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The Netherlands

Back in control : the episodic retrieval of executive control

Spapé, M.M.A.

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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

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.

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.