UC Merced

Proceedings of the Annual Meeting of the Cognitive Science Society

Title
Invariant Effects of Working Memory Load in the Face of Competition

Permalink
https://escholarship.org/uc/item/9k23f7hh

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 27(27)

ISSN
1069-7977

Authors
Gaukrodger, Stephen J.
Neumann, Ewald

Publication Date
2005

Peer reviewed

eScholarship.org Powered by the California Digital Library
University of California

Invariant Effects of Working Memory Load in the Face of Competition

Ewald Neumann (ewald.neumann@canterbury.ac.nz)
Department of Psychology, University of Canterbury
Christchurch, New Zealand

Stephen J. Gaukrodger (sjg81@student.canterbury.ac.nz)
Department of Psychology, University of Canterbury
Christchurch, New Zealand

Abstract

The influence of working memory load on visual selective attention was examined using a dual selective attention and working memory task. This dual task required participants to ignore distractor faces while categorizing superimposed celebrity names under low or high memory loads. Surprisingly, both memory load conditions produced equivalent interference effects from concurrent famous (compared to anonymous) distractor faces, and equivalent subsequent negative priming effects. These findings were consistent across all four of the present experiments, but they diverge from the dual-task memory load literature on interference and negative priming. Implications regarding the interaction between working memory and attentional selection are addressed.

Introduction

In a recent article in *Science*, de Fockert, Rees, Frith, & Lavie (2001) reported that working memory is crucial for reducing distraction by maintaining the prioritization of relevant over irrelevant information. They arrived at this conclusion by combining two unrelated tasks – one requiring visual selective attention and the other working memory – to see if increasing load in the working memory task would increase the processing of visual distractors in the selective attention task. Participants were asked to remember the order of four digits presented either in a random order (high working memory load) or in a fixed order (low load), while categorizing famous names superimposed on irrelevant distractor faces. Significantly more interference from an irrelevant face in the name classification ("politician" vs. "pop-star") task was obtained in the high memory load condition, compared to the low memory load condition. High load seemed to reduce the efficiency of selection and thereby increased the interfering effects of irrelevant stimuli. Accordingly, de Fockert et al. concluded that participants were better able to block out the interfering effects of an incongruent face when concurrent memory load obligations are low, whereas when memory load is high, there is more extensive processing of the distractor face resulting in more interference. The main goal of the present study was to further examine the notion that selection is efficient when working memory load is low and inefficient when memory load is high in this type of dual-task situation.

The four experiments we report use a similar dual-task procedure to that used by de Fockert and his colleagues, but with some methodological modifications. For example, instead of assessing the extent to which distractor faces are processed by comparing congruent with incongruent conditions, we compared the incongruent condition with a neutral face condition. This allowed us to isolate the processing cost specifically due to incongruence without the need to be concerned with the processing benefit due to congruence. In addition we excluded all congruent (e.g., Mick Jagger's name on his own face) stimuli from our experiment because it is known that having congruent stimuli in Stroop-like conflict tasks induces subjects to maintain less attentional selectivity solely to the target. That is why, for example, participants consistently show greater amounts of interference in incongruent trials as a function of increasing the proportion of congruent trials in such conflict tasks (e.g., Lindsay & Jacoby, 1994). Since one of the main objectives in using the present paradigm is to investigate selective attention, rather than more diffuse or divided attention, it is important to try to induce maximal attentional selectivity.

Lastly, we included a negative priming measure to supplement the interference measure. Despite being ignored, unattended visual distractors often produce traceable priming effects, which can be used to investigate inhibitory processes in selective attention. Negative priming effects are indexed behaviorally as the increased reaction-time (or reduced accuracy) that occurs in response to a previously ignored stimulus. Evidence from negative priming studies shows that visual distractor stimuli may nonetheless be processed even in the absence of any target-distractor interference (Driver & Tipper, 1989; Mari-Beffa, Estevez, & Danziger, 2000). The strong implication from this work is that in some instances negative priming effects can provide a more sensitive behavioral index, than concurrent interference effects, regarding the depth to which distractors have been processed. Of course, supplementing concurrent interference data with potential subsequent priming data can be useful not only for the purposes of determining the degree to which nontarget distractors have been processed, but also for providing evidence regarding the nature of the conflict resolution processes that have recently transpired (Neumann & DeSchepper, 1992).

Experiment 1

In our selective attention task, observers were asked to classify famous written names as "musicians", "politicians", or "comedians", while ignoring distractor faces that overlapped with the names. The distractor faces were either anonymous or famous and incongruent with the written name (e.g., "John Lennon" written across an anonymous face versus "John Lennon" written across the face of, say, Bill Clinton). Distractor face processing was evaluated by comparing classification reaction times between the anonymous and incongruent conditions to assess interference, and also by determining if ignoring a particular famous face would have a negative priming effect on the subsequent classification of that person's name.

A working memory task for digit order was performed simultaneously with the selective attention task. Memory load was manipulated by requiring participants to remember either a fixed order of four sequential digits (low memory load, e.g., 01234), or a random order of these digits (high memory load, e.g., 03124) for each sequence of two to four trials. After such a sequence of trials, a single digit from the set appeared and the participant was required to press a button consistent with the digit that followed it in the original set. If limits on face processing do apply in the low load condition, then both interference and negative priming effects should be smaller, or nonexistent, compared to the high load condition.

We tested this hypothesis by combining these two unrelated tasks – one requiring visual selective attention and the other working memory – to see if increasing load in the working memory task would increase the processing of visual distractors in the selective attention task. If the conjectures by de Fockert et al. (2001) are correct, then high memory load should reduce the availability of working memory for maintaining stimulus priority in the selective attention task. And because this should lead to more unwanted intrusion of irrelevant distractors, more interference and more negative priming should occur when working memory load is high, compared to low.

Method

We adopted the dual-task methodology used by de Fockert et al. (2001). In our selective attention task, 30 participants were asked to classify famous written names as "musicians," "politicians," or "comedians," while ignoring distractor faces that overlapped with the names (see Figures 1 and 2). To properly conduct the negative priming manipulation, it was necessary to add a category to the two categories used by de Fockert et al. in order to avoid predictable stimulus contingencies between trials. The distractor faces were either anonymous or famous and incongruent with the written name (e.g., "Mick Jagger" written across an anonymous face versus "Mick Jagger" written across the face of Bill Murray). Distractor face processing was assessed by comparing classification reaction times between the anonymous and incongruent conditions, and also by determining if ignoring a particular famous face would have a negative priming effect on the subsequent classification of that person's name. There were sixteen gray-scale faces, with four faces representing each of the four categories of distractor faces (anonymous, comedian, musician, and politician). Twelve names corresponding to the identity of the 12 celebrity faces served as targets. The stimulus pool for the experiment was created by superimposing each name on each face (except for congruent target-distractor stimulus combinations, for the reasons stated earlier).

The working memory task for digit order was performed simultaneously with the selective attention task. In this task, load was manipulated by requiring participants to remember on each trial of a given block either a fixed order of four sequential digits (low memory load, e.g., 01234), or a random order of these digits (high memory load, e.g., 03124). The memory load conditions were presented in two counterbalanced blocks, with half of the participants starting with the high load condition, and the remaining half starting with the low load condition.

Figure 1 shows a sample of a high memory load trial sequence involving an incongruent prime trial followed by an ignored repetition (IR) probe trial. Two to 4 such face-name combinations could be sandwiched in between the memory set and the single digit, and this was determined randomly, so participants never knew exactly how long the memory set would need to be maintained for any given sequence.

Figure 2 shows a sample of all the selective attention conditions in the experiment. The top row conveys the prime interference measure which is derived by contrasting responses to Incongruent versus Neutral displays. The bottom row conveys the probe priming measure. Note that although we included an attended repetition (AR) manipulation in the design of the first two experiments, it is not relevant for present purposes and will not be discussed further in this presentation -- except to say that it produced large facilitatory priming effects under both high and low memory loads in both of these experiments. The more important probe negative priming measure is derived by contrasting responses to IR versus Control displays.

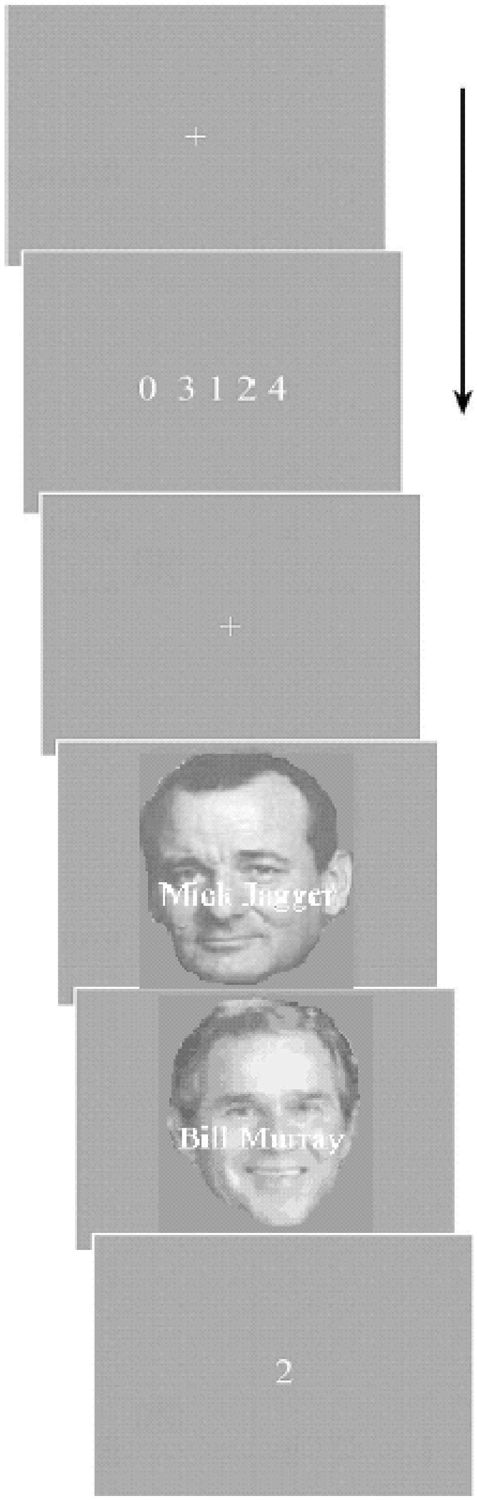

Figure 1: Sample high memory load trial sequence involving an Incongruent prime, followed by an Ignored Repetition probe. Correct answer to the memory load item is 4.

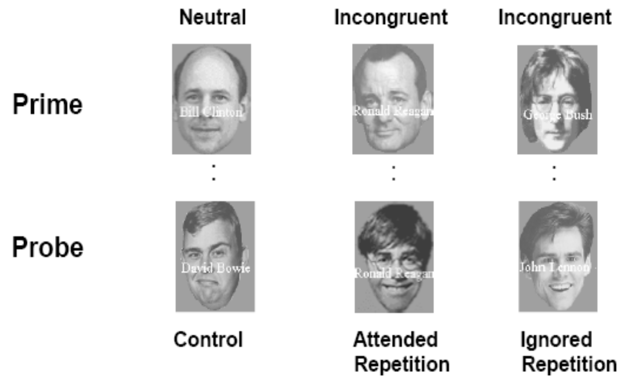

Figure 2: Sample stimulus displays depicting possible prime-probe couplets used in the design of Experiment 1.

Results and Discussion

The main results are summarized in Table 1. Note that accuracy data (% errors) will be reported for the present experiments only when they produced a significant effect and only when this effect could potentially compromise interpretation of the reaction-time (RT) results.

Table 1: Interference and identity negative priming in Experiment 1; ***** indicates $p < .05$

Interference	Low Load	High Load
Incongruent (RT)	586	608
Neutral (RT)	558	584
RT Difference	28*	24*
Negative Priming		
Identity IR (RT)	581	598
Control (RT)	558	587
RT Difference	23*	11n.s.
Identity IR (%Err)	6.6	10.0
Control (%Err)	6.4	6.1
%Err Difference	.2n.s.	3.9*

The prime (Interference) results indicated that there was a significant interference effect from incongruent distractors for both the high and low memory load conditions, with no difference in the amount of interference between the two memory load conditions. The probe (Negative Priming) results indicate that only the low memory load condition produced a significant negative priming effect in RTs. However, although the high load condition produced nonsignificant negative priming for the RTs, it produced significant negative priming in the % error data. Because calculations of RT Interference, as well as Negative Priming, contain only correct RTs, the increase in IR errors in the high load condition may serve to eliminate those trials on which participants had the most difficulty, which could account for the absence of negative priming in the RT results.

The overall results from Experiment 1 suggest that distractor faces are processed to the same degree regardless of the working memory obligations that are imposed. These findings are thus inconsistent with the hypothesis that low memory load leads to more efficient filtering of distractors.

Experiment 2

The second experiment was designed to replicate and extend the results of the first. If the findings are replicable, then there should be significant and similar amounts of prime interference and probe negative priming, regardless of whether the concurrent memory load is low or high. In addition, it is currently not known whether the negative priming effects we observed in Experiment 1 were due to identity negative priming, or to a categorical negative priming effect. This issue was investigated by replacing the identity negative priming manipulation by a semantic negative priming manipulation. For example, instead of ignoring Mick Jagger's face and then having to categorize the name "Mick Jagger" as a musician in an Ignored Repetition trial, as in the first experiment, this follow-up involved ignoring a different musician's face followed by having to categorize the name "Mick Jagger" as a musician. As such, the Ignored Repetition trials were all replaced by "Ignored Semantic" trials. Everything else was held constant with Experiment 1 – thus enabling us to determine the specificity (identity versus categorical) of the negative priming effect in this type of task with a new group of 30 participants.

Results and Discussion

The main results are summarized in Table 2.

Table 2: Interference and semantic negative priming in Experiment 2; * indicates $p < .05$

Interference	Low Load	High Load
Incongruent (RT)	573	595
Neutral (RT)	548	563
RT Difference	25*	32*
Negative Priming		
Semantic IR (RT)	552	584
Control (RT)	525	550
RT Difference	27*	34*

As was the case in Experiment 1, the prime (Interference) results indicated that there was a significant interference effect from incongruent distractors for both the high and low memory load conditions, with no difference in the amount of interference between the two memory load conditions ($F < 1$). The probe (Negative Priming) results indicated that both memory load conditions produced significant negative priming effects, with no difference in the amount of negative priming ($F < 1$).

Overall, these results corroborate the findings from Experiment 1 and reinforce the suggestion that distractor faces are processed to the same degree, regardless of varying working memory load obligations. These findings are again inconsistent with the hypothesis that low memory load leads to more efficient blocking, gating, or filtering of distractors. Finally, the semantic negative priming effect indicates that the inhibitory processes applied to distractor faces are not limited to the specific identity of the face, but actually spreads to the categorical level.

Experiment 3

The third experiment was designed to replicate and extend the results of the first two experiments. Because the findings of Experiment 1 were somewhat ambiguous in the high memory load condition (i.e., showing significant negative priming only for the error data, but not the RT data), we re-introduced the identity ignored repetition manipulation and tested a new group of 30 participants. There were two other differences between this experiment and Experiment 1. First, the attended repetition (AR) manipulation was removed so that instead of requiring 60-70 minutes to complete, the present experiment only required about 40-45 minutes. Second, we added a catch trial at the end. The catch trial was added to determine if participants could explicitly identify the nontarget face in a forced-choice recognition task conducted immediately after a final attention display. The catch trial always involved an incongruent attention display (i.e., no neutral faces ever appeared in the catch trial). One-third of the participants encountered the face of a politician, another 1/3 a comedian, and the remaining 1/3 a musician.

Results and Discussion

The main results are summarized in Table 3.

Table 3: Interference and identity negative priming in Experiment 3; ^ $p < .06$ (one-tailed); * $p < .05$

Interference	Low Load	High Load
Incongruent (RT)	563	576
Neutral (RT)	526	542
RT Difference	36*	34*
Negative Priming		
Identity IR (RT)	531	568
Control (RT)	514	532
RT Difference	17^	36*

As was the case in Experiments 1 and 2, the prime (Interference) results indicated that there was a significant interference effect from incongruent distractors for both the high and low memory load conditions, with no difference in the amount of interference between the two memory load conditions ($F < 1$). The probe (Negative Priming) results indicated that both memory load conditions produced significant negative priming effects, with no difference in the amount of negative priming ($F = 1.43, p > .24$).

Overall, these results corroborate the findings from Experiment 1 and reinforce the suggestion that distractor faces are processed to the same degree, regardless of varying working memory loads. They are, however, again inconsistent with the hypothesis that low memory load leads to more efficient blocking or filtering of distractors. Finally, for the catch trial, each participant was presented with a sheet containing all 16 faces, and asked to circle the face that best matched the face in the immediately preceding display. Two out of 30 (6.7%) chose the correct face, where 6.3% would be expected by random chance. Six out of 30 (20%) picked the correct category of faces, where 25% would be expected by random chance. Interestingly, 8 of the 30 participants picked a neutral face. Apparently, subjects were not explicitly identifying the nontarget face or even aware that they just encountered an incongruent attention display. If they had been aware of the latter, they could have eliminated the neutral faces as an option, but this was not the case as more than 25% of them chose a neutral face.

The last experiment explored a potential methodological reason why our results might be inconsistent with earlier findings in this type of dual-processing task.

Experiment 4

One of the main differences in our task is that three, instead of two, categories of celebrities was used. It is possible that requiring participants to remember this additional information (along with its requisite response) imposed additional memory load. Our "low memory load" condition may therefore not have been as "low" as de Fockert et al's. We thus attempted to reduce memory load in our task by not requiring subjects to respond to the memory digits. Instead of a block of Low and a block of High load manipulations, the present experiment had two blocks of "No Load." The digits still appeared just as they did in Experiment 3, but participants were informed that they were there to signal the beginning and end of each trial sequence, and that they should press any button on the button-box to advance to the next trail whenever a single digit appeared. Otherwise, this experiment was identical to Experiment 3, but with a new group of 30 participants.

Results and Discussion

The main results are summarized in Table 4. Note that because there were no interaction effects involving block for either the prime interference or probe negative priming measures, these data are collapsed across block.

As was the case in the previous experiments, the Interference results indicated that there was a significant interference effect from incongruent distractors, despite "no" memory load in the present experiment. This is inconsistent with the idea that distractors are more likely to be filtered or blocked from processing under low memory load situations. Significant probe (Negative Priming) was also observed.

Table 4: Interference and identity negative priming in Experiment 4; * indicates $p < .05$

Interference	No Load
Incongruent (RT)	531
Neutral (RT)	505
RT Difference	26*
Negative Priming	
Identity IR (RT)	495
Control (RT)	482
RT Difference	13*

However, because the identity negative priming effect appeared numerically somewhat reduced relative to the previous experiments, an additional ANOVA was conducted with "Experiment" (1 vs. 3 vs. 4) as a between-subjects variable. Based on the outcome – since "Experiment" did not interact with any other variable – there is no indication that the negative priming effect was significantly affected by No, Low, or High memory load conditions. This is again inconsistent with the idea that distractors are more efficiently blocked or filtered from processing under low memory load situations. In a planned follow-up experiment, congruent stimuli will be incorporated into our design, to see if the addition of congruent stimuli can account for the disparities in the results between the two laboratories.

Overall, Experiment 4 corroborates the findings from each of the present experiments and reinforces the suggestion that distractor faces are processed to the same degree, regardless of varying working memory load obligations. These findings are thus inconsistent with the hypothesis that low memory load leads to more efficient blocking, gating, or filtering of distractors.

Conclusions

Contrary to the findings and predictions derived from the work of de Fockert et al. (2001), the magnitude of interference from the incongruent distractor faces was invariant across the high, low, and even no working memory load conditions in the present experiments. Additional disconfirmations of expected results were evidenced by the significant and comparable magnitudes of negative priming obtained under all of the memory load conditions. Instead, our findings strongly imply that high load does not reduce the efficiency of attentional selectivity, nor does low load increase it; instead, working memory load appears to have no effect on the efficiency of selection in this type of dual-task paradigm. Our evidence for the nonselectivity of 'selective' seeing, regardless of memory load, is especially surprising in that it emerged in a task that was specifically designed to induce relatively greater attentional selectivity specifically to target stimuli than was the case in previous work. We hope that these findings will provide some useful background for developing more complete and accurate neural and psychological models regarding not only the mechanisms underpinning selective attention, but also how selective attention and working memory interact. On the basis of the present results, for example, working memory and attentional selection do not appear to involve the same executive control system.

Acknowledgments

We would like to thank Jan de Fockert for generously sharing stimulus materials with us and Mary Bamford for assistance in data collection.

References

de Fockert, J.W., Rees, G., Frith, C.D., & Lavie, N. (2001). The role of working memory in visual selective attention. *Science, 291,* 1803-06.

Driver, J., & Tipper, S.P. (1988). On the nonselectivity of 'selective' seeing: Contrasts between interference and priming in selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 15,* 304-314.

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

Mari-Beffa, P., Estevez, A.F., & Danziger, S. (2000). Stroop interference and negative priming: Problems with inferences from null results. *Psychonomic Bulletin and Review, 7,* 499-503.

Neumann E., & DeSchepper, B.G. (1992). An inhibition-based fan effect: Evidence for an active suppression mechanism in selective attention. *Canadian Journal of* Psychology, *46*, 1-40.