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Short-Term Consolidation of Individual Identities Leads to Lag-1 Sparing

Roberto Dell'Acqua
University of Padova

Pierre Jolicœur
University of Montreal

Angelo Pascali
University of Ferrara

Patrik Pluchino
University of Padova

A rapid serial visual presentation (RSVP) technique was used to investigate the role of the nature of processing carried out on targets in the Lag-1 sparing phenomenon. Lag-1 sparing refers to a higher accuracy in the task associated with the 2nd target when the 2 targets are immediately successive in the RSVP stream relative to when there are 1 or 2 intervening items between the targets. In 5 experiments, 0, 1, or 2 digits were embedded with equal probability in RSVP streams of letter distractors. In 4 of the experiments, subjects identified the digits in some blocks of trials, and they counted the number of presented digits in other blocks. In a 5th experiment, the counting task was replaced with a digit-sum task. The most interesting results were those from trials with 2 digits. Lag-1 sparing was always evident when the task involved the explicit identification of the digits. In addition, Lag-1 sparing was evident when subjects were required to sum 2 digits or to count digits of a prespecified parity subclass (e.g., count only even digits). In striking contrast, Lag-1 sparing was absent when subjects were required to count the digits independent of their parity subclass. These results suggest that the occurrence of Lag-1 sparing depends on the type of mental representation that must be generated on the basis of target information.

Keywords: visual attention, identification, consolidation, Lag-1 sparing

The rapid serial visual presentation (RSVP) technique is a valuable tool to study some striking limitations of the human information processing system. One such limitation has been termed the attentional blink (AB; Raymond, Shapiro, & Arnell, 1992). The AB is a marked difficulty to identify the second of two sequential targets, commonly labeled *T1* and *T2*, embedded in a RSVP stream of distractors when the targets are presented in close temporal contiguity. The duration of the effect, anywhere from 200 ms to over 1 s, has been shown to depend on the duration of central processing of the first target (e.g., Jolicœur, 1999b). It is interesting to note that when the interval between the targets is equal to, or shorter than, 100 ms, the AB is virtually abolished—that is, T2 is identified with apparently no difficulty. From the start, Lag-1 sparing has been seen as an important phenomenon because of the theoretical challenge it poses for most models of the AB and because of the implicit promise that understanding this aspect of the AB phenomenon would reveal something fundamental about the underlying information-processing mechanisms mediating performance in RSVP tasks. In their review of the literature, Visser, Bischof, and Di Lollo (1999) found that Lag-1 sparing was generally eliminated when the spatial location of T2 changed relative to the location of T1 (e.g., Juola, Botella, & Palacios, 2004; Visser, Zuvic, Bischof, & Di Lollo, 1999) or when two or more attributes of T2 used for the selection of T2 from the RSVP stream were different from the attributes used to select T1. In the latter case, it was thought that the change in selection cues constituted a task switch (for a review, see Monsell, 2003) and that task switching was the factor leading to the drop in accuracy of report of T2 at Lag 1 and, thus, to the elimination of Lag-1 sparing (Potter, Chun, Banks, & Muckenhoupt, 1998; see also Chun & Potter, 2001).

Current thinking about Lag-1 sparing is dominated by two divergent theoretical interpretations of the causes of the AB effect and the causes of Lag-1 sparing. We outline these two classes of models below and reconsider them in more detail in light of the results of the present investigation in the General Discussion.

Models of the AB and Lag-1 Sparing

One perspective on the AB and Lag-1 sparing is provided by models postulating that the processing of targets encoded for later report proceeds in two stages: an initial high-capacity identification stage followed by a low-capacity memory-encoding stage. This idea is instantiated in two-stage models like those of Chun and Potter (1995) and of Jolicœur and Dell'Acqua (1998). According to these models, all alphanumeric characters composing an RSVP sequence are processed up to the level of individual character identities at an early stage (Stage 1), but only T1 and T2 are selected for access to a later stage of processing (Stage 2) that consolidates T1 and T2 into durable memory representations that are stored in visual short-term memory (VSTM). The metaphor of

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Roberto Dell'Acqua and Patrik Pluchino, Department of Developmental Psychology, University of Padova, Padova, Italy; Pierre Jolicœr, Department of Psychology, University of Montreal, Montreal, Quebec, Canada; Angelo Pascali, Department of Human Sciences, University of Ferrara, Ferrara, Italy.

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Correspondence concerning this article should be addressed to Roberto Dell'Acqua, Department of Developmental Psychology (DPSS), Via Venezia 8, 35131, Padova, Italy. E-mail: dar@unipd.it

an attentional gate is normally invoked by these models to explain how the system isolates T1 and T2 for further processing. The onset of T1 elicits the opening of the gate, which is held to operate sluggishly—that is, the gate takes some time to close. The result is that if T2 immediately follows T1, both T1 and T2 can be passed to Stage 2 for simultaneous consolidation. Given that short-term consolidation is a capacity-limited process, some competition between T1 and T2 ensues such that some of the gain in performance for T2 occurs at a cost to performance for T1 (Chun & Potter, 1995).

Recent work by Potter and her colleagues has allowed researchers to better understand the conditions leading to trade-offs between T1 and T2 at very short T1–T2 stimulus onset asynchronies (SOAs). Presenting word targets in two streams of stimuli—one directly above the other—at 53 ms/item, Potter, Staub, and O'Connor (2002) replicated previous results showing an AB for T2 at a T1–T2 SOA of 213 ms and sparing of T2 at an SOA of 107 ms (Lag 2 in this experiment). Surprisingly, however, at an SOA of 53 ms (Lag 1), T2 report was significantly better than T1 report: the reverse of the AB effect. The advantage of T2 over T1 was obtained at SOAs as short as 13 ms and extended to SOAs of 53 and sometimes 107 ms. Potter et al. (2002) proposed a two-stage competition model to account for these results. Stage 1 begins when T1 is detected as a potential target, opening the attentional gate, and ends when it is lexically identified. During Stage 1 processing of T1, the onset of T2 attracts resources away from T1: The two targets are in competition. At very short SOAs of 53 ms or less, T2 is hypothesized to gain a competitive edge over T1 because T2 benefits from the already open attentional gate, often allowing T2 to be identified first. At longer SOAs, however, there is an increasing probability that T1 will be the first to be identified. Crucially, the first-identified target (whether T1 or T2) enters Stage 2, in which short-term consolidation of the target occurs, allowing it to be reported (Chun & Potter, 1995; Jolicœur & Dell'Acqua, 1998). Stage 2, according to Potter et al. (2002), is a serial-processing bottleneck lasting several hundred milliseconds in which only one target can be processed. The other target must wait for entrance to Stage 2 and is vulnerable to forgetting or erasure (e.g., Dell'Acqua, Pascali, Jolicœur, & Sessa, 2003; Giesbrecht & Di Lollo, 1998).

The central interference theory proposed by Jolicœur (1998; see also Jolicœur & Dell'Acqua, 1998; Jolicœur, Tombu, Oriet, & Stevanovski, 2002) is somewhat more complex, however. Although short-term consolidation is capacity limited, these authors postulate that several items can be consolidated simultaneously. However, the simultaneous consolidation of several items must begin at the same time (or close to it). It is hypothesized that short-term consolidation operates on the principle of a batch processor. A consolidation batch can contain more than one item. However, once initiated, a batch must be completed before new items can be added to the batch. This would allow two targets to be consolidated simultaneously if they are presented in very close temporal contiguity (i.e., at Lag 1), but not at longer lags, if T1 already triggered a new batch and an ensuing consolidation cycle. At longer lags, processing of T1 initiates a consolidation batch before the processing of T2 prepares T2 for consolidation. In this case, T2 arrives too late to enter the consolidation batch containing T1, and so T2 must wait for the consolidation cycle of T1 to finish. During this waiting time, T2 can be lost due to decay or overwriting by items trailing T2 in the RSVP stream.

Several recent proposals seem to be in line with the general idea that T1 and T2 can be subject to simultaneous consolidation, sometimes at the expense of information of report order (e.g., Akyürek & Hommel, 2005; Hommel & Akyürek, 2005; Potter et al., 2005). Furthermore, the notion of substantial overlap in the processing of T1 and T2 within the Lag-1 sparing window has recently been provided with the magnetoencephalography (MEG) technique (Kessler et al., 2005a, 2005b) by showing an overlap of the M300 responses elicited by T1 and T2 (the MEG equivalent of the P300 event-related component observed with electrophysiological recordings) as the temporal interval between their onsets was reduced. It is interesting to note that the overlap of M300 peak responses was observed in regions held to be of interest for identification processes (e.g., inferotemporal regions) but not in regions more likely involved in sequencing (e.g., frontoparietal regions).

A different perspective on the Lag-1 sparing phenomenon, and on the AB effect in general, has recently been proposed by Di Lollo, Kawahara, Ghorashi, and Enns (2005) on the basis of findings that are admittedly hard to reconcile with the multistage proposals summarized above. Di Lollo et al. (2005) compared the identification performance on RSVP triplets of characters of the same alphanumerical class (e.g., three consecutive letters of the English alphabet) with the identification performance on RSVP triplets of characters, the second of which varied in alphanumeric class compared with the other targets (e.g., one letter, followed by one digit, and then by one letter again). The first letter in each triplet acted as T1 in these experiments. Critically, if the triplet was uniform (all characters from the same class), the third letter in the triplet (T3) benefited from a prolonged sparing effect. The sparing effect was absent, however, if the triplet was not uniform in alphanumeric class. Together with analogous findings reported by Olivers, van der Stigchel, and Hulleman (in press), the results of Di Lollo et al. (2005; see also Kawahara, Enns, & Di Lollo, 2005; Kawahara, Kumada, & Di Lollo, in press) argue strongly for the involvement of attention control mechanisms as modulatory factors of both the AB effect and Lag-1 sparing.

Di Lollo et al. (2005) proposed that the AB is brought about by a temporary loss of control on attentional settings. According to this proposal, subjects are initially set to filter the information conveyed to them through the RSVP technique on the basis of the features that are thought to be relevant for the task at hand (for evidence concerning the *contingent capture* effect in the AB that support this suggestion, see Folk, Leber, & Egeth, 2002; Leblanc & Jolicœur, 2005). Maintaining this *attentional set*, however, requires constant monitoring on the part of a central processor, which sways momentarily the resources needed to control the input attentional filter toward consolidation mechanisms on detection of target information (i.e., T1). If the temporary loss of control occurs under conditions in which the RSVP stream of stimuli is uniform, the loss does not hamper the encoding of further target information. If instead the stream is discontinuous, and a distractor slips in when the control of attention settings is forcedly diminished, attention settings are exogenously reset in favor of the newly incorporated information (i.e., that conveyed by the distractor) at the expense of successive information that may be relevant for the task—namely, T3 in the present case. Converging with the idea of the crucial role of control in modulating the AB effect and Lag-1 sparing, Olivers and Nieuwenhuis (2005) showed an attenuation of the AB impairment under conditions in which subjects' investment of attention resources for the execution of the AB task was attenuated by having them perform a concurrent task-irrelevant activity.

The Present Study

We now turn to the issue at the core of the present investigation, which is related to the complex interplay between attention control of input filter mechanisms, on the one hand, and aspects of processing taking place prior to the capacity-demanding consolidation of representations selected for further processing on the other.

In the two-stage framework (e.g., Chun & Potter, 1995; Jolicœur, 1998), it is hypothesized that stimuli are processed up to the level of individual identities before consolidation. The logical implication of this hypothesis is that the production of identity codes for T1, T2, and the distractors should take place regardless of whether the task associated with T1 and T2 requires identification. Put in another way, whether identity is the information that must be reported from T1 and T2, the identity codes are generated, likely via the automatic activation of the corresponding identity nodes at the level of conceptual short-term memory (Potter, 1976, 1993). However, Di Lollo et al. (2005), as well as all other authors of the temporary loss of control type of accounts, have argued that an input filter is tuned to detect the relevant characteristics of target information for filtering purposes. The central operator in this framework sends signals back to earlier processing stages to keep them tuned to the target information that is relevant for the task at hand. The emphasis in this view is on the important role played by early processing of the information that is critical to isolate target from distractor information.

Most experiments working with the AB paradigm have used stimuli for which subjects have long-term memory representations (e.g., letters, digits), and it is surprising that the specific role of such representations in the modulation of the AB effect and Lag-1 sparing has so far never been explicitly addressed. It is interesting to note that Raymond (2003) reported two AB experiments in which novel objects were used as stimuli. The stimuli were simple geometric shapes (tridentlike or arrowhead patterns), presented using the RSVP technique. The distractors included in each RSVP stream were always tridents, and T1 was distinguished from distractors because it carried a unique feature, a thicker line segment superimposed horizontally on either a trident or an arrowhead. In this way, T1 was defined as an old object when it was a trident (because it was preceded by several distractors with the same "identity" or a new object when it was an arrowhead). In two experiments, Raymond showed the presence of an AB effect only when T1 was a new object and no AB effect when T1 was an old object. Raymond argued that the need to generate a new object file is an important determinant for the occurrence of an AB effect (see also Kellie & Shapiro, 2004). However, when Raymond observed an AB, Lag-1 sparing was absent. This raises the interesting possibility that the absence of Lag-1 sparing in Raymond's experiments might have resulted from the fact that subjects had to process stimuli that were novel. More specifically, one may hypothesize that when the task requires the consolidation of stimulus identities for which there is a unique correspondence in long-term memory (as in the case of to-be-reported familiar stimuli such as alphanumeric characters, real-world objects, scenes, faces, etc.), the resulting *identification code* (Kawahara, Di Lollo, & Enns, 2001), or *token instantiation* (Chun, 1997), receives re-entrant support from long-term memory, which is likely to prolong a fleeting activation caused by a brief (and masked) stimulus presentation. A reasonable supposition is that this activation prolongation may be the critical element for the integration of two (or more) such codes generated on the basis of sequential stimuli and for their simultaneous short-term consolidation which results in Lag-1 sparing.

The paradigm that we designed to test whether the requirement to generate a reportable identity code from a visual stimulus (vis-à-vis other forms of codes) had a modulatory role in the AB and Lag-1 sparing was the following: We embedded an unpredictable number of digits (ranging from 0 to 2) in an RSVP stream of letters and instructed subjects either to identify the digits for delayed report, as has been often required in the studies of Lag-1 sparing reviewed above, or to simply count the digits, followed by a delayed report of the total number of digits rather than of which digits had been presented. This procedure allowed us to maintain a similar selection cue in all cases (i.e., select digit targets and reject letter distractors) while varying what operations following the initial selection had to be performed on the basis of the selected objects. The assumption underlying this design was that whereas the task to report what digits had been displayed on a given trial could be carried out only via the consolidation of specific digit-identity codes, the counting task relied solely on information about the stimulus class (digits vs. letters)—that is, on the detection of a discontinuity at the alphanumeric level in the flow of visual information. Neither two-stage models nor temporary loss of control (TLC)-like models would make a differential prediction on the presence (or amount) of Lag-1 sparing in the two tasks. Lag-1 sparing should be observed with counting and identifying in the two-stage framework because the generation of identity codes is not subject to voluntary control. Lag-1 sparing should be observed with counting and identifying in the TLC-type of framework because the information used to filter target from distractor information is the same in both tasks. Therefore, finding a dissociation in terms of Lag-1 sparing between the tasks that we adopted would represent a challenge for both models.

Experiment 1

Experiment 1 was the starting point of the present investigation. Zero, 1, or 2 digits were embedded in RSVP sequences of letters, and the subjects were instructed to identify the digits in half of the blocks of trials and to count the digits in the other half. Target selection had the same basis in both cases—namely, select digits and reject letters.

Method

Subjects. A total of 90 university students (52 female, 38 male) from the University of Padova, Padova, Italy, ranging in age from 19 to 33 years, were assigned at random to the five experiments in the present study ($n = 18$ in each experiment). The subjects were paid or received course credit for their participation. All subjects had normal or corrected-to-normal acuity, and none reported a history of prior neurological disorders.

Stimuli. The stimuli were 22 letters of the English alphabet (all except the letters *B*, *I*, *O*, and *Z*) and the digits *2* to *9*. These characters were displayed in light gray (34 cd/m^2) on a uniform black background (6 cd/m^2) on a cathode ray tube computer screen placed about 70 cm from a subject's eyes. Luminance measurements were performed using a Minolta LS-100 chromameter. All characters fit in a square portion of the screen with a side of 0.95°. The characters were displayed using the RSVP technique. Each character was displayed for 85 ms at the center of the screen and was immediately replaced by the next item (interstimulus interval [ISI] was 0 ms), yielding a presentation rate of approximately 12 item/s. Each RSVP stream of stimuli was generated by randomly selecting letters without replacement from the list of 22 letters. In 2-digit trials, there were 6–9 letters before T1, and T2 could occur at Lags 1, 3, or 7 after T1. There were 1–4 distractors presented starting at Lag 8, ensuring that T2 was always followed by at least 1 distractor. In 1-digit trials, T1 was replaced by a distractor in the RSVP sequence. In 0-digit trials, both T1 and T2 were replaced by distractors.

Procedure. Each trial began with the presentation of a *plus* sign at the center of the screen. The trial started with a spacebar press, which caused the *plus* sign to disappear. After a blank interval of 800 ms, the RSVP stream was displayed. Streams with 0 digits, 1 digit, and 2 digits were equally likely to be presented throughout the experiment. The task was either to count the number of presented digits or to report which digits had been presented. Subjects performed three blocks of 54 trials for each task, and task order was counterbalanced across subjects, with half of the subjects performing the counting task first and the identification task second and the other half performing the tasks in the reverse order. In the identification task, a question was displayed 800 ms after the end of the RSVP stream, inviting subjects to report the digit(s) by pressing the corresponding keys on the numeric keypad of the computer keyboard or *0* if no digit was presented. The instructions mentioned explicitly that the order in which the responses were given in the identification task (when more than one response was made) was not important. In the counting task, a question was displayed 800 ms after the end of the RSVP stream presentation inviting subjects to indicate the number of digits seen in the RSVP sequence by pressing one among the *0*, *1*, or *2* keys of the numeric keypad. In both the identification task and the counting task, responses were made without speed pressure. One block of 18 practice trials preceded the series of three blocks in a given task. In each block of trials, the three levels of the lag manipulation were equiprobable.

Results

The proportions of correct responses in 0-digit, 1-digit, and 2-digit trials were analyzed separately using an analysis of variance (ANOVA) in which lag (in 1-digit and 2-digit trials only) and task were treated as within-subject factors. In the identification task, the order in which subjects indicated the identity of T1 and T2 in 2-digit trials was not taken into account.

0-digit condition. The proportion of correct responses in the identification task and in the counting task was the same (i.e., .87). Errors in both tasks were entirely false alarms involving the incorrect indication of the presence of one digit in the RSVP streams—that is, no false alarms due to the incorrect report of two digits ever occurred in this condition.

1-digit condition. The proportions of correct responses were .95 in the identification task and .84 in the counting task. These proportions differed significantly, $F(1, 17) = 18.7$, $MSE = 0.017101$, $p < .001$. It is interesting to note that the analysis revealed that most errors in the counting task were represented by false alarms (i.e., subjects responding *2* incorrectly), whereas false alarms were virtually absent in the identification task (.13 vs. .01), $F(1, 17) = 35.7$, $MSE = 0.010786$, $p < .001$, with a small proportion of misses as remaining errors (i.e., .016). The manipulation of lag (reflecting the absolute position of the digit in the RSVP stream) produced no significant effects in this condition ($F < 1$).

2-digit condition. Consider first the identification task (see Figure 1, top panel). The proportion of correct responses to T1 was affected by the lag manipulation, with a lower proportion of

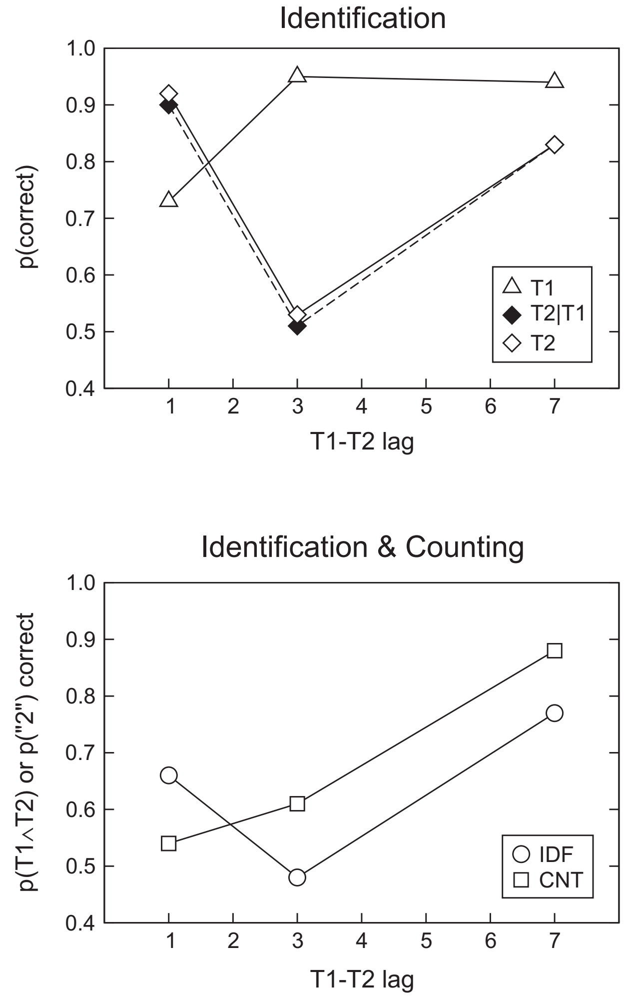

Figure 1. Results in the 2-digit condition of Experiment 1. Top: Mean proportions of correct responses in the identification task. Bottom: Mean proportions of correct responses in the identification and counting tasks, calculated on the basis of trials in which both Targets 1 and 2 (T1 and T2) were correctly identified and trials in which a correct *2* response was emitted. IDF = identification task; CNT = counting task.

correct responses to T1 at Lag 1 compared with that at the other lags, $F(2, 34) = 50.1$, $MSE = 0.005302$, $p < .001$. When the data at Lag 1 were discarded from the analysis, the proportion of correct responses to T1 at Lag 3 and at Lag 7 did not differ significantly ($F < 1$).

The proportion of correct responses to T2 was first analyzed by considering only trials in which T1 was identified correctly. The analysis indicated a marked effect of lag, $F(2, 34) = 34.4$, $MSE = 0.021848$, $p < .001$, that was qualified by the characteristic U-shaped function of the AB effect (see Figure 1, top panel). The difference between the proportion of correct responses to T2 at Lag 1 and the proportion of correct responses to T2 at Lag 3 was significant, $F(1, 17) = 70.5$, $MSE = 0.020059$, $p < .001$, as was the difference between the proportion of correct responses to T2 at Lag 3 and the proportion of correct responses to T2 at Lag 7, $F(1, 17) = 34.2$, MSE $= 0.025651$, $p < .001$. Another analysis was carried out on the proportion of correct responses to T2 independent of whether T1 was correctly identified on a given trial. The results were similar to those produced by the previous analysis, with a strong effect of lag, $F(2, 34) = 41.6$, $MSE = 0.018513$, $p < .001$, and a U-shaped distribution of the mean proportion of correct responses to T2 across lags (see Figure 1, top panel). The difference between the proportion of correct responses to T2 at Lag 1 and the proportion of correct responses to T2 at Lag 3 was significant, $F(1, 17) = 54.3$, $MSE = 0.024518$, $p < .001$, as was the difference between the proportion of correct responses to T2 at Lag 3 and the proportion of correct responses to T2 at Lag 7, $F(1, 17) = 33.5$, $MSE = 0.024259$, $p < .001$. As can be seen in the top panel of Figure 1, conditionalizing accuracy for T2 on a correct response to T1 made no difference.

For the counting task, the open squares in the bottom panel of Figure 1 show the proportion of correct trials (i.e., when subjects responded *2*) for each lag. These means were submitted to an ANOVA with lag as a within-subject factor, which revealed a significant effect of lag, $F(2, 34) = 21.3$, $MSE = 0.022513$, $p < .001$. In the counting task, it was not possible to determine which target was missed (the first or the second) when subjects responded *1* instead of *2*. We suppose that it was the second target that was missed in the majority of these trials but that sometimes the reverse may have occurred.

We also compared overall success in the identification task with that in the counting task. To do so, we scored overall success in the identification task as the proportion of trials in which T1 and T2 were both identified correctly. The resulting overall accuracy means are also displayed in the bottom panel of Figure 1. We submitted the means from both tasks to an ANOVA that treated lag and task as within-subject factors, which revealed a main effect of task, $F(1, 17) = 4.8$, $MSE = 0.013849$, $p < .05$; a main effect of lag, $F(2, 34) = 19.2$, $MSE = 0.039906$, $p < .001$; and a Task × Lag interaction, $F(2, 34) = 14.1$, $MSE = 0.011492$, $p < .001$. Evidence for Lag-1 sparing was clearly present for the identification task but entirely absent for the counting task.

A separate analysis carried out on errors in the identification task revealed a significant effect of lag on the proportion of misses, $F(2, 34) = 37.4$, $MSE = 0.013022$, $p < .001$, but not on the proportion of incorrect responses to T2 ($F < 1$). In the counting task, errors were represented exclusively by cases in which subjects pressed incorrectly *1* (and not *0*, i.e., the alternative response option) after being exposed to 2-digit trials.

Discussion

The main goal of Experiment 1was to compare performance for 2-digit trials across the counting task and the identification task. For the identification task, T1 was identified correctly more frequently than T2 at all lags except at Lag 1, where T2 was identified correctly more frequently than T1 (see Figure 1, top panel). As in previous work, the Lag-1 sparing effect[1] in the T2 accuracy scores was accompanied by a marked drop in accuracy of report for T1, suggesting some competition for limited processing capacity. This competitive trade-off between T1 and T2 makes the analysis of either score alone (T1 or T2) difficult to interpret[2] and, thus, difficult to compare with results from the counting task. For this reason, we also estimated an overall measure of success in the identification task by computing the proportion of 2-digit trials in which both digits were reported accurately (see Figure 1, bottom panel). Evidence for Lag-1 sparing was still observed in the composite T1–T2 accuracy scores, suggesting an overall advantage at Lag 1 relative to Lag 3, over and above any trade-off between T1 and T2.

In contrast, the results in the counting task provided no evidence for Lag-1 sparing (see Figure 1, bottom panel), and these different patterns of results (Lag-1 sparing for the identification task and the absence of Lag-1 sparing for the counting task) were statistically significant. There was no easy way to determine which digit was missed in 2-digit trials in the counting task other than by trying to infer it from the results of the identification task. But, given that the two tasks produce different results (at Lag 1, at least), this approach must be considered with caution. Useful indications come from the analysis of the patterns of errors in 2-digits trials in the two tasks. Errors in the identification task for T2 could be of one of two types, either misses of T2 (i.e., subjects typed in only T1) or incorrect responses to T2 (i.e., subjects typed in two digits, one of which [T2] was incorrect). The distribution of errors in the identification task observed in Experiment 1 was in fact informative of the tendency on the part of subjects actually “not to see” T2 in many 2-digit trials, as witnessed by a proportion of missed T2 that was substantially higher (.07, .46, and .10 from the shortest to the longest lag, respectively) compared with a negligible proportion of incorrect responses to T2 (.01, .02, and .02 from the shortest to the longest lag, respectively). This particular result converges with recent findings by Sergent, Baillet, and Dehaene (2005), who integrated the standard behavioral variable monitored in RSVP designs (i.e., success in reporting target information) with a procedure aimed at estimating the subjective visibility of targets embedded in RSVP streams. The logic in this study was to compare the binary outcome associated with the first type of dependent

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[1] In Visser, Bischof, and Di Lollo’s (1999) meta-analysis, Lag-1 sparing was said to have occurred in a given AB experiment if the level of performance at Lag 1 exceeded by 5% the lowest level of performance indicated in the AB function (which is usually observed between Lag 2 and Lag 3). In the present study, the criterion for the definition of Lag-1 sparing was more conservative, given that we associated to an indication of the quantity of the “sparing” the relative value of probability that the better performance at Lag 1 compared with that at the other lags was not due to chance.

[2] The T1–T2 trade-off could not be a result of report-order errors because accuracy was scored without regard to order.

variable (T2 reported vs. T2 not reported) with a more continuous (on a 100-point scale) estimate of the visibility of T2 in the AB. It is interesting to note that the rate of subjective visibility of T2 and the rate of report were almost perfectly correlated. The rate of visibility was bimodally distributed and, more important, the modes coincided with the extremes of the scale of visibility, suggesting that the AB produced in the majority of cases a dichotomous outcome: T2 was either seen and reported, or T2 was lost radically (as the close-to-nil subjective rating of T2 visibility suggested).

Experiment 2

In Experiment 1, the targets were digits, and the task in the counting task was to count how many digits had been presented. We were concerned that updating a mental count for digits could produce a conflict between the state of the mental counter and the numeric value represented by the digits that were counted. Resisting this conflict could be particularly difficult when two digits were presented at short lag, perhaps resulting in the abolition of Lag-1 sparing in the counting task. To rule out this possibility, the alphanumeric class of targets and distractors was reversed in Experiment 2—namely, letters were used as targets and digits as distractors. If the absence of Lag-1 sparing in the counting task was caused by a potential conflict between the identity of the counted targets and the state of the mental counter, then counting letters should eliminate it, and Lag-1 sparing should now be equivalent across the counting task and the identification task.

Method

The stimuli and procedure were the same as those used in Experiment 1 except that the targets were letters and the distractors were digits. In the identification task, subjects typed the identity of target letters using the computer keyboard. All other aspects of Experiment 2 were identical to those of Experiment 1.

Results

The proportions of correct responses in 0-letter, 1-letter, and 2-letter trials were analyzed separately using an ANOVA in which lag (in 1-letter and 2-letter trials only) and task were treated as within-subject factors. In the identification task, the order in which subjects indicated the identity of T1 and T2 in 2-letter trials was not taken into account.

0-letter condition. The proportions of correct responses were .93 in the identification task and .88 in the counting task. These proportions differed significantly, $F(1, 17) = 13.3$, $MSE = 0.001517$, $p < .003$. Errors in both tasks were entirely due to false alarms in which subjects reported seeing one letter—that is, no false alarms were due to the incorrect report of two letters.

1-letter condition. The proportions of correct responses were .92 in the identification task and .80 in the counting task. These proportions differed significantly, $F(1, 17) = 65.3$, $MSE = 0.007277$, $p < .001$. A tendency analogous to that observed in Experiment 1 was observed in Experiment 2. The analysis revealed that most errors in the counting condition were represented by false alarms (i.e., subjects responded *2* incorrectly), whereas false alarms were virtually absent in the identification condition (.14 for counting vs. .01 for identification), $F(1, 17) = 33.2$, $MSE = 0.014715$, $p < .001$. A close-to-nil proportion of misses constituted the remaining errors. The lag manipulation produced no significant effects in this condition ($F < 1$).

2-letter condition. Consider first the identification task (see Figure 2, top panel). The proportion of correct responses to T1 was affected by the lag manipulation, with a lower proportion of correct responses to T1 at Lag 1 compared with that at the other lags, $F(2, 34) = 27.9$, $MSE = 0.010527$, $p < .001$. When the data at Lag 1 were discarded from the analysis, the proportion of correct responses to T1 at Lag 3 and at Lag 7 did not differ significantly ($F < 1$).

The proportion of correct responses to T2 was first analyzed by considering only trials in which T1 was identified correctly. The analysis indicated a marked effect of lag, $F(2, 34) = 46.4$, $MSE = 0.024681$, $p < .001$, reflected in the classic U-shaped function of the AB effect (see Figure 2, top panel). The difference between the

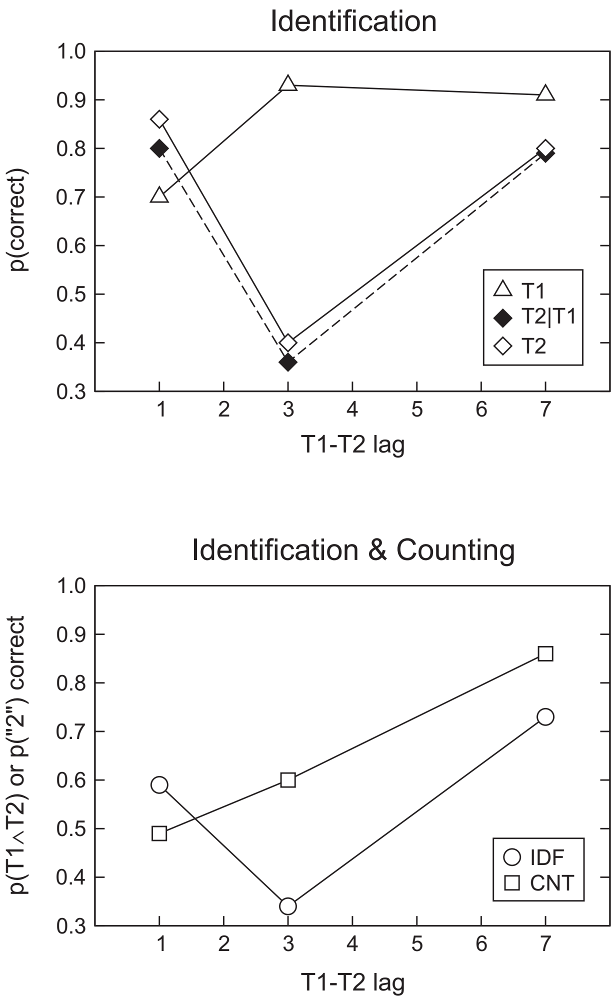

Figure 2. Results in the 2-letter condition of Experiment 2. Top: Mean proportions of correct responses in the identification task. Bottom: Mean proportions of correct responses in the identification and counting tasks, calculated on the basis of trials in which both Targets 1 and 2 (T1 and T2) were correctly identified and trials in which a correct *2* response was emitted. IDF = identification task; CNT = counting task.

proportion of correct responses to T2 at Lag 1 and the proportion of correct responses to T2 at Lag 3 was significant, $F(1, 17) = 111.1$, $MSE = 0.017833$, $p < .001$. The difference between the proportion of correct responses to T2 at Lag 3 and the proportion of correct responses to T2 at Lag 7 was also significant, $F(1, 17) = 87.9$, $MSE = 0.018891$, $p < .001$. An analogous analysis was carried out on the proportion of correct responses to T2 independent of whether T1 was correctly identified. The results were virtually identical to those produced by scoring T2 accuracy conditionalized on a correct response to T1, with a strong effect of lag, $F(2, 34) = 68.8$, $MSE = 0.016649$, $p < .001$, and a U-shaped distribution of the mean proportion of correct responses to T2 across lags (see Figure 2, top panel). The difference between the proportion of correct responses to T2 at Lag 1 and the proportion of correct responses to T2 at Lag 3 was significant, $F(1, 17) = 67.8$, $MSE = 0.026115$, $p < .001$. The difference between the proportion of correct responses to T2 at Lag 3 and the proportion of correct responses to T2 at Lag 7 was significant, $F(1, 17) = 79.9$, $MSE = 0.017591$, $p < .001$. As usual, results for T2 accuracy differed only negligibly as a function of whether accuracy for T2 was conditional on a correct T1 response.

For the counting task, the open squares in the bottom panel of Figure 2 show the proportion of correct trials (i.e., when subjects responded *2*) for each lag. These means were submitted to an ANOVA with lag as a within-subject factor, which revealed a significant effect of lag, $F(2, 34) = 24.0$, $MSE = 0.022923$, $p < .001$. A direct comparison of overall accuracy in the identification task and accuracy in the counting task was carried out by considering the proportion of trials in which T1 and T2 were both identified correctly in the identification task and trials in which subjects responded *2* correctly in the counting task. An ANOVA on these results revealed a main effect of task, $F(1, 17) = 26.7$, $MSE = 0.014901$, $p < .001$; a main effect of lag, $F(2, 34) = 26.9$, $MSE = 0.038412$, $p < .001$; and a significant Task × Lag interaction, $F(2, 34) = 22.2$, $MSE = 0.008314$, $p < .001$. As in Experiment 1, Lag-1 sparing was found in the identification task and was completely absent in the counting task.

An analysis of the errors in 2-letter trials in the identification task produced analogous results to those found in Experiment 1. Specifically, the larger proportion of errors in the identification task was composed of misses (.10, .49, and .18 from the shortest to the longest lag, respectively) compared with a relatively small proportion of incorrect responses to T2 (.02, .01, and .01 from the shortest to the longest lag, respectively). Separate analyses on errors revealed significant effects of lag on misses, $F(2, 34) = 37.4$, $MSE = 0.013022$, $p < .001$, but not on incorrect responses to T2 ($F < 1$).

Discussion

The pattern of results in Experiment 2 was the same as that in Experiment 1. Again, we found clear-cut evidence for Lag-1 sparing when character identities had to be individuated for short-term consolidation (in the identification task) but not when targets were simply counted, which likely does not require consolidating individuated representations. Most important, Experiment 2 rules out the possibility that the absence of Lag-1 sparing in the counting task observed in Experiment 1 was due to conflict between the identities of the counted characters (digits) and the internal (numerical) state of the mental counter.

Experiment 3

Experiments 1 and 2 clearly demonstrated differences in the patterns of results between the counting task and the identification task. We believe that such differences arose because of fundamental differences in the processing requirements of the targets in the two tasks. Namely, character identities must be individuated for short-term consolidation in the identification task but not in the counting task. Before we accept this interpretation, however, another (perhaps simpler) account must be ruled out. It appears that the counting task was generally easier than the identification task. Perhaps this task difference somehow could account for the modulation of the Lag-1 sparing effect. However, the difference in task difficulty may be more apparent than real, if we take into account different probabilities of producing a correct response simply by guessing. In the identification task, the probability of guessing correctly the identity of a target was 1/9 in Experiment 1 and 1/22 in Experiment 2. The probability of guessing the correct number of digits in the counting task was much higher than these latter values—that is, 1/3. This difference, per se, might explain why performance appears generally better in the counting task than in the identification task when considering the proportion of correct scores that are not corrected for guessing.

Nonetheless, the idea that the counting task may have been easier than the identification task cannot be dismissed entirely. Counting targets among categorically distinct distractors may simply be easier than identifying the targets to the level of individual character identities because counting requires a less detailed encoding of the targets beyond the initial categorization as either a digit or letter. In Experiment 3, we presented the stimuli behind a camouflage mask that consisted of a scattering of random dots, which were displayed throughout the presentation of a particular RSVP stream. Our aim was to degrade the perceptual representation of the stimuli in the RSVP stream (T1, T2, and distractors) so as to render the task more difficult in the presence of the camouflage mask relative to trials in which the stimuli were presented without the mask. Prior research has shown that such a mask can impair accuracy by degrading the information required to perform the task (Bachmann & Allik, 1976; Brehaut, Enns, & Di Lollo, 1999; Enns, 2004; for a review, see Breitmeyer, 1984). The presence of a camouflage mask should impair performance in the AB and, thus, make the task more difficult (Ouimet & Jolicoeur, in press). Such manipulation would allow us to test whether the presence versus absence of Lag-1 sparing could not be accounted for simply on the basis of a vague notion of "task difficulty."

Method

The stimuli and procedure were the same as those used in Experiment 1, with the following exceptions. On a random half of the trials, a 1.1° square region centered on the RSVP stream was partially filled with a cloud of 200 randomly positioned pixels, as shown in Figure 3. This cloud of pixels was present throughout the RSVP stream. A new cloud was generated at random for each masked trial.

Figure 3. Example of the unmasked (left) and masked (right) stimuli used in Experiment 3.

Results

The data were analyzed as in Experiment 1 but with the addition of the masking variable. The most important results are shown in Figure 4. As predicted on the basis of the analysis of Ouimet and Jolicœur (in press), camouflage masking reduced overall accuracy but did not increase or decrease Lag-1 sparing in either task, nor did it affect the overall shape of the AB function (see also Giesbrecht & Di Lollo, 1998).

0-digit condition. The proportions of correct responses in the identification task was the same as that in the counting task (.85 vs. .85, respectively; $F < 1$). Errors in both cases were entirely due to false alarming the presence of one digit in the RSVP streams—that is, no false alarms due to the incorrect detection of two digits when none was presented ever occurred in 0-digit trials.

1-digit condition. The proportions of correct responses were .88 in the identification task and .77 in the counting task. These proportions differed significantly, $F(1, 17) = 19.1$, $MSE = 0.034310$, $p < .001$. As in Experiments 1 and 2, most errors in the counting task were false alarms, but there were very few false alarms in the identification task (.13 vs. .01), $F(1, 17) = 35.7$, $MSE = 0.010786$, $p < .001$. As in the previous experiments, the rate of misses was negligible in this condition (i.e., $M = .01$). The effect of the mask was to decrease the proportion of correct responses relative to the trials without the mask (.80 vs. .85, respectively), $F(1, 17) = 6.5$, $MSE = 0.017823$, $p < .03$. No other factor or interaction between factors produced significant effects in 1-digit trials (all Fs < 1).

2-digit condition. In the identification task (see Figure 4, top panel), the proportion of correct responses to T1 depended on lag, with a lower proportion of correct responses to T1 at Lag 1 compared with that at the other lags, $F(2, 34) = 46.4$, $MSE = 0.009636$, $p < .001$. When the data at Lag 1 were temporarily excluded from the analysis, the proportion of correct responses to T1 at Lag 3 and at Lag 7 did not differ significantly ($F < 1$). The proportion of correct responses to T1 was lower when the mask was present relative to when the mask was absent (.71 vs. .81, respectively), $F(1, 17) = 14.0$, $MSE = 0.017241$, $p < .002$. The lag and mask factors did not produce interactive effects on the proportion of correct responses to T1 ($F = 1$).

Considering the subset of trials in which T1 was identified correctly, the analysis of the proportion of correct responses to T2 revealed a marked effect of lag, $F(2, 34) = 46.4$, $MSE = 0.024681$, $p < .001$, with an evident reduction of the proportion of correct responses to T2 at Lag 3 compared with that at the other lags (see Figure 4, top panel). The difference between the proportion of correct responses to T2 at Lag 1 and the proportion of correct responses to T2 at Lag 3 was significant, $F(1, 17) = 111.1$, $MSE = 0.017833$, $p < .001$. The difference between the proportion of correct responses to T2 at Lag 3 and the proportion of correct responses to T2 at Lag 7 was also significant, $F(1, 17) = 45.3$, $MSE = 0.048870$, $p < .001$. The proportion of correct responses to T2 was lower when the mask was present relative to when the mask was absent, $F(1, 17) = 7.0$, $MSE = 0.020851$, $p < .02$. Lag and masking were statistically additive effects ($F < 1$); masking did not increase the degree of Lag-1 sparing.

When 2-digit trials were further analyzed independently of whether T1 was correctly identified, the analysis revealed an effect of lag, $F(2, 34) = 35.4$, $MSE = 0.017974$, $p < .001$, again with a U-shaped pattern of mean proportions of correct responses to T2 across lags. The difference between the proportion of correct responses to T2 at Lag 1 and the proportion of correct responses to T2 at Lag 3 was in fact significant, $F(1, 17) = 50.3$, $MSE =$

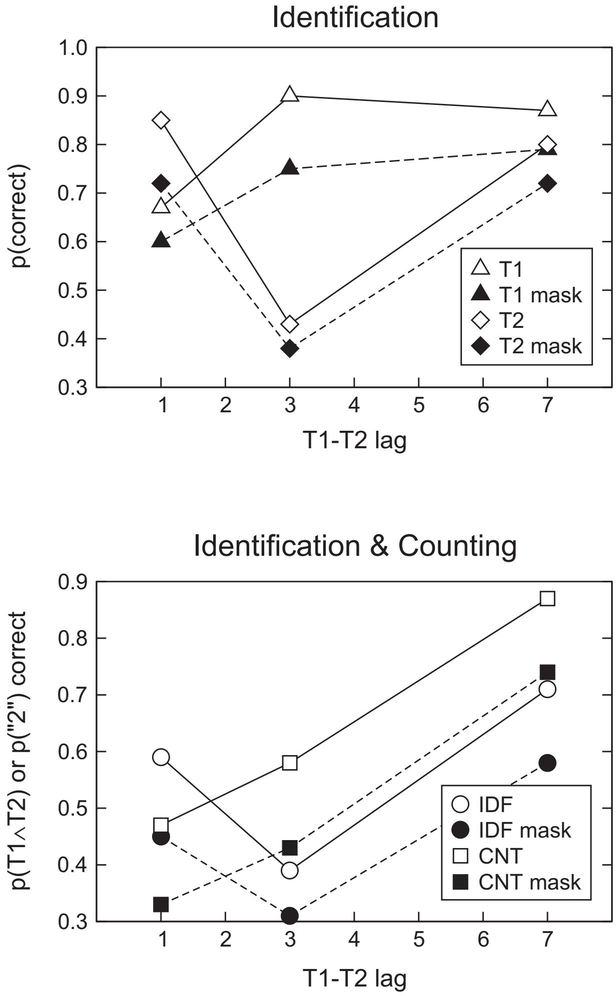

Figure 4. Results in the 2-digit condition of Experiment 3. Top: Mean proportions of correct responses in the identification task. The mean proportion of correct responses to T2 is calculated on the basis of trials in which T1 was identified correctly. Bottom: Mean proportions of correct responses in the identification and counting tasks, calculated on the basis of trials in which both T1 and T2 were correctly identified and trials in which a correct *2* response was emitted. IDF = identification task; CNT = counting task.

0.055001, $p < .001$. The difference between the proportion of correct responses to T2 at Lag 3 and the proportion of correct responses to T2 at Lag 7 was also significant, $F(1, 17) = 42.9$, $MSE = 0.000005$, $p < .001$. In this analysis, however, the mask factor produced effects that were only marginally significant, $F(1, 17) = 3.3$, $MSE = 0.017974$, $p < .07$, and the Mask × Lag interaction did not produce significant effects in this analysis ($F < 1$).

The proportion of trials in which T1 and T2 were both identified correctly in the identification task and the proportion of trials in which subjects responded *2* correctly in the counting task are shown in the bottom panel of Figure 4. Accuracy was better overall in the counting task than in the identification task, $F(1, 17) = 7.0$, $MSE = 0.045782$, $p < .02$. There was also a main effect of lag, $F(2, 34) = 38.0$, $MSE = 0.052204$, $p < .001$; a main effect of mask, $F(1, 17) = 33.0$, $MSE = 0.021333$, $p < .001$; and a significant Task × Lag interaction, $F(2, 34) = 16.8$, $MSE = 0.028615$, $p < .03$. No other factor or interaction approached statistical significance (all Fs < 1).

Discussion

Experiment 3 was designed to rule out explanations of the presence versus absence of Lag-1 sparing across the identification and counting tasks on the basis of the notion that more difficult tasks lead to Lag-1 sparing and easier tasks lead to the abolition of Lag-1 sparing. Any such simplistic attempt at an explanation of the differential Lag-1 sparing effects across tasks can be categorically rejected on the basis of the present results. As can be seen in the bottom panel of Figure 4, overall accuracy in the masked counting condition was essentially the same as in the not-masked identification condition (at Lags 3 and 7), and yet the identification task produced very clear Lag-1 sparing, whereas the counting task did not.

Experiment 4

Experiments 1–3 point to a fundamental difference between encoding specific target identities and counting instances of members of a category in the causes of the Lag-1 sparing phenomenon. We hypothesize that this difference is taking place at the time targets are encoded rather than when they are later recalled. However, the counting task and the identification task are also quite different in their output requirements. Two distinct target identities have to be retrieved and output for the identification, whereas a single response is required in the counting task. Although it is not immediately obvious how retrieval operations would affect results at Lag-1 differentially from other lags, it is logically possible that the observed differences in Lag-1 sparing across the tasks arose at the time of retrieval from VSTM and motor output of the response(s) rather than at encoding.

Experiment 4 was designed to require similar encoding operations across two tasks but different forms of response. The identification task used in previous experiments remained unchanged. However, rather than asking observers to count presented digits, we asked them in Experiment 4 to report the sum of all seen digits. As in reporting a count, reporting the sum involves a single response. We assumed that each of the two digits would need to be identified to the level of individual character identity for subjects to compute the correct sum. Consequently, we hypothesized that the identification task and the digit-sum task would be very similar in terms of what information that needed to be encoded but different principally in terms of how the encoded information had to be translated into overt responses. If it was the nature of the encoding operations required for T1 and T2 at the time of their presentation, and not at the time of their retrieval, that was critical for the Lag-1 sparing effect, we reasoned that we should observe equivalent Lag-1 sparing effects in the identification task and the digit-sum task in the present experiment.

Method

The stimuli were the same as those used in Experiments 1–3, with the exception that the digits set was restricted to the digits *2* to *5*. The same masking manipulation used in Experiment 3 was used here. The identification task was the same as in Experiments 1–3. The counting task was replaced by a digit-sum task in which subjects reported the sum of perceived digits, at the end of the trial, without speed pressure. Otherwise, Experiment 4 was the same as the previous experiments.

Results

0-digit condition. The proportion of correct responses was superior in the digit-sum task compared with the proportion of correct responses in the identification task (.93 vs. .80, respectively), but the effect was statistically marginal, $F(1, 17) = 4.4$, $MSE = 0.088416$, $p < .06$. In the identification task, errors were entirely due to 1-digit false alarms—that is, there were no false alarms due to the incorrect report of two digits when none was presented. It was hard to disentangle whether the digit typed in by a subject at the end of a given trial in the digit-sum task represented a sum of one digit and 0 or the sum of two digits unless the digit *2* was given in response in the digit-sum task. The proportion of such cases was minimal, however ($M = .022$), and consequently inappropriate for a statistical analysis.

1-digit condition. The proportions of correct responses were .93 in the identification task and .84 in the digit-sum task. These proportions differed significantly, $F(1, 17) = 25.2$, $MSE = 0.024517$, $p < .001$. The mask manipulation in this condition did not produce significant effects: The proportion of correct responses was similar when the mask was present and when the mask was absent (.88 vs. .90, respectively), $F < 1$. No other factor or interaction between factors produced significant effects in this condition (all Fs < 1).

2-digit condition. In the identification task (see Figure 5, top panel), the proportion of correct responses to T1 depended on lag, with a lower proportion of correct responses to T1 at Lag 1 compared with those at the other lags, $F(2, 34) = 11.7$, $MSE = 0.026641$, $p < .001$. When the data at Lag 1 were temporary excluded from the analysis, the proportion of correct responses to T1 at Lag 3 and at Lag 7 did not differ significantly ($F < 1$). The proportion of correct responses to T1 was lower when the mask was present relative to when the mask was absent (.84 vs. .90, respectively), $F(1, 17) = 5.0$, $MSE = 0.014316$, $p < .04$. The lag and mask factors did not produce interactive effects on the proportion of correct responses to T1 ($F < 1$).

Considering only trials in which T1 was identified correctly, the analysis of the proportion of correct responses to T2 revealed a

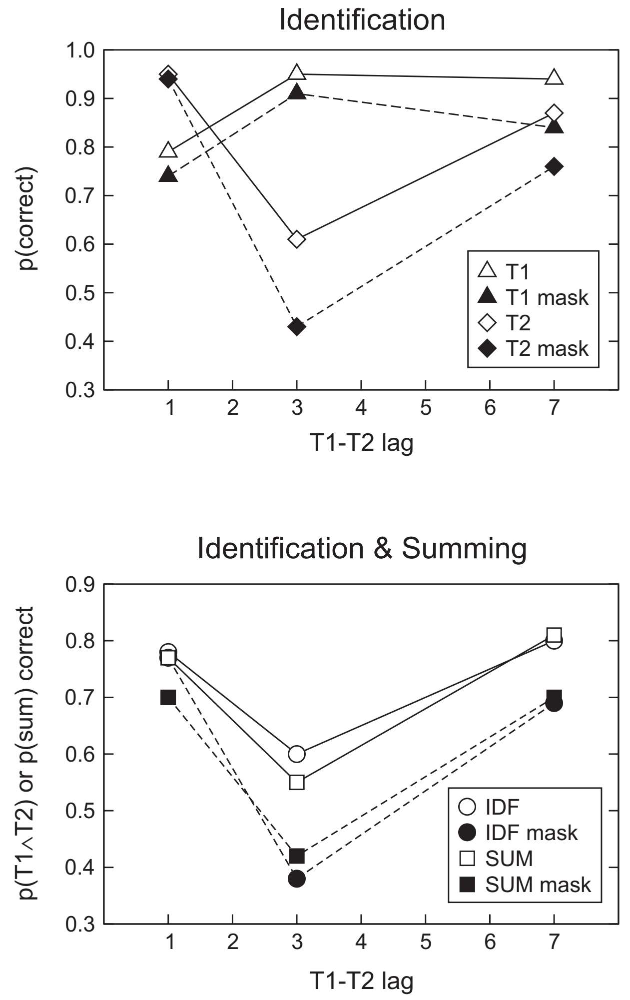

Figure 5. Results in the 2-digit condition of Experiment 4. Top: Mean proportions of correct responses in the identification task. The mean proportion of correct responses to T2 is calculated on the basis of trials in which T1 was identified correctly. Bottom: Mean proportion of correct responses in the identification and digit-sum tasks, calculated on the basis of trials in which both T1 and T2 were correctly identified and trials in which a correct sum was emitted. IDF = identification task; SUM: digit-sum task.

marked effect of lag, $F(2, 34) = 45.4$, $MSE = 0.040080$, $p < .001$, with an evident reduction of the proportion of correct responses to T2 at Lag 3 compared to that at the other lags (see Figure 5, top panel). The difference between the proportion of correct responses to T2 at Lag 1 and the proportion of correct responses to T2 at Lag 3 was indeed significant, $F(1, 17) = 60.1$, $MSE = 0.054235$, $p < .001$. The difference between the proportion of correct responses to T2 at Lag 3 and the proportion of correct responses to T2 at Lag 7 was also significant, $F(1, 17) = 49.7$, $MSE = 0.041448$, $p < .001$. The proportion of correct responses to T2 was lower when the mask was present relative to when the mask was absent, $F(1, 17) = 15.9$, $MSE = 0.006233$, $p < .001$, with the masking effect varying across lags, as indicated by a significant Mask × Lag interaction, $F(2, 34) = 10.9$, $MSE = 0.009221$, $p < 001$. We address the apparent discrepancy between the present outcome and that of Experiment 3 in the *Discussion* section.

In the identification task, the trend for the masking effects was that of being substantially reduced at Lag 1 compared with the masking effects at other lags. This impression, brought about by visual inspection of the top panel of Figure 5, found statistical support in a separate analysis in which the data at Lag 1 were temporarily excluded from consideration. In the analysis, the interaction between mask and lag was no longer significant ($F < 1$).

An equivalent pattern of results emerged when trials associated with an incorrect response to T1 were included in the data set. There was a main effect of lag, $F(2, 34) = 49.0$, $\mathrm{MSE} = 0.034085$, $p < .001$, again with a U-shaped pattern of mean proportions of correct responses to T2 across lags. The difference between the proportion of correct responses to T2 at Lag 1 and the proportion of correct responses to T2 at Lag 3 was in fact significant, $F(1, 17) = 69.4$, $MSE = 0.044380$, $p < .001$. The difference between the proportion of correct responses to T2 at Lag 3 and the proportion of correct responses to T2 at Lag 7 was also significant, $F(1, 17) = 44.5$, $MSE = 0.039266$, $p < .001$. The mask factor produced significant effects, $F(1, 17) = 26.6$, $MSE = 0.005810$, $p < .001$. The Mask × Lag interaction was also significant, $F(1, 17) = 12.2$, $MSE = 0.009522$, $p < .001$. Variations of the masking effects across lags with the unconditional trials were analogous to those observed in the context of the conditional trials—that is, the masking effects were basically absent at Lag 1 compared with masking effects at the other lags. Indeed, as before, when the data at Lag 1 were excluded from consideration, the interaction between mask and lag was no longer significant ($F < 1$).

The proportion of trials in which T1 and T2 were both identified correctly in the identification task and the proportion of trials in which subjects responded correctly in the digit-sum task (see Figure 5, bottom panel) were submitted to an ANOVA that revealed a main effect of lag, $F(2, 34) = 24.6$, $MSE = 0.078186$, $p < .001$, and a main effect of mask, $F(1, 17) = 16.8$, $MSE = 0.021813$, $p < .001$. The Lag × Mask interaction was only marginally significant, $F(2, 34) = 3.1$, $MSE = 0.027408$, $p < .07$. No other factor or interaction reached the significance level in this analysis (all Fs < 1).

Discussion

In contrast with the results of the previous three experiments, Lag-1 sparing was observed in a context in which two sequential digits had to be summed rather than counted. With similar output requirements as in the counting task (a single count), the digit-sum task (a single sum) produced a virtually identical pattern of overall accuracy across lags as found in the identification task. The results suggest that Lag-1 sparing was not caused by differential output requirements across the identification task and counting task in previous experiments but, rather, was due to differences at the time of encoding. The results are discussed in more detail in the General Discussion.

In Experiment 3, the masking manipulation had effects that were additive with lag for both tasks. In the present experiment, we observed an interaction in which the difference between the not-masked and masked conditions was reduced at Lag 1 relative to what was observed at longer lags. This result, however, appears to be substantially compromised by the likely possibility of a ceiling effect in accuracy results for T2 at Lag 1 in Experiment 4 (as can be seen in the top panel of Figure 5). When performance was lower and not near ceiling, as in Experiment 3, the interaction was not observed. For this reason, and because we did not observe a modulation of Lag-1 sparing by the mask in the digit-sum task, we would interpret only with extreme caution the apparent interaction between masking and lag in the identification task as support for the contribution of task difficulty in the causes of the Lag-1 sparing effect.

Experiment 5

Experiment 5 was designed to test whether the presence and absence of Lag-1 sparing was caused by general processing differences associated with the two tasks (identification vs. counting). In Experiment 5, subjects were asked to count the digits of a given parity subclass. That is, half of the subjects counted the occurrences of even digits, and the other half counted the occurrences of odd digits. As in all other previous experiments, subjects were also required to identify the digits. Our choice to restrict the objects of the counting task to a subclass of digits was motivated by the following logic. Our hypothesis is that Lag-1 sparing is modulated by the need to process targets up to the level of individual character identities. This is required for the identification task but not for the general counting task. It is required for counting just odd or just even digits, however, because people do not have a highly learned preexisting category of just odd or just even digits. The consequent prediction was that if it was the counting task per se that played a crucial role in determining the absence of Lag-1 sparing in Experiments 1–3, then Lag-1 sparing should also be absent in Experiment 5, because counting was still explicitly required in the present context. If it was, instead, the type of mental representation created to perform the counting task that was crucial for observing Lag-1 sparing with sequential digits, the prediction was radically different: We should observe Lag-1 sparing in Experiment 5 insofar as counting digits of a given subclass was likely to rely more heavily on information about the digit identities than the counting task carried out on any digit.

Method

The stimuli were the same as those used in Experiment 1. In the identification task, subjects typed the identity of target digits using the numeric keypad of a computer keyboard. In the counting task, half of the subjects were instructed to count only the even digits, and the other half were instructed to count only the odd digits. Digit parity and digit number were fully crossed within each block of experimental trials.

Results

The proportions of correct responses in 0-digit, 1-digit, and 2-digit trials were analyzed separately using an ANOVA in which lag (in 1-digit and 2-digit trials only) and task were treated as within-subject factors. In the identification task, the order in which subjects indicated the identity of T1 and T2 in 2-letter trials was not taken into account.

0-digit condition. The proportions of correct responses were .89 in the identification task and .88 in the counting task. These proportions did not differ significantly ($F < 1$). Errors in both tasks were entirely due to false alarms in which subjects reported seeing one digit, with no false alarms due to the incorrect report of two digits.

1-digit condition. The proportions of correct responses were .86 in the identification task and .85 in the counting task. No factor or interaction reached statistical significance (all Fs < 1) in this condition.

2-digit condition. Consider first the identification task (see Figure 6, top panel). The proportion of correct responses to T1 was affected by the lag manipulation, with a lower proportion of correct responses to T1 at Lag 1 compared with that at the other lags, $F(2, 34) = 40.1$, $MSE = 0.004728$, $p < .001$. When the data at Lag 1 were discarded from the analysis, the proportion of correct

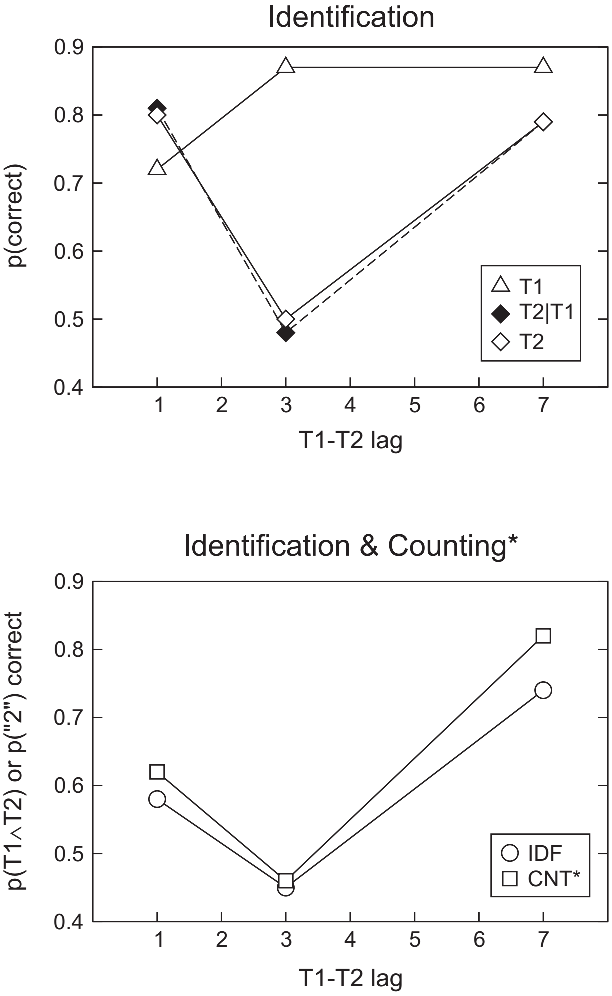

Figure 6. Results in the 2-digit condition of Experiment 5. Top: Mean proportions of correct responses in the identification task. Bottom: Mean proportions of correct responses in the identification and counting tasks, calculated on the basis of trials in which both T1 and T2 were correctly identified and trials in which a correct *2* response was emitted. The asterisk marks the difference of the counting task in Experiment 5 (which was contingent on digit parity) and the counting task of Experiments 1, 3, and 4, in which digits had to be counted independent of their parity class. IDF: identification task; CNT: counting task.

responses to T1 at Lag 3 and at Lag 7 did not differ significantly ($F < 1$).

When only trials in which T1 was identified correctly were taken into account, the analysis indicated a marked effect of lag, $F(2, 34) = 26.1$, $MSE = 0.022686$, $p < .001$, reflected in the classic U-shaped function of the AB effect (see Figure 6, top panel). The difference between the proportion of correct responses to T2 at Lag 1 and the proportion of correct responses to T2 at Lag 3 was significant, $F(1, 17) = 47.6$, $MSE = 0.020328$, $p < .001$. The difference between the proportion of correct responses to T2 at Lag 3 and the proportion of correct responses to T2 at Lag 7 was also significant, $F(1, 17) = 28.8$, $MSE = 0.027951$, $p < .001$.

An analogous analysis was carried out on the proportion of correct responses to T2 independent of whether T1 was correctly identified. The results were virtually identical to those produced by scoring T2 accuracy conditionalized on a correct response to T1, with a strong effect of lag, $F(2, 34) = 26.5$, $MSE = 0.017922$, $p < .001$, and a U-shaped distribution of the mean proportion of correct responses to T2 across lags (see Figure 6, top panel). The difference between the proportion of correct responses to T2 at Lag 1 and the proportion of correct responses to T2 at Lag 3 was significant, $F(1, 17) = 52.5$, $MSE = 0.014596$, $p < .001$. The difference between the proportion of correct responses to T2 at Lag 3 and the proportion of correct responses to T2 at Lag 7 was significant, $F(1, 17) = 30.6$, $MSE = 0.021344$, $p < .001$.

For the counting task, the bottom panel of Figure 6 shows the proportion of trials in which subjects responded *2* correctly when two digits of the to-be-monitored parity class were presented. These data were submitted to an ANOVA, which revealed a significant effect of lag, $F(2, 34) = 11.5$, $MSE = 0.053290$, $p < .001$. A direct comparison of overall accuracy in the identification task and accuracy in the counting task was carried out by considering the proportion of trials in which T1 and T2 were both identified correctly in the identification task and trials in which subjects responded *2* correctly in the counting task (see Figure 6, bottom panel). An ANOVA on these data revealed only a main effect of lag, $F(2, 34) = 18.1$, $MSE = 0.048724$, $p < .001$. The effect of task was nonsignificant, $F(1, 17) = 1.7$, $p > .2$, as was the Lag × Task interaction, $F(1, 17) = 1.2$, $p > .3$. When the data from Lag 7 were temporarily excluded from consideration, the effect of lag was significant, $F(1, 17) = 7.0$, $MSE = 0.047443$, $p < .02$; the effects of task and the Task × Lag interaction were not significant ($F\text{s} < 1$).

Discussion

Experiment 5 was designed to deconfound the type of mental representation generated under RSVP conditions and the type of task subjects were required to carry out with the targets once selected from the RSVP sequences. Subjects were instructed to count only digits of a given parity class (only odd or only even), on the assumption that this would have induced the processing of target digits not as simple discontinuities in alphanumeric class (as was hypothesized to occur in Experiments 1–3) but also at the level of individual identities. The results of Experiment 5 were clear-cut. In striking contrast with the results from the counting task in Experiments 1–3, the AB function in the counting task in Experiment 5 was characterized by the clear presence of Lag-1 sparing. In our perspective, this makes it extremely unlikely that the counting task per se played any crucial role in suppressing the Lag-1 sparing effect in the counting task of Experiments 1–3. Rather, it must have been the nature of the processing required after potential targets were selected from the RSVP streams that determined whether Lag-1 sparing for T2 occurred or did not occur.

General Discussion

Lag-1 sparing, the surprisingly good performance for T2 when T2 immediately follows T1 in some versions of the AB paradigm, has been one of the most interesting and counterintuitive findings in the AB literature (Visser, Bischof, & Di Lollo, 1999). The present study has produced new findings concerning the nature of Lag-1 sparing that are largely unexpected—based on extant accounts of the AB, in general, and of Lag-1 sparing, in particular.

The targets in Experiment 1 were digits presented among letters. In different trials, 0, 1, or 2 digits were presented, and the task was to identify them and report their identity at the end of the trial without speed pressure or to count how many digits had been presented and to report this count at the end of the trial, also without speed pressure. A clear Lag-1 sparing effect was observed in the identification task in the combined probability of reporting both T1 and T2 correctly. In contrast, there was no Lag-1 sparing in the counting task (for trials with 2 digits), as shown in the bottom panel of Figure 1.

We were concerned that the absence of Lag-1 sparing found in Experiment 1 in the counting task might have resulted from interference between the need to count digits and the meaning of the counted objects. Experiment 2 ruled out this possibility by requiring observers to count letters presented among digits. Again, Lag-1 sparing was found in the identification task but not in the counting task (see Figure 2, bottom panel).

Experiment 3 tested the hypothesis that Lag-1 sparing with identification but not with counting could be in some way correlated with the overall difficulty of the two tasks (possibly easier in the counting task than in the identification task). In Experiment 3, we lowered overall accuracy, thereby increasing overall task difficulty, by presenting the RSVP sequences through a cloud of random dots (a camouflage mask) in half of the trials. As expected, accuracy was lower when the stimuli (T1, T2, and the distractors) were degraded by the camouflage mask. However, the masking effect was additive with lag and did not modulate the size of the AB effect or the size of the Lag-1 sparing effect in either task. In addition to corroborating the analysis of Ouimet and Jolicœur (in press), these results are important because they rule out any explanation of the modulation of the Lag-1 sparing effect by appeal to differences in overall task difficulty across the counting and identification tasks.

Experiment 4 was designed to test whether the difference in output requirements between the identification task and the counting task may have played any modulatory role on the Lag-1 sparing effect. In Experiment 4, the counting task was replaced with a digit-sum task. Subjects also performed the identification task in different trial blocks. Clear evidence of Lag-1 sparing effect was observed in the identification task as well as in the digit-sum task. These findings rule out output factors (e.g., memory load for two response codes in identification vs. one response code for counting and summing) among the possible modulatory causes of the Lag-1 sparing effect. However, the results are consistent with the view that computing the sum of two digits requires knowing precisely which two digits had been presented. That is, the digit-sum task requires the individuation of the two digits, just as in the identification task.

In Experiment 5, we tested more directly the nature of the codes generated for each target and the interplay between the mechanisms hypothesized to generate such codes with the attentional filter responsible for selecting T1 and T2 from the distractors in a given RSVP stream. Instead of performing a general counting operation based on an alphanumeric distinction between targets and distractors, the task was to count digits of only a given parity subclass (i.e., count only odd or only even digits). In other blocks of trials, subjects also performed the digit-identification task. Lag-1 sparing was found in both tasks. Thus, counting any digit (e.g., Experiment 1) abolished Lag-1 sparing, but counting only odd digits or only even digits restored Lag-1 sparing. Clearly, it was not the difference in task (identification vs. counting) that was most critical in controlling whether Lag-1 sparing was present or absent. Rather, it was the nature of the representations of the targets that appears to be critical. Counting just odd or just even digits, we believe, required the generation of individual digit identities, just as in the identification task. Lag-1 sparing was found consistently when individual character identities were required by the task, and it was abolished when the task could be performed on the basis of less specific category-level information.

Structural Limitation and Temporary Loss of Control

The present results represent a challenge for both theoretical frameworks examined in the introduction—namely, those based on a two-stage architecture of processing targets under RSVP conditions, such as the central interference theory of Jolicœur and Dell'Acqua (1998), and the TLC account of Di Lollo et al. (2005). Recently published results (i.e., Kawahara et al., 2005) have already highlighted the difficulty of providing a unified account of all aspects of the AB paradigm, including the Lag-1 sparing effect, the likely related Lag-*N* sparing effect (Di Lollo et al., 2005; Olivers et al., in press), and results showing that the time taken to process T1 at central stages modulates the AB (e.g., Crebolder, Jolicœur, & McIlwaine, 2002; Jolicœur, 1999b; Ouimet & Jolicœur, in press). The present findings follow along the same lines by showing that the cited AB models and interpretations lack a set of valid principles to incorporate modulations of Lag-1 sparing effect that are due to the likely different nature of the mental operations subserving counting and identifying (i.e., the tasks used in the present series of designs).

The TLC account puts strong emphasis on the notion of endogenous and exogenous control over the selection criteria implemented at early stages of processing used to separate targets from distractors. Both the occurrence of Lag-1 sparing and the absence of Lag-1 sparing are explained by the principle that Lag-1 sparing occurs only when T2 fits the input configuration set up for T1. Lag-1 sparing is found when the two targets belong to the same (alphanumeric) category but not when they differ from one another in two or more dimensions that are important for target selection (Di Lollo et al., 2005; Visser, Bischof, & Di Lollo, 1999). Presenting a distractor following T1, in this view, causes an exogenous reconfiguration of selection filters that makes the processing of T2 less efficient than when T2 immediately follows T1. When T2 is presented immediately after T1, the same input filters that were applied to T1 can be applied to T2, and this is thought to result in very efficient processing of T2 and in Lag-1 sparing (relative to performance when one intervening distractor is present between T1 and T2). The present results cannot be explained adequately by the TLC hypothesis, because Lag-1 sparing was present in the identification task and absent in the counting tasks when the selection rules required for T1 and T2 were identical. The TLC hypothesis predicts that Lag-1 sparing should have been observed in both tasks, given that nothing in the presentation sequence would cause an exogenous or endogenous reconfiguration of input filters. It is obvious that the mere similarity of processing operations used on T1 and T2 and/or the state of input filters at the time of the presentation of T1 and T2 are insufficient to explain the present results. Clearly, what happens after selection has a critical role to play in Lag-1 sparing, and exactly how this is to be understood in the context of the notion of input filters is, as of yet, not clear. The absence of Lag-1 sparing in the counting task thus appears to be a troublesome exception for the model proposed by Di Lollo et al. (2005).

On the other hand, perhaps a more elaborated version of accounts based on the TLC type of logic cannot be disregarded entirely. Experiments 1–3, for instance, consistently showed that the absence of Lag-1 sparing was accompanied by better performance at longer lags in the counting condition compared with the identification condition, regardless of whether masking by camouflage was used to data-limit the flow of information coming from the RSVP stream. This was reflected in a significant effect of task across these experiments in which the counting task was globally easier than the identification task, when counting did not involve items of a specific parity class (as it did in Experiment 5). This apparent difference in overall task difficulty suggests the possible applicability of an account of Lag-1 sparing proposed by Olivers and Nieuwenhuis (2005; see also Olivers et al., in press). In this account, Lag-1 sparing and the AB are a consequence of observers overinvesting resources in T1, which leads to the spilling of resources onto the next item in the stream. This overshoot of resources not only accounts for Lag-1 sparing, it also entails that task difficulty may affect Lag-1 sparing. More specifically, it might be that observers allocated fewer resources to T1 in the easier counting task than in the more difficult identification task. Control for target selection was thus relaxed in the counting task, with the consequent reduction of the chances of resources spilling over onto the item next to T1, causing the absence of Lag-1 sparing. The proposal that Lag-1 sparing may be sensitive to effort and/or perceived difficulty on the part of the observers could seemingly provide an alternative account of the results, even though it might be suboptimal to explain why Lag-1 sparing was reinstated when observers were required to count digits on the basis of parity class (Experiment 5). Other results, which must be mentioned for the sake of completeness, are admittedly handled more naturally by the TLC account compared with other types of AB accounts, including the central interference theory. Consider, for instance, the results of Kawahara et al. (in press), Olivers et al. (in press), and Nieuwenstein, Chun, van der Lubbe, and Hooge (2005) showing that the report of a second or third target presented during the AB is surprisingly good when the target is precued by either another target or by a distractor matching the attentional set used to filter targets from distractors. These findings are clearly at odds with the notion that following the encoding of a batch, encoding of further information suffers from a refractory phase that lasts until the batch is transferred to VSTM. Nieuwenstein and Potter (2006), in particular, showed that observers can report up to four items from an RSVP sequence of six items without any sign of an AB.

However, the present results make it mandatory to consider the specific nature of the postselection processing of targets required by various tasks to provide a complete understanding of the AB phenomenon both in the present study and in previous studies (Chun & Potter, 1995; Crebolder et al., 2002; Dell'Acqua & Jolicœur, 2000; Dell'Acqua, Jolicœur, Pesciarelli, Job, & Palomba, 2003; Dell'Acqua, Sessa, Jolicœur, & Robitaille, 2006; Dell'Acqua, Turatto, & Jolicœur, 2001; Jolicœur, 1998, 1999a, 1999b, 1999c; Jolicœur & Dell'Acqua, 2000; Jolicœur, Dell'Acqua, & Crebolder, 2000; Jolicœur, Dell'Acqua, & Crebolder, 2001; Jolicœur, Sessa, Dell'Acqua, & Robitaille, 2006a, 2006b; Vogel & Luck, 2003; Vogel, Luck, & Shapiro, 1998). The difference in the postselection processing of targets may explain why Lag-1 sparing was observed in the identification task but not in the general counting task. According to the central interference theory, short-term consolidation takes a considerable time, and the duration of consolidation sometimes depends on the amount of to-be-consolidated information (Jolicœur & Dell'Acqua, 1998; but see Vogel, Woodman, & Luck, 2006, for a different proposal). If T1 and T2 are presented at very short SOA (e.g., at Lag 1), there will be a high probability that T1 and T2 could enter the same short-term consolidation batch and, thus, be consolidated simultaneously. This would lead to the occurrence of Lag-1 sparing in standard identification tasks. Consider next the case of the absence of Lag-1 sparing in the counting task of Experiments 1–3. In these experiments, the selection cue for the targets was the same for T1 and T2 and presumably required achieving a classification of each stimulus to the level of the character class (digit vs. letter). Following this classification, when finding a target, the observer would retrieve the current state of a mental counter and update the counter value. Presumably, the value of the target count is maintained in a store in short-term memory, and it is likely that each of the steps involving operations in short-term memory is capacity demanding (Logie & Baddeley, 1987). Akyürek, Hommel, and Jolicœur (in press), for example, demonstrated that scanning the contents of VSTM is an operation that increases the size of the AB. The present results in the counting tasks provide further converging evidence that accessing and updating a mental count is capacity demanding and may cause an AB. For letters and digits, merely categorizing T1 as a target is likely to take less time than deciding exactly which character had been presented (Brawn & Snowden, 2000; Hick, 1952; Jolicœur, Gluck, & Kosslyn, 1984; Kawahara et al., 2001). In this vein, one may attribute the modulations of Lag-1 sparing to the notion that postselection capacity-demanding operations would be initiated sooner in the counting task than in the identification task. The consequence would be that the probability of T2 to be included in the T1 consolidation batch would be higher when consolidation initiates later (with identification) than when consolidation is more prompt (with classification).

The AB With Identification and Categorization

We hypothesized that counting in the present designs would depend largely on an initial categorization of each character as either a letter or a digit, followed by further processing associated with updating a mental counter. Despite the apparent simplicity of these operations, performance in the counting task was lower than in the identification task at Lag 1, and the counting task also had a higher false alarm rate in 1-digit (or 1-letter) trials. At longer lags, however, performance was higher in the counting task than in the identification task. What these results show is that the observed performance likely reflects a complex interplay between mechanisms leading to the categorization and selection of items in the RSVP streams and the further processing required to perform the task associated with selected stimuli.

These results lend themselves to a direct comparison with results obtained in different empirical contexts. Grill-Spector and Kanwisher (2005) compared subjects' ability to detect single objects in grayscale photographs with their ability to categorize the objects and identify them for a delayed report. They also manipulated the exposure duration of the photographs using values that ranged from a few tenths of a millisecond to 200 ms. In three experiments, the results were unequivocal. Whether the level of accuracy following the presentation of masked objects (Experiments 1 and 2) or the reaction times to the same unmasked objects (Experiment 3) were monitored, performance in identification was always worse than both categorization and detection at all levels of exposure duration of the photographs. The authors concluded that detection and categorization are similar under many aspects and both different from identification, which likely engages either different functional and neural mechanisms or the same set of mechanisms for a substantially longer time (e.g., Grill-Spector, 2003).

Results of Evans and Treisman (2005) also suggest that something qualitatively different distinguishes the categorization of objects into a small number of categories from identification. They showed RSVP sequences of natural scenes including objects of different semantic categories to their subjects. Two objects of one or two prespecified categories were embedded in each sequence, and subjects had to make an immediate buttonpress on determining that an object belonged to a target category (categorization), followed by a delayed identification response made by typing the object name with no speed pressure at the end of the trial. The manipulation of interest was the temporal interval separating the first from the second object in each sequence. It is interesting to note that whereas a robust AB was found for the identification of two successive objects, no AB was found for their categorization, implying that the categorization of an object as a member of a prespecified category was "attention free" (for a similar conclusion, see also Bonnel, Stein, & Bertucci, 1992).

On the basis of these empirical premises, one may wonder why we found an AB with counting at all in the present experiments. If counting task was based on categorization, and if categorization is attention free as suggested by Evans and Treisman (2005), then we should have observed either no AB or a much reduced AB compared with the identification task. We are inclined to attribute the discrepancy between the present results and those of Evans and Treisman (2005) to factors that are not related to counting per se but that owe instead to something peculiar in the visual structure of letters and digits that made them different from the stimuli used in other investigations involving categorization. Levin, Takarae, Miner, and Keil (2001) have shown that searching for an animal among distracting artifacts (or vice versa) was as efficient when the search target was displayed tachistoscopically in a canonical format as when the target was cut in parts and the parts were randomly scattered around fixation. Analogous examples involve the use of faces as stimuli. It has been shown repeatedly that categorizing an inverted face as a face is an immediate operation, whereas identifying an inverted face is much more difficult (e.g., Rousselet, Mace, & Fabre-Thorpe, 2003). These results suggest that categorization (and detection) may be attention free only when it can be performed on the basis of rudimentary—and possibly unique—features. Very efficient categorization may only be possible when the spatial relations between features and/or parts of an object are not necessary to distinguish objects of different categories. It is possible that the real-world objects used by Evans and Treisman (2005), and by Grill-Spector and Kanwisher (2005) could be categorized on the basis of simple features (see also Kawahara et al., 2001) or individual parts.

The case appears to be different for the alphanumeric characters used in the present context. Letters and digits are composed by combining very similar low-level shape features. Although one can argue that the features are not entirely identical, and that extensive learning can allow subjects to use these differences, we believe that with the present stimuli and levels of practice, that letters and digits were categorized primarily via an initial activation of the identity of each character. The visual similarity between letters and digits has recently been the object of empirical scrutiny in a study carried out by Maki, Bussard, Lopez, and Digby (2003). These authors scored letters, digits, mathematical symbols, and false font characters on two conceptual dimensions (familiarity, meaningfulness), as well as on a number of visual dimensions (feature density, feature dissimilarity, pixel density, pixel dissimilarity), and showed that letters and digits were similar under all the aspects scored, and both were dissimilar from symbols (on feature dissimilarity, pixel density, and dissimilarity) and false fonts (on familiarity and meaningfulness). It was on the basis of this type of analysis that we supposed that the initial categorization of characters as either letter or digit would require the activation of a representation corresponding to the identity of the character, and that following this activation of the character "type," the category membership of the stimulus could be determined. Following this categorization, either a mental updating of a counter (in the counting task) or something akin to the individuation of a "token" for the identification task (Kanwisher, 1987), which we referred to as the individuation of a particular character identity, would precede the short-term consolidation of that individuated identity (in the identification task).

Absence of Lag-1 Sparing Due to Repetition Blindness?

In foregoing sections, we have alluded to the notion that a key difference between the tasks that produced Lag-1 sparing and those that abolished Lag-1 sparing was the need to associate specific character identities with the targets. Kanwisher (1987) referred to this operation as *tokenization* or *token instantiation* (see also Chun, 1997). Token instantiation can be said to be necessary when instances of a certain stimulus category have to be consolidated into VSTM, usually for the explicit report of the identity of such instances within seconds after their presentation. Token instantiation, in this optic, corresponds to binding information about the semantic identity of a stimulus with information about the spatiotemporal characteristics of the context in which the stimulus was physically displayed. Phenomena like repetition blindness suggest that, whereas information about the stimulus category are promptly and automatically activated on presentation of a stimulus with virtually no impediment, instantiating a token corresponding with the visual information may result in significant interference if two identical instances of a stimulus category are presented in close temporal succession.

AB effects and repetition blindness effects have been shown to be functionally dissociable in tasks requiring the identification of target stimuli. Chun (1997) presented target letters embedded in RSVP streams of different types of distractors. On a proportion of trials, the letters could be different, whereas in other trials the letters were the same. The critical result was produced by varying the nature of the distractors composing the RSVP sequence: When the distractors were visually and categorically dissimilar from the target letters (i.e., symbols such as =, %, or ?), the AB effect disappeared when the targets were distinct letters, but a clear repetition blindness effect was still observed at the shortest lags when the targets were identical letters. The repetition blindness effect, specifically, brought about a linear decrease in report accuracy as lag was decreased.

Could the generic counting task induce a form of repetition blindness because of the repetition of a stimulus category? One might imagine that such an effect could come about because the general counting task might shift the functionally relevant level of categorization from specific digit identities to the category level (digits vs. letters). Perhaps repetition blindness would appear as a function of the repetition of the functionally relevant level of representation in the task, in this case stimulus alphanumeric class. If so, perhaps the absence of Lag-1 sparing in the general counting task would be due to the repetition of this task-defined functionally relevant level of processing. Note that this level of processing would be what many experts would characterize as semantic in nature. The hypothesis, however, of repetition blindness mediated by semantic processing of repeated stimuli is not uncontroversial.

One indication that repetition blindness does not seem to reflect the repetition of categorical information comes from a repetition blindness study conducted by Kanwisher and Potter (1990) using words as stimuli. To test whether repetition blindness could affect information about words' meaning, and not simply their orthographic representations, these authors presented either identical words or different words with the same meaning (i.e., synonyms) embedded in apparently well-structured sentences. These authors found no evidence of repetition blindness for word meanings, whereas (not surprisingly) a robust repetition blindness effect was found for identical words. On the basis of these results, Kanwisher and Potter (1990) concluded that repetition blindness was unlikely to exert effects beyond the lexical (repeated) codes. However, one could argue that Kanwisher and Potter's results do not test the hypothesis that we are entertaining here. In Kanwisher and Potter's experiment, the task was not to categorize the words but, rather, to report individual words. This would mean that the functionally relevant level of representation in the task was not the category level (or the level at which meaning repeated) but, rather, at the level of individual lexical (or phonological; see Bavelier & Potter, 1992) entry, which could explain why they did not observe category-level repetition blindness.

A similar objection applies to a study that has instead reported results that may be raised to support the opposite argument. MacKay and Miller (1994) had proficient bilingual subjects read sentences in which target words in English and Spanish were preceded by within- and across-language identical, semantically related, or different pretarget words. The results were clear in indicating that a semantic version of repetition blindness for semantically similar words occurred even across languages, suggesting that a semantic level of analysis of the word stimuli was probably involved in the effect found. Further work will be required to clarify the possible role of category-level repetition blindness in our results.

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