Effects of memory load on visual search

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It remains unclear how memory load affects attentional processes in visual search (VS). No effects, as well as beneficial and detrimental effects of memory load, have been found in this type of task. The main goal of the present research was to explore whether memory load has a modulating effect on VS by means of a different attentional set induced by the order of trials (mixed vs. blocked) and by the time presentation of visual display (long vs. short). In Experiment 1, we randomized the order of type of trial (5, 10 and 15 items presented in the display) while it remained constant (10 items) in Experiments 2A and 2B. In the later experiments, we also changed time presentation of visual display (3000 vs. 1300 ms, respectively). Results showed no differential effects of memory load in Experiments 1 and 2A, but they showed up in Experiment 2B: RTs were longer in the attentional task for trials under high memory load conditions. Although our hypothesis of the attentional set is supported by the results, other theoretical implications are also worth discussing in order to better understand how memory load may modulate attentional processes in VS.

Efectos de la carga de memoria en la búsqueda visual. No está claro el efecto que la carga de memoria tiene sobre la atención en la Búsqueda Visual (BV): se ha encontrado tanto ausencia como efectos negativos y positivos de la carga de memoria en BV. El principal objetivo del presente trabajo fue explorar si la carga de memoria puede modular una tarea de BV por medio de la influencia del «estado o set atencional» de los participantes, generado a través del orden (aleatorio versus bloqueado) y el tiempo (largo versus corto) de presentación de los ensayos. En el experimento 1 se aleatorizó el orden de presentación (5, 10 y 15 estímulos), mientras que para los experimentos 2A y 2B permaneció constante (10 estímulos). En estos últimos cambiamos el tiempo de presentación (3000 versus 1300, respectivamente). Los resultados mostraron ausencia de efectos de la carga de memoria en los experimentos 1 y 2A, mientras que sí se encontraron en el experimento 2B: los TRs en la tarea de BV fueron significativamente mayores con carga alta de memoria; apoyando nuestra hipótesis sobre el «set atencional». Se discuten también otras posibles implicaciones teóricas para comprender mejor cómo la carga de memoria puede modular los procesos atencionales involucrados en BV.

The relationship between attention and working memory is a main topic in cognitive psychology. Many recent publications have shown the importance of studying those relations for a better understanding of how we select, maintain and process information. There has been a wide interest in the study of the relationship between them in dual-task environments, where two tasks must be performed concurrently. In dual-task paradigms participants must retain given information in working memory (figures, letters…) while performing an attentional task (Stroop-like, flanker-task, Visual Search…). The comparison of performance in the attentional task between the not loaded or «low loaded» and the highly loaded condition has been used to study the relationship between working memory and selective attention. However, this diversity of attentional paradigms has produced contradictory results, probably because different attentional processes are involved.

In situations where an exogenous component of attention is involved (attentional capture tasks where behavioral, eye movements recordings and early ERPs have been measured) the results show a wide agreement: items in working memory can lead to a selection advantage for related relevant material over irrelevant material in the attentional task (Downing, 2000; Jha, 2002; Roberts, Hager, & Heron, 1994; Soto, Heinke, Humphreys, & Blanco, 2005).

Likewise, in tasks typically used in the context of endogenous attention (such as Stroop-like, flankers, or negative priming tasks) there is strong evidence showing that as memory load increases, attentional resources are diminished and selective attention to relevant material is impaired (Conway, Tuholski, Shisler, & Engle, 1999; Hester & Garavan, 2005; Kiefer, Ahlegian, & Spitzer, 2005; Long & Prat, 2002). To the extent that attention and working memory share cognitive resources, increasing the load of either process should impair the functioning of the other (Cowan, 1995; Engle, Kane, & Tuholski, 1999; Lavie, Hirst, De Fockert, & Viding, 2004). Thus, neuroimaging studies have shown that high memory load conditions produce both more interference effects in visual processing and more activity in the visual cortex related with distractor information; the to-be-ignored visual background

stimuli are processed more extensively under high memory load conditions (De Fockert, Rees, Frith, & Lavie, 2001; Yi, Woodman, Widders, Marois, & Chun, 2004). However, there are a few studies that failed to find that relationship (eg., Stins, Vosse, Boomsma, & De Geus, 2004), and more interestingly there has also been found a reduction in the Stroop interference using verbal and spatial information under high memory load conditions. This has been shown both for behavioural measures (Kim, Kim, & Chun, 2005; Park, Kim, & Chun, 2007) as well as in brain activity (Kim, Min, Kim, & Won, 2006). Furthermore, far from a casual effect, recent research has also found similar facilitation effects in attentional tasks under memory load conditions in different situations (Gil-Gómez de Liaño & Botella, in press; SanMiguel, Corral, & Escera, 2008; Smilek, Enns, Eastwood, & De Geus, 2006a).

On the other hand, in Visual Search (VS) tasks, where both exogenous and endogenous attention may take place (Wolfe, 1994), there is also evidence of the relationship between visual working memory and attention. Working memory can play an important role in search: as memory load increases, attention to relevant material is impaired (Lavie & De Fockert, 2006). Nevertheless, a few experiments have failed to find clear effects of memory load (Logan, 1978; Woodman, Vogel, & Luck, 2001). Even more, Smilek et al., (2006a) found that VS was accomplished more efficiently when performed with a concurrent memory task than when performed alone. They explained the results arguing that improved efficiency can result when reliance on slow executive control processes is replaced with reliance on more quick automatic processes for directing attention during the search.

Smilek et al.'s explanation is based on the idea that cognitive load may have an impact on our attentional set during the attentional task, mediated by a different cognitive strategy. Specifically, as the amount of executive control available during the search task is reduced by holding some information in working memory, the exogenous attentional system plays a more important role in performing the VS task. In fact, there is strong evidence that differences in the cognitive strategy may have an effect, improving or impairing performance in a given task; in certain situations a more exogenous driven strategy may result in higher efficiency (Bacon & Egeth, 1994; Jacoby & Brooks, 1984; Smilek, Dixon, & Merikle, 2006b; Smilek et al., 2006a).

In the present research we explore whether the impact of memory load in a VS task can be mediated by changes in the attentional set (expectancies or predispositions about the task that may modulate attentional processes). Thus, the main goal of present experiments is to investigate differences in memory load effects due to different attentional sets induced by the task. Specifically, we assess the effects of holding some information in working memory while performing a VS task where time of visual display presentation is manipulated as well as the number of items in the display (display size or set size) is mixed or blocked during the experiment. In one hand, in conditions where the display size changes for each trial randomly (mixed blocks) the observers experience higher uncertainty about the category of a forthcoming event than in pure blocks (where the set size is constant), resulting in costs on reaction time. Therefore, the attentional set may be different when trials are mixed or blocked in the attentional task (for a review see Los, 1996). On the other hand, we may induce a different attentional set by manipulation the time of presentation of the visual search display. Long presentations (about 3000 ms) are usually used to ensure a correct response in VS in order to

measure RTs in different experimental conditions. However, when presentation of visual display is shorter (e.g., 1300 ms) the task is more difficult and not only RTs may be measured but also correct responses may be appreciable to experimental conditions variations (because errors are more likely to occur). Therefore, long presentation may lead to an easier search task while short ones may lead to a more difficult search. As Smilek et al., (2006) suggested, when there is more time to respond the participant usually adopts a more relaxed strategy than when time to respond is shorter, affecting the attentional set in the visual search task.

In experiment 1, the conditions of display size in the search task were mixed within the blocks, as in most studies of VS. As it seems that the effects of memory load are more probably observed in a difficult VS task (Smilek et al., 2006a) we used a quite difficult attentional task by presenting the VS display in a short period of time (1300 ms). In experiments 2A and 2B we used the same search task, but the set size was blocked by using a constant number of items for each trial (10 items). Diverse exposure durations for the display differentiated Experiments 2A and 2B (3000 and 1300, respectively). In experiment 1, we expect to find no interaction between set size and memory load: as the mixed blocked trials in the attentional task generate a stronger «state of uncertainty», the memory load condition would only generate a more difficult situation, but no interaction effects are expected between the set size and the memory load factor. In fact, if memory load may lead to a more exogenous attentional set (Smilek et al., 2006a), the uncertainty of the mixing costs may lead to a more endogenous one because of the «uncertainty state», so both effects are expected to cancel each other, and therefore no interaction effects between the independent variables are expected. On the other hand, in experiment 2A the duration of the visual search display was increased, so the task was easier and the participants may «relax». We expect that the memory load manipulation would lead to a more exogenous attentional set, so no effects or even a more effective selection under the high memory load condition would take place in the VS task (as in Smilek et al., 2006a). On the contrary, in experiment 2B the exposure duration was shorter, what seems to lead to a more endogenous strategy because of the increment of the task difficulty, so the manipulation of memory load would affect the VS task performance under high memory load conditions by impairing attentional selection (Smilek et al., 2006a).

<center>EXPERIMENT 1</center>

<center>Method</center>

Participants

Twenty-four volunteer students of the Autónoma University of Madrid participated initially in the experiment. The final sample was composed by 18 women, with a mean age of 18.05 (range 17-19); six of the initial sample did not have enough correct responses to analyze the data (people with less than 30 correct trials in any experimental condition were removed from the analyses). All of them reported normal or normal-corrected vision.

Stimuli and materials

Six different words (in Spanish) were used for the VS: yellow, blue, white, black, red, and pink. They were randomly located in

a virtual circle centered at the fixation point. All of them were written in black and lower-case, except for the target, which was capitalized. The maximum size of the words was 0.57º × 3.90º.

We used trials of 5, 10 or 15 words in the display. The difficulty of the simultaneous working memory task was manipulated with two load conditions. In the low load condition the participants had to remember one digit during a trial, whereas in the high load condition they had to retain six digits. Memory conditions were blocked while the trials of the three set size conditions were randomized within the blocks.

Procedure

The participants had to make a response, as rapidly and accurately as possible, identifying the only word in capital letters in the display. This was done by pressing the corresponding digit-key, from the set 1, 2, 3, 8, 9, and 0 on the keyboard. Each key was associated with a different color-word (a preliminary training phase was used previously to insure fast and accurate selection of the appropriate key for each word). The VS display remained 1300 ms in the screen. Before the presentation of the words display, either one or six digits (depending on the memory load condition)

appeared in the centre of the screen (500 ms for the one-digit condition and 2000 ms for the six-digit condition). These were to be retained during each trial and reported at the end (no speeded response was demanded for the memory task). The procedure is summarized in Figure 1.

The experiment was composed of six blocks with 54 trials in each block where the three different conditions (number of items 5, 10 & 15) were randomized within blocks and counterbalanced for memory load conditions (ABABAB/BABABA). There were the same number of trials of each set size condition (18 trials) within each block.

Data analyses

The statistical analyses were done using the SPSS 15.0 computer package. Differences in the memory task were studied by descriptive statistics and T-tests for related samples. On the other hand, the relationship between memory load and set size variables was also studied by descriptive statistics and analyzed by a repeated measures ANOVA (2×3) both for hits and RTs. High and low memory load were the levels of the memory load factor while 5, 10 and 15 items in the display were the levels of the set size.
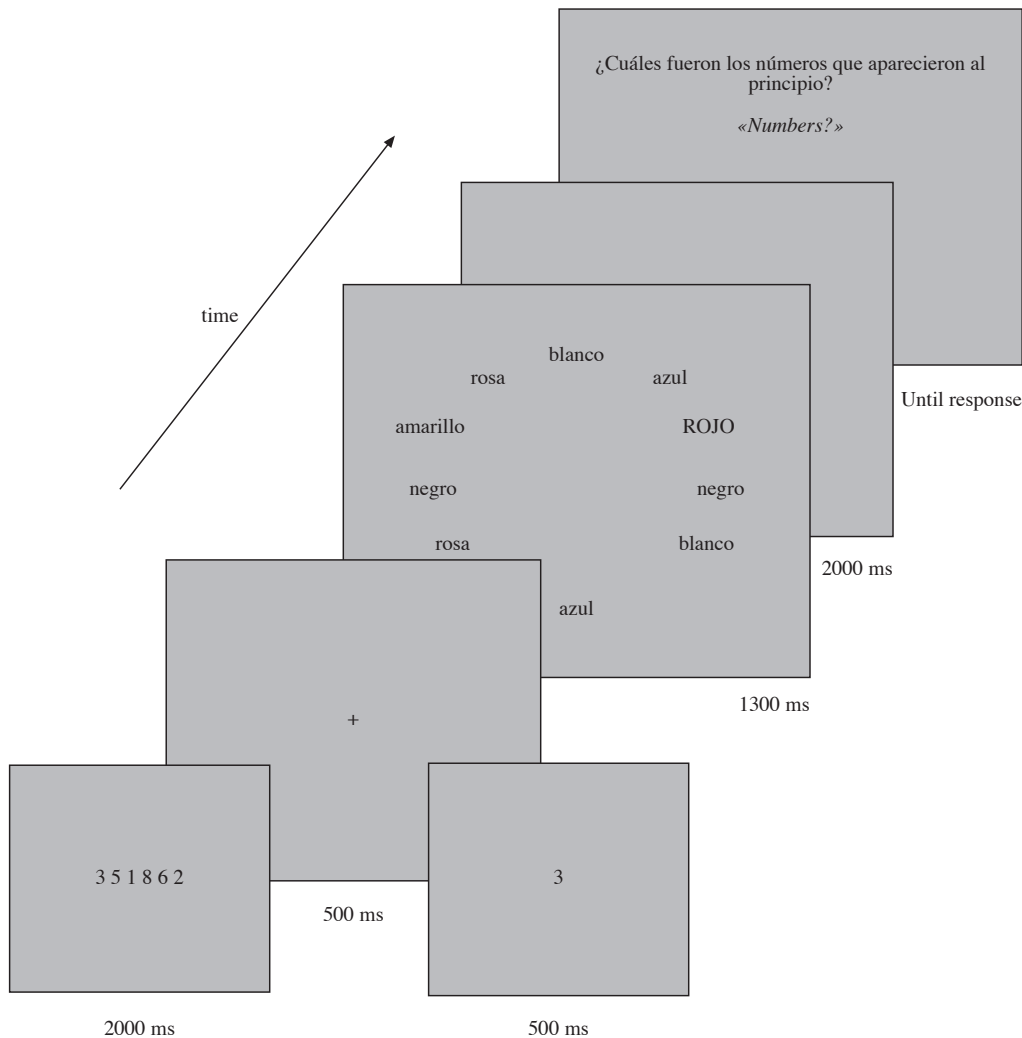

Figure 1. Example of the Procedure in Experiment 1

Results

The goal of having a high level of difficulty was satisfactorily accomplished by employing exposure duration in the VS task of only 1300 ms. In fact, a significant number of participants (6 of 24) could not perform the task properly (as mentioned before, people with less than 30 correct trials in any experimental condition were removed from the analyses), and the mean RT of all participants was longer than 1000 ms.

As expected, performance in the memory task was significantly better in the low load condition (94% correct recall) than in the high load condition (77%) [t(17)= 5.49; p<.001]. All analyses in the attentional task are based only in the trials in which recall was correct in the memory task.

The proportion of hits in the attentional task did not show a significant effect of memory load or the interaction (F<1), but the set size was marginally significant [F(2,34)= 2.80; p= .075]. The mean proportion of correct responses and mean RTs for each condition are shown in Table 1.

Results for correct target identification RTs are very similar to accuracy results. No effects were found for memory load nor for the interaction (F<1), although the set size effect was statistically significant [F (2,34)= 98.94; p<.001]; as Figure 2 show, mean RT is larger as the set size increases.

Discussion

The main goal of experiment 1 was determining whether when performing a VS task with set size trials mixed, the attentional set could modulate the effect of memory load in the task. If in the high memory load there is a more exogenous attentional set and the uncertainty of the mixing costs yields a more endogenous situation, both effects could compensate; therefore, no interaction effect between the variables was expected. Indeed, no interaction effects

were found for hits or RTs. There was only a significant main effect of the set size for RTs, as has been previously reported in many VS experiments: the RTs increase as a function of the set size (Figure 2). Moreover, the results found in the present experiment replicate some other results found in VS, where a similar memory load manipulation was also made (Logan, 1978; Woodman et al., 2001).

The main problem of the present experiment is that the interpretation of results is not unequivocal. We cannot eliminate some alternative interpretations. The first one is that the difficulty of the task may turn out other masked variables. A second possible explanation is based on the fact that different type of material has been used in both tasks: for the memory load manipulation, digits have to be retained in working memory, whereas in the VS task the response had to be done to words. There is some evidence that the different type of material in both tasks does not produce interaction effects, probably because they are processed in different modules in the brain (Oh & Kim, 2004; Woodman et al., 2001). So the explanation of the present data can be related first of all with the difficulty of the task, which resulted in the possibility of a "biased sample" in terms that only those participants with high memory and high attentional span could accomplish the task (although only six of 24 participants were excluded of the analysis), and the possibility of an increment of noise modulated by other possible variables involved in the task (for example, the type of response used where a trainning phase must be accomplished may increase the difficulty of the response selection, increasing the number of masked variables). On the other hand, and what seems more plausible according to the previous literature, the differences between the type of material in the memory and the attentional task may explain the lack of interaction.

We tried to solve those problems with experiments 2A and 2B. In both experiments we blocked the order of set size presentation by maintaining constant the same display size during the whole experiment (10 items). In experiment 2A we also reduced the difficulty

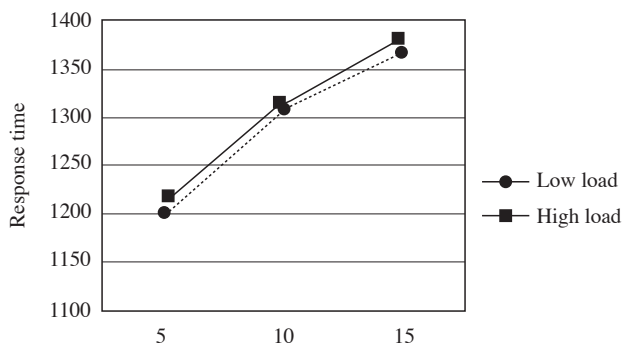| Table 1 Mean and Sd for the proportion of correct responses and RTs in Experiment 1											
	Proportion of correct responses						**Response time (RTs)**					
	Low load			**High load**			**Low load**			**High load**		
	5 items	**10 items**	**15 items**	**5 items**	**10 items**	**15 items**	**5 items**	**10 items**	**15 items**	**5 items**	**10 items**	**15 items**
Mean	.93	.90	.90	.92	.90	.89	1198	1310	1363	1208	1312	1383
Sd	.06	.06	.07	.06	.08	.10	125	176	143	159	170	152

Figure 2. Mean RTs for each condition in Experiment 1

of the task by increasing the exposure duration of the attentional display (3000 ms, a more frequently employed duration; e.g., Logan, 1978) while in experiment 2B it was used the same exposure duration as in experiment 1. In short, the only difference between experiments 2A and 2B was the exposure duration of the VS display, both with a blocked condition of 10 items through the experiment.

Selecting the proper groups of trials from the three experiments we can make specific comparisons of interest. Thus, we may compare the results of experiments 2A & 2B with those found for experiment 1 focussing on the idea that a mixed trials procedure may foster a different attentional set than a blocked one (Los, 1996). On the other hand, with experiment 2A, where the duration of the VS display was increased and, therefore, the task may be

easier to perform, we can see if the high difficulty could explain the results of experiment 1. Regarding to the different type of material in the attentional and memory task, we may reach more evidence supporting or, on the contrary, rejecting the hypothesis depending on the results of experiment 2A: if different type of material is, in fact, the explanation of the lack of an effect in experiment 1, we should also find no effects of memory load in experiment 2B; if it is more related with the blocking or mixing issue (what may lead to differential attentional sets that promote more endogenous or exogenous types of attention) we should find an effect of memory load (regardless of whether it makes the search in the attentional task more or less efficient).

Experiments 2A & 2B

Method

Participants

Forty volunteer students of the Autónoma University of Madrid participated in the experiment. For experiment 2A: 16 women and 4 men with a mean age of 19.05 (range 18-39). For experiment 2B: 15 women and 5 men with a mean age of 19.65 (range 17-27). Unlike in experiment 1, in both experiments 2A & 2B all participants were included in the analyses because they had more than 30 correct trials in each experimental condition. All of them reported normal or normal-corrected vision.

Stimuli, materials and procedure

Stimuli were the same as in Experiment 1. Set size was held constant in 10 items across the experiments. The only difference between experiments 2A and 2B is the exposure duration of the VS display: 3000 ms in experiment 2A and 1300 ms in experiment 2B. Everything else remained the same as in experiment 1.

Data analyses

Like in experiment 1, the statistical analyses were done using the SPSS 15.0 computer package. Differences in the memory task were also studied by descriptive statisticss and T-tests for related samples as well as the effect of memory load in VS both for hits and RTs.

Results and discussion

As in Experiment 1, memory task performance was significantly better for the low load condition in both experiments [Experiment 2A: 97% vs. 74%; t(19)= 5.91; p<.001; experiment 2B: 96% vs. 79%; t(19)= 5.72; p<.001]. The statistical analyses of the attentional task were done only for trials correctly answered in the memory task.

In the target word identification data, there were no effects of memory load in experiment 2A [t(19)= .94; p= .358] as well as in experiment 2B [t(19)= .76; p= .454], being the averages in all conditions over 96% of correct responses (Table 2).

For mean correct RTs, although the tendency of means are similar for both experiments (longer RTs in the high load condition, see table 2) there is a statistical significant difference between memory load conditions in experiment 2B [t(19)= 3.04 p= .007] that does not appear in experiment 2A [t(19)= 1.46; p= .161].

The results of experiment 2A show no modulation of the memory load condition for performance in the VS task, as in experiment 1. Thus, the high difficulty of the task in Experiment 1 does not seem to explain the lack of effect of the memory load, as it does not appear here (although the lack of an effect in a particular experiment does not prove that the effect does not exist, so any interpretation from such result should be made with extreme caution). On the other hand, the results of Experiment 2B show a differential effect in the VS task modulated by the memory load: there is in fact a detrimental effect in VS when memory is highly loaded. Apparently, the fact that different type of material is used for the memory and attentional task is not the key for the lack of interaction in Experiment 1. Being that the case, we should have not found differential effects of memory load in Experiment 2B either.

On the other hand, the lack of load effects on RTs in the VS task in Exp2A seems to be due to greater dispersion of the RT scores in the experiment (see Table 2). In fact, the numerical difference between the two load conditions is by far greater in Experiment 2A than in experiment 2B (see Table 2). However, in experiment 2A response time is generally slower which might also result in more disperse scores. This difference between experiment 2A and 2B seems to genuinely show a strategy change between these two experiments and therefore, the fact that there are load effects in 2B and not in 2A renders more support to our hypothesis.

General discussion

The main goal of the present research was to explore whether memory load has a modulating effect in performance in a VS task, by means of an influence in the attentional set of the participants. We have assessed that by comparing the effect of memory load in different VS tasks where the time of presentation and the number of items in the visual display were manipulated. In experiment 1 the trials of the search set size conditions (5, 10 or 15) were mixed in the blocks within memory load conditions (low versus high load), whereas in experiments 2A and 2B the number of items in the display remained constant (10 items). The exposure duration of the display was varied between the experiments (2A: 3000 ms; 2B: 1300 ms). The results showed no differential effects of memory load (experiment 2A) and no interaction effects between memory and attentional manipulations in experiment 1. However, differential effects of memory load were found in experiment 2B: RTs were longer in the attentional task for trials under high memory load conditions.

As we have seen before, there is also evidence of no interaction effects between the number of items in a VS task and the level of memory load (Logan, 1978; Woodman et al., 2001). Being the endogenous component a critical element, we should have found

Table 2
Mean and Sd for the proportion of correct responses and RTs in Experiments 2A & 2B

	Proportion of correct responses				Response time (RTs)			
	Exp. 2A		Exp. 2B		Exp. 2A		Exp. 2B	
	Low	High	Low	High	Low	High	Low	High
Mean	.974	.969	.986	.990	1625	1666	1040	1055
Sd	.017	.025	.028	.018	158	199	6.01	7.81

a significant interaction between the factors. However, we have also seen that the interaction between factors may appear by manipulating certain variables: finding detrimental effects in VS under high memory load conditions (Lavie & De Fockert, 2006) and finding a more efficient search under high load conditions (Smilek et al., 2006a). Following Smilek et al's hypothesis, our point of view is that the differential effects may be due to a different attentional set. That may yield a more endogenous or exogenous attentional process and, therefore, can modulate the effects of memory load in VS. The appearance of a differential effect of memory load in experiment 2B also supports this view. However, the difficulty of the task (mainly in experiment 1) can make this statement difficult to support. The results of experiment 2A allow a stronger assumption; however other interpretations are possible. In fact, the lack of an effect in experiment 2A might be explained as a ceiling effect: as the task is easy enough, there are enough resources to do both tasks with no detrimental effects. In fact, the longer RTs found in Experiment 2A as compared to those found in Experiment 2B (where the only difference was that the exposure duration of the display was 1300 ms instead of 3000 ms) points at this idea; they were more «relaxed», so that the participants spent more time for doing the task (both for high and low memory load conditions). However, we believe that the main point stands in the differences found between the effects in Experiment 1 and Experiment 2B. The appearance of an effect in Experiment 2B seems to show that there is something different there. In fact, comparing the results in the condition with 10 items in Experiment1 and the results of Experiment 2B, we can see that memory load effects only appear in experiment 2B. The only difference between the experiments is that in experiment 1 the trials with 10 items were mixed with the trials with 5 or 15 items, while in experiment 2B the condition with 10 items was blocked. The mixed condition in Experiment 1 generates a different situation, and that may be due to a different attentional set (Los, 1996) that might yield the involvement of differential attentional mechanisms in both tasks, as pointed by Smilek et al. (2006a). As we showed before, an explanation based on the differences between the type of material in the memory and attentional tasks does not support the effect found in experiment 2B.

However, while we have found that VS is less efficient under high memory load conditions in our task, Smilek et al., (2006a) found that VS was more efficient under high memory load conditions. This discrepancy does not invalidate the idea that working memory may promote a more exogenous or endogenous attentional set that modulate performance in VS; it can be pointing that there is something more about all those results. In fact, other researchers have reached evidence that the type of material may play an important role in the modulation of attentional processes by memory load. Perhaps the key is not the type of material per se, but its relationship with target and distractors in the attentional task (Kim et al., 2005). In fact, in Smilek et al's task the items that had to be retained in working memory were exactly the same items as the target in the VS task. As we have seen before, there is evidence showing that items in working memory can produce a selection advantage for related relevant material over irrelevant material in the attentional task (Downing, 2000; Roberts et al., 1994; Soto et al., 2005). In our experiments the material in the memory task is different than the target or the distractors in the VS task (digits vs words), and this could explain the differential effect. On the contrary, we could explain the results by other evidence found in the context of endogenous attention. Digits might be retained verbally because of our tendency to verbalize this type of material (Hitch, Woodin, & Baker, 1989; Silverberg & Buchanan, 2005). As they may be verbal material, as words in the attentional task, they might be sharing mechanisms in working memory. So, as memory load increases, attentional resources are diminished and selective attention to relevant material is impaired (Cowan, 1995; De Fockert et al., 2001).

Although our hypothesis of the attentional set is supported by the results found in the present experiments, other possible hypothesis should be explored. The idea that the type of material in the memory task may modulate attentional performance depending on whether it is related with target or distractors in the attentional task is worth to be explored. More research is needed to understand the relationships between memory and attention in this type of research paradigms. A meta-analysis could also shed light on this issue.

<div style="text-align:center">References</div>

Bacon, W. F., & Egeth, H.E. (1994). Overriding stimulus-driven attentional capture. *Perception and Psychophysics*, *55*, 485-496.

Conway, A.R.A., Tuholski, S.W., Shisler, R.J., & Engle, R.W. (1999). The effect of memory load on negative priming: An individual differences investigation. *Memory & Cognition*, *27*(6), 1042-1050.

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

De Fockert, J.W., Rees, G., Frith, C.D., & Lavie, N. (2001). The role of working memory in visual selective attention. *Science*, *291*, 1803-1806.

Downing, P.E. (2000). Interactions between visual working memory and selective attention. *Psychological Science*, *11*(6), 467-473.

Engel, R.W., Kane, M.J., & Tuholski, S.W. (1999). Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence and functions of the prefrontal cortex. En A. Miyake & P. Shah (Eds.): *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 102-134). Cambridge: Cambridge University Press.

Gil-Gómez de Liaño, B., & Botella, J. (in press). Concurrent memory load can make RSVP Search More Efficient.

Hester, R., & Garavan, H. (2005). Working memory and executive function: The influence of content and load on the control of attention. *Memory & Cognition*, *33*(2), 221-233.

Hitch, G.J., Woodin, M.E., & Baker, S. (1989). Visual and phonological components of working memory in children. *Memory & Cognition*, *17*, 175-185.

Jacoby, L.L., & Brooks, L.R. (1984). Nonanalytic cognition: Memory, perception and concept learning. *Psychology of Learning and Motivation* , *18*, 1-46.

Jha, A.P. (2002). Tracking the time-course of attentional involvement in spatial working memory: An event-related potential investigation. *Cognitive Brain Research, 15*, 61-69.

Kiefer, M., Ahlegian, M., & Spitzer, M. (2005). Working memory capacity, indirect semantic priming and Stroop interference: Pattern of interindividual prefrontal performance differences in healthy volunteers. *Neuropsychology*, *19*(3), 332-344.

Kim, S.Y., Kim, M.S., & Chun, M.M. (2005). Concurrent memory load can reduce distraction. *PNAS*, *102*(45), 16524-16529.

Kim, M.S., Min, S.-J., Kim, K., & Won, B.-Y. (2006). Concurrent working memory load can reduce distraction: An fMRI study [Abstract]. *Journal of Vision*, *6*(6), 125a. Available at http://www.journalofvision.org/6/6/125/.

Lavie, N., & De Fockert, J. (2006). Frontal control of attentional capture in visual search. *Visual Cognition*, *14*, 863-876.

Lavie, N., Hirst, A., De Fockert, J.W., & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General*, *133*(3), 339-354.

Logan, G.D. (1978). Attention in character-classification tasks: Evidence for the automaticicity of component stages. *Journal of Experimental Psychology: General*, *107*, 32-63.

Long, D.L., & Prat, C.S. (2002). Working memory and Stroop interference: An individual differences investigation. *Memory & Cognition*, *30*(2), 294-301.

Los, S.A. (1996). On the origin of mixing costs: Exploring information processing in pure and mixed blocks of trials. *Acta Psychologica, 94,* 145-188.

Oh, S.H., & Kim, M.S. (2004). The role of spatial working memory in visual search efficiency. *Psychonomic Bulletin & Review*, *11*(2), 275-281.

Park, S., Kim, M.-S., & Chun, M.M. (2007). Concurrent working memory load can facilitate selective attention: Evidence for specialized load. *Journal Experimental Psychology: Human Perception and Performance*, *33*(5), 1062-1075.

Roberts, R.J., Jr., Hager, L.D., & Heron, C. (1994). Prefrontal cognitive processes: Working memory and inhibition in the antisaccade task. *Journal of Experimental Psychology: General, 123,* 374-393.

SanMiguel, I., Corral, M.J., & Escera, C. (2008). When loading working memory reduces distraction: Behavioral and electrophysiological evidence from an auditory-visual distraction paradigm. *Journal of Cognitive Neuroscience*, *20*, 1131-1145.

Silverberg, N., & Buchanan, L. (2005). Verbal mediation and memory for novel figural designs: A dual interference study. *Brain and Cognition*, *57*, 198-209.

Smilek, D., Enns, J.T., Eastwood, J.D., & Merikle, P.M. (2006a). Relax! Cognitive strategy influences visual search. *Visual Cognition*, *14*, 543-564.

Smilek, D., Dixon, M.J., & Merikle, P.M. (2006b). Revisiting the category effect: The influence of meaning and search strategy on the efficiency of visual search. *Brain Research*, *1080*, 73-90.

Soto, D., Heinke, D., Humphreys, G.W., & Blanco, M.J. (2005). Early, involuntary top-down guidance of attention from working memory. *Journal of Experimental Psychology: Human Perception and Performance, 31*(2), 248-261.

Stins, J.F., Vosse, S., Boomsma, D.I., & De Geus, E.J.C. (2004). On the role of working memory in response interference. *Perceptual and Motor Skills*, *99*, 947-958.

Wolfe, J.M. (1994). Guided Search 2.0: A revised model of visual search. *Psychonomic Bulletin and Review*, *1*, 202-238.

Woodman, G.F., Vogel, E.K., & Luck, S.J. (2001). Visual search remains efficient when visual working memory is full. *Psychological Science*, *12*, 219-224.

Yi, D.J., Woodman, G.F., Widders, D., Marois, R., & Chun, M.M. (2004). Neural fate of ignored stimuli: Dissociable effects of perceptual and working memory load. *Nature Neuroscience*, *7*(9), 992-996.