ondersteund door de neurowetenschappen: hier heeft men door middel van functionele hersenscans gevonden dat bij verschillende conflicttaken eenzelfde gebied wordt geactiveerd.

Ten tweede wordt er iets gedaan met het gedetecteerde probleem – bij voorkeur voordat er iets gezegd wordt: de aandacht wordt verhoogd (i.e. men gaat opletten), of de verkeerde respons dan wel het automatisme, wordt onderdrukt. Een sterk bewijs voor deze functie wordt gezien in een gerelateerd effect dat bekend staat onder namen als het 'Gratton-effect' (naar Gratton, Coles & Donchin, 1992, die dit effect opmerkten) of het 'Conflict-Adaptation' effect. Dit effect komt erop neer dat nadat men een conflict heeft opgemerkt (na het woord groen in een blauwe kleur), de meeste mensen beter zijn in verdere conflictsituaties (wanneer het woord blauw in een groene kleur wordt aangeboden, bijvoorbeeld).

Een ezel zal zich dan niet twee keer aan dezelfde steen stoten, maar in dit proefschrift wordt gesteld dat de realiteit enigszins complexer is. Ten eerste is het zo dat wanneer 'groen-in-een-rode-kleur' wordt opgevolgd door een stimulus als 'groen-in-een-rode-kleur', men weliswaar sneller kan reageren, maar dat 'conflict-adaptatie' niet noodzakelijk de reden is: mensen zijn vrijwel altijd beter wanneer ze twee keer hetzelfde doen.

Ten tweede heeft eerder onderzoek aangetoond dat zelfs wanneer twee opeenvolgende stimuli geheel niet lijken op elkaar (rood-in-een-groene-kleur na blauw-in-een-gele-kleur) proefpersonen sneller zijn dan wanneer de stimuli enigszins lijken op elkaar (rood-in-een-groene-kleur na rood-in-een-gele-kleur). Ook hieraan ligt een proces ten grondslag dat in principe niets met conflict te maken heeft: geheugen- en aandachtonderzoek naar kenmerkintegratie heeft aangetoond

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dat wanneer een stimulus wordt getoond, de kenmerken ervan worden geïntegreerd tot één geheugenspoor – een herinnering aan het-woord-blauw-in-een-gele-kleur is niet hetzelfde als de herinnering aan het woord blauw en de herinnering aan de kleur geel afzonderlijk. Dat onderzoek heeft aangetoond dat wanneer later een stimulus wordt getoond die gelijk is in bepaalde kenmerken, de eerder gevormde herinnering wordt teruggehaald uit het geheugen. Als deze twee gebeurtenissen (de herinnering versus de actuele situatie) echter verder niet overeenkomen ontstaat er een meetbare 'verwarring' die in hoofdstuk twee en drie 'gedeeltelijke herhalingkosten' worden genoemd. Aangezien er in conflict-adaptatie situaties (conflict na conflict) nooit sprake is van gedeeltelijke herhaling, kan voorspeld worden dat men sneller en meer accuraat is in dergelijke situaties zonder dat dit iets met controle te maken hoeft te hebben.

In het afgelopen decennium hebben onderzoekers getracht conflict-adaptatie-effecten te scheiden van de verschillende verstrengelde effecten, zodat men kon vaststellen of sequentiële effecten (zoals de opeenvolgende Stroop-taken) überhaupt inzicht kan geven in executieve controle. De soms tegenstrijdige bevindingen die dit debat heeft opgeleverd, vormen de inspiratiebron van het voornaamste deel van dit proefschrift. In plaats van executieve controle of conflict-adaptatie en kenmerk-integratie of geheugenprocessen te scheiden, wordt gesteld dat controle afhangt van de mate waarin geheugensporen herinnerd worden.

In hoofdstuk vier wordt deze hypothese getoetst met een Stroop-taak waarin proefpersonen wordt gevraagd de frequentie (hoog of laag) van tonen te benoemen terwijl woorden ("hoog" en "laag") digitaal door de tonen zijn gemixt. Conform de originele Stroop-taak met kleuren wordt er uiteraard bevonden dat men trager is als het woord incongruent is met de toon. Vervolgens wordt er getoond dat men sneller is wanneer een incongruentie gevolgd wordt door incongruentie dan wanneer congruentie gevolgd wordt door incongruentie, wat overeenkomt met het conflictadaptatie-effect. Hoewel dit geheel onbelangrijk was

voor de proefpersoon werden echter verschillende stemmen gebruikt voor de afleidende woorden: soms hoorde men mannelijke stemmen en soms vrouwelijke. Wanneer twee keer dezelfde stem werd waargenomen werd er een grote mate van conflictadaptatie gemeten, maar wanneer de stem veranderde, verdween dit effect vrijwel geheel.

Conflictadaptatie – of executieve controle – leek dus afhankelijk te zijn van de gelijkheid tussen de situatie waarin het huidige conflict plaatsvindt en die van het voorafgaande conflict. In hoofdstuk vijf wordt dit effect gegeneraliseerd naar een ander conflict-effect: het Simon effect. Ook in dit effect waarbij de compatibiliteit tussen de stimulus- en responslocatie centraal staat (i.e. men is trager wanneer men links moet reageren op iets wat rechts plaatsvindt) wordt conflictadaptatie onderzocht in een taak waarin soms iets gebeurt wat niet gerelateerd is aan het conflict als zodanig. Tussen twee conflictsituaties roteert de stimuluspresentatie om haar as waardoor de herinnering aan de eerdere conflictsituatie aangepast zou moeten zijn (wat voortkomt uit onderzoek dat in hoofdstuk drie wordt gerapporteerd). Met een drietal experimenten wordt sterk bewijs gegeven voor de stelling dat conflictadaptatie afhankelijk is van de herinnering aan eerder conflict.

Tot slot wordt het tijdsdomein van deze 'sequentiële Simon-taak' met behulp van elektro-encefalogram (EEG) vastgesteld. Door de elektrische lading van de linker, versus de rechter hersenhelft te meten kan gezien worden wanneer respectievelijk een rechter, versus linker, reactie wordt voorbereid. In de taak (dezelfde als die van hoofdstuk vijf) worden sterke effecten van conflictadaptatie op responsvoorbereiding gevonden, dewelke echter te niet gedaan of zelfs omgedraaid worden door de rotatie. Ook een andere EEG component dat in de wetenschappelijke literatuur vaak wordt gerelateerd aan aandacht en conflict – de N2 – ondergaat dergelijke veranderingen door het effect dat in principe niets met conflict te maken heeft. Vervolgens blijkt dat al dit plaatsvindt door de herinnering

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die veroorzaakt wordt door de huidige stimulus: de veranderingen die voortkomen uit de rotatie van de eerste stimulus worden pas gevonden nadat de tweede stimulus wordt aangeboden.

Al met al geeft dit proefschrift een goede hoeveelheid bewijs voor de hypothese dat executieve controle afhangt van wat we herinneringen zouden kunnen noemen. In de discussie van hoofdstuk zeven wordt kort geschetst wat dit zou kunnen betekenen, en wordt er gesteld dat het scheiden van geheugen en executieve controle door middel van cognitieve taken een zeer kunstmatige praktijk is. In een Stroop-situatie kan men bijvoorbeeld vrij aardig stellen dat men na het reageren op een incongruente stimulus een soort 'verhoogde aandacht' heeft, maar men zou niet moeten vergeten dat er in de eerste plaats een conflict optreedt doordat men kan lezen. Met andere woorden: de gekleurde woorden doen ons herinneren aan het lezen, wat weer kan interfereren met het benoemen van de kleur van de inkt. In plaats van herinneringen, 'kenmerkintegratie', executieve controle en automatisme dus te scheiden met een eindeloze hoeveelheid aan psychologische taken zou de wetenschap zich meer bezig moeten houden met de dynamiek van de verschillende functies en hoe deze afhangen van elkaar.

Curriculum Vitae

Michiel Spapé was born on the 22nd of February 1981, in the small village of Oost Knollendam, Netherlands. From there, he and his family moved to the coastal town of Noordwijk, Zuid-Holland, where he received his early education. (Atheneum Northgo college). Upon finishing secondary education in 1999, he moved to Leiden in order to study Psychology at the University of Leiden. His study, which specialised in Cognitive Psychology, was further enriched by several teaching (methodology and cognitive psychology) and research (educational science) assistantships. From 2005 on, however, he mainly devoted himself to a Ph. D. student position at the cognitive psychology unit of the University of Leiden. He has recently accepted a Post Doctorate position at the University of Nottingham, where he seeks to better understand the functional and neuropsychological factors behind perception-action integration and cognitive control.

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