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Memory operations in rapid serial visual presentation

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Short-term memory (STM) has often been considered to be a central resource in cognition. This study addresses its role in rapid serial visual presentation (RSVP) tasks tapping into temporal attention—the attentional blink (AB). Various STM operations are tested for their impact on performance and, in particular, on the AB. Memory tasks were found to exert considerable impact on general performance but the size of the AB was more or less immune to manipulations of STM load. Likewise, the AB was unaffected by manipulating the match between items held in STM and targets or temporally close distractors in the RSVP stream. The emerging picture is that STM resources, or their lack, play no role in the AB. Alternative accounts assuming serial consolidation, selection for action, and distractor-induced task-set interference are discussed.

One of the most intriguing demonstrations of humans' limitations in processing rapid sequences of visual information (rapid serial visual presentation or RSVP) is the attentional blink (AB) phenomenon (Raymond, Shapiro, & Arnell, 1992). Commonly described as the decrease in the accuracy of identifying the second of two targets (T2) when it follows the first (T1) at a lag shorter than about 500 ms, it has been studied intensively for some years now. Despite the accumulation of an impressive body of research, numerous questions regarding how the phenomenon comes about remain unanswered, partly due to the lack of a comprehensive model of the attentional processes underlying it. However, virtually all accounts of the AB (for overviews, see Shapiro, Arnell, & Raymond, 1997; Visser, Bischof, & Di Lollo, 1999) have linked the capacity limitation expressed as AB to working memory or short-term memory (STM; Baddeley, 2000), by assuming either rate limitations in the consolidation of target-related information into STM (e.g., Chun & Potter, 1995) or interference within STM (e.g., Shapiro & Raymond, 1994). Accordingly, the aim of the present study was to

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investigate the relation and possible interactions between STM and the attentional processes responsible for the AB in more detail.

In a previous study, we had participants perform an AB task while concurrently holding information in STM, to see whether the number of items held would affect the size of the AB (Akyürek & Hommel, 2005). However, even though increasing STM load tended to decrease general performance in the RSVP task, there was no evidence that this decrease would be more pronounced at shorter lags, that is, in cases where T1 and T2 processing overlaps in time. Moreover, we found that using more task-related items to load STM (i.e., items from the same category as the targets or the distractors) led to a stronger drop in performance on the RSVP task but, again, this drop was independent of the lag between T1 and T2. These observations suggest that STM load and content affect T1 and T2 maintenance—presumably by modulating the amount of competition in STM (Duncan, Ward, & Shapiro, 1994; Shapiro & Raymond, 1994)—but not the processes underlying the AB proper. Given the central role STM plays in the majority of AB models suggested so far this is an astonishing finding. Consolidation accounts would lead one to expect that consolidating sensory traces of targets into STM gets more difficult, or takes longer, the more filled-up STM already is. Likewise, interference models suggest that competition increases with the number of items held in STM. Hence, from either point of view, increasing STM load should have a considerable impact on the size of the AB.

However, one may argue that the Akyürek and Hommel (2005) study provided a rather conservative and limited test of the interaction between STM and RSVP tasks. We identified two aspects with regard to which this may have been the case and, accordingly, carried out two experiments addressing these concerns in the present study. The first aspect relates to the STM loads employed, which were two, four, and six items. Considering the drop of almost 23% from the easiest to the most difficult condition, the range of these loads seems to be sufficiently broad to expect some impact on AB size. However, as no baseline without any STM-related extra activity was obtained, Akyürek and Hommel may have missed the impact of the presence of the STM task as such. The need to deal with a concurrent STM task and to coordinate it with the RSVP task may be considered to increase demands on what Baddeley (1986) calls the "central executive". It may be the presence or absence of these task-coordination demands—but not the number of STM items—that make the difference, so that the theoretically most important contrast may not be that between two and six items but between zero and two. The present Experiment 1 tested this prediction.

A second aspect with regard to which Akyürek and Hommel (2005) test may have been rather conservative concerns the choice of STM items. Although they used items from the same category as targets or distractors of the RSVP task, none of the STM items could occur as target or distractor in the RSVP stream. This makes sense for a test of merely capacity-related interactions between attention and STM but may underestimate content-related interactions. Several studies have shown that the AB is sensitive to the similarity between targets and distractors in the RSVP stream, with more similarity producing a greater AB (e.g., Isaak, Shapiro, & Martin, 1999; Maki, Bussard, Lopez, & Digby, 2003; Maki, Couture, Frigen, & Lien, 1997). This suggests that distractors compete with targets for selection to a degree that depends on their match with the implemented target template, that is, with the cognitive representation of the task-relevant stimuli held in STM (cf. Bundesen, 1990; Duncan & Humphreys, 1989)—a mechanism that Desimone and Duncan (1995) called "biased competition". If we assume that the similarity between targets and distractors is not all or none but a matter of degree (considering that both always share at least some task-relevant features, such as location or appearance by abrupt onset; see Maki et al., 2003), it seems possible that STM impacts the processing of RSVP streams (and the AB in particular) not only in a capacity-related fashion, as tested in Experiment 1, but (also) in a more specific, content-related fashion. The present Experiment 2 tested whether these kinds of interactions might play a role in the AB.

To summarise, we carried out two experiments to tap into possible interactions between the AB and STM. In particular, we considered task coordination (Experiment 1), and competition bias (Experiments 2A and 2B). To the degree that these aspects play a role in creating the attentional bottleneck reflected by the AB we would expect that taxing them by means of appropriate experimental manipulations has a specific impact on the AB. That is, increasing the load on a particular STM operation should impair performance in the RSVP task more the shorter the lag between T1 and T2.

EXPERIMENT 1: TASK COORDINATION

The first experiment was carried out to compare performance on an RSVP task of participants who performed a concurrent STM task and those who did not. Since the inclusion of an STM task will present additional difficulty, performance in the dual-task group is likely to be worse compared to the single-task group. If so, this might be due to either of two factors: One potential source of difficulty results from limits on STM capacity, as the STM items were to be maintained while the RSVP task was performed. Capacity problems should increase with STM load, so that the contribution of this factor was expected to grow with the number of to-be-maintained STM items. The other possible source derives from the executive overhead and coordination demands in the dual-task situation, so that this factor was expected to show up as a main effect of experimental group. The central question was, however, whether the effect of load and/or group would interact with the AB, that is, whether increased load and/or executive costs would boost the lag effect expected in the RSVP task. As Akyürek and Hommel (2005) found little evidence for interactions between load and lag, our main focus was on the group or task effect.

Both groups of participants received an identical RSVP task that in one group was embedded into an STM task. The design included the presentation of a set of items, followed by the RSVP stream with two targets, and a comparison item to probe STM. There were only two differences between the two groups: (1) The single-task group was told to ignore the STM items presented at the beginning of each trial and the comparison item at the end, whereas both of these stimuli were to be attended to in the dual-task group. (2) The dual-task group received an additional prompt to decide whether the comparison item was a member of the STM set or not.

Method

Design. Within-subjects factors in the repeated measures ANOVA were (1) the temporal distance between RSVP targets expressed in the number of intervening distractors, which is referred to as lag, and (2) the size of the STM set, referred to as load. The former consisted of four levels: lags 1, 3, 5, and 8; and the latter of three levels: 2, 4, and 6 items. Group was the only between-subjects factor: the dual-task group performed the RSVP task together with the STM task and the single-task group the RSVP task only. Accordingly, the load factor refers to the number of presented and to-be-recalled items in the dual-task group but to the number of presented items only in the single-task group. Dependent measures were T1 accuracy, T2 accuracy given T1 was correct (T2|T1), and accuracy in the STM task (in the dual-task group only).

Participants. Thirty-eight Leiden University students (19 per group, 32 female and 6 male) participated for pay or course credit. All participants reported having normal or corrected-to-normal vision and were not aware of the purpose of the experiment. Mean age was 20.9 years.

Apparatus and procedure. All experimental sessions took place in a standardised environment. Participants were seated in a small, dimly lit room. Stimuli were presented on an Intel Pentium III computer using the Intel i815 onboard graphics system. The E-Prime™ runtime component controlled presentation and data logging. The 17-inch LG FlatTron 776FM screen was fixed at 75% contrast and brightness. Using a resolution of 800 × 600 pixels, the screen was refreshed at 100 Hz. Viewing distance was not strictly controlled but averaged about 50 cm. All participants completed a single, 1 hour session of 456 trials, 24 of which were initial practice trials and not included in any analysis. The instruction sheet stressed accuracy on all dependent variables, but at the same time discouraged a slow or elaborative response mode.

Trials were started by the participants by pressing the spacebar on the keyboard. After a short pause of 300 ms the STM items were presented for 1000 ms. Then a fixation cross ("+") appeared for 250 ms, followed by an RSVP stream of 20 stimuli. Each of them appeared for 60 ms and was followed by a blank of 30 ms, amounting to a stimulus onset asynchrony of 90 ms. A 200 ms pause ensued, after which a single STM probe was presented for 1000 ms. In the dual-task group, a response screen appeared after a 250 ms blank pause. Participants in this group were asked whether the STM probe had been part of the STM set or not. Two additional response screens were presented in both single- and dual-task groups. The first screen prompted participants to identify T1 by pressing the corresponding digit on the keyboard, and the second screen did the same for T2.

All stimuli were randomly selected within the bounds of the experimental design. STM items were groups of 2, 4, or 6 digits and a single probe, selected from the complete digit set. The STM probe item had a probability of 50% of having been part of the STM set. RSVP targets were drawn independently in a similar fashion from the full digit set. STM items and RSVP targets were never repeated within their respective tasks. T1 was presented at position 7, 8, or 9 in the 20-item stream, randomly chosen but equally distributed. T2 followed T1 with a lag of 1, 3, 5, or 8 items. Lag 8 is a time interval long enough (660 ms) to be considered out of range for potential attentional blink effects, and was thus taken to represent a suitable performance baseline for a two-target RSVP task. RSVP distractors were capital letters drawn from the complete alphabet, without repetition. All stimuli were presented in 16 point Times New Roman font in black (RGB 0, 0, 0) on a grey background (RGB 128, 128, 128).

Results and discussion

We used standard analysis of variance for repeated measures designs and substituted Greenhouse-Geisser adjusted values (rounded to one decimal) in case of a significant test of sphericity. The full factorial ANOVA for STM performance (in the dual-task group) showed a main effect of load, $F(1.4, 25) = 36.04$, $MSE = 0.023$, $p < .001$, and an interaction effect of load by lag, $F(6, 108) = 2.19$, $MSE = 0.003$, $p < .05$. The former was due to a continuous decrease of performance with increasing load (90.8%, 83.2%, and 73.7% for set sizes of 2, 4, and 6 items, respectively), providing clear evidence that the STM task was not trivial. The interaction effect was less clear-cut. The differences between accuracy on each set size on the four lags were modest at best and involved a limited effect size; see Table 1. In any event, the fact that the set size effect was numerically largest at the longest lag does not point to a particular processing problem related to the AB.

Accuracy on T1 was influenced by main effects of lag, $F(3, 108) = 7.64$, $MSE = 0.005$, $p < .001$, and task group, $F(1, 36) = 5.93$, $MSE = 0.105$, $p < .05$. The interactions of load by group, $F(2, 72) = 5.70$, $MSE = 0.007$, $p < .005$, and load by lag were also significant, $F(6, 216) = 2.27$, $MSE = 0.003$, $p < .05$. Figure 1 (black symbols) shows T1 performance as a function of lag. Clearly, performance dropped a bit when T2 was presented rapidly after T1. This effect is common to task versions in which T1 and T2 are defined as targets by the same features and presumably reflects competition for selection between T1 and T2 codes (Hommel & Akyürek, 2005; also see Botella, Barriopedro, & Suero, 2001; Potter, Staub, & O'Connor, 2002). The task-group main effect is obvious from Figure 1 as well; adding the STM task resulted in overall lower T1 identification performance. As expected, STM load primarily affected the dual-task group. While performance in the single-task group remained virtually unchanged for the presentation of 2, 4, and 6 items (89.2%, 89.0%, and 90.3%, respectively), performance in the dual-task group dropped from 84.6% for 2 items to 82.2% (4 items) and finally to 79.5% (6 items). Consequently, the difference between groups was much more pronounced with STM loads of four or six than with a load of two items, suggesting that task difficulty as such was determined more strongly by load than by the number of tasks. The last interaction of load and lag was difficult to interpret, as no meaningful trend was apparent in the data. There was a hint of slightly increased performance at lag 3 and 5 in the most difficult 6-item STM condition, compared to performance at the other lags. The other load conditions seemed to result in higher T1 accuracy for longer lags. This pattern had no mirror in STM performance that might indicate a trade-off between tasks.

TABLE 1

Mean STM performance in the dual-task group of Experiment 1 by lag and STM load (number of items) in per cent

	Lag			
Load	*1*	*3*	*5*	*8*
2	89.8	90.1	91.8	91.7
4	83.8	82.9	84.9	81.0
6	76.6	74.6	72.5	71.1

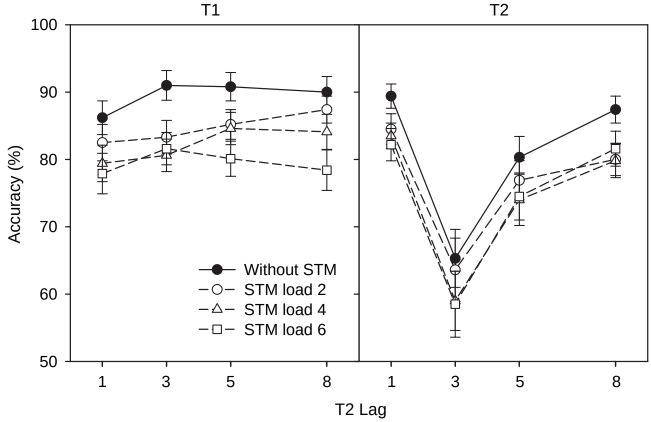

Figure 1. Experiment 1: T1 accuracy (left panel) and T2 accuracy given T1 correct (right panel) as a function of T2 lag. Solid lines represent performance in the single-task group; dotted lines represent performance in the dual-task group, for each STM load.

T2|T1 performance produced a main effect of lag, $F(2.0, 71.4) = 40.78$, $MSE = 0.031$, $p < .001$, that also showed a violation of the assumption of sphericity, which was why Greenhouse-Geisser adjusted degrees of freedom were used. The task group variable was also marginally significant, $F(1, 36) = 3.49$, $MSE = 0.108$, $p < .07$. Figure 1 (white symbols) shows a pronounced AB effect with performance on T2 dropping clearly on lag 3. Also visible is the lag 1 sparing phenomenon (Chun & Potter, 1995), which satisfies the criteria of Visser et al. (1999). The task group trend showed that if adding the STM task had an effect it would just decrease overall performance and not *in*crease the AB.

To summarise, Experiment 1 shows that the presence of an STM task interferes with the overall performance in concurrent RSVP and it does more so with higher STM load, at least when T1 is concerned. At the same time, however, the STM task does not increase the AB and thus impair the attentional processes underlying it. If the dual-task condition invoked additional executive processes for coordinating these tasks (Baddeley, 1986), its failure to boost the AB can be taken to imply that these executive processes are unrelated to those responsible for the AB.

EXPERIMENT 2A: COMPETITION BIAS TOWARDS DISTRACTORS

The outcome of Experiment 1 suggests that loading STM impairs performance on a concurrent RSVP task to a degree but does not specifically affect the processing bottleneck reflected by the AB. However, this test was purely in terms of capacity without consideration of *what* is loaded into STM. If we assume that, first, targets and distractors compete for selection (or some other crucial processing step) to the degree that the distractors match the target descriptions held in STM and that, second, targets and distractors are always similar to some degree (that varies as a function of the concrete stimulus sets chosen), it is possible that the impact of STM on the AB depends more on the particular content of STM than the rationale of Experiment 1 considered.

To investigate the impact of the specific content of STM on the AB we made use of the observation that items held in STM impact the selection of incoming stimulus events even if the reason for why they are held in STM is unrelated to these events. In particular, Downing (2000) and Pratt and Hommel (2003) demonstrated that maintaining items in STM for later use biases spatial attention towards locations where objects sharing features with these items are presented. For instance, in Downing's task, people were shown a picture of a face and asked to remember it for a later comparison task. In the interval between the initial presentation and the comparison task a repeated (irrelevant) showing of the same face in a particular spatial location automatically attracted attention to that location. This suggests that incoming information is continuously matched against information STM currently contains and receives top-down support to the degree that it matches (Bundesen, 1990; Duncan & Humphreys, 1989).

According to this logic, interactions between the content of STM and a concurrent RSVP task would only, or at least mainly, be expected if some relation existed between the particular stimuli held in STM (be that a target template, as in the standard RSVP task, or an item stored for another reason) and the stimuli processed in the RSVP task. Experiment 2A was designed to manipulate the relationship between STM items and particular distractors in the RSVP stream. Various authors have argued and provided evidence that selecting a target is particularly affected by competition from temporally close nontargets, especially the one immediately following the target (Bottella et al., 2001; Chun, 1997; Dell'Acqua, Pascali, Jolicœur, & Sessa, 2003; Hommel & Akyürek, 2005; Potter et al., 2002). If so, and if this competition can be biased in a top-down fashion by the content of STM, we should be able to influence its outcome, that is, performance on T1 and T2, by providing top-down support for distractors that follow T1 or T2. This is what we attempted to do in Experiment 2A. In particular, we had participants to maintain items in STM that were either (a) all unrelated to the stimuli in the RSVP stream, or a set including one item that matched the distractor presented (b) immediately following T1, (c) immediately following T2, or (d) at a position close to the end of the stream. If a match would provide top-down support for the respective distractor, condition (b) should specifically impair performance on T1 and condition (c) performance on T2.

Method

The design was very similar to Experiment 1, but we dropped two of the STM load conditions (2 and 6) and hence used a load of four items exclusively. Letters were used as items for the STM task, and a new factor was added, which concerned the position of the STM-related RSVP item in the stream. Apart from the control condition where no STM item matched the items of the stream, one item of the STM set matched the distractor following T1, or T2, or a distractor at position 19 (position 20 being the last item in the stream). The probability of each of these four conditions was 25%. In order to be able to present a matching STM item at lag 1, T2 was not presented at that position, but rather at lag 2 instead (and at lags 3, 5, and 8 as previously). Another 30 students (27 female, 3 male) participated in this experiment for course credit or a small fee. Mean age was 20.7 years.

Results and discussion

STM performance was unaffected by any factor, as was to be expected in the absence of a load manipulation. Performance was very good but not at ceiling (90% correct). T1 performance was also not sensitive to lag or the match with STM items (see Figure 2, left panel).

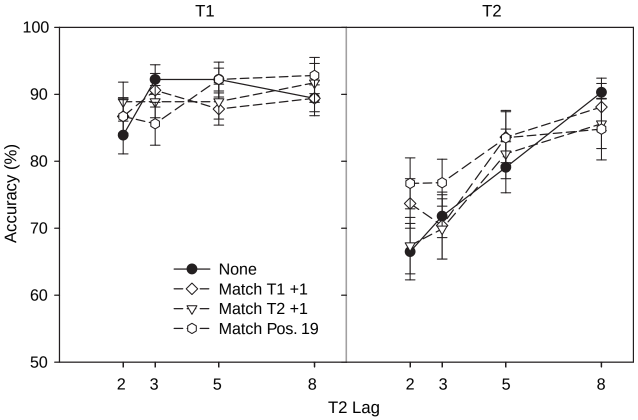

Figure 2. Experiment 2A: T1 accuracy (left panel) and T2 accuracy given T1 correct (right panel) as a function of lag. Separate lines show performance for each match condition.

T2|T1 accuracy depended on lag only, $F(1.9, 56.2) = 15.07$, $MSE = 0.074$, $p < .001$. Figure 2 (right panel) shows that T2 accuracy followed a rather typical AB curve with performance slightly above 70% at the lowest point and approaching 90% at its peak. There was no evidence whatsoever that the repetition of an STM item at any position in the stream had any effect, $p > .27$.

The outcome of Experiment 2A does not provide any support for the hypothesis that STM content can directly bias competitors of T1 or T2 and, thus, modulate performance on T1 or the size of the AB. Given the high level of STM performance, this failure to find an interaction between the two tasks was unlikely due to a neglect of the STM task. However, before jumping to conclusions we need to consider that our rationale depended on a number of intermediate assumptions that may or may not hold. In particular, even though previous findings are consistent with our crucial assumption that T1 and T2 codes compete with codes from succeeding nontarget stimuli for selection, so that strengthening the competitor codes should impair performance on T1 and T2, some element in this chain of arguments may be incorrect. To rule out that this was the reason for our failure to find an interaction we went for a more direct test in Experiment 2B. The rationale was very similar to that of Experiment 2A but instead of trying to strengthen potential competitors of T1 and T2 we this time attempted to provide top-down support for T1 and T2 themselves. That is, in some trials one item of the STM set matched either T1 or T2, with the expectation that this would facilitate the selection and/or further consolidation of the respective target and thus increase the likelihood that it will be correctly reported.

EXPERIMENT 2B: COMPETITION BIAS TOWARDS TARGETS

Method

The design was as in Experiment 2A, with only minor changes concerning the STM set and repetition variable. The STM set consisted of four digits instead of letters. One random digit of this set could match T1 (25% probability) or T2 (25%). In the remaining 50% of the trials no STM item matched any RSVP target—so to work against possible anticipatory strategies. Lags of T2 were 1, 3, 5, and 8, as in Experiment 1. The total number of trials was 600, 24 of which were practice trials and not considered in analyses. The experiment lasted for slightly longer than 1.5 hours and participants were encouraged to pause when halfway through. Twenty new students (16 female, 4 male) participated for course credit or a small fee. Mean age was 21.7 years.

Results and discussion

STM accuracy was affected by the interaction between lag and match, $F(6, 114) = 2.43$, $MSE = 0.003$, $p < .05$, which possibly reflected a small benefit of item overlap: Performance was unaffected by lag in the no-match and match T2 conditions ($p > .69$, and $p > .14$, respectively), but slightly increased for lags 3 and 5 with T1 matches, $F(2.2, 41.7) = 4.08$, $MSE = 0.004$, $p < .05$, as separate match condition analyses revealed. Table 2 shows the full set of STM performance means.

The analysis of T1 performance showed a significant main effect of lag, $F(3, 57) = 3$, $MSE = 0.005$, $p < .05$. This effect reflected a slight drop of performance when T2 follows T1 immediately, similar to what was seen in Experiment 1. Figure 3 (left panel) plots T1 performance as a function of lag.

Most importantly, T2|T1 accuracy was affected by lag, $F(1.8, 33.9) = 19.42$, $MSE = 0.062$, $p < .001$, indicating a fairly sizeable AB (see the right panel of Figure 3), but there was no hint to an interaction with match, $p > .25$.

As evident from the complete absence of match-related effects, Experiment 2B fully supports the (negative) conclusions suggested by Experiment 2A. As we will point out in the General Discussion, these observations need not be taken to stand in conflict with previous findings of interactions between STM and visual attention (Downing, 2000; Pratt & Hommel, 2003). What seems clear, however, is that such interactions do not underlie and do not seem to play a role in the emergence of the AB.

GENERAL DISCUSSION

The aim of this study was to investigate possible interactions between cognitive operations related to STM on the one hand and performance on RSVP tasks and the AB in particular on the other. With respect to the first aspect of this aim our endeavour was successful: The empirical outcomes demonstrate interactions between STM and RSVP tasks that point to

TABLE 2
Mean STM performance in Experiment 2B by lag and match in per cent

	Lag			
Match	*1*	*3*	*5*	*8*
None	85.0	85.9	84.6	84.5
T1	83.6	88.6	87.9	85.4
T2	88.1	85.1	85.8	83.3

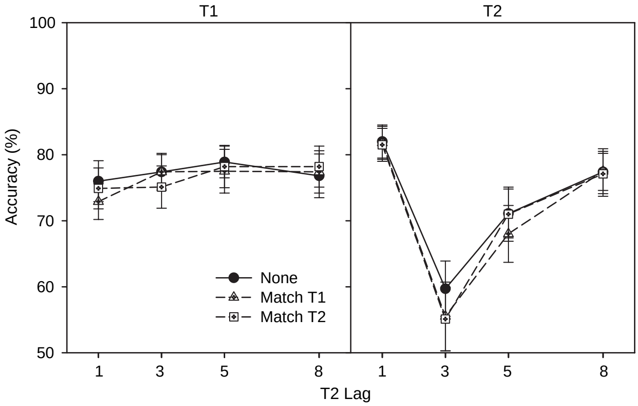

Figure 3. Experiment 2B: T1 accuracy (left panel) and T2 accuracy given T1 correct (right panel) as a function of T2 Lag. Separate lines show performance for each match condition.

dependencies between the processes underlying these tasks. Performance on T1 and probably T2 was sensitive to presence of a secondary STM maintenance task and, more strongly so, to the number of items to be maintained (Experiment 1). Importantly with respect to the second aspect of our goal, however, none of these interactions varied reliably with lag. This suggests that STM maintenance is a process that impairs performance in an RSVP task but that it does so in a broad, temporally rather constant fashion. In other words, maintenance seems not to affect temporal attention.

Together with the findings of Akyürek and Hommel (2005), these observations are surprising from a theoretical point of view. If the AB is due to interference within STM (Shapiro & Raymond, 1994), one would expect that, first, this interference should increase with STM load so that, second, the AB should increase with load as well. In view of the pronounced impact of load on T1 and T2 performance, our findings provide evidence for the first assumption and, yet, we found no support for the second. Accordingly, we conclude that existing interference accounts of the AB are correct in predicting the general performance level in an RSVP task but they do not provide a tenable explanation for the AB (Akyürek & Hommel, 2005).

How surprising our findings are from a consolidation point of view depends on the (commonly not well defined) details of the particular view. Generally speaking, consolidation theorists assume some sort of rate limitation in the consolidation of target-related information into STM (e.g., Chun & Potter, 1995; Jolicœur, Tombu, Oriet, & Stevanovski, 2002) but the possible reason for this limitation, and the mechanism producing it, are not yet well understood. The term “consolidation” is usually meant to refer to the transformation of a transient and fragile perceptual code of a target stimulus into a more enduring format, which in an RSVP task enables a participant to report the target a few seconds later. In view of the available theoretical considerations, we can imagine at least four reasons for why this process might lead to a performance deficit as represented by the AB.

First, consolidating into STM may take longer the more filled up it already is (which is more problematic for T2 than T1) and the more recently the last element was entered (and hence the more active it still is; which is more problematic for T2 if lag is short). This possibility would have predicted considerable interactions between load and lag and, thus, can be rejected based on the lack of such interactions both in the present study and in Akyürek and Hommel's (2005).

Second, the consolidation process may be unable to operate on more than one event at a time, so that T2 cannot be consolidated if it occurs while T1 is being operated on (note that given the observation of T1-related performance drops at lag 1 by Hommel & Akyürek, 2005, and Potter et al., 2002, this does not stand in conflict with lag-1 sparing). According to this approach we may have failed to find interactions between STM operations and the AB because the processes involved in the maintenance STM do not overlap with, or do not draw on the same source of capacity as, STM consolidation.

Third, consolidation may or may not be serial but it in any case may require operations that have side effects producing the AB. Consolidating a particular event presupposes that it is somehow selected for consolidation so to avoid the storage of other, temporally close events that compete for selection. Targets are assumed to be selected by providing top-down support, that is, additional activation for stimuli that match goal templates held or stored in memory (Bundesen, 1990; Duncan & Humphreys, 1989). In a competitive system, increasing the activation of one event must lead to relative inhibition; a decrease of activation of its competitors. Accordingly, to the degree that T1 receives top-down support T2 must be inhibited, at least if it appears before T1 selection is completed, which is consistent with the observation that T2 performance is better the less neural activation T1 produces (Shapiro, Schmitz, Martens, Hommel, & Schnitzler, in press). One may consider this to be the most elegant explanation because it does not require particular assumptions to account for the AB—instead, the AB emerges as a natural consequence of the fact that selection for (later) action is a competitive process. If so, our findings would be not surprising at all, because the operation that produces AB would not have any logical relation with maintenance. The only contribution of STM to selection would be the fact that some of its compartment would need to hold the target templates. This is likely to create main effects of load, as templates may be maintained less efficiently as STM load increases, and the more so the more related the STM items are to the targets—exactly as observed in the present study and by Akyürek and Hommel (2005). However, there would be no reason to expect any interaction with lag, because top-down support is an automatic consequence of having implemented the target templates (Downing, 2000; Pratt & Hommel, 2003), and the inhibition it indirectly produces is an automatic consequence of competitive selection.

Fourth, selecting and consolidating a target may be controlled by a task set, which may be fragile and sensitive to interference while a target is processed. According to Di Lollo, Kawahara, Ghorashi, and Enns (2005), task sets need to be maintained by a "central processor" that for this purpose issues endogenous control signals. While processing a target no control signals can be issued, so that external stimuli can take over control and effect a task set change if they do not match the task-set specific target template. That is, if a distractor appears while T1 is processed a task-set change is induced so that T2 cannot be processed until the old set has been reestablished, which again cannot happen before T1 processing is completed. Note that this account makes no reference to STM and hypothetical STM resource limitations, so that it remains unchallenged by our failure to find a systematic relationship between lag and load. That is, the observations of Akyürek and Hommel (2005) and those from the present study are consistent with a task-set account. More direct evidence in favour of this account comes from two recent findings. One is that stimuli can indeed become associated with the task sets they were processed under previously, so that presenting a stimulus again activates the corresponding task set automatically (Waszak, Hommel, & Allport, 2003). Even more interestingly, this association transfers to other, not-yet encountered stimuli of the same category (Waszak, Hommel, & Allport, 2004). That is, repeatedly not processing and consolidating distractors in an RSVP task may indeed create an association of both the encountered distractors and the whole distractor category with a representation of the "don't process" set assumed during distractor presentations, which then can be triggered by any stimulus related to the previous distractors. Another supporting observation stems from Gross et al.'s (2004) MEG study of the AB. They found that successful processing of T1 and/or T2 is associated with a substantial increase of neural synchronisation between the brain areas that form the attentional network involved in handling RSVP tasks (for an overview, see Hommel et al., in press), whereas failures to process T2 were not accompanied by such an increase. Interestingly, distractors induced reliable *de*creases of synchronisation, that is, their presence inhibited communication between the components of the attentional network, not unlike the scenario of Di Lollo et al. (2005) might be taken to suggest.

To summarise, our findings are consistent with accounts that attribute the AB to side effects of target selection, to a distractor-triggered change of the task set, or, with some additional assumptions, to the serial nature of target consolidation. In contrast, they do not provide support for accounts that relate to capacity limitations of or interference in STM. In other words, it looks as if STM, which is sometimes thought of as the "forge" of cognition, does not have much to do with the AB phenomenon.

Lastly, we considered the implications of our failure to find matching effects in Experiments 2A and 2B. As pointed out in the introduction, previous observations revealed that holding event-related information in STM biases spatial attention towards locations where events sharing features with the remembered event appear (Downing, 2000; Pratt & Hommel, 2003). Given these findings we expected that holding an item related to T1 or T2 would somehow affect the processing of the respective target and, thus, facilitate reporting it. In the absence of further systematic research we can only speculate why we failed to find such an impact. One possible reason may have to do with the lack of spatial variability in stimulus presentation. Previous evidence of the impact of STM–stimulus matches relates to spatial attention: The focus of attention was attracted to the location where the matching stimulus appeared. However, our stimuli all appeared in the same location so that a possible effect on the control of spatial focusing had no way to express itself in the data. If so, one would expect measurable (negative) effects of a T1-related match on T2 if T1 and T2 appeared in different locations. Another possible reason for our null effects may have to do with the particular tasks used. The participants of Pratt and Hommel (2003) were using the information held in STM to detect and identify a target stimulus and to carry out a speeded response to it. This suggests that held information was integrated into the current task set in a format that enabled a direct match against incoming stimuli. Obviously, this was not necessary in Experiments 2A and 2B or any other experiment of the present study, where the STM comparison item was only presented long after the RSVP stream so that holding it "ready for matching" during the RSVP was neither necessary nor useful. The fly in the ointment here is the fact that Downing (2000) had a similar set-up comprising of presentation of the STM item, an inserted dot detection task, and an unspeeded STM comparison—yet he did find a spatial effect of irrelevant primes matching the STM item on the dot detection task. A possible explanation may be that both tasks of Downing (holding one STM item and detecting a single dot) were much easier than ours (holding one STM item and selecting two targets from an RSVP stream), so that Downing's participants may have had more "resources" left and/or a greater motivation to hold the STM content in a ready-to-match format. However, in the absence of more research on this issue this remains a mere speculation.

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