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Attention and spatial stimulus coding in the Simon task: A rejoinder to van der Lubbe and Abrahamse (2010)

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ABSTRACT

Hommel (2011-this issue) has reviewed the major lines of research and ongoing controversies on and around the Simon effect. Van der Lubbe and Abrahamse (2010) take issue with Hommel's assessment of the role of attention shifting in the Simon effect. This rejoinder argues that van der Lubbe and Abrahamse's criticism is off target because it (a) fails to distinguish between the attention-shifting account of (spatial stimulus coding in) the Simon effect—which Hommel discusses and criticizes—and the premotor theory of attention—which Hommel does not discuss; (b) confuses the relationship between the attention-shifting account and the referential-coding account of spatial stimulus coding in the Simon effect—the actual topic of Hommel's discussion—with the relationship between the premotor theory and the theory of event coding—which the criticism focuses on; and (c) confuses the uncontroversial role of attention in stimulus selection with the controversial role of attention in the generation of location codes.

On the occasion of the 43rd anniversary of the Simon (Simon & Rudell, 1967) effect, Hommel (2011-this issue; henceforth referred to as "Hommel") has discussed several reasons for why the effect had and still has such an important impact on the literature, and he has based this discussion on a review of the major lines of research, theoretical developments, and ongoing controversies on and around the Simon effect. In their comment on this article, van der Lubbe and Abrahamse (2010; henceforth referred to as "van der Lubbe and Abrahamse") take issue with Hommel's assessment of the role of attention in the emergence of the Simon effect. In seeming contrast to Hommel's skeptical view with regard to the relevance of attentional shifts for the spatial coding of stimuli, van der Lubbe and Abrahamse argue that spatial attention plays a crucial role in the Simon effect. In the following, I will argue that van der Lubbe and Abrahamse's criticism is off target because it (a) fails to distinguish between the attention-shifting account of (spatial stimulus coding in) the Simon effect—which Hommel discusses and criticizes—and the premotor theory of attention (PMTA; Rizzolatti, Riggio, Dascola, & Umiltà, 1987)—which Hommel does not discuss or criticize; (b) confuses the relationship between the attention-shifting account and the referential-coding account of spatial stimulus coding in the Simon effect—the actual topic of Hommel's discussion—with the relationship between the PMTA and the theory of event coding (TEC; Hommel, Müsseler, Aschersleben, & Prinz, 2001a)—which the criticism focuses on; and (c) confuses the uncontroversial role of attention in stimulus selection with the controversial role of attention in the generation of location codes.

1. Attention-shifting account and premotor theory

One problem with van der Lubbe and Abrahamse's reply is that its main argument is actually unrelated to Hommel's review. In the literature on the role of attention shifting in the Simon effect, two approaches are commonly contrasted. One is the attention-shifting approach (Nicoletti & Umiltà, 1994; Stoffer & Umiltà, 1997). As sketched in Fig. 1 (leftmost column), it assumes that visual stimuli outside the current attentional focus are first registered without being spatially coded, then a shift of attention towards their location is programmed and executed, and only then the non-spatial stimulus features can be analyzed and, if necessary, a response is selected. According to this early-selection approach, the spatial code of the stimulus is generated specifically for programming the attention shift (so that the absence of attention-shift programming would leave stimuli spatially uncoded), and it is this code that intrudes in some (theoretically not further specified) way into response selection—thus producing the Simon effect. This attention-shifting approach has been challenged by, and is thus commonly contrasted with the referential-coding account (Hommel, 1993a). Rather than attributing spatial stimulus coding to attention shifting, this account assumes that perceivers/actors are coding spatial and non-spatial features of stimuli alike (i.e., irrespective of the direction of any attentional shift; see Fig. 1, column 2) but, in the case of spatial location, relative to a number of reference frames (Logan, 1994), with the currently attended stimulus and/or location being the origin of one of these frames. Hence, according to the attention-shifting account a stimulus is coded as left/right if and because it triggers a left/

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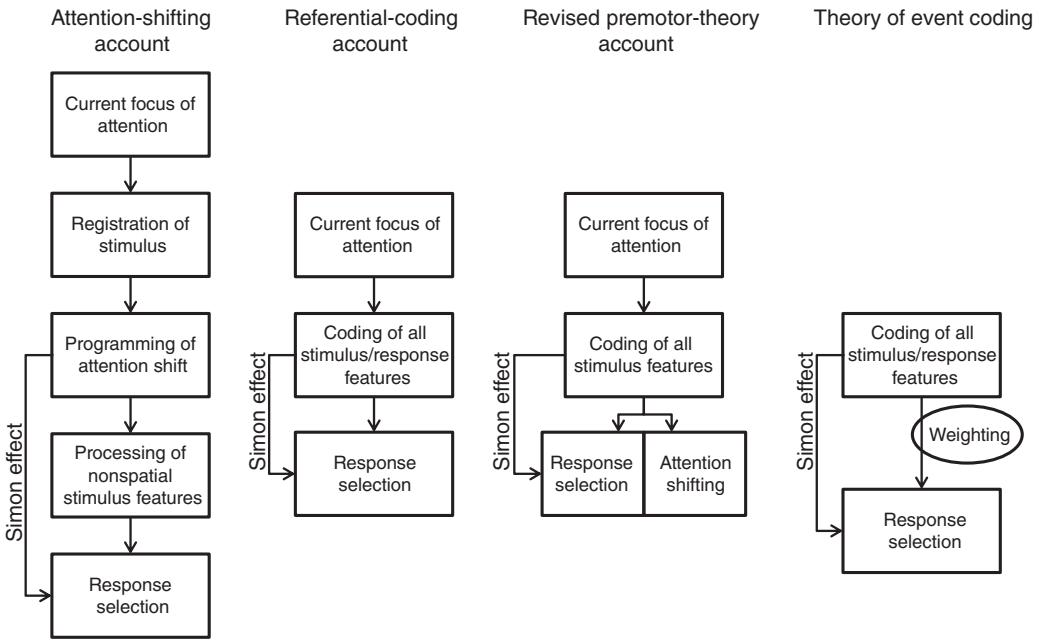

Fig. 1. Basic structure of four different accounts of the Simon effect. Note that the attention-shifting account (after Nicoletti & Umiltà, 1994; Stoffer & Umiltà, 1997) is basically an early-selection approach, while the referential-coding account (after Hommel, 1993a), the revised premotor-theory account (after Sheliga et al., 1997), and the theory of event coding (after Hommel et al., 2001a,b) imply a late-selection approach to attention.

right-ward shift of attention, whereas what matters for the referential-coding account is the actual (relative) location of the stimulus—just like color coding relates to the actual color and shape coding to the actual shape of a stimulus. Hence, the referential-coding account treats spatial and non-spatial features alike.

Hommel's review considered the evidence supporting the attention-shifting account and found it wanting, hence the skeptical conclusion. Apart from the still existing empirical gaps, Hommel also criticized the tendency of proponents of the attention-shifting approach to link this approach to the PMTA (Rizzolatti et al., 1987). The attention-shifting account does not provide a dedicated mechanism responsible for the creation of spatial stimulus codes but it relies on PMTA in this respect. Accordingly, it is problematic that, according to Hommel's theoretical analysis, the PMTA is structurally incompatible with the attention-shifting approach: Whereas the former assumes that the currently *fixated* location provides the origin of the reference frame for referential stimulus coding, the latter assumes that the currently *attended* location provides this origin. That does not necessarily render one or the other approach incorrect—as they were both developed for different purposes—it only means that one cannot provide the basis for the other. Given that the attention-shifting approach derives its major mechanistic assumptions from PMTA, this leaves no mechanistic basis for the former. Van der Lubbe and Abrahamse's reply does not discuss or challenge any of Hommel's arguments but, rather, is devoted to an issue that Hommel actually did not touch: whether and how PMTA might account for spatial stimulus coding in the Simon effect. Even though that is an interesting topic, it is difficult to see why van der Lubbe and Abrahamse present their discussion as if it would stand in any contradiction to Hommel's claims and conclusions. In fact, not one of the findings they discuss is inconsistent with Hommel's assessment of the attention-shifting account of spatial stimulus coding in the Simon effect.

2. Premotor theory and Theory of Event Coding

Whereas Hommel's review contrasted the attention-shifting account and the referential-coding alternative, van der Lubbe and Abrahamse's reply discusses the relationship between the PMTA (Rizzolatti et al., 1987) and the TEC of Hommel et al. (2001a). It is difficult to see what the purpose of this endeavor is. These two theories were motivated in different ways and developed for different purposes, so that it is not surprising that they differ in structure, emphasis, and detail. The PMTA was originally suggested as an account for a particular pattern of spatial-cueing effects observed by Rizzolatti et al. (1987) and only later generalized to characterize the relationship between attentional control and response selection (e.g., Sheliga, Craighero, Riggio, & Rizzolatti, 1997). It aims at understanding the dynamics of attention and its interplay with action, and therefore focuses on attentional processes but not so much on the representations they operate on. In contrast, TEC is a broad theoretical framework that aims at explaining the interrelationship between perception and action control in wide variety of phenomena, ranging from perceptual learning, feature integration, and sensorimotor synchronization to action planning, imitation, and observational learning. Unlike PMTA, TEC focuses on the types of representations that relate perception to action, and vice versa, but not so much on the processes operating on these representations.

Moreover, as Hommel et al. (2001a) have repeatedly emphasized, TEC is a *theoretical framework* rather than a theory, which provides theoretical and conceptual tools for building specific models of specific phenomena. In that respect, TEC can be compared to Sternberg's (1969) processing-stage approach or Anderson's (1996) ACT-R, which also are theoretical systems that suggest a particular theoretical perspective and a number of theoretical principles and elements for building more detailed phenomenon-specific models. These specific models are valuable to the degree that they stand empirical test, which implies that they need to be falsifiable. In contrast, theoretical frameworks are commonly too vague to be tested as a whole, so that their value depends on whether they motivate and allow for the construction of successful specific models. In other words, what counts for theoretical frameworks is not their degree of detail but their heuristic potential (cf., Hommel, Müsseler, Aschersleben, & Prinz, 2001b)—which renders van der Lubbe and Abrahamse's worry that TEC might be a "nearly unfalsifiable theory" justified but off-target.

Given that context, the arguments put forward by van der Lubbe and Abrahamse are difficult to appreciate. First, it is difficult to see

why their reply considers TEC and PMTA as "alternative frameworks"; this would presuppose that the two approaches aim at explaining the same phenomena—which they do not and which they cannot. Second, it is not surprising that theoretical approaches with little or no overlap with regard to their theoretical aims and conceptual mechanisms (such as PMTA and TEC) "are not mutually exclusive" and that they may complement each other in explaining more complex phenomena. Accordingly, one might consider the respective conclusion of van der Lubbe and Abrahamse as factually correct but self-evident. Third, it is difficult to see why van der Lubbe and Abrahamse first add a number of specific assumptions to TEC that TEC proponents had never suggested, and then accuse TEC for making them. In van der Lubbe and Abrahamse's Table 1, it is said that TEC would make assumptions regarding the "moment of formation of spatial codes" and the referential "value of code" and that it would hold "critical predictions" regarding the necessity of attentional shifts for spatial coding, the decay of code activation, and the like. However, not one of these assumptions or predictions were ever made or defended with regard to TEC and, indeed, it is difficult to see why such assumptions might be essential for a framework interested in the general principles underlying perception–action interactions. What van der Lubbe and Abrahamse seem to do here is to attribute all assumptions and predictions to TEC that the authors of the original TEC article (Hommel et al., 2001a,b) have defended in any of their other articles—which does not seem to be a fair procedure to evaluate a theoretical approach.

All these caveats aside, it is interesting to note what a rough comparison of the few ideas that PMTA and TEC do share reveals. Consider the revised version of PMTA suggested by Sheliga et al. (1997). On the one hand, this revised and generalized version does not imply any different interpretation of Rizzolatti et al.'s (1987) original findings than the original version. This does not support van der Lubbe and Abrahamse's suggestion that Hommel's assessment of the role of attention shifting in spatial stimulus coding would have been more positive if he had considered the premotor version of Sheliga et al. (1997). On the other hand, however, Sheliga et al. point out that their generalized approach does have theoretical implications for the interpretation of the Simon effect. In particular, they suggest that the coded stimulus features (of which they however discuss only spatial ones) are assumed to automatically activate brain circuits that have two intertwined functions: activating the spatially corresponding response and directing attention to the location of the stimulus. Note, that this does not follow the sequential logic of the attention-shifting approach, which claims that attention shifting is the *cause* of response activation (see Fig. 1, leftmost column). Quite to the contrary, Sheliga et al. consider "a distinction between a 'real' attentional mechanism that allocates the attentional focus on the imperative stimulus and a nonattentional sensorimotor mechanism responsible for the Simon effect… artificial" (p. 348).

In my view, this scenario (sketched in Fig. 1, column 3) fits well with the referential-coding approach suggested by Hommel (1993a; column 2) but not so much with the sequence of attentional shifting followed by response activation suggested by attention-shifting approaches (e.g., Nicoletti & Umiltà, 1994). If there is a processing sequence at all, one may even consider the reverse order (i.e., response activation followed by attention shifting) more plausible (Hommel, 2010). Moreover, it becomes obvious that the revised PMTA does not differ much from TEC (see Fig. 1, rightmost column), which does not make assumptions regarding spatial attention but suggests that, in the Simon task, all stimulus and response features can bias response selection after being weighted according to the task relevance of their respective feature dimensions. Nevertheless, neither TEC nor the PMTA are sufficiently equipped to make concrete predictions regarding spatial coding in the Simon task, whereas the attention-shifting account and the referential-coding account do—which is why Hommel's comments on spatial stimulus coding in the Simon task considered the latter two but not the former two.

3. Spatial stimulus coding and stimulus selection

Notwithstanding differing ideas about the mechanisms generating spatial stimulus and response codes, most theories on the Simon effect agree that the effect results from some sort of match or mismatch between these codes (e.g., Kornblum, Hasbroucq, & Osman, 1990). Now, consider a spatially symmetric display, in which the actual target stimulus (say, the black letter O or X) appears on one side of the display and a task-irrelevant distractor (say, a white digit) appears on the other (e.g., Hommel, 1993a). If under these conditions a Simon effect would occur (i.e., faster responses with target-response correspondence)—which numerous studies have shown to be the case—this must have to do with attention. Given that the physical characteristics of the stimulus display are entirely symmetric, they cannot account for a spatial-compatibility effect; rather, it must be the case that discriminating the target from the distractor and selecting it for further processing allowed the spatial location of the target to have a stronger impact on response selection than the spatial location of the distractor. In other words, target selection is a process that needs to be considered when explaining the occurrence of the Simon effect with multiple-stimulus display.

Even though it is true that not all approaches to the Simon effect have devoted equal amounts of consideration to the theoretical implications of multi-stimulus displays—a reflection of the fact that the standard Simon task uses single-stimulus displays—no theorist would deny that representations of target stimuli can activate feature-overlapping responses only after the cognitive system has determined what the actual target stimulus is. Accordingly, it is difficult to see why van der Lubbe and Abrahamse's reply emphasizes this rather obvious and uncontroversial issue and why it reviews so much evidence in its favor. The reply seems to confuse the uncontroversial assumption that attentional selection as an important precondition for the stimulus–response interactions responsible for the Simon effect with the controversial claim that the spatial codes of stimuli are derived from, and thus dependent upon shifts of spatial attention.

It is also difficult to see why van der Lubbe and Abrahamse are putting so much emphasis on the temporal dynamics of spatial codes. As suggested by Hommel (1993b) and De Jong, Liang, and Lauber (1994), the fact that, in the Simon task, stimulus location is irrelevant might result in a more or less spontaneous decay of the activation of spatial codes, which would explain why the Simon effect tends to disappear as the reaction time level increases. Many questions with regard to decay are still open however. For instance, some authors have doubted that the decay is really spontaneous (Ridderinkhof, 2002) and some have found decay patterns with some but not with other experimental setups and spatial reference frames (e.g., Wiegand & Wascher, 2005). It is therefore not entirely clear what it means that under some circumstances decay seems to begin when attention is shifted (van der Lubbe, Jaśkowski, & Verleger, 2005). It might mean that shifting attention changes reference frames and/or overwrites spatial codes in working memory, but it may also mean that decay results from competition between the response to the (selected) target and the response implied by the distractor, that spatial coding takes place at stimulus presentation but can start biasing a response only when one spatial code is stronger than the others, that spatial stimulus codes can access the response selection stage only after target identification has been completed (Kornblum, Stevens, Whipple, & Requin, 1999), and so forth and so on. These are interesting possibilities that call for further investigation, but it seems asking too much to bind the success of one or another theoretical approach to the degree that it can account for the currently rather colorful pattern of findings pertaining to spatial-code decay.

4. Conclusion

To summarize, van der Lubbe and Abrahamse criticize Hommel's pessimistic conclusion with regard to the role of attention shifting in

the creation of spatial stimulus codes (as suggested by Nicoletti & Umiltà, 1994; Stoffer & Umiltà, 1997). However, rather than considering the arguments that led Hommel to draw that conclusion (lack of empirical evidence; structural incompatibility between the attention-shifting account and PMTA; existence of multiple spatial codes), van der Lubbe and Abrahamse's reply turns to an unrelated topic that Hommel did not touch: the connection between PMTA and TEC. The reply points out some abstract commonalities of these two approaches—which exist but do not speak to the role of attention in spatial coding; it attributes assumptions and predictions to TEC that TEC does not, cannot, and should not make, and then criticizes these predictions for unclear empirical reasons. And it reviews massive empirical evidence for what I consider a non-issue in research on the Simon effect: that target stimuli need to be selected from competing distractors in order to selectively bias response selection. What van der Lubbe and Abrahamse's reply fails to provide is evidence that spatial stimulus codes are generated by, and thus rely on the process of shifting attention. Accordingly, I see little reason to reconsider Hommel's conclusion: that the claim that spatial codes are generated by attention shifts is lacking empirical support and that it is inconsistent with the theory it is said to rely on—the premotor theory of attention.

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