University of Essex

Research Repository

Action Field Theory: The Roles of Memory and Action in Automaticity of Cognitive Control

Accepted for publication in the American Journal of Psychology

Research Repository link: https://repository.essex.ac.uk/41267/

Please note:

Changes made as a result of publishing processes such as copy-editing, formatting and page numbers may not be reflected in this version. For the definitive version of this publication, please refer to the published source. You are advised to consult the published version if you wish to cite this paper.

https://doi.org/10.5406/19398298.139.1.05

www.essex.ac.uk

This is the accepted draft of the manuscript and may not be identical with the final publication.

Yamaguchi, M. (2025). Action field theory: The roles of memory and action in the automaticity of cognitive control. *American Journal of Psychology*.

Action Field Theory: The Roles of Memory and Action in the Automaticity of Cognitive Control

Motonori Yamaguchi

Author Notes

For the purpose of open access, the author has applied a Creative Commons Attribution (CC-BY) license to any Author Accepted Manuscript version arising.

This theoretical review was written originally for the author's PhD dissertation, completed and submitted in 2010 under the supervision of Robert Proctor, and was revised for the present article. It is a synthesis of the author's 5-year collaboration with Robert on stimulus-response compatibility, and it would not have existed without his pioneering work on the topic. Robert's numerous publications set the groundwork for the theoretical framework proposed in this article. In addition, much of the contents was also inspired by the work of Gordon Logan and of Bernhard Hommel. The name "Action Field Theory" was inspired by Jerome Busemeyer's Decision Field Theory but is nothing to do with the actual content of his theory. I thank Robert Proctor, Gordon Logan, Bernhard Hommel, Iring Koch, and Jan De Houwer for their comments on earlier versions of the manuscript.

Correspondence concerning this article should be addressed to Motonori Yamaguchi (motonori.yamaguchi@essex.ac.uk or cog.yamaguchi@gmail.com).

Abstract

Task-irrelevant features are processed even when people are fully aware of their undesired effects on task performance. This fact is exemplified by several types of interference effects in choice-reaction tasks, such as Stroop interference and the Simon effect. The observations are typically attributed to inextricable consequences of automatic cognitive processes involved in performing these tasks. However, evidence has accumulated suggesting that processes underlying these effects depend on one's intention to perform particular tasks, rather than being strictly automatic. Thus, there exists a paradox: the interference from task-irrelevant features presumes processes that are under intentional control. The present review attempts to resolve this paradox. I propose an integrated view of attentional control, *Action Field Theory*, which formulates principles that account for a range of phenomena concerning automatic control of human behavior.

Keywords: Selective attention; automaticity; Stroop task; Simon effect; action-based selection.

Introduction

We live in an inherently multidimensional environment and act on multivalent objects that afford several different actions in any given context. The utilities of these dimensions and object attributes change constantly depending on the task in which one is currently engaged. To optimize task performance, attention should be allocated across feature dimensions according to their utilities in the current task context. Understanding how people select appropriate stimulus features or dimensions has been of great interest in cognitive psychology (e.g., Allport, 1989; Logan, 2004; Treisman, 1988). *Selective attention* is a mechanism by which the cognitive system optimizes its processes to achieve a desired outcome more efficiently and effectively. Selective attention has traditionally been conceived of as a filtering process that blocks out irrelevant information from entering the system (Broadbent, 1958). Although people are remarkably capable of focusing on target information based on its physical properties (Cherry, 1953), early studies also showed that the filtering does not block all irrelevant information. For instance, people tend to notice information that has personal significance (e.g., own names; Moray, 1959), which could disrupt the task they are currently engaging. They may also mistakenly switch attending to a wrong source of information when its content matches the context of the currently attended information (Treisman, 1960), which could cause confusion and interference with the intended action. Nevertheless, the other side of the coin of these findings is an implication that processing of irrelevant information depends on a fixed set of factors, such as the contextual relevance or general pertinence of the information. Thus, task-irrelevant information is not processed arbitrarily. If so, the investigations into the cognitive principles behind processing of task-irrelevant information could help control or even eradicate its inadvertent consequences in one's action.

The goal of the present article is to review available evidence and synthesize a theoretical framework to understand the principles behind processing of task-irrelevant information. The framework delineates the mechanisms underlying selection across feature dimensions that give rise to automatic processing of task-irrelevant stimuli. To clarify the fundamental issues, this review will focus on the literatures concerning interference effects from task-irrelevant sources of information, such as Stroop interference and the Simon effect. Because comprehensive reviews of these phenomena already exist (e.g., Cespón et al., 2020; Lu & Proctor, 1995; MacLeod, 1991; Parris et al., 2022; Proctor & Vu, 2006; Simon, 1990), the purpose of this review is not to list all past findings from the large literature in an exhaustive manner. Instead, the review will focus on findings that are most relevant to my efforts to synthesize a theoretical framework, *Action Field Theory*. The main issues are considered in light of existing theoretical approaches, and unresolved issues are identified. The principles derived from the theory are discussed in comparison to other prominent approaches in the field.

The Paradox of Automaticity

Experimental demonstrations of interference from task-irrelevant stimulus dimensions are abundant in the literature. A representative example is *Stroop interference*, the phenomenon in which naming the color of a word is considerably slowed if the word spells a color name incongruent with the to-be-named print color (Stroop, 1935). The *Simon effect* is another example that exhibits interference from task-irrelevant spatial attributes of stimuli (e.g., locations) that are incompatible with the action to be made in response to the stimuli (Simon & Rudell, 1967). These observations have been attributed to automatic processing of task-irrelevant stimuli (e.g., Kornblum et al., 1990; MacLeod, 1991; Posner & Snyder, 1976). However, researchers have expressed their doubts about such explanations (e.g., Bargh, 1989; Kahneman

& Treisman, 1986), and evidence has accumulated to support the idea that interference is not due to “purely” automatic processing of irrelevant stimuli that satisfy a list of defining properties of automaticity as opposed to “controlled” processes, such as being unintentional, unconscious, uncontrollable, non-attentional, and interruptible (e.g., see Logan, 1988; Moors & De Houwer, 2006, for a review). Studies in the last half century illustrate how our conception of automatic processes have evolved over time, and there are findings indicating how automatic processes are dependent on intentional processes (e.g., Oberauer, 2019; Soto et al., 2008), as well as how intentional processes operate in an automatic fashion, on the other hand (e.g., Hommel, 2000b; Meiran et al., 2017). Nevertheless, it is also true that interference from task-irrelevant information is robust and difficult to eliminate even if one is fully aware of the detrimental effects on performance. Thus, the paradox is that interference from automatic processing depends on intentionally controlled cognitive processes but is still difficult to eliminate intentionally. This motivated the development of the current theoretical framework. To illustrate the paradox in more detail, the following sections will review available evidence that indicates three key observations; (1) seemingly automatic processes depend on one’s intention to perform a specific task, (2) intentional processes do operate in an automatic fashion, and (3) the main source of automaticity of cognitive processes is the actions set for a specific task. These observations serve as the primers for the forthcoming theoretical framework that provides a solution to the paradox in the present article.

The Primers for the Framework

Primer 1: Intentional Control of Automatic Processes

Psychological dimensions are analyzed separately for different ‘features’ of stimuli. This assumption is common in theories of visual attention (e.g., Liu, 2019; Treisman & Gelade, 1980;

Wolfe, 2021), and evidence supporting this assumption is abundant (e.g., Fagioli et al., 2007; Mordkoff & Yantis, 1993; Mortier et al., 2005; Müller & Krummenacher, 2006; Treisman, 1986, 1988; Treisman & Gormican, 1988). For example, a target stimulus can be visually searched for more quickly when the observers know in advance which stimulus dimension defines the target than when they do not (Treisman, 1988). Also, there is a cost of switching target-defining features across dimensions as compared to switching target-defining features within a dimension (Found & Müller, 1996). These findings suggest that attention is dimensionally selective.

Selection across feature dimensions can be achieved by filtering out information that belongs to task-irrelevant dimensions. This selection mechanism apparently depends on a top-down or intentional process that allows pursuit of a specific goal. If this were not so, one would hardly be capable of, for example, naming the color of a word that denotes an incongruent color name (e.g., saying "red" for the word *BLUE* printed in red). However, it is also true that people have difficulty ignoring certain aspects of the environment, producing interference in task performance. Researchers have attributed such difficulty to automatic processing of task-irrelevant information (e.g., MacLeod, 1991; Posner & Snyder, 1976). Automatization is thought to occur when tasks are overlearned (e.g., Hasher & Zacks, 1979; LaBerge & Samuel, 1984), especially in an invariant context (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). Once automatized, as the notion goes, processing of task-irrelevant information cannot be prevented, even though people may be fully aware of the interference that such information can cause to their performance.

Nonetheless, several researchers have challenged this view of automaticity on the ground that influences of task-irrelevant information are contextually dependent (e.g., Bargh, 1989; Logan, 1988; see Moors & De Houwer, 2006, for a review). For instance, exogenous attention capture, which is typically attributed to an automatic process (e.g., Jonides, 1981), has been shown to be contingent on the task-defined feature dimension (Folk et al., 1992). Likewise, studies suggest that even preattentive perceptual processes are subject to top-down control that determines task-relevant stimulus dimensions (Müller & Krummenacher, 2006). Thus, there seems to be close interplay between processes that operate in a stimulus-driven fashion and those that require top-down control (Yamaguchi et al., 2018). The present section attempts to clarify factors involved in such interactions and draw a preliminary picture of the mechanisms underlying intentional control of automatic processes.

Reversing Automatic/Control Relations

Stroop interference has been used as a textbook example of an automatic process that operates independently of, or even against, one's intention to perform a specific task (see Logan, 1989; MacLeod, 1991, for reviews). A strong form of this automaticity view holds that there are fundamental differences between automatic and controlled processes (Posner & Snyder, 1975). An implication of this approach is that interference is unidirectional from automatic to controlled processes. This interference asymmetry is a robust finding in the Stroop task: word-meaning interferes with color-naming, but word-color does not interfere with word-reading, which is known as the *Stroop asymmetry*. According to the automaticity account, word-reading is an over-practiced skill that has become automatized, whereas color-naming is not required very often in everyday activities and so requires deliberate control to initiate and complete the task. This account explains that the Stroop asymmetry occurs because automatic word-reading is insensitive to contextual factors and cannot be interfered with by color-naming, whereas controlled color-naming is flexibly modulated by task contexts but can be interfered with by the automatic word-reading.

However, the traditional conception of automaticity as defined by a set of properties has been challenged in Stroop studies (e.g., Besner, Stolz, & Boutilier, 1997; Kahneman & Treisman, 1986; MacLeod & Dunbar, 1988). Kahneman's contributions were particularly significant in this respect, showing that word-meaning does not interfere with color-naming if the word is printed in a color not included in the set of to-be-named colors (Kahneman & Henik, 1981; also see Francolini & Egeth, 1980; Proctor, 1978) and that the influence of word-meaning is reduced, or diluted, when an additional neutral word is presented (Kahneman & Chajczyk, 1983). Moreover, Bauer and Besner (1997) reported an experiment in which one group of participants performed a two-alternative color-classification task (Stroop task), and another group performed a color-detection task (judge the presence or absence of 'red' stimulus). Importantly, both tasks involved the same stimulus configurations (congruent or incongruent color words), manual responses (pressing one or the other key), and stimulus-response (S-R) mappings (pressing one key to 'red' stimuli and the other key to 'green' stimuli), but Stroop interference occurred only for color classification but not for color detection. The findings imply that automatic processes involved in the Stroop task are sensitive to contextual factors.

Most strikingly, McClain (1983) demonstrated that the Stroop asymmetry can be reversed by changing how people respond to stimuli. In her study, participants were presented with the words 'HIGH" or "LOW", spoken in high or low pitch, and were to utter a relevant dimension (word meaning or voice pitch) or hum in a pitch corresponding to the relevant dimension. Interference from an incongruent word occurred when verbally reporting the stimulus pitch but not when humming that pitch. In contrast, interference from stimulus pitch occurred when humming the pitch indicated by a word but not when verbally reporting the word, reversing the direction of interference (also see Flowers et al., 1979; Lu & Proctor, 2001; O'Leary & Barber, 1993; Virzi & Egeth, 1985). This finding implies the importance of stimulus-response compatibility in Stroop interference: A task-irrelevant stimulus interferes with responding to a task-relevant stimulus when the task-irrelevant stimulus is more compatible with the required response than the task-relevant stimulus, but not vice versa.

Stimulus-response compatibility was originally reported by Fitts and Seeger (1953), which showed better performance when the spatial layout of alternative responses was similar to the spatial layout of possible positions in which a stimulus can occur. Although these researchers used relatively complex stimulus and response configurations in their study, an illustration of a simpler version of stimulus-response compatibility would be a case in which a flash light can occur on the left or right side of a display, to which one respond by pressing one of the two response keys that are located on the left and right side of the actor or above and below the actor. In this case, the former key layout is structurally more similar to the stimulus layout than the latter key layout; hence, the horizontal layout is said to be more compatible with the stimuli than the vertical key layout. Fitts and Deininger (1954) subsequently reported that when the stimulus and response layouts were the same (e.g., both involved left and right positions), task performance was better if stimuli were mapped to responses at the same position within the layout than if they were mapped to responses at a different position; that is, task performance would be better if the left and right stimuli are mapped to the left and right keys, respectively, than the other way around.

The Simon effect is a special case of this stimulus-response compatibility effect that occurs when people respond to non-spatial aspects of stimuli (e.g., colors) but their performances are influenced by the spatial compatibility between the stimuli and the responses (Simon & Rudell, 1967; also see Lu & Proctor, 1995, for a review). McClain's (1983) and others' findings that Stroop-like interference depended on the compatibility of the task-irrelevant stimulus attribute with the required response seems to indicate that Stroop interference is a type of the Simon effect. That is, there is nothing inherent in a specific stimulus feature that makes it automatic by itself; instead, interference from one stimulus attribute to another attribute is a function of the degrees of compatibility between the stimulus attributes and the required response. Stroop interference and the stimulus-response compatibility effect are typically considered to be distinct phenomena (e.g., Kornblum & Lee, 1995; Pratte et al., 2010), but the findings seem to imply that these phenomena share a common underlying mechanism.

Strategic Modulations of Automatic Processing

An early account of stimulus-response compatibility described the phenomenon in terms of the efficiency of translation process from stimulus to response (Fitts & Deininger, 1954; Fitts & Seeger, 1993). Fitts and Switzer (1962) suggested that when a stimulus is physically similar to a response, this process proceeds via a ‘direct association’ between the stimulus and the response, bypassing time-consuming response-selection processes. Consistent with this view, *dual-route models* of stimulus-response compatibility, which have been prominent from the 1990s to early 2000s, assume two routes for response selection (e.g., De Jong et al., 1994; Eimer et al., 1995; Kornblum et al., 1990; van Duren & Sanders, 1988). The dual-route accounts retain the traditional automaticity explanation of Stroop interference, in that, as the name indicates, a key feature is the assumption of two qualitatively distinct response-selection routes, one automatic and the other controlled. The accounts state that a stimulus automatically activates a spatially corresponding response, regardless of the relevance of that response to the task goal, and it interferes with processing of task-relevant information if the activated response is incompatible with the correct response required in that context. This illustrates that the dual-route accounts of stimulus-response compatibility follow the dichotomy between automatic and controlled processes implicated for Stroop interference, suggesting that processes may be strictly automatic only when stimulus and response are highly compatible. However, evidence against the dual-route accounts has also accumulated in the last decades.

For instance, Shaffer (1965) showed that the advantage of the compatible mapping can be eliminated when participants must select an S-R mapping on each trial (De Jong, 1994; Yamaguchi & Proctor, 2006), and, as in the Stroop task, the Simon effect depends on the relative frequency of compatible and incompatible trials (Hommel, 1994; Marble & Proctor, 2000; Toth et al., 1995). Similarly, the Simon effect is modulated according to task-instructions (Hedge & Marsh, 1975; Hommel, 1993) and task-demands (Koch & Prinz, 2005; Yamaguchi & Proctor, 2011b). For tasks in which the location information is conveyed by words or arrow directions, the effect is reduced when an additional neutral stimulus is simultaneously displayed (Miles, Yamaguchi, & Proctor, 2009), suggesting that processing underlying the Simon effect is contextually sensitive and attentionally limited. These observations imply that automatic response activation is not an inevitable consequence of similarity or feature overlap between stimulus and response. Indeed, contemporary researchers seem to agree that the automatic process can be altered strategically (e.g., De Jong, 1995; Hommel, 2000a; Stürmer et al., 2002).

The exact mechanism that gives rise to strategic control of automatic processes is still subject to further research. One of the central questions in this issue is why task-irrelevant stimuli are encoded in the first place if automatic processes can be controlled when the stimuli are irrelevant to selecting the correct response or even activate an incorrect response. It is possible that all stimuli are processed and analyzed in parallel when they occur, regardless of their relevance to the task (Kornblum et al., 1990), which is consistent with late selection views of attention (Deutsch & Deutsch, 1965; Norman, 1968). It is also possible that encoding is selective with respect to which irrelevant stimuli should be processed according to the task goal, as contemporary theories of visual attention propose (e.g., Müller & Krummenacher, 2006; Wolfe, 2021). O'Leary and Barber (1993) showed that response-irrelevant stimulus location interfered with reading a location word even though the spatial attribute is less compatible with naming a word than is the task-relevant word stimulus. This interference may happen because attending to the stimulus location is necessary to identify the word meaning and, thus, processing of location information is obligatory (e.g., Logan, 1998; Treisman & Gelade, 1980). This explanation seems consistent with the *attention-shifting account* of the Simon effect (Stoffer, 1991; Umiltà & Liotti, 1987), according to which encoding of an irrelevant spatial feature is required in order to shift spatial attention toward the stimulus location. However, although this may be true, the attention-shifting account is severely limited in its scope and unable to explain phenomena outside of the spatial domain, such as the Simon effect based on color (Wühr & Biebl, 2009), numerosity (Wühr et al., 2008), duration (Grosjean & Mordkoff, 2001), or intensity (Romaiguère et al., 1993). Critically in the present context, it cannot explain Stroop interference. At the same time, O'Leary and Barber (1993) also showed that although irrelevant word meaning did not produce interference when the relevant dimension was word location, it did produce interference when the task was modified to necessitate intentional processing of word meaning by requiring participants to identify the target stimulus (spatial word) from two simultaneously presented words.

Like O'Leary and Barber (1993), Eimer and Schlaghecken (1998) demonstrated that subliminal priming of a response depended on whether the response matched the target stimulus. Their participants responded to a double-arrow (<< or >>) that occurred right after a prime stimulus. Although the participants were unable to perceive the primes according to a separate recognition test, rapid initial activation of the response spatially compatible with the prime was observed in the lateralized readiness potential (LRP) measure of brain activity (which is assumed to reflect automatic activation of a response; e.g., Eimer, 1995) when the prime was also a double-arrow. Yet, the researchers found that the arrow-prime did not produce the automatic activation of a contralateral response when the targets were replaced with letters (LL or RR). These results demonstrated that the same double-arrow prime was processed to activate a response subliminally when their participants prepared to process the same, or similar, target stimulus but not when they prepared to process a target that differed from the subliminal prime. The finding implies that not all stimuli are processed to the point where associated responses can be activated automatically. Instead, automatic response activation presumes intentional processes that decide what task dimensions need to be processed to perform the task.

Ansorge and Wühr (2004) also showed that the Simon effect is produced based on one stimulus dimension but not on another, depending on how responses are defined in the task. In their study, participants started each trial by placing their index finger at the center key and moved it to one of two keys in response to the color of stimuli that appeared at one of four positions (left, right, top, and bottom). The Simon effect was obtained based on the vertical spatial dimension in a condition for which two response keys were located to the top-left and bottom-left of the center key. In contrast, the Simon effect was obtained based on the horizontal spatial dimension when response keys were located to the top-left and top-right of the center key. To explain these findings, Ansorge and Wühr (2004) proposed the *response-discrimination account* (also see Wühr & Ansorge, 2007), according to which the Simon effect occurs based only on stimulus features overlapping with response features that help discriminate between the alternative responses. They argued that pressing a key with either response set should have involved motor parameters for controlling the finger movements in the horizontal and vertical dimensions, but only the spatial dimension that was helpful for discriminating the alternative responses yielded a Simon effect.

Similar results were obtained in Wühr et al.'s (2008) experiments in which responses were varied in spatial location, numerosity (number of keypresses), or both. Again, the Simon effect occurred based only on the S-R correspondence in spatial location when the location of responses varied while the numerosity was held constant; it occurred based on the S-R correspondence in numerosity when the numerosity of responses varied while the response locations were held constant; and it occurred based on the S-R correspondences in both spatial location and numerosity when both factors varied between two alternative responses. These results are consistent with the notion that automatic processes presume intention to process certain task dimensions. The response-discrimination account emphasizes that, in order for a stimulus dimension to produce the Simon effect, alternative responses must be represented in working memory (WM) in terms of features in that dimension (Ansorge & Wühr, 2009). The importance of response representations may simply be because of automatic response activation being mediated by representations that are currently held in WM. Alternatively, there may be a more fundamental reason that response representations must be kept active in order for automatic response activation to occur.

The Role of Working Memory Contents in Attentional Selection

Many recent studies in spatial attention underscore the importance of WM contents in exogenous attention orienting that is thought to be stimulus-driven or automatic (e.g., Beck & Vickery, 2019; Hollingworth & Hwang, 2013; Olivers et al., 2011; Zhang & Yamada, 2023).

This was first demonstrated by Downing (2000), who had participants remember a human face at the beginning of each trial for a later recognition test. During the retention interval, participants performed a classification task for simple visual stimuli. The key manipulation was that two faces (the studied face and a novel face) were briefly presented on the left and right sides of the screen just before the target for the classification task occurred. Responses to the intervening visual task were faster when the target occurred at the location that had been occupied by the studied face than when it occurred at the location that was occupied by a novel face. This result was interpreted as indicating that visual attention was captured by stimuli that matched the contents of WM. Downing showed that the effect was not obtained when the recognition test was eliminated in the procedure. These results have been replicated in subsequent studies (Olivers et al., 2006; Pratt & Hommel, 2003; Soto et al., 2008; Woodman & Luck, 2007). Researchers disagree as to whether the memory-driven attention capture is purely automatic (Soto et al., 2008) or strategically driven (Downing & Dodds, 2004; Woodman & Luck, 2007). In particular, the strategic view suggests that the memory-driven attention capture is allowed when it (at least occasionally) benefits the goal attainment but not when it always disrupts performance (Woodman & Luck, 2007). It appears that one has control over setting an attentional template to direct attention, and, once it is set, it can be used in a reflexive manner regardless of whether it facilitates or impairs attention orienting (Yamaguchi et al., 2018).

This memory-driven attention capture is typically explained with reference to the biased competition model of selective attention (Desimone, 1996; Desimone & Duncan, 1995). According to the model, an exemplar of the target object is retrieved into working memory as an attentional template, and a visual object that matches the template (Chelazzi et al., 1993) or that is semantically associated with the template (Moores et al., 2003) is favored in competition for visual attention. Although the studies of memory-driven attention capture have focused on its role at a feature-level, Pan et al. (2009) demonstrated that capture can also occur at a dimension-level. These findings in memory-driven attention capture suggest that selective encoding of task-irrelevant information, and the contingency of its influence on the task performance, may be due to the need to keep certain memory representations highly active in WM to perform the assigned task. Provided that maintaining information in WM is an intentional act, it follows that stimulus-driven processes have to be internally motivated and presume an intentional act of control. It is conceivable that the same mechanism is at work in the Simon task and Stroop task, which explains why the Simon effect and Stroop interference depend on the specific response requirements imposed by the tasks. In these tasks, response representations must be kept highly active in WM and act as attention templates, so attention may be drawn to stimuli that share some attributes of the response representation in WM.

There are studies that suggest a close link between Stroop interference and WM capacity (e.g., Kane & Engle, 2003). This link may originate from greater difficulty of people with low WM capacity to bring the attentional focus to the task-relevant attentional template than those with high WM capacity. Kane and Engle termed the failure of attending to the task-relevant stimulus features “goal neglect,” which tends to occur to a greater degree in individuals who have lower WM capacity (also see Engle, 2002). A possible reason for this association between low WM capacity and the extent of goal neglect may be that response representations compete against the goal and task-relevant stimulus representations for limited resources, given that all of these representations are necessary to perform the task. If the WM capacity is exceeded, some of these representations may need to be put aside, which weakens the influences of some of these task attributes on performance, depending on which representations are kept in WM.

Primer 2: Automaticity of Voluntary Actions

Logan (1978) investigated the influence of memory load on a visual search task and tested whether load would interact with other experimental variables that were assumed to selectively influence distinct processing stages (encoding, response selection, response execution, etc.). Participants were required to remember a set of digits presented at the beginning of a trial for later recall, and they performed a visual search task during the retention period. It was reasoned that if a processing stage is automatic, memory load would not interact with an experimental variable associated with the stage. These variables included the number of targets, stimulus quality, presence/absence of an exogenous attention cue, decision type (yes/no), stimulus-response compatibility, and response mode (vocal/manual). The results indicated, however, that only the number of targets interacted with memory load.

Logan's (1978) interpretation of these results was that, although the task required attention (as memory load always had a main effect), component processing stages operated automatically and were free from attentional limitations. He stated:

> The components of the task seem automatic, but the task itself is not. Perhaps the stage structure of a task should be viewed as a temporary assembly of automatic, special-purpose processors organized by attention to deal with the task at hand. […] It may take attention, then, to *prepare* an appropriate sequence of structures and *maintain* it until a stimulus has appeared. (p. 57)

While the last section discussed evidence that automatic, stimulus-driven processes must be internally motivated, Logan's proposal is that presumably controlled processes operate in an automatic fashion. Thus, two nominally different types of cognitive processes appear to operate in similar manners. The main objective of the present section is to establish how it is possible that one process operates in both automatic and controlled fashions.

Stimulus-Driven Response Activation via Task-Defined Rules

Automatic processes are not independent of one's intention to act, and intentional processes can operate in an automatic fashion. In the aforementioned study of Eimer and Schlaghecken (1998), for example, the LRP measures indicated rapid initial activation of responses even when the prime and target did not have explicit spatial features (i.e., when the prime and target were <> or ><) that would be shared with the required spatial responses. Such a demonstration provides evidence that stimulus-driven response activation is not restricted to conditions in which intrinsic S-R associations exist, but arbitrary S-R mappings can also yield automatic activation. This observation is consistent with the occurrence of the flanker compatibility effect (Eriksen & Eriksen, 1974). In the flanker task, response competition arises between currently relevant and irrelevant S-R mappings, both of which are established by task instructions and cannot be attributed to pre-existing S-R associations. More recently, De Houwer (2004) showed that when participants were to respond to the color of stimuli with arbitrary utterances ("cole" or "cale"), responses were faster when the stimulus appeared at the location compatible with other spatial stimuli (arrows and location words) to which that response was assigned. That is, if a left-pointing arrow, the word "LEFT", and 'green' circle were mapped to the "cole" response, the response to the green circle was faster if it appeared on the left than if it appeared on the right (see De Houwer, 2003, for an analogous finding in an affective version of the Simon task). De Houwer et al. (2005) further provided evidence that, to yield this 'extrinsic' Simon effect, it is sufficient only to instruct participants about how to respond to the arrows and the words, even though these stimuli never actually occurred during the experiment. That is, even in absence of pre-existing S-R associations, an arbitrary association between response and other spatial stimuli induces a Simon-like effect, implying that stimulus-driven response activation depends on a purposeful task preparation.

Hommel (2000b) characterized stimulus-driven response activation via task-defined rules as a *prepared reflex*. As Logan (1978) proposed, the prepared-reflex notion suggests that the actor's intention does not appear to be situated somewhere between perception of stimulus and response programming, but it takes place at the very beginning of the task at which relevant task algorithms are prepared for future implementations (see also, Eder et al., 2010; Hommel, 2010). The role of intention may be more properly conceived of as establishment of a task plan (Logan, 2007; Miller et al., 1960), instead of implementations of mapping rules. Although relevant S-R mappings must be maintained in an active state during the task, application of the S-R rules may be carried out without volitional processes once a task plan is established unless there is a need to alter the plan. This idea appears consistent with the findings of dual-task studies.

Researchers generally agree that there is a bottleneck in the stream of cognitive processes that can operate one task at a time, although they disagree as to whether this bottleneck is due to a structural limitation (Pashler, 1994; Welford, 1952) or strategically created to optimize the task (Logan & Gordon, 2001; Meyer & Kieras, 1997). In a dual-task experiment, a robust finding is that responding to the second of the two tasks is delayed when the stimuli for the two tasks occur in a rapid succession. Researchers agree that this delay is because of an attentional bottleneck that restricts the start of response selection for the second task until that for the first task completes. However, Hommel (1998a) found that the response to the first task was made more quickly when it was compatible with the response to the second task (e.g., the first task required a left manual response when the second required uttering "left") than when it was incompatible (the first task required a left response when the second required uttering "right"). This effect was termed the *backward compatibility effect* (also see Way & Gottsdanker, 1968). It seems to show that the response activation for the second task bypasses the attentional bottleneck and occurs in parallel to the response selection for the first task, as if the response activation is automatic even though it follows a task-defined rule with which participants have not been trained extensively and should not have been automatized in the traditional sense (e.g., Schneider & Shiffrin, 1977). Subsequently, Logan and Schulkind (2000) varied the types of two tasks to be performed in the dual-task condition and found that the backward compatibility effect occurred only when the two tasks were of the same kind but not when they were of different kinds, indicating that the effect is obtained when the task does not need to be reprogrammed or switched. That is, the backward compatibility effect suggests that response selection can operate in parallel without executive control if the necessary control parameters have been prepared in advance. Consistent with these findings, Koch and Rumiati (2006) found that R2 was also faster when it was spatially compatible with S1 only if the spatial attribute of S1 was a task-relevant dimension (see also, Koch, 2009).

Another line of research also supported seemingly automatic implementation of instructed task-defined rules without prior experience to implement them (see Meiran et al., 2017, for a review). Liefooghe et al. (2012) demonstrated what they termed an *instruction-based congruency effect*, which is observed when participants are instructed on two tasks involving different stimulus-response mappings. In their experiments, participants are prepared to perform both tasks, but one of the tasks (called the *inducer task*) is required only on the final trial of a series (e.g., after they performed the other task, called the *diagnostic task*, for 16 trials). Liefooghe et al. found that even before their participants performed the inducer task, the stimulus-response mapping rules for the inducer task could influence responses for the diagnostic task (i.e., responses were faster when the stimuli for the diagnostic task required the same response for the diagnostic and inducer tasks than when they required different responses for the two tasks; also see Wenke et al., 2007). They also found that this instruction-based congruency effect was observed only when participants remembered the task rule for later implementation but not when they remembered it for a memory test, suggesting that merely keeping the rule in their mind was not sufficient to produce the effect. Liefooghe et al. (2013) further demonstrated that the instruction-based congruency effect occurred only when sufficient preparation for the inducer task took place before the diagnostic task started, supporting the idea that the effect arises from proactive cognitive processes to perform a task later. Furthermore, Meiran and Cohen-Kdoshay (2012) found that an instruction-based congruency effect disappeared under high WM memory load (also see Cohen-Kdoshay & Meiran, 2007; Meiran et al., 2016).

According to Logan and Gordon's (2001) model of dual-task performance, the capacity-limited executive control is required to program parameters of subordinate systems that implement S-R mappings, which would result in dual-task interference. Importantly, executive control is necessary when the parameters of the subordinate systems must be changed (e.g., from Task 1 to Task 2) but not when the parameters for the previous trial can be reused for the current trial. Once the parameters have been programmed, operations of the subordinate systems are autonomous. Hence, the executive control is not necessarily involved in response selection on a trial-by-trial basis. In a more extreme case, the executive control may be unnecessary even to change control parameters if they can be retrieved automatically. Indeed, there is evidence that such automatic implementation of intentional acts is possible without relying on a capacity-limited executive process or working memory.

Automaticity of Voluntary Acts without working memory

In dual-task situations, task-defined rules may be implemented automatically because multiple task rules must concurrently be maintained in WM. As the prepared-reflex notion suggests, the flanker and backward compatibility effects may be due to erroneous implementation of wrong S-R mappings. Yet evidence supports that actively maintaining task rules in WM may not be necessary for automatic implementation of task-defined rules. For instance, Yamaguchi and Proctor (2011a) had participants perform two-choice reaction tasks based on the color or shape of stimuli and examined the *response congruity effect* (faster responses when the color and shape are assigned to the same response than when they are assigned to different responses), which is analogous to the flanker compatibility effect but when two stimuli are parts of the same stimulus. If concurrent maintenance of S-R rules is required for stimulus-driven response activation to occur, the influence should be eliminated when task uncertainty is excluded.

This prediction was tested in two ways. First, it was hypothesized that the influence of stimulus-driven response activation should decline as the interval between a task cue and stimulus (cue-target interval, CTI) increases if concurrent maintenance of irrelevant S-R mappings is necessary. With the task procedure, the cost of switching tasks (longer response times when the task performed on the preceding trial switches for the current trial than when it repeats) is found to dissipate over CTIs. This task-switching cost is thought to stem from relative activation of relevant and irrelevant task-sets (e.g., Allport et al., 1994; Rogers & Monsell, 1995; but see Logan & Bundesen, 2003; Mayr & Kliegl, 2003), which implies that the influence of irrelevant S-R mappings should also dissipate over CTIs. However, in the study, the switching cost declined but the congruity effect did not. Second, Yamaguchi and Proctor (2011a) separated two tasks into different blocks, assuming that irrelevant S-R mappings would no longer be actively maintained in WM because participants knew that the mappings would never be used in a given block. Consistent with this prediction, responses were much faster when tasks were blocked than when they were intermixed (even when the blocked condition was compared to task-repeat trials of the mixed condition), implying that irrelevant S-R mappings were unloaded from WM. Yet, the congruity effect persisted in the blocked condition. Taken together, these results suggested that the congruity effect was not due to irrelevant S-R mappings being held active in WM, implying that automatic implementation of task-defined rules does not depend on the content of WM alone. The fact that automatic effects can be obtained with such a short practice indicates that automatic processes can develop much faster than what might be believed from classic studies of automaticity (e.g., LaBerge & Samuels, 1974; Schneider & Shiffrin, 1977). This observation is consistent with the *memory view* of automaticity (Logan, 1988).

The Memory View of Automaticity

The traditional view of automatic processes, underlying the dual-route accounts of stimulus-response compatibility and the automaticity account of Stroop interference, is sometimes called the *modal view* because of its close association with the Donders-Sternberg-type model of information processing (Donders, 1868/1969; Sternberg, 1969b). The modal view suggests that automatization involves a shift of processing modes through extensive training, without specifying the underlying processes responsible for the qualitative shift (Logan, 1992). Alternatively, the memory view states that processes are automatic if they depend on retrieval of past S-R episodes (Logan, 1988). This *instance theory* of automaticity diverges from the modal view, in that it proposes that automatic processes are not constrained by a set of properties that define the kind of processes in the modal view. Instead, the memory view argues that it is the underlying mechanism that determines whether performance is automatic or not. It suggests that both automatic and controlled processes can demonstrate some properties in one context but other properties in another context, so no fixed set of properties can define them. An implication of the memory view is that automatic processes can occur without extensive training (Logan & Etherton, 1994; Zbrodoff, 1999). It predicts that automaticity can arise even after single encounters with particular S-R episodes or after the task is instructed without actually performing the task (Logan & Klapp, 1991). These predictions are consistent with the aforementioned effects of instructions, as well as other findings such as those of Waszak et al. (2003) who found that there was a larger cost of starting a new task if a stimulus had been encountered previously in a different task context even once.

There has been increasing emphasis on the role of memory retrieval in cognitive control, and this view is becoming dominant in the field. This trend has emerged mostly from studies investigating forms of sequential effects (e.g., Egner, 2014; Frings et al., 2020; Schmidt et al., 2020). For instance, the Simon effect, Stroop interference, and the flanker effect are smaller in trials that immediately follow an incompatible trial as compared to trials that follow a compatible trial (e.g., Gratton et al., 1992; Notebaert et al., 2005; Stürmer et al., 2002). These sequential modulations have been interpreted as implying involvement of executive control that adjusts the cognitive system to resolve processing conflict (Botvinick et al., 2004; Gratton et al, 1992; MacLeod, 1991). According to this account, a processing route responsible for task-irrelevant information is suppressed when response conflict is detected, and this suppression carries over to the immediately following trial (Stürmer et al., 2002). However, other studies have suggested that the sequential modulations are due to priming of a previous task episode (e.g., Hommel et al., 2004; Mayr et al., 2003).

Hommel et al. (2004) provided a detailed analysis of sequential modulations and showed that responses were faster in the Simon task either when both relevant and irrelevant stimuli repeated (complete repetition) or when both switched (complete alternation) than when only one of the stimulus attributes repeated (partial repetition). The Simon effect is large after a compatible trial because a subsequent compatible trial is a complete repetition or complete alternation, whereas an incompatible trial is a partial repetition. In contrast, the Simon effect is small after an incompatible trial because a subsequent compatible trial is a partial repetition, whereas an incompatible trial is a complete repetition or complete alternation. To account for the pattern of the Simon effect, Hommel et al. suggested that task-relevant and irrelevant features are integrated into a task episode, and there is a cost of unbinding these features when only one of them is repeated but not when all features repeat or alternate. This priming view emphasizes automatic retrieval of task episodes, which is also supported by other studies. For instance, Mayr et al. (2003) found that the sequential effect was task specific. They alternately administered two versions of the flanker stimuli (horizontally or vertically oriented) and showed that the reduction of the flanker effect at the current *n*th trial depended on the compatibility on trial $n - 2$ of the same stimulus type but not that on trial $n - 1$ of a different stimulus type. Spapé and Hommel (2008) also found similar stimulus-specific sequential modulations using female and male voices to present auditory Stroop stimuli. Wendt et al. (2006) and Fernandez-Duque and Knight (2008) further showed that the sequential modulations of the Stroop or Simon effect are not altered by the compatibility of an intervening flanker task. In addition, Fischer et al. (2010) intermixed dual- and single-task trials and found that sequential modulations of the Simon effect depended on whether the previous trial was of the same trial type. These findings imply that sequential modulations of the Simon effect or Stroop interference are due to stimulus-driven retrieval of a task episode rather than stimulus-independent adaptation to conflicting stimuli.

The role of memory retrieval has also been demonstrated in the task-switching procedure, which is believed to involve highly controlled processes (e.g., Logan & Bundesen, 2003; Mayr & Kliegl, 2000; see Logan, 2009, for a review). As mentioned, task-switching cost has been attributed to residual activation of an irrelevant task-set (Allport et al., 1994) or intentional reconfiguration of the relevant task-set (Meiran, 1996; Rogers & Monsell, 1995). However, Mayr and Kliegle (2000) showed that task switching cost depends on memory-retrieval demands but not on task complexity or difficulty, questioning the attribution of task-switching cost to executive control. Logan and Bundesen (2003) and Mayr and Kliegle (2003) also showed that a major component of task-switching cost is due to switching of task-cues when the relevant task is explicitly cued in advance, thus implying that the cost reflects benefit of task-cue repetitions. Rogers and Monsell (1995) suggested that task-defined rules can be retrieved in a stimulus-driven manner. They reported that responses were generally faster when task-irrelevant stimuli were neutral with respect to response selection as compared to when they were compatible or incompatible with the task-relevant stimuli. Likewise, Arrington and Logan (2004; Arrington, 2008) proposed that a stimulus-driven retrieval process contributes to voluntary selection between alternative tasks, in that the probability of task repetition in their experiments depended on the availability of relevant stimuli. In a similar manner, Weaver and Arrington (2010) proposed that irrelevant memory items held in WM determine voluntary task selection. When the tasks are as simple as selecting between a few (typically two) alternative responses, cognitive control can operate based on automatic retrieval of temporary S-R associations.

A Unitary View of Memory and Attention

In the context of the present article, the memory view of automaticity raises an important challenge for the traditional distinction between automatic and controlled processes. Whereas the earlier sections highlighted evidence supporting the involvement of intentional processes or goal-settings in operations of automatic processes, there is also evidence that automatic processes are independent of WM. From the view that WM is associated with executive control (e.g., Baddeley, 1992), the conclusions seem contradictory. However, the observations are reconciled in a unitary view of memory and attention (e.g., Anderson, 1983; Cowan, 1988).

As discussed earlier, the instruction-based congruency effect appears to depend on WM (e.g., Meiran & Cohen-Kdoshay, 2012), whereas the response congruity effect in cued task-switching does not (Yamaguchi & Proctor, 2011a). Meiran and Kessler (2008) examined the congruity effect in the task-switching paradigm and raised a paradox associated with the effect that mirrors the present issue. They pointed out that the congruity effect depends on task preparation, in that the effect is obtained even when task switching is expected but never occurs (Yehene et al., 2005). The congruity effect does not interact with concurrent memory load (Kiesel et al., 2007), suggesting that the effect does not depend on WM. To resolve the paradox, Meiran and Kessler suggested that the congruity effect stems from an “activated region” of long-term memory (LTM). Echoing with their proposal, Liefooghe et al. (2013) also asserted that the seeming independence of the response congruity effect in Yamaguchi and Proctor’s experiments could be understood that the practice-based automaticity relied on the activated region of LTM, whereas the instruction-based automaticity relies on the region of immediate access (Oberauer, 2002; also see Oberauer et al., 2013). These ideas originate from a unitary view of memory that sees WM as a sub-region of LTM (e.g., Anderson, 1983; Cantor & Engle, 1993; Cowan, 1988; Öztekin et al., 2010), not a structurally distinct component as popularly assumed (Atkinson & Shiffrin, 1971; Baddeley, 1992).

A widely known unitary view is Cowan’s (1988, 1995) framework that distinguishes subregions of LTM into the *focus of attention*, which can contain a limited number of items, and the activated region of LTM, which can expand without a limit. This unitary view is supported by several studies (e.g., Klapp et al., 1983; Oberauer, 2001). Of most relevance is Oberauer's study, in which he used a variation of Sternberg's (1969a) memory scan task. Participants were presented with two lists of memory items and were later cued to judge whether a probe was present in a target list while ignoring the other list. Responses were faster when the set size of the relevant or irrelevant item list was smaller. This set-size effect based on the relevant list increased, but the effect based on the irrelevant list decreased, as the interval between the study lists and the probe (i.e., CTI) increased. However, Oberauer also suggested that the influence of irrelevant list on task performance even after the set-size effect had ceased, because response time was generally longer to reject the probe when it was from the irrelevant list than when it was from neither list. This intrusion effect remained even with a 5-s CTI. Oberauer interpreted these results that the divergence between the set-size effects was due to a gradual shift of attentional focus toward the relevant list and away from the irrelevant list, but the irrelevant list remained in the activated region of LTM, producing the persistent intrusion effect. Oberauer (2002) later proposed a further distinction between a region of immediate access, which can hold a limited number of items (e.g., 4 items), and the focus of attention, which can only hold a single item. This approach appears consistent with the findings that the congruity effect remained significant after irrelevant S-R mappings were unloaded from WM and that the effect was independent of CTI (Yamaguchi & Proctor, 2011a). That is, as suggested by Meiran and Kessler (2008), the congruity effect arises from the activated portion of LTM, rather than a capacity-limited focus of attention (or the region of immediate access in Oberauer's model). This conclusion also explains the larger congruity effect in the mixed-task condition than in the blocked-task condition (Yamaguchi & Proctor, 2011a), because activation of LTM assumedly dissipates over time when it is not used for a period (Oberauer, 2005).

Intention and Automaticity in the Same Nest

From the memory view of automaticity (Logan, 1988), automatic processes are those that operate based on retrieval of task episodes or instances. This proposal is consistent with the unitary view (e.g., Anderson, 1983). For example, Cowan (1988) explained that both automatic and controlled actions arise from the activated region of LTM, which provides an explanation for the role of intention in automatic retrieval of task episodes. Several studies have demonstrated automatic processes based only on instructions without actually administering the task (e.g., De Houwer et al., 2005; Yehene et al., 2005; Zbrodoff, 1999) or after a single encounter with the task (e.g., Waszak et al., 2003). These findings can be explained if task rules or episodes remain active in LTM, without being active in WM. Conversely, other studies have shown that automatic processes do not occur if task features that encourage intention to process task-irrelevant information were excluded (e.g., Ansorge & Wühr, 2004; Eimer & Schlaghecken, 1998; Koch & Prinz, 2005; Yamaguchi & Proctor, 2011b). The observations are also consistent with the framework in that relevant LTM becomes deactivated when such features are no longer present in the task context. Thus, automatic processes require pre-activation of LTM representations, and they are retrieved when stimuli associated with the representations are encoded into memory. On the other hand, controlled processes are those that operate by shifting attentional focus in LTM (or the region of immediate access; Oberauer, 2002). Thus, task-switching costs may be obtained because the attentional focus must be shifted from one place to another, though what is attended during this operation is still a matter of controversy (e.g., task rules vs. task cues; Logan & Bundesen, 2003).

This nested view of automatic and controlled processes appears radically different from typical explanations of interference phenomena such as the Simon effect and Stroop interference. These explanations rely on qualitative differences between automatic and controlled processes (e.g., Kornblum et al., 1990; Posner & Snyder, 1976), but the present interpretation suggests that these processes do not differ in their qualities. Instead, controlled and automatic processes differ only in the degree to which activation depends on the operations that must be implemented to accomplish the immediate goal. Note that the present interpretation also differs from the continuous view of automaticity, according to which the degree of automaticity is simply a function of the amount of training (e.g., Dunbar & MacLeod, 1988; Hasher & Zacks, 1979), because this view is silent as to the mechanism underlying automatic processes.

The nested view of automatic and controlled processes also shares the core structural assumption of cognitive control with the hierarchical theory of skilled performance (Logan & Crump, 2011). According to the hierarchical theory, highly trained skills are controlled by nested control loops that have different processing units. For example, in skilled typewriting, lower-level control loops process smaller chunks (e.g., letters or individual keystrokes) and are embedded within a higher-level control loop that processes larger chunks (e.g., words). When they intend to type words, typists would implement the higher-level loop, but the operations of the lower-level loops are also triggered automatically without intending to type each letter because the lower-level loops are embedded within the higher-level loop. From this view, automatic and intentional processes are not separate routes of cognitive processes, but they are part of a larger system in which both automatic and intentional processes are utilized in concert. It is, thus, misleading to consider automatic and intentional processes as qualitatively distinct processes or routes of information processing. In fact, skilled typists can shift their attention from a higher-level loop to a lower-level loop, for example, when they are required to type unfamiliar words or when they type on an unfamiliar keyboard (e.g., Yamaguchi & Logan, 2014; Yamaguchi et al., 2017), which deteriorates their typing performance. The hierarchical structure of cognitive control allows skilled actors to perform a task without thinking about the details of the task (Logan, 2018), but it also allows them to think of the details if it is needed to optimize the performance outcomes (e.g., the accuracy of typing letters).

A hierarchical model provides a dynamic view of cognitive control that can also take place in more simple tasks, such as the Stroop task and the Simon task. The actors would set and maintain a specific task goal at a higher level, and they let the lower-level processes take care of specific actions. In the Stroop task, the goal may be to utter a color word on each trial, which would require the lower-level process to, for example, encode the stimulus, retrieve a corresponding action, and implement the action. If there are multiple features of a word stimulus, the encoding process may encode all features, and the retrieval process may retrieve all corresponding actions for the multiple features. These processes can occur autonomously and simultaneously, which could result in cognitive conflict if incompatible actions are retrieved. The higher-level process may then resolve the conflict to execute the most appropriate response for the given stimulus. However, this view still does not explain why conflict results in some situations but not in others, even when the actor must act on the same multi-feature stimuli (e.g., as in the Stroop asymmetry discussed above). This caveat requires consideration of the final primer, which is discussed in the next section.

Primer 3: Action-Based Selection across Feature Dimensions

As discussed above, empirical evidence showed that automaticity of cognitive processes involves intentional control, whereas task-defined rules that should require intentional control of relevant operations can exhibit characteristics of automatic processes. These observations are readily accommodated by the nested model of automaticity and cognitive control. Yet, such a model does not explain why a complete elimination of interference is hardly ever achieved. It is not immediately clear either why Stroop interference and similar effects can occur in one context but not in another. There is still a missing piece that needs to be considered for the paradox of automaticity to be resolved. This missing piece is the notion of action-based selection, which is the idea that features in the environment are selected for cognitive processing according to its relevance and resemblance to the actions being prepared for a given task.

The Role of Action in Stimulus Encoding

Evidence supporting the notion of action-based selection has been provided in studies using a variety of experimental paradigms, such as visual search (Bekkering & Neggers, 2002; Hannus et al., 2005; Wykowska et al., 2009), target detection (Craighero et al., 1999; Fagioli et al., 2007), and choice reactions (Hommel, 2007; Hommel & Schneider, 2002; Müsseler & Hommel, 1997a). For instance, Bekkering and Neggers (2002) had participants look for a rectangular target embedded among distractors that differed in color or orientation. They found that initial saccades were made toward distractors that differed in orientation more frequently when participants were asked to point to the target than when they were asked to grasp it. In contrast, initial saccades were made toward distractors with different colors equally often for the two types of response conditions. The researchers suggested that preparing to grasp enhanced attention to the orientation because the stimulus feature dimension provides important information regarding how the grasping action should be carried out. Likewise, in Fagioli et al.'s (2007) study, participants were presented with a sequence of visual displays in which a circular object moved in a regular fashion. Two types of display sequences were prepared. For one type, the object trajectory deviated from the regular route on one of the displays, and for the other type, the size of the object on one display deviated from that on others. Participants' goal was to detect either type of deviation and respond by reaching a button with the index finger or grasping an object with the hand. A location deviation was responded to faster when the responses were reaching than grasping, but a size deviation was responded to faster when responses were grasping than reaching. Wykowska et al. (2009) used a visual search task that required a grasping or reaching response and found that the target was detected quicker when it was defined by its size if the response was grasping an object rather than reaching the object, whereas the pattern was reversed when target was defined based on luminance. These results indicate that processing of stimuli is facilitated when the stimuli are closely related to the actions required to perform the task.

Enhancement of Stimulus Encoding by Response Preparation

The role of response preparation for enhancing stimulus encoding is further supported by Hommel and Schneider's (2002) study, in which detection of a target in a visual search task was found to be more accurate when the target location spatially corresponded to a response that was prepared for a preceding stimulus but that had not yet been executed when the search display appeared. Likewise, in Hommel's (1998) aforementioned dual-task study, the backward compatibility effect was found when R2 was compatible with S1. In this task variation, manual responses (R1) were made to the stimulus color (S1; green or red), and vocal responses (R2) were made to the stimulus shape (S2). The vocal responses were the utterances "green" and "red". R1 was faster when S1 was compatible with R2, suggesting that processing of S1 was facilitated. Such a finding is consistent with the notion of action-based selection.

Furthermore, in Verfaellie et al.'s (1988) Simon experiment, the correct response was signaled by the direction of arrows prior to onset of the imperative stimuli. This response precuing enhanced the Simon effect (also see Proctor et al., 1992; Proctor & Wang, 1997). The enhancement of the Simon effect may be due to preparation of a response increasing the activation of a spatial code associated with that response. Thus, a small but rapid increment of response activation by the presentation of a corresponding spatial feature is sufficient to produce that response, which facilitates the corresponding response on validly cued trials. However, this explanation fails to account for the finding that the Simon effect tended to disappear or reverse (Proctor et al., 1992) or at least decrease (as compared to no-cue trials; Wühr, 2006) on invalidly cued trials. An alternative explanation is that preparation of a response activates the spatial code associated with the response, and the activation directs visual attention toward the location corresponding to the spatial code, facilitating encoding of stimuli on that location (Hasbroucq & Possamai, 1994; but see Proctor et al., 1992, and Verfaellie et al., 1988, which show that cuing stimulus location had no influence on the Simon effect). This seems to suggest that the phenomenon is akin to memory-driven attention capture (Downing, 2000) that has been discussed earlier. The explanation is consistent with the facilitation of the Simon effect on validly cued trials and the reduction on invalidly cued trials. It is also consistent with Wascher and Wolber's (2004) finding that response precuing increased the N2pc component of ERP. Furthermore, an equally likely explanation of the phenomenon is that a response precue activates not only the spatial code but any memory in LTM that is associated with the precued response. This would facilitate encoding of any stimuli associated with the response representation.

There have been a limited number of studies that investigated the role of response precuing in the Simon effect, so further explorations are necessary to provide better understanding of the phenomenon. In fact, some results are difficult to explain based on the current perspective. For instance, Buckolz et al. (1996) found no enhancement of the Simon effect when responses were precued by a letter (“L” or “R”). Also, Koch (2007) found the Simon effect to be reduced when participants could predict the response sequence in advance, which is in contrast to the effect of response precuing (but see Miles et al., 2010). Although more investigations are needed to examine the conditions under which the enhancement is obtained, the effect of response precuing still points to a close relationship between advance response preparation and stimulus processing.

Interference in Stimulus Encoding by Response Preparation

The emphasis on action in perception and cognition is not a new concept. For instance, Washburn (1916) proposed a motor theory to explain consciousness, and the motor theory of speech perception has been prominent for many years (Galantucci et al., 2006; Liberman & Mattingly, 1985). An even older action-oriented cognitive approach is that of ideomotor theory (e.g., James, 1890; see, Shin et al., 2010, for a review of contemporary versions), which states that imagining or thinking about sensory consequences of an action, or *action effect*, is sufficient to activate and prepare that action. Consistent with the theory, when certain effects always follow specific actions, presenting stimuli similar to the effects facilitates execution of the associated actions (see Hommel & Elsner, 2009, for a review). Also, it has been shown that the Simon effect can occur based on the compatibility between stimuli and action effects (Hommel, 1993; Yamaguchi & Proctor, 2009, 2011a). Because action effects are not present before responses are made, their influence can be attributed to anticipation of the action’s consequences, consistent with ideomotor theory.

A contemporary version of the ideomotor theory is the *Theory of Event Coding* (TEC; Hommel, 2009; Hommel et al., 2001; see Hommel, 2019, for a recent update). According to the

TEC, any perceptual and action events are represented as event codes or event files, which consist of more elementary entities called feature codes that represent individual stimulus and response attributes (e.g., color, shape, location, etc.). When the actor perceives an event, all feature codes that comprise the perceptual event are activated and bound together to form an event file. Once this binding has occurred, the feature codes become unavailable to form other event codes. Consequently, perceiving or planning events that include these preoccupied features takes longer than usual because they must be unbound to form another event file. That is, action planning and stimulus encoding must be delayed. The idea of binding, originating from Treisman's (1988) feature integration theory, enables the TEC to predict the bidirectionality between perception and action, which is the major advantage of the theory to account for findings that action preparation hampers, rather than facilitates, encoding of compatible stimuli. This phenomenon is referred to as *blindness to compatibility* (Müsseler & Hommel, 1997a) or compatibility blindness.

In Müsseler and Hommel's (1997a) study, participants were presented an arrow stimulus (S1) pointing to the left or right and made a sequence of two responses: simultaneous presses of the left and right keys (R0), immediately followed by a press of the key spatially corresponding to the arrow direction (R1). R0 triggered brief display of another arrow stimulus (S2), also pointing to the left or right, which was responded to by a single press of the key corresponding to the direction of S2 (R2) or verbally reporting the S2 direction at leisure after execution of R1. In both cases, R2 was less accurate when R1 and S2 were spatially compatible than when they were incompatible. This result was replicated when the words LEFT and RIGHT were used instead of arrows for S1, to exclude S1-S2 similarity, and when S1 was incompatibly mapped to R1, dissociating correspondence between S1 and S2 from that between R1 and S2. Also, Müsseler et al. (2000) obtained similar results when S1 was omitted, requiring participants to press one key on every two consecutive trials and then switch to the other. In subsequent studies, the researchers also confirmed that compatibility blindness occurs when S2 requires detection (presence/absence of S2) rather than classification (Müsseler & Hommel, 1997b), and that the sensitivity measure (*d′*) was lower for R1-compatible stimuli than for R1-incompatible stimuli (Müsseler et al., 2001). Wühr and Müsseler (2001) found that compatibility blindness is not bound to response execution; the effect was even larger when S2 was presented about 2000 ms before R1 was executed than when it was presented at around the moment R1 was execution. Thus, it is the preparation of a particular response that causes the blindness. In fact, the effect disappeared as soon as R1 was executed. These observations suggest that the compatibility blindness is not due to a refractory period associated with response execution. In consequence, the researchers concluded that preparation of R1 hampered, or blinded, S2 encoding when they were compatible.

However, some issues remain in the studies of compatibility blindness. First et al. (2002) used the stop-signal paradigm (Logan & Cowan, 1984) and showed that blindness occurred only on stop-signal trials, implying that active response inhibition may be involved. Also, some studies suggest that, without response preparation, processing of S1 still yields the compatibility blindness (e.g., Stevanovski et al., 2003). Hommel and Müsseler (2006) found that the blindness was modality specific (i.e., verbal vs. manual), whereas Kunde and Wühr (2003) found the opposite (see also Eder & Klauer, 2009). Moreover, Koch and Prinz (2002, 2005) used an experimental design that was similar to Müsseler and Hommel's task, but did not obtain the blindness effect. Instead, they found that R1 was faster when it was compatible with S2, a result not obtained in Müsseler and Hommel's (1997a) study. Thus, although several studies indicate that preparing a set of responses enhances processing of stimuli related to the responses (e.g., Bekkering & Neggers, 2002; Fagioli et al., 2007), there are unresolved issues concerning influences of preparing a particular response in the studies of compatibility blindness. Nevertheless, more recent electrophysiological studies have shown that preparing a particular magnitude of grasping selectively influenced perceptual processing of object sizes (Job et al., 2017) and that a grasping action can attenuate neural responses reflecting a sensory adaptation (Wamain et al., 2019). These findings seem to demonstrate a promising link between action and perception that indicates an early perceptual effect of prepared (and executed) actions (also see Dignath et al, 2020; Harrison & Ziessler, 2016; Waszak et al., 2012).

Action Field Theory

The three primers for the new framework presented above include (1) seemingly automatic processes are under control, or at least the influence, of one's intention, (2) new task-defined processes can be automatized without extensive training, and (3) attentional selection depends on prepared actions. Encoding of task-irrelevant stimulus features is determined at least in part by the type of action required to perform the task. These results agree with the *selection-for-action view* (Allport, 1987; Humphreys & Riddoch, 2005), which states that processing of stimulus information is enhanced if it is relevant to a prepared action, whereas processing that is not related to the action is degraded. The Action Field Theory proposed here embraces the selection-for-action view, but it goes further by integrating this notion into the memory-based theory of cognitive control in which each task episode is stored as a separate instance in memory (Logan, 1988). The main purpose of the Action Field Theory is to formulate the roles of memory and action in automaticity of cognitive control.

The memory view of automaticity has been elaborated into a more general framework for modeling attention and memory phenomena (*Instance Theory of Attention and Memory*, or ITAM; Logan, 2002). As in the original theory, the ITAM assumes instance retrieval as the basis of response selection. The retrieval process uses similarity-based matching between the current set of stimuli and the instances of past events. That is, encoded stimuli become efficient retrieval cues for instances stored in LTM to the degree that the stimuli are similar to the features recorded in the instances. An important extension of this instance-based response-selection mechanism in the Action Field Theory is the constraint imposed to the types of instances that can effectively be retrieved in a given context. In the theory, it is assumed that the probability of instance retrieval depends on the pre-activation (or base activation rate) of the instance. That is, certain instances are activated prior to stimulus onset, and these instances can be retrieved whenever associated stimuli are encoded, which results in automatic response activation associated with those instances. On the other hand, other instances are deactivated at the time of stimulus onset, so they cannot be retrieved automatically when associated stimuli are encoded. To retrieve these instances, attention must be shifted to them, so that they can be retrieved intentionally. The retrieval probability of deactivated instances is close to zero unless focus of attention is shifted to them to activate them. Hence, not all instances are equal in the Action Field Theory, because automatic retrieval is a function of the amount of pre-activation.

Furthermore, the pre-activation of instances is determined by a “goal-setting” for which the action to be executed plays a central role. Setting a specific goal enhances the activation of relevant features in memory, and the central element of a task goal is usually the action to be made. Thus, the goal-setting enhances the activation of action representations, and this activation spreads to associated instances according to the relatedness of these instances to the action representations. Borrowing Cowan's embedded processing framework and Oberauer's extension of the framework, which were discussed above, one could exert control over their own behavior by selecting the contents of WM (or focus of attention), which in turn determines what to become active in LTM. It is possible that WM is intruded by task-irrelevant but highly salient stimuli (e.g., by a burst of an emergency buzzer or strong sensory stimulations), but assuming that such stimuli are absent, WM would only hold task-relevant representations that determines activated instances in the LTM. It should be noted here that a "task-relevant representation" could be an object that includes both task-relevant and task-irrelevant features (e.g., a colored word when only the color, but not the word-meaning, is task-relevant, or the hands wearing red and green gloves when only the colors of the gloves, but not the side of the hands, are task-relevant).

Consequently, stimuli become efficient retrieval cues and elicit automatic retrieval only if they are closely associated with the prepared actions. Because planned actions play a central role in a task that we perform, automatic memory retrieval is largely dependent on the relation between the instances and the action representations. In this manner, the Action Field Theory integrates the notion of action-based selection into the framework of instance-based models of attention and memory. To illustrate the present framework in more detail, the remaining sections discuss three principles of the Action Field Theory.

First Principle: Instance Representation

One of the core assumptions of the Action Field Theory is that response selection is performed by retrieving an instance in memory. Specific task-episodes are assumed to be stored as separate instances that record actions taken in a particular context. These actions are selected and implemented upon retrieval. Moreover, any contextual information present at the creation of an instance serves as a retrieval cue for that instance, so an S-R association is preserved in an instance. There is redundancy among instances that represent similar task episodes in which the same S-R association occurs, and the redundancy is important in the theory because it determines the probability of instance retrieval reflecting the strength of S-R association. In principle, therefore, the probability and speed of retrieving an instance increase with the number of similar instances stored in the memory (Logan, 1988). The original instance theory distinguished response selection based on memory retrieval from that based on algorithms, but the theory left mechanisms underlying the algorithmic processes unspecified because there could be many different algorithms to perform the same task (Logan, 1989). In the present framework, however, algorithmic processes are also based on memory retrieval.

The difference between automatic and controlled processes is that the former can be achieved by a 'one-shot' memory retrieval, whereas the latter requires a series of memory retrievals. For instance, once automatized, addition can be performed when an equation triggers the answer from memory without intermediate steps (e.g., the stimulus "3 + 2" cues the instance "3 + 2 = 5"). Before being automatized, the same addition may require retrieval of an instance that links an operand to a physical action ("3" cues "raising three fingers") and another instance that links another operand to another physical action ("2" cues "raising two fingers"). Then, the actor would retrieve instances that represent digits in a sequence until all fingers have been assigned a digit, which constitutes counting the number of fingers. This is obviously not the only way to formulate the processes of performing addition, but the example illustrates the fact that memory retrieval is sufficient to perform algorithmic operations. Hence, the underlying principles behind automatic and algorithmic processes should be the same.

Furthermore, more complex tasks would require a recurrent process of deliberately searching candidate instances in the memory storage and rejecting them until one is satisfied with the current solution. This process requires shifting the attentional focus across the memory pool (Cowan, 1995), which changes the background activation of instances in such a way that activation of instances that are associated with the current focus of attention increases. The activation of an instance should dissipate as attention shifts away from it. This may be illustrated by the finding that the response congruity effect can occasionally interact with task sequence without being influenced by CTI, in such a way that the effect is larger when the task switches than when it repeats (e.g., Yamaguchi & Proctor, 2011a), suggesting that shift of the attentional focus still affects automatic processes that reside outside the attentional focus. Consequently, certain instances are retrieved more easily than others, depending on the relationship with the current attentional focus (Oberauer, 2002). It should also be noted that most complex tasks involve a sequence of events and actions. As discussed above, such complex tasks are performed by hierarchically structured control processes (Logan & Crump, 2011). The order of events may be maintained as a task representation at the higher level, which would serve as an instruction to shift attention from one instance to another in a specific order, or the order could also be built in as a network of associations between instances representing the component events in memory. The operations at the higher level can be seen as an algorithmic process, but it still involves active retrieval of instances from memory.

As discussed earlier, the current perspective is in contrast to the modal view of automaticity. The principle of instance representation is crucial in that it allows automatic processes to operate conditionally upon the task goal, and task-defined, temporary S-R associations to be implemented in an automatic fashion. Thus, the principle of instance representation gives a plausible mechanism behind the interplay between automatic and controlled processes. At the same time, the current perspective is compatible with another prominent approach in cognitive psychology, the connectionist framework (e.g., Rumelhart et al., 1986). Connectionist models have been developed for Stroop interference (e.g., Cohen et al., 1990; Phaf et al., 1990) and for the Simon effect (Zorzi & Umiltà, 1995). A difference from our approach is that the connectionist models assume the strength of S-R associations to be the driving force of response activation, whereas the instance theory assumes the number of similar instances as the determinant of response activation, but this difference may be a minor detail. At a computational level, the instance approach and the connectionist framework likely mimic each other, unless further assumptions are made in particular task contexts to restrict predictions of specific model instances (e.g., Tagliabue et al., 2000), although the present approach arguably offers a more intuitive conceptualization of the interplay between automatic and controlled processes than the connectionist representation. However, because of the rapid resurrection of neural network models, thanks to the rise of Generative Artificial Intelligence since 2022, the trend might be soon to be taken over by neural network models in the near future.

Second Principle: Compound-Cue Retrieval

Not all stimuli are encoded automatically. This is illustrated by the observation that a stimulus produces Stroop interference or the Simon effect only when the task necessitates processing of that stimulus, for example, by having a subliminal prime identical with the target stimulus (Eimer & Schlaghecken, 1998), by presenting extra stimuli that requires identifying a stimulus attribute uninformative of the correct response (O'Leary & Barber, 1993), or by pre-activating LTM directing visual attention to similar stimuli (Downing, 2000). In either case, task-irrelevant stimuli can get encoded, and, once encoded, they affect response selection. That is, all encoded stimuli act together in retrieving an associated instance and activates a corresponding response. This is the principle of compound-cue retrieval. The principle is a primary assumption in the memory view of automaticity (Logan, 1988) and is central in the explanation of the task-switching cost without involvement of a central executive (Logan & Bundesen, 2003; Logan & Schneider, 2010; Schneider & Logan, 2005, 2009). Each stimulus present in the current context is potentially an effective cue to retrieve instances that contain the stimulus as a feature of the past task episodes. Instance retrieval becomes obligatory when the stimulus is encoded, but competition among activated instances allows only a limited number of instances (typically, a single instance) to be retrieved. The competitiveness of an instance for retrieval is a function of matching between the instance and each of the encoded stimuli, which is determined partly by the similarity between the instance and the current task context (e.g., Yamaguchi & Proctor, 2012).

The compound-cue retrieval model of task switching is aligned well with connectionist models (e.g., Cohen et al., 1990; Phaf et al., 1990; Zhang et al., 1999; Zorzi & Umiltà, 1995) that assume coactivation of a response code by multiple S-R associations. This assumption is consistent with the findings, for example, that the Simon effect occurs based on multiple feature dimensions (e.g., Lamberts et al., 1992; Lleras et al., 2004; Wühr et al., 2008). Yet, an alternative perspective has been proposed to explain the role of stimulus-response compatibility in Stroop interference (Virzi & Egeth, 1985; see also Palef, 1978), which is known as the *translational account* (also see Magen & Cohen, 2007). The translational account states that stimulus features are processed separately by modality-specific analyzers that operate in parallel. If stimuli and responses belong to the same modality, stimuli can directly activate the responses; if they belong to different modalities, however, the stimuli must be translated into the response modality. Thus, from this perspective, stimulus-response compatibility means that stimuli and responses belong to the same modality (also see, Kornblum et al., 1990). When responses are compatible with task-irrelevant stimuli than task-relevant ones, Stroop interference occurs because the task-relevant stimuli must be translated into the analyzer that processes the task-irrelevant stimuli, in which response competition occurs. However, the interference does not occur when responses are more compatible with the task-relevant stimuli because there is no translation across analyzers and no competition between the task-relevant and -irrelevant stimuli. Although the translational account places an emphasis on the role of response in stimulus processing as in the Action Field Theory, a number of observations suggest difficulty of the translational approach.

The central tenet of the translational account is that response competition does not occur as long as stimuli are processed in different modules, and translation is necessary only if task-relevant stimuli are incompatible with responses. Thus, response competition should not occur when task-relevant stimuli are compatible with responses. As mentioned, however, studies have found reversed Stroop interference from task-irrelevant locations when participants read spatial words or from word-meaning when participants pressed keys to word locations (e.g., Lu & Proctor, 2001; O’Leary & Barber, 1993), and it is a common finding that the Simon effect emerges based on irrelevant word meaning when responses are keypresses (e.g., Proctor et al., 2009). A recent study also showed that the Simon effect can occur simultaneously based on multiple stimulus dimensions (e.g., numerosity and spatial location; Wühr et al., 2008), and there are cases where not only stimuli but also responses are multidimensional (e.g., Yamaguchi & Proctor, 2009, 2011a), for which it is difficult to talk about a single response modality. It is of course possible to assume that a response code consists of different elementary features that differ in modality (e.g., Hommel et al., 2001), and stimulus features activate the respective response features, but this implies that multiple stimulus features coactivate a response code as a whole. Therefore, although the translational account is an attractive concept in explaining the role of responses in Stroop interference, the notion does not seem to have an empirical or logical advantage over the compound-cue retrieval theory.

Third Principle: Action-Based Selection

The main thesis of the Action Field Theory is that preparation of a certain response set determines processing of task-irrelevant stimuli. It assumes that the activation of response representations increases with response preparation and spreads to other instances that are associated with the prepared actions. This establishes an “Action Field” in the memory pool, the activated region of LTM that is most sensitive to action-related retrieval cues. The spreading activation facilitates processing of response-relevant stimulus information, and automatic processes arise from the Action Field. This is the principle of action-based selection. In addition to the evidence reviewed in the earlier sections, Valle-Inclán and Redondo (1998) also showed, using the LRP, that onset of a stimulus triggers activation of a spatially compatible response only when participants are informed about the task-relevant S-R mapping before the stimulus onset but not when the mappings are informed after a stimulus has been presented. Thus, automatic response activation seems to require preparing a particular set of actions in response to pre-specified stimuli, that is, activating the Action Field.

The Action Field Theory emphasizes selection across dimensions rather than individual features. This emphasis is in line with theories of visual attention (e.g., Müller & Krummenacher, 2006; Treisman, 1988) as well as with the fact that the role of stimulus-response compatibility in Stroop interference is at a *set level* rather than an *element level* (Kornblum et al. 1990). That is, the occurrence of Stroop interference depends on the prepared set of responses (e.g., saying the names of the colors red, green, and blue; Proctor, 1978) as opposed to an element of the set (e.g., saying “red”). This may be because performing a task requires increasing the readiness of all alternative responses rather than that of an individual response. This assumption seems consistent with the finding that the Simon effect is obtained based on features that discriminate alternative responses (Ansorge & Wühr, 2004), since the observation implies that it is the contrast between alternatives, rather than characteristics of an individual response, that give rise to the Simon effect. Likewise, Hommel (2010) proposed the *action-induced attention model*, which states that attention weights of perceptual dimensions are biased according to action-relevance of the dimensions. The present framework agrees with this proposal. Yet, there are also findings implying an element-level influence of action representation (e.g., Müsseler & Hommel, 1997a). Although empirical clarifications are yet to be established for these observations, as pointed out earlier, future investigations might prove that the distinction between set- and element-levels is indeed inconsequential.

Instead, the current framework can be compared to that of the TEC, which also explains action-based selection. A most unique assumption of the TEC framework is that of feature binding, according to which a task episode is constructed by binding a set of elementary feature representations, or feature codes (Hommel et al., 2001). The binding mechanism is not necessarily a new concept (e.g., Treisman, 1988), but its application to stimulus-response compatibility effects and related phenomena was a novel approach. In particular, the TEC account of compatibility blindness (i.e., the occupation hypothesis; Stoet & Hommel, 1999) is a unique idea that represents the strength of the TEC framework. At the same time, however, this prediction also raises some issues. The fundamental assumption underlying the TEC concept is sharing of feature codes by multiple event files. The theory can account for the Simon effect, for example, by assuming that stimulus and response representations share a feature code if they are compatible, so that activating the stimulus representation partially activates the response representation as well. Likewise, the TEC accounts for compatibility blindness by assuming that a feature code that belongs to a stimulus becomes unavailable if the code has been integrated into another event file that represents planning of an action. A problem is that it is not clear as to which of these opposing effects will occur in a given condition (cf. Koch & Prinz, 2005 vs. Müsseler & Hommel, 1997a). However, this problem may not be fundamental if it is only a matter of gathering more data and evidence that allow discriminating conditions in which these opposing effects are obtained.

More problematic is a second issue, that two event files are not allowed to contain the same feature code at the same time. The unique predictions of the TEC depend on this assumption. For example, the occupation hypothesis does not arise from the theory if more than one feature code can exist for a particular contextual feature and can be integrated separately into different event files. Also, coactivation of event files (i.e., the stimulus-response compatibility effect) would not occur if multiple feature codes exist that represent the same feature. Thus, the assumption that a single feature code is shared by multiple event files is fundamental in the TEC. Instances in the Action Field Theory are similar to event files, in that both assume a task episode that is a collection of features, but the Action Field Theory differs from the TEC in that it does not assume a single representation for each feature. Thus, multiple task episodes can contain the same feature code at the same time. This assumption seems to be more consistent with studies that have examined transfer of incompatible S-R mappings to the Simon task (e.g., Proctor & Lu, 1999). In the experimental procedure, participants first perform an incompatible-mapping task for which they respond to stimulus locations by pressing spatially incompatible keys. Subsequently, participants transfer to the Simon task, for which the Simon effect is typically eliminated or reversed (e.g., Proctor & Lu, 1999). This transfer effect does not appear to replace the existing Simon effect. Instead, the effect gradually develops as the amount of the incompatible-mapping trials increases (Proctor et al., 2007; Proctor et al., 2009; see MacLeod & Dunbar, 1988, for similar results in a Stroop-like task). Thus, in the course of reversal, there must be a phase in which the preexisting S-R associations compete against newly acquired associations (see also, Tagliabue et al., 2000). Such results suggest that a feature code can exist in multiple event files at the same time, in contrast to the TEC assumption. The Action Field Theory states that task episodes are stored as separate instances, so it does not suffer from the same constraint as the TEC. Hence, the findings in the transfer studies are consistent with the Action Field Theory. Although the Action Field Theory may be reformulated to incorporate the TEC-like feature binding without altering other assumptions, an evaluation of such a possibility is left for future investigations.

General Discussion

This article focused on experimental paradigms in which selective attention across feature dimensions plays a central role in optimizing task performance. While performing the Stroop task, for example, efforts must be made to focus attention on the colors of words in order to satisfy the task's requirement of naming the colors rather than reading the words. Although researchers have thought of this interference effect as arising from an overlearned tendency to read words, that apparently is not the case. Instead, the difficulty of focusing on the relevant stimulus dimension results from the involvement of an irrelevant dimension that is more compatible with the required response than the task-relevant dimension. In fact, the effect can be eliminated when responses are replaced with those that are more compatible with the relevant dimension, indicating that the effect depends on what responses are required and prepared to perform the task. Unfortunately, however, the once dominant accounts of stimulus-response compatibility (dual-route models) are not suggestive of the underlying mechanisms for this selection bias in that they merely reiterate the automatic-controlled distinction that was devised to describe Stroop interference but has been refuted largely by contemporary researchers (e.g., Hommel, 2019). A problem of such a modal view is that no mechanism is specified, so the account does not provide useful implications about the nature of performance. Instead, an alternative perspective suggests that memory-based response selection is what leads to automaticity of performance. The theory also proposes that there is no qualitative difference between mechanisms that underlie automatic processes and those that underlie controlled processes. Evidence supporting this proposition is abundant in recent studies investigating cognitive control, such as dual-task and task-switching studies, as well as in the literature concerning sequential modulations of interference effects. These studies agree that cognitive control is achieved by automatic retrieval of task episodes from memory. Furthermore, it is argued here that the unitary view of memory and attention, which shares the assumption with the instance theory regarding the basic mechanism of response selection, provides an important distinction between the focus of attention and activated region of LTM. This distinction explains how automatic processes are dependent on contextual and intentional factors that are incompatible with the traditional modal view of automaticity underlying the dual-route models of stimulus-response compatibility and the automaticity account of Stroop interference. The distinction is also critical in accounting for findings that dissociate between aspects of performance that reflect capacity limitation and aspects that do not (e.g., task-switching cost vs. response congruity effect, list-length effect vs. intrusion effect, etc.). Based on these conceptions, the Action Field Theory is synthesized, whose main thesis is that activation of instances in memory depends on planned actions.

Resolving the Paradox of Automaticity

The instance theory states that memory retrieval presumes stimulus encoding, and stimulus encoding registers cues that initiate memory retrieval. To control automatic processes, one could manipulate retrieval cues by changing (1) the current state, (2) the focus of attention, or (3) the goals (Logan, 1989). In the present framework, the current state is equivalent to activated LTM. The activation of LTM depends on what is necessary to perform the task; that is, the overall task goal and the immediate goals (and sub-goals) that need to be attained to meet the overall goal (cf. Anderson & Lebiere, 1998). The focus of attention at any given moment is determined by shifting attention between these sub-goals. In most experiments (if not all), one of such sub-goals is to make a choice and report it by executing a specific action. Thus, a set of action representations must always be active in the background, even if they are not at the immediate focus of attention. Stroop interference and the Simon effect are robust and difficult to eliminate because stimuli always contain action features (i.e., color names in the Stroop task and spatial features in the Simon task) that are compatible with multiple action representations in the activated LTM and result in competitions among them. Several factors determine the likelihood of these stimulus features being encoded into memory, such as the eccentricity or categorical similarity to the target stimuli (Kahneman & Chajczyk, 1983; Miles et al., 2009) and the nature of the task that required processing these features (O'Leary & Barber, 1993). Attention tends to be attracted toward these features because action representations are active at the time of encoding, as the memory-driven attention capture suggests (Downing, 2000; but see Olivers et al., 2011, who argued that memory-driven attention capture depends only on the contents at the focus of attention but not those in the activated LTM). Consequently, the response-overlapping stimuli are encoded and serve as retrieval cues for the action representations even if the stimuli are not appropriate in a given context. The influence of action-relevant features might be reduced by increasing attentional weights for other stimulus features (Hommel, 2019; Yamaguchi & Proctor, 2012), but it is highly unlikely that the underlying processing will be suppressed entirely (Jacoby et al., 2003; Lindsay & Jacoby, 1994; Logan & Zbrodoff, 1982) because that requires suppressing the action representations and making selection and execution of these actions difficult (if not possible at all). Seemingly automatic phenomena, such as Stroop interference and the Simon effect, are robust and difficult to eliminate because stimuli involve action-overlapping features that must be kept active in memory to perform the tasks. Consequently, one could conclude that the paradox of automaticity results from the need to control one's actions.

Further Extensions of the Framework

Although the present article is concerned only with the conceptual framework for selection across feature dimensions, formal models that encompass the principles of the theory are easily conceivable. For instance, Logan's (2002) ITAM could provide a main quantitative framework for instance-based models that involve the principle of compound-cue retrieval as well as the principle of instance representation. The framework can be elaborated by incorporating the principle of action-based selection as a bias-determining factor in a systematic fashion. Logan's (1996) CODE Theory of Visual Attention (CTVA) assumes that stimuli are stochastically distributed across space as partially overlapping representations, and the observer perceives the stimuli by setting a threshold at an arbitrary value. Physically distinct stimuli are perceived as a single object when their representations overlap at the threshold, but they appear to be separate objects when their representations do not overlap. CTVA potentially provides mechanics that are useful to quantitatively define regions of activated LTM.

There has been a strong emphasis on the contribution of *episodic retrieval* in the current literature on cognitive control. For example, Schmidt et al. (2020) proposed the parallel episodic processing (PEP) model for task switching performance, which proposes that the task-switch cost observed in cued task-switching can be explained by the combination of various types of feature repetitions and alternations that can happen with or without repeating/switching tasks. They pointed out, for example, that the task cue indicating which task to perform can only repeat when the task repeats but never when the task switches. Similarly, when the same stimulus or response repeats on two trials, the same stimulus-response association can always be used when the same task repeats but can only be used sometimes when the task switches. Schmidt et al. used computer simulations to show that an instance mechanism that stores and retrieves past episodes of stimulus-response co-occurrences is sufficient to account for task performance in cued task-switching.

Similar to the PEP model, the BRAC (Binding and Retrieval in Action Control) is a framework that also emphasizes episodic retrieval as the basis for cognitive control (Frings et al., 2020). The core assumption of the BRAC framework includes the shared representational structure borrowed from the TEC, which proposes that stimuli, responses, and effects of responses, are bound together as event files. The differences between the TEC's shared representational structure and the instance theory were already considered above. Both the PEP model and the BRAC framework were proposed to account for sequential phenomena (also see Schmidt, 2013, for the PEP model in sequential effects in the Stroop task), which received much attention in the cognitive control literature in the last two decades (e.g., Duthoo et al., 2014; Egner, 2014; Schmidt & Weissman, 2014; Spinelli & Lupker, 2022). The main difference between the PEP model and the BRAC framework is their assumptions about the involvement of top-down control. The upshot of the PEP model is that it is meant to exclude the need of a *homunculus*, that is, top-down control that sets a task-set for a particular task, whereas the BRAC assumes that the roles of top-down processes in both binding and retrieval of event files. Nevertheless, the PEP model still involves “goal-setting” as a key factor to perform a specific task, which is a *de facto* top-down control process. In the PEP model, there is little emphasis on action, but a goal could be making a specific action. Then, goal-setting in the model would activate instances that are associated with the action. If so, the PEP model could provide a viable computational framework for the Action Field Theory.

Alternatively, Yamaguchi and Proctor (2012) developed the *multidimensional vector* (MDV) *model*, a mathematical modeling framework for choice-reaction performance, that assumes a multidimensional psychological space as the basis of response selection. The MDV proposes that the subjective utility (or discriminability) of stimuli is determined by a joint product of stimulus and response attributes, and this is one way to instantiate the principle of action-based selection in a systematic manner. Also, the MDV assumes multidimensional representation of stimuli and responses that are compatible with the principles of compound-cue retrieval and instance representation, considering the psychological space as the Action Field. Neverthelss, the MDV adopted a so-called geometric representation of the psychological space, which involves certain weaknesses in accounting for some learning phenomena, such as transfer asymmetry (Yamaguchi, 2025), and it is not always clear how this psychological space is constructed. In the MDV, the psychological space is assumed to be fixed, but the instances in the psychological space are convolved with a vector (called the decision axis) that represents subjective utilities of the instances in a given context. This is equivalent to a layer of a neural network that is convolved with a one-dimensional kernel. As in an application of the MDV that involves multiple spaces and layers (see Yamaguchi & Proctor, 2012, Experiments 3-5), it is possible to extend the decision axis to a set of kernels that represent different contextual as vectors. Such an extension of the MDV is computationally demanding but could be powerful as has already been shown by convolutional neutral networks (LeCun et al., 2015) that consists of massive layers and a huge number of kernels per layer.

There seems to be promising approaches and extensions of previous models that can incorporate the principles of the Action Field Theory. A challenge of such approaches is that they are concerned only with tasks that are as simple as choice reactions. The emphasis of simple tasks is certainly valid in experimental settings, given that they are primary vehicles in the studies of cognitive processes and mechanisms. Action control in more complex tasks might involve something more than memory retrieval, but performance in complex tasks can also be conceived of a series of simple routines that operate based on memory retrieval. For example, the hierarchical theory of skilled performance mostly relies on memory retrieval (Logan & Crump, 2011; Logan, 2018). By extension, a complex task performance can be seen as a series of sub-routines, each having a specific sub-goal. The sub-routine may be performed by a specialized sub-system (by an inner loop) that can operate autonomously or may be performed more effortfully a part of the main routine (by the outer loop). If the performance involves highly trained skills, setting a goal may activate multiple sub-routines in parallel; if not, the main routine may breaks down a sub-routing into even smaller routines and sets a more specific goal to implement a specific cognitive operation or action. Although the sizes of routines may be different, depending on the actor’s prior experience with the task, they can always be conceived of as memory instances that must be retrieved from memory. The actor would then need to maintain an action plan that consists of a series of sub-routines and retrieves one instance after another based on the plan, or if these routines are associated with each other, the retrieval of one action triggers the retrieval of the next action. This activation and retrieval loop would achieve the overall goal of the actor to perform a complex task. If so, the principles discussed in the present article should still hold in complex task settings as well. This possibility should be subjected to future scrutiny.

Concluding Remarks

The distinction between controlled and automatic processes has been popular in many fields of psychology. It has provided a convenient, and powerful, language to explain a range of psychological phenomena. However, characteristics that are attached to these processes are often violated, and there are theories of automaticity that do not characterize these processes in terms of operational criteria (e.g., Logan, 1988). As introduced in the present review, recent studies provided evidence that automatic processes are not independent of the actor's intention. At the same time, it has been shown that intentional processes involve characteristics that are usually attached to automatic processes. Whereas many psychological theories assume independent contributions of automatic and controlled processes, there are few theories that describe how the automatic and intentional processes interplay. The Action Field Theory is one such theory highlighting the fact that automatic processes operate in accordance with the actor's intention to implement certain actions. This is achieved by putting the preparatory state at the beginning of psychological processes that is the basis of automatic processes (Hommel, 2000b; Logan, 1978). Rather than assuming physical stimuli as the starting point of the psychological processes, the present perspective emphasizes that the actor's internal state is the appropriate stating point of the cognitive chain (Prinz, 1997; Thurstone, 1927; Tolman, 1949). Automatic processes are purposeful, and automaticity allows for a greater control of one's own actions.

References

Allport, A. (1987). Selection for action: Some behavioral and neurophysiological considerations of attention and action. In H. Heuer & A. F. Sanders (Eds.), *Perspectives on perception and action* (pp. 395-419). Hillsdale, NJ: Lawrence Erlbaum.

Allport, A. (1989). Visual attention. In M.I. Posner (Ed.), *Foundations of cognitive science* (pp. 631-682). Cambridge, MA: MIT Press.

Allport, D. A., Styles, E. A., & Hsieh, S. (1994). Shifting intentional set: Exploring the dynamic control of tasks. In C. Umiltà & M. Moscovitch (Eds.), *Attention and performance 15: Conscious and nonconscious information processing* (pp. 421-452). The MIT Press.

Anderson, J. R. (1983). Retrieval of information from long-term memory. *Science, 220*(4592), 25-30. https://doi.org/10.1126/science.6828877

Anderson, J. R., & Lebiere, C. (1998). *The atomic components of thought.* Lawrence Erlbaum Associates Publishers.

Ansorge, U., & Wühr, P. (2004). A Response-Discrimination Account of the Simon Effect. *Journal of Experimental Psychology: Human Perception and Performance, 30*(2), 365-377. https://doi.org/10.1037/0096-1523.30.2.365

Ansorge, U., & Wühr, P. (2009). Transfer of response codes from choice-response to go/no-go tasks. *The Quarterly Journal of Experimental Psychology, 62*(6), 1216-1235. https://doi.org/10.1080/17470210802426866

Atkinson, R. C., & Shiffrin, R. M. (1971). The control of short-term memory. *Scientific American, 225*(2), 82-90. https://doi.org/10.1038/scientificamerican0871-82

Baddeley, A. (1992). Working memory. *Science, 255*(5044), 556-559. https://doi.org/10.1126/science.1736359

Barber, P., & O'Leary, M. (1997). The Relevance of Salience: Towards an Activational Account of Irrelevant Stimulus-Response Compatibility Effects. In B. Hommel & W. Prinz (Eds.), *Theoretical issues in stimulus-response compatibility* (pp. 135-172). Elsevier Science/JAI Press. https://doi.org/10.1016/S0166-4115(97)80031-3

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

Bauer, B., & Besner, D. (1997). Processing in the Stroop task: Mental set as a determinant of performance. *Canadian Journal of Experimental Psychology / Revue canadienne de psychologie expérimentale, 51*(1), 61-68. https://doi.org/10.1037/1196-1961.51.1.61

Beck, V. M., & Vickery, T. J. (2019). Multiple states in visual working memory: Evidence from oculomotor capture by memory-matching distractors. *Psychonomic Bulletin & Review, 26*(4), 1340-1346. https://doi.org/10.3758/s13423-019-01608-7

Bekkering, H., & Neggers, S. F. W. (2002). Visual search is modulated by action intentions. *Psychological Science, 13*(4), 370-374. https://doi.org/10.1111/j.0956-7976.2002.00466.x

Besner, D., Stolz, J. A., & Boutilier, C. (1997). The Stroop effect and the myth of automaticity. *Psychonomic Bulletin & Review, 4*(2), 221-225. https://doi.org/10.3758/BF03209396

Botvinick, M. M., Cohen, J. D., & Carter, C. S. (2004). Conflict monitoring and anterior cingulate cortex: An update. *Trends in Cognitive Sciences*, *8*, 539-546. https://doi.org/10.1016/j.tics.2004.10.003

Broadbent, D. E. (1958). *Perception and communication.* Pergamon Press.

https://doi.org/10.1037/10037-000

Buckolz, E., O'Donnell, C., & McAuliffe, J. (1996). The Simon effect: Evidence of a response processing "functional locus" *Human Movement Science, 15*(4), 543-564. https://doi.org/10.1016/0167-9457(96)00021-8

Caessens, B., & Vandierendonck, A. (2002). Inhibition and blindness to response compatible stimuli: A reappraisal. *Acta Psychologica*, *111*, 45-57. https://doi.org/10.1016/s0001-6918(02)00018-5

Cantor, J., & Engle, R. W. (1993). Working-memory capacity as long-term memory activation: An individual-differences approach. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*(5), 1101-1114. https://doi.org/10.1037/0278-7393.19.5.1101

Chelazzi, L., Miller, E. K., Duncan, J., & Desimone, R. (1993). A neural basis for visual search in inferior temporal cortex. *Nature, 363*(6427), 345-347. https://doi.org/10.1038/363345a0

Cohen, J. D., Dunbar, K., & McClelland, J. L. (1990). On the control of automatic processes: A parallel distributed processing account of the Stroop effect. *Psychological Review, 97*(3), 332-361. https://doi.org/10.1037/0033-295X.97.3.332

Cohen-Kdoshay, O., & Meiran, N. (2007). The representation of instructions in working memory leads to autonomous response activation: Evidence from the first trials in the flanker paradigm. *The Quarterly Journal of Experimental Psychology, 60*(8), 1140-1154.

Cowan, N. (1988). Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information-processing system. *Psychological Bulletin, 104*(2), 163-191. https://doi.org/10.1037/0033-2909.104.2.163

Cowan, N. (1995). *Attention and memory: An integrated framework.* Oxford University Press.

Craighero, L., Fadiga, L., Rizzolatti, G., & Umiltà, C. (1999). Action for perception: A motor-visual attentional effect. *Journal of Experimental Psychology: Human Perception and Performance, 25*(6), 1673-1692. https://doi.org/10.1037/0096-1523.25.6.1673

Cespón, J., Hommel, B., Korsh, M., & Galashan, D. (2020). The neurocognitive underpinnings of the Simon effect: An integrative review of current research. Cognitive, Affective, & Behavioral Neuroscience, 20, 1133-1172. https://doi.org/10.3758/s13415-020-00836-y

De Houwer, J. (2003). The extrinsic affective Simon task. *Experimental Psychology, 50*(2), 77-85. https://doi.org/10.1026/1618-3169.50.2.77

De Houwer, J. (2004). Spatial Simon effects with nonspatial responses. *Psychonomic Bulletin & Review, 11*(1), 49-53. https://doi.org/10.3758/BF03206459

De Houwer, J., Beckers, T., Vandorpe, S., & Custers, R. (2005). Further evidence for the role of mode-independent short-term associations in spatial Simon effects. *Perception & Psychophysics, 67*(4), 659-666. https://doi.org/10.3758/BF03193522

De Jong, R. (1995). Strategical determinants of compatibility effects with task uncertainty. *Acta Psychologica, 88*(3), 187-207. https://doi.org/10.1016/0001-6918(94)E0067-P

De Jong, R., Liang, C.-C., & Lauber, E. (1994). Conditional and unconditional automaticity: A dual-process model of effects of spatial stimulus-response correspondence. *Journal of Experimental Psychology: Human Perception and Performance, 20*(4), 731-750. https://doi.org/10.1037/0096-1523.20.4.731

Desimone, R. (1996). Neural mechanisms for visual memory and their role in attention. *Proceedings of the National Academy of Sciences, USA*, *93*, 13494-13499. https://doi.org/10.1073/pnas.93.24.13494

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual*

Review of Neuroscience, 18, 193-222. https://doi.org/10.1146/annurev.ne.18.030195.001205

Dignath, D., Kiesel, A., Frings, C., & Pastötter, B. (2020). Electrophysiological evidence for action-effect prediction. *Journal of Experimental Psychology: General, 149*(6), 1148-1155. https://doi.org/10.1037/xge0000707

Donders, F. C. (1969). On the speed of mental processes. In W. G. Koster (Ed.), *Attention and performance II*. *Acta Psychologica*, *30*, 412-431. (Original work published in 1868).

Downing, P. E. (2000). Interactions between visual working memory and selective attention. *Psychological Science, 11*(6), 467-473. https://doi.org/10.1111/1467-9280.00290

Downing, P. E., & Dodds, C. M. (2004). Competition in visual working memory for control of search. *Visual Cognition, 11*(6), 689-703. https://doi.org/10.1080/13506280344000446

Duthoo, W., Abrahamse, E. L., Braem, S., Boehler, C. N., & Notebaert, W. (2014). The hererogeneous world of congruency sequence effects: An update. *Frontiers in Psychology*, *5*, Article 1001. https://doi.org/10.3389/fpsyg.2014.01001

Eder, A. B., & Klauer, K. C. (2009). A common-coding account of the bidirectional evaluation-behavior link. *Journal of Experimental Psychology: General, 138*(2), 218-235. https://doi.org/10.1037/a0015220

Eder, A. B., Rothermund, K., & Proctor, R. W. (2010). The prepared emotional reflex: Intentional preparation of automatic approach and avoidance tendencies as a means to regulate emotional responding. *Emotion, 10*(4), 593-598. https://doi.org/10.1037/a0019009

Egner, T. (2014). Creatures of habit (and control): A multi-level learning perspective on the modulation of congruency effects. *Frontiers in Psychology, 5,* Article 1247. https://doi.org/10.3389/fpsyg.2014.01247

Eimer, M. (1995). Stimulus-response compatibility and automatic response activation: Evidence from psychophysiological studies. *Journal of Experimental Psychology: Human Perception and Performance, 21*(4), 837-854. https://doi.org/10.1037/0096-1523.21.4.837

Eimer, M., Hommel, B., & Prinz, W. (1995). S-R compatibility and response selection. *Acta Psychologica, 90*(1-3), 301-313. https://doi.org/10.1016/0001-6918(95)00022-M

Eimer, M., & Schlaghecken, F. (1998). Effects of masked stimuli on motor activation: Behavioral and electrophysiological evidence. *Journal of Experimental Psychology: Human Perception and Performance, 24*(6), 1737-1747. https://doi.org/10.1037/0096-1523.24.6.1737

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science*, *11*(1), 19-23. https://doi.org/10.1111/1467-8721.00160

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16*(1), 143-149. https://doi.org/10.3758/BF03203267

Fagioli, S., Hommel, B., & Schubotz, R. I. (2007). Intentional control of attention: Action planning primes action-related stimulus dimensions. *Psychological Research, 71*(1), 22-29. https://doi.org/10.1007/s00426-005-0033-3

Fernandez-Duque, D., & Knight, M. (2008). Cognitive control: Dynamic, sustained, and voluntary influences. *Journal of Experimental Psychology: Human Perception and Performance, 34*(2), 340-355. https://doi.org/10.1037/0096-1523.34.2.340

Fitts, P. M., & Deininger, R. L. (1954). S-R compatibility: Correspondence among paired elements within stimulus and response codes. *Journal of Experimental Psychology, 48*(6), 483-492. https://doi.org/10.1037/h0054967

Fitts, P. M., & Seeger, C. M. (1953). S-R compatibility: spatial characteristics of stimulus and response codes. *Journal of Experimental Psychology, 46*(3), 199-210. https://doi.org/10.1037/h0062827

Fitts, P. M., & Switzer, G. (1962). Cognitive aspects of information processing: I. The familiarity of S-R sets and subsets. *Journal of Experimental Psychology, 63*(4), 321-329. https://doi.org/10.1037/h0047838

Fischer, R., Plessow, F., Kunde, W., & Kiesel, A. (2010). Trial-to-trial modulations of the Simon effect in conditions of attentional limitations: Evidence from dual tasks. *Journal of Experimental Psychology: Human Perception and Performance, 36*(6), 1576-1594. https://doi.org/10.1037/a0019326

Flowers, J. H., Warner, J. L., & Polansky, M. L. (1979). Response and encoding factors in ignoring irrelevant information. *Memory & Cognition, 7*(2), 86-94. https://doi.org/10.3758/BF03197589

Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance, 18*(4), 1030-1044. https://doi.org/10.1037/0096-1523.18.4.1030

Found, A., & Müller, H. J. (1996). Searching for unknown feature targets on more than one dimension: Investigating a "dimension-weighting" account. *Perception & Psychophysics, 58*(1), 88-101. https://doi.org/10.3758/BF03205479

Francolini, C. M., & Egeth, H. E. (1980). On the nonautomaticity of "automatic" activation: Evidence of selective seeing. *Perception & Psychophysics, 27*(4), 331-342. https://doi.org/10.3758/BF03206122

Frings, C., Hommel, B., Koch, I., Rothermund, K., Dignath, D., Giesen, C., Kiesel, A., Kunde, W., Mayr, S., Moeller, B., Möller, M., Pfister, R., & Philipp, A. (2020). Binding and retrieval in action control (BRAC). *Trends in Cognitive Sciences, 24*(5), 375-387. https://doi.org/10.1016/j.tics.2020.02.004

Galantucci, B., Fowler, C. A., & Turvey, M. T. (2006). The motor theory of speech perception reviewed. *Psychonomic Bulletin & Review, 13*(3), 361-377. https://doi.org/10.3758/BF03193857

Gratton, G., Coles, M. G. H., & Donchin, E. (1992). Optimizing the use of information: Strategic control of activation of responses. *Journal of Experimental Psychology: General, 121*(4), 480-506. https://doi.org/10.1037/0096-3445.121.4.480

Grosjean, M., & Mordkoff, J. T. (2001). Temporal stimulus-response compatibility. *Journal of Experimental Psychology: Human Perception and Performance, 27*(4), 870-878. https://doi.org/10.1037/0096-1523.27.4.870

Hannus, A., Cornelissen, F. W., Lindemann, O., & Bekkering, H. (2005). Selection-for-action in visual search. *Acta Psychologica, 118*(1-2), 171-191. https://doi.org/10.1016/j.actpsy.2004.10.010

Harrison, N. R., & Ziessler, M. (2016). Effect anticipation affects perceptual, cognitive, and motor phases of response preparation: Evidence from an event-related potential (ERP) study. *Frontiers in Human Neuroscience, 10,* Article 5. https://doi.org/10.3389/fnhum.2016.00005

Hasbroucq, T., & Possamaï, C.-A. (1994). What can a precue enhance? An analysis of the experiments of Proctor, Lu and Van Zandt (1992). *Acta Psychologica, 85*(3), 235-244. https://doi.org/10.1016/0001-6918(94)90037-X

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General, 108*(3), 356-388. https://doi.org/10.1037/0096-3445.108.3.356

Hedge, A., & Marsh, N. W. (1975). The effect of irrelevant spatial correspondence on two-choice response-time. *Acta Psychologica, 39*(6), 427-439. https://doi.org/10.1016/0001-6918(75)90041-4

Hollingworth, A., & Hwang, S. (2013). The relationship between visual working memory and attention: Retention of precise colour information in the absence of effects of perceptual selection. *Philosophical Transactions of the Royal Society B*, *368*, 20130061. https://doi.org/10.1098/rstb.2013.0061

Hommel, B. (1993). Inverting the Simon effect intention: Determinants of direction and extent of effects of irrelevant spatial information. *Psychological Research, 55*(4), 270-279. https://doi.org/10.1007/BF00419687

Hommel, B. (1994). Spontaneous decay of response-code activation. *Psychological Research, 56*(4), 261-268. https://doi.org/10.1007/BF00419656

Hommel, B. (1998). Automatic stimulus-response translation in dual-task performance. *Journal of Experimental Psychology: Human Perception and Performance*, *24(5)*, 1368-1384. https://doi.org/10.1037//0096-1523.24.5.1368

Hommel, B. (2000a). Intentional control of automatic stimulus-response translation. In Y. Rossetti & A. Revonsuo (Eds.), *Beyond dissociation: Interaction between dissociated* *implicit and explicit processing* (pp. 221-242). John Benjamins Publishing Company. https://doi.org/10.1075/aicr.22.12hom

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

Hommel, B. (2007). Feature intregration across perception and action: Event files affect response choice. *Psychological Research, 71*(1), 42-63. https://doi.org/10.1007/s00426-005-0035-1

Hommel, B. (2009). Action control according to TEC (theory of event coding). *Psychological Research, 73*(4), 512-526. https://doi.org/10.1007/s00426-009-0234-2

Hommel, B. (2010). Grounding attention in action control: The intentional control of selection. In B. Bruya (Ed.), *Effortless attention: A new perspective in the cognitive science of attention and action* (pp. 121-140). Boston Review. https://doi.org/10.7551/mitpress/9780262013840.003.0006

Hommel, B. (2019). Theory of Event Coding (TEC) V2.0: Representing and controlling perception and action. *Attention, Perception, & Psychophysics*, *81*, 2139-2154. https://doi.org/10.3758/s13414-019-01779-4

Hommel, B., & Elsner, B. (2009). Acquisition, representation, and control of action. In E. Morsella, J. A. Bargh, & P. M. Gollwitzer (Eds.), *Oxford handbook of human action* (pp. 368-397). Oxford University Press.

Hommel, B., & Müsseler, J. (2006). Action-feature integration blinds to feature-overlapping perceptual events: Evidence from manual and vocal actions. *The Quarterly Journal of Experimental Psychology, 59*(3), 509-523. https://doi.org/10.1080/02724980443000836

Hommel, B., Müsseler, J., Aschersleben, G., & Prinz, W. (2001). The Theory of Event Coding (TEC): A framework for perception and action planning. *Behavioral and Brain Sciences, 24*(5), 849-937. https://doi.org/10.1017/S0140525X01000103

Hommel, B., Proctor, R. W., & Vu, K.-P. L. (2004). A feature-integration account of sequential effects in the Simon task. *Psychological Research, 68*(1), 1-17. https://doi.org/10.1007/s00426-003-0132-y

Hommel, B., & Schneider, W. X. (2002). Visual attention and manual response selection: Distinct mechanisms operating on the same codes. *Visual Cognition, 9*(4-5), 392-420. https://doi.org/10.1080/13506280143000511

Humphreys, G. W., & Riddoch, M. J. (Eds.) (2005). *Attention in action*. New York: Psychology Press. https://doi.org/10.4324/9780203449226

Jacoby, L. L., Lindsay, D. S., & Hessels, S. (2003). Item-specific control of automatic processes: Stroop process dissociations. *Psychonomic Bulletin & Review, 10*(3), 638-644. https://doi.org/10.3758/BF03196526

James, W. (1890). *The principles of psychology, Vol. 1.* Henry Holt and Co. https://doi.org/10.1037/10538-000

Job, X. E., van Velzen, J., & de Fockert, J. W. (2017). Grasp preparation modulates early visual processing of size and detection of local/global stimulus features. *Cortex*, *96*, 46-58. https://doi.org/10.1016/j.cortex.2017.08.034

Jonides, J. (1981). Voluntary vs. automatic control over the mind’s eye’s movement. In J. B. Long & A. D. Baddeley (Eds.), *Attention and performance IX* (pp. 187-203). Hillsdale, NJ: Erlbaum.

Kahneman, D., & Chajczyk, D. (1983). Tests of the automaticity of reading: Dilution of Stroop effects by color-irrelevant stimuli. *Journal of Experimental Psychology: Human Perception and Performance, 9*(4), 497-509. https://doi.org/10.1037/0096-1523.9.4.497

Kahneman, D., & Henik, A. (1981). Perceptual organization and attention. In M. Kubovy & J. R. Pomerantz (Eds.), *Perceptual organization* (pp. 181-211). Hillsdale, NJ: Erlbaum.

Kahneman, D., & Treisman, A. (1984). Changing views of attention and automaticity. In R. Parasuraman, & R. Davies (Eds.), *Varieties of Attention* (pp. 29-61). New York: Academic Press.

Kane, M. J., & Engle, R. W. (2003). Working-memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General, 132*(1), 47-70, https://doi.org/10.1037/0096-3445.132.1.47

Kiesel, A., Wendt, M., & Peters, A. (2007). Task switching: On the origin of response congruency effects. *Psychological Research, 71*(2), 117-125. https://doi.org/10.1007/s00426-005-0004-8

Klapp, S. T., Marshburn, E. A., & Lester, P. T. (1983). Short-term memory does not involve the "working memory" of information processing: The demise of a common assumption. *Journal of Experimental Psychology: General, 112*(2), 240-264. https://doi.org/10.1037/0096-3445.112.2.240

Koch, I. (2007). Anticipatory response control in motor sequence learning: Evidence from stimulus-response compatibility. *Human Movement Science, 26*(2), 257-274. https://doi.org/10.1016/j.humov.2007.01.004

Koch, I. (2009). The role of crosstalk in dual-task performance: Evidence from manipulating response-set overlap. *Psychological Research*, *73*, 417-424.

https://doi.org/10.1007/s00426-008-0152-8

Koch, I., & Prinz, W. (2002). Process interference and code overlap in dual-task performance. *Journal of Experimental Psychology: Human Perception and Performance, 28*(1), 192-201. https://doi.org/10.1037/0096-1523.28.1.192

Koch, I., & Prinz, W. (2005). Response preparation and code overlap in dual tasks. *Memory & Cognition, 33*(6), 1085-1095. https://doi.org/10.3758/BF03193215

Koch, I., & Rumiati, R. I. (2006). Task-set inertia and memory-consolidation bottleneck in dual tasks. *Psychological Research, 70*(6), 448-458. https://doi.org/10.1007/s00426-005-0020-8

Kornblum, S., Hasbroucq, T., & Osman, A. (1990). Dimensional overlap: Cognitive basis for stimulus-response compatibility--A model and taxonomy. *Psychological Review, 97*(2), 253-270. https://doi.org/10.1037/0033-295X.97.2.253

Kunde, W., & Wühr, P. (2004). Actions blind to conceptually overlapping stimuli. *Psychological Research, 68*(4), 199-207. https://doi.org/10.1007/s00426-003-0156-3

LaBerge, D., & Samuels, S. J. (1974). Toward a theory of automatic information processing in reading. *Cognitive Psychology, 6*(2), 293-323. https://doi.org/10.1016/0010-0285(74)90015-2

Lamberts, K., Tavernier, G., & D'Ydewalle, G. (1992). Effects of multiple reference points in spatial stimulus-response compatibility. *Acta Psychologica, 79*(2), 115-130. https://doi.org/10.1016/0001-6918(92)90028-C

LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature*, *521*, 436-444. https://doi.org/10.1038/nature14539

Liberman, A. M., & Mattingly, I. G. (1985). The motor theory of speech perception revisited.

Cognition, *21*, 1-36. https://doi.org/10.1016/0010-0277(85)90021-6

Liefooghe, B., De Houwer, J., & Wenke, D. (2013). Instruction-based response activation depends on task preparation. *Psychonomic Bulletin & Review, 20*(3), 481-487. https://doi.org/10.3758/s13423-013-0374-7

Liefooghe, B., Wenke, D., & De Houwer, J. (2012). Instruction-based task-rule congruency effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*(5), 1325-1335. https://doi.org/10.1037/a0028148

Lien, M.-C., & Proctor, R. W. (2002). Stimulus-response compatibility and psychological refractory period effects: Implications for response selection. *Psychonomic Bulletin & Review, 9*(2), 212-238. https://doi.org/10.3758/BF03196277

Lindsay, D. S., & Jacoby, L. L. (1994). Stroop process dissociations: The relationship between facilitation and interference. *Journal of Experimental Psychology: Human Perception and Performance, 20*(2), 219-234. https://doi.org/10.1037/0096-1523.20.2.219

Liu, T. (2019). Feature-based attention: Effects and control. *Current Opinion in Psychology*, *29*, 187-192. https://doi.org/10.1016/j.copsyc.2019.03.013

Lleras, A., Moore, C. M., & Mordkoff, J. T. (2004). Looking for the source of the Simon effect: Evidence of multiple codes. *The American Journal of Psychology, 117*(4), 531-542. https://doi.org/10.2307/4148990

Logan, G. D. (1978). Attention in character-classification tasks: Evidence for the automaticity of component stages. *Journal of Experimental Psychology: General, 107*(1), 32-63. https://doi.org/10.1037/0096-3445.107.1.32

Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review, 95*(4), 492-527. https://doi.org/10.1037/0033-295X.95.4.492

Logan, G. D. (1989). Automaticity and cognitive control. In J. S. Uleman & J. A. Bargh (Eds.), *Unintended thought* (pp. 52-74). The Guilford Press.

Logan, G. D. (1992). Attention and preattention in theories of automaticity. *The American Journal of Psychology, 105*(2), 317-339. https://doi.org/10.2307/1423031

Logan, G. D. (1996). The CODE theory of visual attention: An integration of space-based and object-based attention. *Psychological Review, 103*(4), 603-649. https://doi.org/10.1037/0033-295X.103.4.603

Logan, G. D. (1998). What is learned during automatization? II. Obligatory encoding of spatial location. *Journal of Experimental Psychology: Human Perception and Performance, 24*(6), 1720-1736. https://doi.org/10.1037/0096-1523.24.6.1720

Logan, G. D. (2002). An instance theory of attention and memory. *Psychological Review, 109*(2), 376-400. https://doi.org/10.1037/0033-295X.109.2.376

Logan, G. D. (2004). Cumulative progress in formal theories of attention. *Annual Review of Psychology, 55,* 207-234. https://doi.org/10.1146/annurev.psych.55.090902.141415

Logan, G. D. (2007). What it costs to implement a plan: Plan-level and task-level contributions to switch costs. *Memory & Cognition, 35*(4), 591-602. https://doi.org/10.3758/BF03193297

Logan, G. D. (2009). The role of memory in the control of action. In E. Morsella, J. A. Bargh, & P. M. Gollwitzer (Eds.), *Oxford handbook of human action* (pp. 427-441). Oxford University Press.

Logan, G. D. (2018). Automatic control: How experts act without thinking. *Psychological Review, 125*(4), 453-485. https://doi.org/10.1037/rev0000100

Logan, G. D., & Bundesen, C. (2003). Clever homunculus: Is there an endogenous act of control in the explicit task-cuing procedure? *Journal of Experimental Psychology: Human Perception and Performance, 29*(3), 575-599. https://doi.org/10.1037/0096-1523.29.3.575

Logan, G. D., & Cowan, W. B. (1984). On the ability to inhibit thought and action: A theory of an act of control. *Psychological Review, 91*(3), 295-327. https://doi.org/10.1037/0033-295X.91.3.295

Logan, G. D., & Crump, M. J. C. (2011). Hierarchical control of cognitive processes: The case for skilled typewriting. In B. H. Ross (Ed.), *The psychology of learning and motivation: Advances in research and theory* (pp. 1-27). Elsevier Academic Press.

Logan, G. D., & Delheimer, J. A. (2001). Parallel memory retrieval in dual-task situations: II. Episodic memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*(3), 668-685. https://doi.org/10.1037/0278-7393.27.3.668

Logan, G. D., & Etherton, J. L. (1994). What is learned during automatization? The role of attention in constructing an instance. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*(5), 1022-1050. https://doi.org/10.1037/0278-7393.20.5.1022

Logan, G. D., & Klapp, S. T. (1991). Automatizing alphabet arithmetic: I. Is extended practice necessary to produce automaticity? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*(2), 179-195. https://doi.org/10.1037/0278-7393.17.2.179

Logan, G. D., & Gordon, R. D. (2001). Executive control of visual attention in dual-task situations. *Psychological Review, 108*(2), 393-434. https://doi.org/10.1037/0033-295X.108.2.393

Logan, G. D., & Schneider, D. W. (2010). Distinguishing reconfiguration and compound-cue retrieval in task switching. *Psychologica Belgica, 50*(3-4), 413-433.

https://doi.org/10.5334/pb-50-3-4-413

Logan, G. D., & Schulkind, M. D. (2000). Parallel memory retrieval in dual-task situations: I. Semantic memory. *Journal of Experimental Psychology: Human Perception and Performance, 26*(3), 1072-1090. https://doi.org/10.1037/0096-1523.26.3.1072

Logan, G. D., & Zbrodoff, N. J. (1979). When it helps to be misled: Facilitative effects of increasing the frequency of conflicting stimuli in a Stroop-like task. *Memory & Cognition, 7*(3), 166-174. https://doi.org/10.3758/BF03197535

Lu, C.-H., & Proctor, R. W. (1995). The influence of irrelevant location information on performance: A review of the Simon and spatial Stroop effects. *Psychonomic Bulletin & Review, 2*(2), 174-207. https://doi.org/10.3758/BF03210959

Lu, C.-H., & Proctor, R. W. (2001). Influence of irrelevant information on human performance: Effects of S-R association strength and relative timing. *Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 54A*(1), 95-136. https://doi.org/10.1080/02724980042000048

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109*(2), 163-203. https://doi.org/10.1037/0033-2909.109.2.163

MacLeod, C. M., & Dunbar, K. (1988). Training and Stroop-like interference: Evidence for a continuum of automaticity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*(1), 126-135. https://doi.org/10.1037/0278-7393.14.1.126

Magen, H., & Cohen, A. (2007). Modularity beyond perception: Evidence from single task interference paradigms. *Cognitive Psychology, 55*(1), 1-36. https://doi.org/10.1016/j.cogpsych.2006.09.003

Marble, J. G., & Proctor, R. W. (2000). Mixing location-relevant and location-irrelevant choice-reaction tasks: Influences of location mapping on the Simon effect. *Journal of Experimental Psychology: Human Perception and Performance, 26*(5), 1515-1533. https://doi.org/10.1037/0096-1523.26.5.1515

Mayr, U., Awh, E., & Laurey, P. (2003). Conflict adaptation effects in the absence of executive control. *Nature Neuroscience, 6*(5), 450-452.

Mayr, U., & Kliegl, R. (2000). Task-set switching and long-term memory retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*(5), 1124-1140. https://doi.org/10.1037/0278-7393.26.5.1124

Mayr, U., & Kliegl, R. (2003). Differential effects of cue changes and task changes on task-set selection costs. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*(3), 362-372. https://doi.org/10.1037/0278-7393.29.3.362

McClain, L. (1983). Stimulus-response compatibility affects auditory Stroop interference. *Perception & Psychophysics, 33*(3), 266-270. https://doi.org/10.3758/BF03202864

Meiran, N. (1996). Reconfiguration of processing mode prior to task performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*(6), 1423-1442. https://doi.org/10.1037/0278-7393.22.6.1423

Meiran, N. (2000). Modeling cognitive control in task-switching. *Psychological Research, 63*(3-4), 234-249. https://doi.org/10.1007/s004269900004

Meiran, N., & Cohen-Kdoshay, O. (2012). Working memory load but not multitasking eliminates the prepared reflex: Further evidence from the adapted flanker paradigm. *Acta Psychologica, 139*(2), 309-313. https://doi.org/10.1016/j.actpsy.2011.12.008

Meiran, N., & Kessler, Y. (2008). The task rule congruency effect in task switching reflects activated long-term memory. *Journal of Experimental Psychology: Human Perception and Performance, 34*(1), 137-157. https://doi.org/10.1037/0096-1523.34.1.137

Meiran, N., Liefooghe, B., & De Houwer, J. (2017). Powerful instructions: Automaticity without practice. *Current Directions in Psychological Science, 26*(6), 509-514. https://doi.org/10.1177/0963721417711638

Meiran, N., Pereg, M., Givon, E., Danieli, G., & Shahar, N. (2016). The role of working memory in rapid instructed task learning and intention-based reflexivity: An individual differences examination. *Neuropsychologia, 90,* 180-189. https://doi.org/10.1016/j.neuropsychologia.2016.06.037

Meiran, N., Pereg, M., Kessler, Y., Cole, M. W., & Braver, T. S. (2015). The power of instructions: Proactive configuration of stimulus-response translation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41*(3), 768-786. https://doi.org/10.1037/xlm0000063

Miles, J. D., Witt, J. K., & Proctor, R. W. (2010). Action plans produce separate Simon effects for picking up and transporting objects. *Psychological Research, 74*(5), 468-475. https://doi.org/10.1007/s00426-009-0268-5

Miles, J. D., Yamaguchi, M., & Proctor, R. W. (2009). Dilution of compatibility effects in Simon-type tasks depends on categorical similarity between distractors and diluters. *Attention, Perception, & Psychophysics, 71*(7), 1598-1606. https://doi.org/10.3758/APP.71.7.1598

Miller, G. A., Galanter, E., & Pribram, K. H. (1960). *Plans and the structure of behavior.* Henry Holt and Co. https://doi.org/10.1037/10039-000

Moores, E., Laiti, L., & Chelazzi, L. (2003). Associative knowledge controls deployment of visual selective attention. *Nature Neuroscience*, *6*, 182-189.

Moors, A., & De Houwer, J. (2006). Automaticity: A Theoretical and Conceptual Analysis. *Psychological Bulletin, 132*(2), 297-326. https://doi.org/10.1037/0033-2909.132.2.297

Moray, N. (1959). Attention in dichotic listening: Affective cues and the influence of instructions. *Quarterly Journal of Experimental Psychology, 11,* 56-60. https://doi.org/10.1080/17470215908416289

Mordkoff, J. T., & Yantis, S. (1993). Dividing attention between color and shape: Evidence of coactivation. *Perception & Psychophysics, 53*(4), 357-366. https://doi.org/10.3758/BF03206778

Mortier, K., Theeuwes, J., & Starreveld, P. (2005). Response Selection Modulates Visual Search Within and Across Dimensions. *Journal of Experimental Psychology: Human Perception and Performance, 31*(3), 542-557. https://doi.org/10.1037/0096-1523.31.3.542

Müller, H. J., & Krummenacher, J. (2006). Locus of dimension weighting: Preattentive or postselective? *Visual Cognition, 14*(4-8), 490-513. https://doi.org/10.1080/13506280500194154

Müsseler, J., & Hommel, B. (1997). Blindness to response-compatible stimuli. *Journal of Experimental Psychology: Human Perception and Performance, 23*(3), 861-872. https://doi.org/10.1037/0096-1523.23.3.861

Müsseler, J., & Hommel, B. (1997). Detecting and identifying response-compatible stimuli. *Psychonomic Bulletin & Review, 4*(1), 125-129. https://doi.org/10.3758/BF03210785

Müsseler, J., Steininger, S., & Wühr, P. (2001). Can actions affect perceptual processing? *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 54A*(1), 137-154. https://doi.org/10.1080/02724980042000057

Müsseler, J., Wühr, P., & Prinz, W. (2000). Varying the response code in the blindness to response-compatible stimuli. *Visual Cognition, 7*(6), 743-767. https://doi.org/10.1080/135062800501444416

Norman, D. A. (1968). Toward a theory of memory and attention. *Psychological Review, 75*(6), 522-536. https://doi.org/10.1037/h0026699

Notebaert, W., Verbruggen, F., & Soetens, E. (2005). A sequential analysis of relevant and irrelevant information in the Stroop task. *European Journal of Cognitive Psychology, 17*(5), 642-658. https://doi.org/10.1080/09541440540000095

Oberauer, K. (2001). Removing irrelevant information from working memory: A cognitive aging study with the modified Sternberg task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*(4), 948-957. https://doi.org/10.1037/0278-7393.27.4.948

Oberauer, K. (2002). Access to information in working memory: Exploring the focus of attention. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*(3), 411-421. https://doi.org/10.1037/0278-7393.28.3.411

Oberauer, K. (2005). Binding and Inhibition in Working Memory: Individual and Age Differences in Short-Term Recognition. *Journal of Experimental Psychology: General, 134*(3), 368-387. https://doi.org/10.1037/0096-3445.134.3.368

Oberauer, K. (2019). Working memory and attention–A conceptual analysis and review. Journal of Cognition, 2, 36, 1-23. https://doi.org/10.5334/joc.58

Oberauer, K., Souza, A. S., Druey, M. D., & Gade, M. (2013). Analogous mechanisms of selection and updating in declarative and procedural working memory: experiments and a computational model. *Cognitive Psychology*, *66*, 15-211. https://doi.org/10.1016/j.cogpsych.2012.11.001

O'Leary, M. J., & Barber, P. J. (1993). Interference effects in the Stroop and Simon paradigms. *Journal of Experimental Psychology: Human Perception and Performance, 19*(4), 830-844. https://doi.org/10.1037/0096-1523.19.4.830

Olivers, C. N. L., Meijer, F., & Theeuwes, J. (2006). Feature-based memory-driven attentional capture: Visual working memory content affects visual attention. *Journal of Experimental Psychology: Human Perception and Performance, 32*(5), 1243-1265. https://doi.org/10.1037/0096-1523.32.5.1243

Olivers, C. N. L., Peters, J., Houtkamp, R., & Roelfsema, P. R. (2011). Different states in visual working memory: when it guides attention and when it does not. Trends in Cognitive Sciences, 15, 327-334. https://doi.org/10.1016/j.tics.2011.05.004

Öztekin, I., Davachi, L., & McElree, B. (2010). Are representations in working memory distinct from representations in long-term memory? Neural evidence in support of a single store. *Psychological Science*, *21*, 10967-10976. https://doi.org/10.1177/0956797610376651

Palef, S. R. (1978). Judging pictorial and linguistic aspects of space. *Memory & Cognition, 6*(1), 70-75. https://doi.org/10.3758/BF03197430

Palef, S. R., & Olson, D. R. (1975). Spatial and verbal rivalry in a Stroop-like task. *Canadian Journal of Psychology, 29*(3), 201-209. https://doi.org/10.1037/h0082026

Pan, Y., Xu, B., & Soto, D. (2009). Dimension-based working memory-driven capture of visual selection. *The Quarterly Journal of Experimental Psychology, 62*(6), 1123-1131. https://doi.org/10.1080/17470210802624353

Parris, B. A., Hasshim, N., Wadsley, M., Augustinova, M., & Ferrand, L. (2022). The loci of Stroop effects: a critical review of methods and evidence for levels of processing contributing to color-word Stroop effects and the implications for the loci of attentional selection. *Psychological Research*, *86*, 1029-1053. https://doi.org/10.1007/s00426-021-01554-x

Pashler, H. (1994). Dual-task interference in simple tasks: Data and theory. *Psychological Bulletin, 116*(2), 220-244. https://doi.org/10.1037/0033-2909.116.2.220

Phaf, R. H., Van der Heijden, A. H. C., & Hudson, P. T. W. (1990). SLAM: A connectionist model for attention in visual selection tasks. *Cognitive Psychology*, *22*, 273-341. https://doi.org/10.1016/0010-0285(90)90006-p

Posner, M. I., & Snyder, C. R. R. (2004). Attention and Cognitive Control. In D. A. Balota & E. J. Marsh (Eds.), *Cognitive psychology: Key readings* (pp. 205-223). Psychology Press.

Pratt, J., & Hommel, B. (2003). Symbolic control of visual attention: The role of working memory and attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance, 29*(5), 835-845. https://doi.org/10.1037/0096-1523.29.5.835

Pratte, M. S., Rouder, J. N., Morey, R. d., & Feng, C. (2010). Exploring the differences in distributional properties between Stroop and Simon effects using delta plots. *Attention, Perception, & Psychophysics, 72*(7), 2013-2025. https://doi.org/10.3758/APP.72.7.2013

Prinz, W. (1997). Why Donders Has Led Us Astray. In B. Hommel & W. Prinz (Eds.), *Theoretical issues in stimulus-response compatibility* (pp. 247-267). Elsevier Science/JAI Press. https://doi.org/10.1016/S0166-4115(97)80038-6

Proctor, R. W. (1978). Sources of color-word interference in the Stroop color-naming task. *Perception & Psychophysics, 23*(5), 413-419. https://doi.org/10.3758/BF03204145

Proctor, R. W., & Lu, C.-H. (1999). Processing irrelevant location information: Practice and transfer effects in choice-reaction tasks. *Memory & Cognition, 27*(1), 63-77. https://doi.org/10.3758/BF03201214

Proctor, R. W., Lu, C.-h., & Van Zandt, T. (1992). Enhancement of the Simon effect by response precuing. *Acta Psychologica, 81*(1), 53-74. https://doi.org/10.1016/0001-6918(92)90011-2

Proctor, R. W., & Wang, H. (1997). Enhancement of the Simon effect by response-location precues: Evaluation of the stimulus-identification account. *Acta Psychologica, 95*(3), 279-298. https://doi.org/10.1016/S0001-6918(96)00044-3

Proctor, R. W., Yamaguchi, M., & Vu, K.-P. L. (2007). Transfer of noncorresponding spatial associations to the auditory Simon task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*(1), 245-253. https://doi.org/10.1037/0278-7393.33.1.245

Proctor, R. W., Yamaguchi, M., Zhang, Y., & Vu, K.-P. L. (2009). Influence of visual stimulus mode on transfer of acquired spatial associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35*(2), 434–445. https://doi.org/10.1037/a0014529

Rogers, R. D., & Monsell, S. (1995). Costs of a predictible switch between simple cognitive tasks. *Journal of Experimental Psychology: General, 124*(2), 207–231. https://doi.org/10.1037/0096-3445.124.2.207

Romaiguère, P., Hasbroucq, T., Possamaï, C. A., & Seal, J. (1993). Intensity to force translation: A new effect of stimulus response compatibility revealed by analysis of response time and electromyographic activity of a prime mover. *Cognitive Brain Research*, *1*, 197-201. https://doi.org/10.1016/0926-6410(93)90028-4

Rumelhart, D. E., McClelland, J. L. and the PDP Research Group (1986). *Parallel distributed processing: Explorations in the microstructure of cognition. Volume 1: Foundations*. MIT Press.

Schmidt, J. R. (2013). The Parallel Episodic Processing (PEP) model: Dissociating contingency and conflict adaptation in the item-specific proportion congruent paradigm. *Acta Psychologica, 142*(1), 119–126. https://doi.org/10.1016/j.actpsy.2012.11.004

Schmidt, J. R., Liefooghe, B., & De Houwer, J. (2020). An Episodic Model of Task Switching Effects: Erasing the Homunculus from Memory. *Journal of Cognition*, *3*(1), 22. https://doi.org/10.5334/joc.97

Schmidt, J. R., & Weissman, D. H. (2014). Congruency sequence effects without feature integration or contingency learning confounds. *PLoS ONE*, *9*(7), e102337. https://doi.org/10.1371/journal.pone.0102337

Schneider, D. W., & Logan, G. D. (2005). Modeling Task Switching Without Switching Tasks: A Short-Term Priming Account of Explicitly Cued Performance. *Journal of Experimental Psychology: General, 134*(3), 343-367. https://doi.org/10.1037/0096-3445.134.3.343

Schneider, D. W., & Logan, G. D. (2009). Selecting a response in task switching: Testing a model of compound cue retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35*(1), 122-136. https://doi.org/10.1037/a0013744

Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review, 84*(1), 1-66. https://doi.org/10.1037/0033-295X.84.1.1

Shaffer, L. H. (1965). Choice reaction with variable S-R mapping. *Journal of Experimental Psychology, 70*(3), 284-288. https://doi.org/10.1037/h0022207

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory. *Psychological Review, 84*(2), 127-190. https://doi.org/10.1037/0033-295X.84.2.127

Shin, Y. K., Proctor, R. W., & Capaldi, E. J. (2010). A review of contemporary ideomotor theory. *Psychological Bulletin, 136*(6), 943-974. https://doi.org/10.1037/a0020541

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

Simon, J. R., & Rudell, A. P. (1967). Auditory S-R compatibility: The effect of an irrelevant cue on information processing. *Journal of Applied Psychology, 51*(3), 300-304. https://doi.org/10.1037/h0020586

Soto, D., Hodsoll, J., Rotshtein, P., & Humphreys, G. W. (2008). Automatic guidance of attention from working memory. *Trends in Cognitive Sciences, 12*(9), 342-348. https://doi.org/10.1016/j.tics.2008.05.007

Spapé, M. M., & Hommel, B. (2008). He said, she said: Episodic retrieval induces conflict adaptation in an auditory Stroop task. *Psychonomic Bulletin & Review, 15*(6), 1117-1121. https://doi.org/10.3758/PBR.15.6.1117

Spinelli, G., & Lupker, S. J. (2022). Conflict-monitoring theory in overtime: Is temporal learning a viable explanation for the congruency sequence effect? Journal of Experimental Psychology: Human Perception and Performance, 48(5), 497-530. https://doi.org/10.1037/xhp0000996

Sternberg, S. (1969a). Memory scanning: Mental processes revealed by reaction-time experiments. *American Psychologist*, *57*, 421-457.

Sternberg, S. (1969b). The discovery of processing stages: Extensions of Donders' method. *Acta Psychologica, Amsterdam, 30,* 276-315. https://doi.org/10.1016/0001-6918(69)90055-9

Stevanovski, B., Oriet, C., & Joliecœur, P. (2003). Can blindness to response-compatible stimuli be observed in the absence of a response? *Journal of Experimental Psychology: Human Perception and Performance, 29*(2), 431-440. https://doi.org/10.1037/0096-1523.29.2.431

Stoet, G., & Hommel, B. (1999). Action planning and the temporal binding of response codes. *Journal of Experimental Psychology: Human Perception and Performance, 25*(6), 1625-1640. https://doi.org/10.1037/0096-1523.25.6.1625

Stoffer, T. H. (1991). Attentional focussing and spatial stimulus-response compatibility. *Psychological Research*, *53*(2), 127-135. https://doi.org/10.1007/BF01371820

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*(6), 643-662. https://doi.org/10.1037/h0054651

Stürmer, B., Leuthold, H., Soetens, E., Schröter, H., & Sommer, W. (2002). Control over location-based response activation in the Simon task: Behavioral and electrophysiological evidence. *Journal of Experimental Psychology: Human Perception and Performance, 28*(6), 1345-1363. https://doi.org/10.1037/0096-1523.28.6.1345

Tagliabue, M., Zorzi, M., Umiltà, C., & Bassignani, F. (2000). The role of LTM links and STM links in the Simon effect. *Journal of Experimental Psychology: Human Perception and Performance, 26*(2), 648-670. https://doi.org/10.1037//0096-1523.26.2.648

Thurstone, L. L. (1927). *The nature of intelligence*. Harcourt, Brace, & Company.

Tolman, E.C. (1932). *Purposive Behavior in Animals and Men.* Appleton-Century.

Toth, J. P., Levine, B., Stuss, D. T., Oh, A., Winocur, G., & Meiran, N. (1995). Dissociation of processes underlying spatial S-R compatibility: Evidence for the independent influence of what and where. *Consciousness and Cognition: An International Journal, 4*(4), 483-501. https://doi.org/10.1006/ccog.1995.1052

Treisman, A. M. (1960). Contextual cues in selective listening. *Quarterly Journal of Experimental Psychology, 12,* 242-248. https://doi.org/10.1080/17470216008416732

Treisman, A. (1986). Features and objects in visual processing. *Scientific American, 255*(5), 114B-125. https://doi.org/10.1038/scientificamerican1186-114B

Treisman, A. (1988). Features and objects: The Fourteenth Bartlett Memorial Lecture. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 40A*(2), 201-237. https://doi.org/10.1080/02724988843000104

Treisman, A. M., & Fearnley, S. (1969). The Stroop test: Selective attention to colours and words. *Nature*, *222*, 437-439. https://doi.org/10.1038/222437a0

Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology, 12*(1), 97-136. https://doi.org/10.1016/0010-0285(80)90005-5

Treisman, A., & Gormican, S. (1988). Feature analysis in early vision: Evidence from search asymmetries. *Psychological Review, 95*(1), 15-48. https://doi.org/10.1037/0033-295X.95.1.15

Umiltà, C., & Liotti, M. (1987). Egocentric and relative spatial codes in S-R compatibility. *Psychological Research*, *49*(2-3), 81-90. https://doi.org/10.1007/BF00308672

Valle-Inclán, F., & Redondo, M. (1998). On the automaticity of ipsilateral response activation in the Simon effect. *Psychophysiology, 35*(4), 366-371. https://doi.org/10.1017/S0048577298960917

Van Duren, L. L., & Sanders, A. F. (1988). On the robustness of the additive factors stage structure in blocked and mixed choice reaction designs. *Acta Psychologica, 69*(1), 83-94. https://doi.org/10.1016/0001-6918(88)90031-5

Verfaellie, M., Bowers, D., & Heilman, K. M. (1988). Attentional factors in the occurrence of stimulus-response compatibility effects. *Neuropsychologia, 26*(3), 435-444. https://doi.org/10.1016/0028-3932(88)90096-6

Virzi, R. A., & Egeth, H. E. (1985). Toward a translational model of Stroop interference. *Memory & Cognition*, *13*(4), 304-319. https://doi.org/10.3758/BF03202499

Wamain, Y., Corveleyn, X., Ott, L., & Coello, Y. (2019). Does the motor system contribute to the perception of changes in objects visual attributes? The neural dynamics of sensory binding by action. *Neuropsychologia*, *132*, 107121. https://doi.org/10.1016/j.neuropsychologia.2019.107121

Wascher, E., & Wolber, M. (2004). Attentional and intentional cueing in a Simon task: An EEC-based approach. *Psychological Research, 68*(1), 18-30. https://doi.org/10.1007/s00426-002-0128-z

Washburn, M. F. (1916). *Movement and mental imagery: Outlines of a motor theory of the complexer mental processes.* Houghton Mifflin Company. https://doi.org/10.1037/11575-000

Waszak, F., Cardoso-Leite, P., & Hughes, G. (2012). Action effect anticipation: Neurophysiological basis and functional consequences. *Neuroscience & Behavioral Reviews*, *36*, 943-959. https://doi.org/10.1016/j.neubiorev.2011.11.004

Waszak, F., Hommel, B., & Allport, A. (2003). Task-switching and long-term priming: Role of episodic stimulus-task bindings in task-shift costs. *Cognitive Psychology, 46*(4), 361-

413. https://doi.org/10.1016/S0010-0285(02)00520-0

Way, T. C., & Gottsdanker, R. (1968). Psychological refractoriness with varying differences between tasks. *Journal of Experimental Psychology, 78*(1), 38-45. https://doi.org/10.1037/h0026154

Welford, A. T. (1952). The 'psychological refractory period' and the timing of high-speed performance—a review and a theory. *British Journal of Psychology, 43,* 2-19.

Wolfe, J. M., (2021). Guided Search 6.0: An updated model of visual search. Psychonomic Bulletin & Review, 28, 1060-1092. https://doi.org/10.3758/s13423-020-01859-9

Wendt, M., Kluwe, R. H., & Peters, A. (2006). Sequential modulations of interference evoked by processing task-irrelevant stimulus features. *Journal of Experimental Psychology: Human Perception and Performance, 32*(3), 644-667. https://doi.org/10.1037/0096-1523.32.3.644

Wenke, D. Gaschler, R., & Nattkemper, D. (2007). Instruction-induced feature binding. *Psychological Research*, *71*¸92-106. https://doi.org/10.1007/s00426-005-0038-y

Woodman, G. F., & Luck, S. J. (2007). Do the contents of visual working memory automatically influence attentional selection during visual search? *Journal of Experimental Psychology: Human Perception and Performance*, *33*, 363-377. https://doi.org/10.1037/0096-1523.33.2.363

Wühr, P. (2006). Response preparation modulates interference from irrelevant spatial information. *Acta Psychologica, 122*(2), 206-220. https://doi.org/10.1016/j.actpsy.2005.12.011

Wühr, P., & Ansorge, U. (2007). A Simon effect in memory retrieval: Evidence for the response-discrimination account. *Psychonomic Bulletin & Review, 14*(5), 984-

988. https://doi.org/10.3758/BF03194132

Wühr, P., & Biebl, R. (2009). Logical recording of S-R rules can reverse the effects of spatial S-R correspondence. *Attention, Perception, & Psychophysics*, *71*, 248-257. https://doi.org/10.3758/app.71.2.248

Wühr, P., Biebl, R., & Ansorge, U. (2008). The impact of stimulus and response variability on S-R correspondence effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*(3), 533-545. https://doi.org/10.1037/0278-7393.34.3.533

Wühr, P., & Müsseler, J. (2001). Time course of the blindness to response-compatible stimuli. *Journal of Experimental Psychology: Human Perception and Performance, 27*(5), 1260-1270. https://doi.org/10.1037/0096-1523.27.5.1260

Wykowska, A., Schubö, A., & Hommel, B. (2009). How you move is what you see: Action planning biases selection in visual search. *Journal of Experimental Psychology: Human Perception and Performance, 35*(6), 1755-1769. https://doi.org/10.1037/a0016798

Yamaguchi, M. (2025). Transfer asymmetry: Tversky's contrast model of similarity for perceptual-motor learning. Quarterly Journal of Experimental Psychology. https://doi.org/10.1177/17470218251324185

Yamaguchi, M., & Logan, G. D. (2014). Pushing typists back on the learning curve: Revealing chunking in skilled typewriting. *Journal of Experimental Psychology: Human Perception and Performance, 40*(2), 592-612. https://doi.org/10.1037/a0033809

Yamaguchi, M., & Proctor, R. W. (2006). Stimulus-response compatibility with pure and mixed mappings in a flight task environment. *Journal of Experimental Psychology: Applied, 12*(4), 207-222. https://doi.org/10.1037/1076-898X.12.4.207

Yamaguchi, M., & Proctor, R. W. (2009). Transfer of learning in choice reactions: Contributions of specific and general components of manual responses. *Acta Psychologica, 130*(1), 1-10. https://doi.org/10.1016/j.actpsy.2008.09.008

Yamaguchi, M., & Proctor, R. W. (2011a). Automaticity without extensive training: The role of memory retrieval in automatic implementation of task-defined rules. *Psychonomic Bulletin & Review*, *18*, 347-354. https://doi.org/10.3758/s13423-011-0050-8

Yamaguchi, M., & Proctor, R. W. (2011b). The Simon task with multi-components responses: Two loci of response-effect compatibility. *Psychological Research*, *75*, 214-226. https://doi.org/10.1007/s00426-010-0299-y

Yamaguchi, M., & Proctor, R. W. (2012). Multidimensional vector model of stimulus-response compatibility. *Psychological Review, 119*(2), 272-303. https://doi.org/10.1037/a0026620

Yamaguchi, M., Randle, J. M., Wilson, T. L., & Logan, G. D. (2017). Pushing typists back on the learning curve: Memory chunking improves retrieval of prior typing episodes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 43*(9), 1432-1447. https://doi.org/10.1037/xlm0000385

Yamaguchi, M., Valji, A., & Wolohan, F. D. A. (2018). Top-down contributions to attention shifting and disengagement: A template model of visual attention. *Journal of Experimental Psychology: General, 147*(6), 859-887. https://doi.org/10.1037/xge0000393

Yehene, E., Meiran, N., & Soroker, N. (2005). Task alternation cost without task alternation: Measuring intentionality. *Neuropsychologia, 43*(13), 1858-1869. https://doi.org/10.1016/j.neuropsychologia.2005.03.010

Zbrodoff, N. J. (1999). Effects of counting in alphabet arithmetic: Opportunistic stopping and priming of intermediate steps. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*(2), 299-317. https://doi.org/10.1037/0278-7393.25.2.299

Zhang, L., & Yamada, Y. (2023). Alternating capture of attention by multiple visual working memory representations. *Scientific Reports*, *13*, 13029. https://doi.org/10.1038/s41598-023-40095-8

Zhang, H. (H.), Zhang, J., & Kornblum, S. (1999). A parallel distributed processing model of stimulus-stimulus and stimulus-response compatibility. *Cognitive Psychology, 38*(3), 386-432. https://doi.org/10.1006/cogp.1998.0703

Zorzi, M., & Umiltà, C. (1995). A computational model of the Simon effect. *Psychological Research, 58*(3), 193-205. https://doi.org/10.1007/BF00419634