

Short article

Is verbal–spatial binding in working memory impaired by a concurrent memory load?

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Binding processes play a critical role in memory. We investigated whether the binding of (visually presented) verbal and spatial (locations) information involves general attentional resources, as stipulated in the revised working memory model, by comparing measures of binding in the presence and absence of a concurrent memory load. Using an adaptation of a probe recognition task contrasting performance between intact and recombined conditions, we found that the concurrent retention of a sequence of three pure tones eliminated verbal–spatial binding. The present study constitutes the first to directly measure the impact of a concurrent memory load on verbal–spatial binding and suggests that such binding may indeed recruit attentional resources, consistent with some recent findings in the visual–spatial binding literature.

Keywords: Working memory; Binding; Episodic buffer; Load; Attentional resources.

A central question in the working memory (WM) literature is how different classes of information are conjoined or *bound* into coherent objects or units. Binding in WM can take a variety of different forms. For example, *object–feature binding* refers to the process by which visual properties of an object are conjoined to provide the identity of that object (e.g., a red triangle), while *location*

binding can be defined as the process by which object identity is bound to spatial location so that we are able to remember where items were located in space (e.g., Elsley & Parmentier, 2009). One particular point of current debate surrounds the issue of whether binding processes in WM recruit attentional resources, or whether such processes occur with no additional processing

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demands. The role of attentional resources in the binding process is of particular theoretical importance for at least two reasons. First, if binding occurs relatively automatically, bound items rather than individual features may form the basic units of capacity in WM, extending the storage capability of a system otherwise relatively limited (around 4 units; Cowan, 2001). Secondly, attentional resources are stipulated as key in the operation of the newly proposed episodic buffer (EB; Baddeley, 2000) component of the working memory model, described in more detail below. Accordingly, the experiment presented in this paper investigated whether location binding—the binding of visually presented verbal and spatial information—in WM relies upon attentional resources.

While a great deal of literature exists examining feature integration in terms of visual perception (e.g., Treisman & Gelade, 1980), the investigation of processes underpinning binding in WM have only become the focus of experimentation within the last decade or so. Much past research has focused on demonstrating the relative independence of different classes of information, as prescribed within the working memory model. Verbal and spatial memory processes are a case in point as, according to that model, the two classes of information were proposed to be stored within specialized distinct memory buffers (the phonological loop and the visuospatial sketchpad, respectively). Indeed, support for such a dissociation between verbal and spatial memory processes has been demonstrated by a variety of different research traditions including behavioural selective interference effects (e.g., Logie, 1995), diverging developmental trajectories (e.g., Hitch, 1990), and selective impairments following brain trauma (e.g., Della Sala & Logie, 1993).

However, while studies investigating verbal–spatial binding are scarce, recent behavioural (Bao, Li, & Zhang, 2007) and neuropsychological (e.g., Campo et al., 2008; Prabhakaran, Narayanan, Zhao, & Gabrieli, 2000) investigations challenge the modularity assumption by suggesting that verbal and spatial information may be bound in memory and are not simply

stored in parallel. For example, Bao et al. (2007) demonstrated that switching attention between verbal (number) and spatial (location) features held in WM was faster when both features comprised the same “object”, as opposed to distinct objects. Additionally, Prabhakaran et al. (2000) demonstrated that their participants were significantly faster and numerically more accurate in responding to the presence of both verbal and spatial features when the probe they were judging represented an “object” from the array they were maintaining in memory (a letter in the location it was previously in)—as opposed to verbal and spatial features that were initially parts of distinct objects.

Evidence indicating that different features can be integrated within WM was difficult to account for under the original WM architecture, but this caveat was addressed by the proposal of the EB (Baddeley, 2000). The EB is proposed to be a temporary store for integrated information that forms an interface between memory systems, in which information is integrated into a new composite structure, represented in common multidimensional code. Critically for the present paper, the EB “is assumed to be controlled by the central executive” (Baddeley, 2000, p. 421). Therefore, binding in WM should be constrained by attentional resources available to the central executive in the WM system. In this sense, we refer to attentional resources as a central, general pool of resources within the WM system that can be shared between concurrent tasks (Johnson & Heinz, 1978), rather than the focus of spatial attention referred to in the perception literature (e.g., Treisman & Gelade, 1980). Importantly, a key prediction of the EB proposal is that limiting attentional resources that can be directed toward maintaining bindings, by way of a concurrent memory load task taxing attentional resources, should reduce or prevent binding (the rationale applied here is that the concurrent maintenance of a memory load in working memory would draw on attention resources that would otherwise be available to direct towards the maintenance of bound features).

While the present report is, to our knowledge, the first to directly examine the role of attention

in the verbal–spatial binding process, there are reasons to predict that it may be sensitive to manipulations of memory load. First, a functional magnetic resonance imaging (fMRI) study investigating the binding of verbal and spatial features (Prabhakaran et al., 2000) indicated that the maintenance of bound verbal–spatial representations activated right frontal regions, also implicated in central executive functioning. Secondly, a recent study investigating the role of attention in the binding of visual (shapes) and spatial (location) features using a paradigm adapted from Prabhakaran et al. (2000) suggests that such binding may be eradicated under sufficient memory load (Elsley & Parmentier, 2009). In that paper, we presented participants with an array of three irregular black shapes in distinct locations, followed by a single probe item, and participants indicated whether the single probe item represented both a shape and location that they had seen in the array, irrespective of their original pairing. To measure binding we compared performance between intact probes (a shape presented in its original location) and recombined probes (a shape that had swapped positions with a different to-be-remembered shape). We found that participants were faster and more accurate in responding to intact probes relative to recombined probes (consistent with the idea that the two features were bound in memory), but that this advantage disappeared where participants had to concurrently maintain a string of six digits (Experiment 1) or four monosyllabic words (Experiment 2). The present paper aimed to address the issue of whether the binding of features across distinct feature dimensions (e.g., verbal and spatial) can be disrupted by a concurrent memory load.

In line with Elsley and Parmentier (2009), in the present study, we presented participants with an array of to-be-remembered (TBR) stimuli consisting of four upper-case consonants in distinct locations, followed by the presentation of a single lower-case consonant in a location (the probe). Participants had to judge whether this single probe item represented both a consonant and a location seen before in the TBR array, regardless of their initial pairings. Binding was measured by

comparing recognition performance for *intact probes* (a consonant in a location, as seen in the TBR array) and *recombined probes* (a consonant presented in a location previously occupied by a different TBR consonant). As both probe types are identical at the feature level and differ only in terms of their initial bindings, an advantage of recognizing intact probes would be consistent with the idea that the letter and location features were bound within WM—we refer to this as the *binding effect*. Probes constituting foils (requiring “no” responses) were also included (see Method section for details). In order to assess the contribution of general attentional resources to binding, a memory load condition was implemented requiring the concurrent maintenance of the order of three pure tones, presented at the start of each trial. This task was selected based on the fact that the maintenance of sequences of tone frequencies should not involve phonological or visuospatial codes (ensuring that the impact of the secondary task could not be explained in terms of feature interference).

If consonants are bound to spatial locations in WM, one may expect an advantage of intact probes over recombined probes in the control condition of this experiment, as is observed elsewhere (Elsley & Parmentier, 2009; Prabhakaran et al., 2000). Additionally, if verbal–spatial binding draws upon attentional resources, one may expect a reduction of the binding effect in our memory load condition relative to our control condition. However, if binding between verbal and spatial features is immune to a memory load, our load task should not affect our measure of binding.

Method

Participants

A total of 46 undergraduate volunteers took part in the 90-min study for course credit. All participants reported normal or corrected-to-normal vision, and all were naïve to the experimental aims.

Materials

Stimuli were presented on a 19" computer screen. The task was purpose written using E-prime (Schneider, Eschman, & Zuccolotto, 2002).

Eleven pure tones constituted one octave with the following frequencies: 440 Hz, 493.88 Hz, 523.25 Hz, 554.36 Hz, 587.32 Hz, 622.25 Hz, 659.25 Hz, 698.46 Hz, 739.99 Hz, 783.99 Hz, and 830.60 Hz. The verbal stimuli comprised a set of eight consonants (Arial font; 48 pt), selected so as to differ in appearance between upper- and lower-case forms, and were: D; F; H; J; N; Q; R; T. The spatial stimuli were presented within a set of eight spatial locations placed equidistantly in a circular manner.

Design and procedure

On each trial participants were presented with a TBR array, a visual mask and then a probe item. The TBR array consisted of four white consonants (against a black background) selected at random (without replacement) from the set of eight (so that no letter was repeated in each set of four), each appearing in a different location also randomly selected from the possible set of eight. The letters were presented within a 30×30 mm white frame to reduce variations in spatial configuration caused by the consonants per se (Delvenne, Braithwaite, Riddoch, & Humphreys, 2002).

Each trial began with the presentation of a “ready” signal (all text: white, Arial font; 18 pt) for 2,000 ms, followed by three 350 ms tones presented via headphones. In the load condition, these tones consisted of a random arrangement of 3 frequency neighbour tones (randomly selected from the set of 11), and participants had to memorize their order. In the no-load condition, a single tone (randomly selected from the set of 11) was repeated three times, which participants were asked to ignore. Following the presentation of the third tone, a fixation cross appeared for 500 ms, followed by the presentation of a to-be-remembered array of consonants in locations (2,000 ms). A 50 ms visual mask then replaced the array, followed by the appearance of a fixation for 950 ms (the delay interval). A single probe item was then presented, which belonged to one of five probe types. *Intact* probes comprised a letter in location, as seen in the TBR array on that trial. *Recombined* probes comprised a letter in a location originally occupied by another TBR letter on that trial (both probe types were correctly

responded to with a “yes” response). Trials requiring a “no” response were also included as follows: *Both-features-new* probes comprised a letter in a location, neither of which was present in the TBR array on that trial; *new-letter* probes consisted of a location that was seen in the TBR array on that trial, occupied by a letter that was not seen. Finally, *new-location* probes comprised a letter that was seen on that trial, occupying a location that was not. The participants’ task was to indicate, by pressing keyboard keys, whether a probe (single letter in a location) represented *both* a letter and location that was present in the TBR array, irrespective of original pairings (see Figure 1 for a schematic illustration of a trial in the load condition). Half the participants pressed “J” for “yes” and “F” for “no” (the remaining participants used the opposite mapping), using the index finger of each hand. At the offset of the single probe item, accuracy feedback was presented for 1,000 ms (consisting of the word “correct” or “incorrect”). Then the “ready” signal reappeared for 500 ms, followed by a probe tone. In the load condition, the message “Tone Position?” then appeared. Participants responded by indicating which serial position (1, 2, or 3) the probe tone occupied in the to-be-remembered sequence using the 1–3 number keys on the keyboard. Feedback on this task was then given on tone accuracy (1,000 ms). In the no-load condition, the probe tone was followed by the appearance of a digit (1 to 3, at random). Participants simply had to press the corresponding number key.

For both components of the task participants were informed that speed and accuracy were critical for task performance. There were a total of 288 trials (144 in the load and no-load conditions), rendering 36 intact and recombined trials, and 24 both-new, new-letter, and new-location trials within each experimental condition (no-load and load). The order of the load condition was counterbalanced across participants.

Results

Performance in the verbal-spatial task was analysed for all trials in the no-load condition. In the load condition, only trials in which a correct

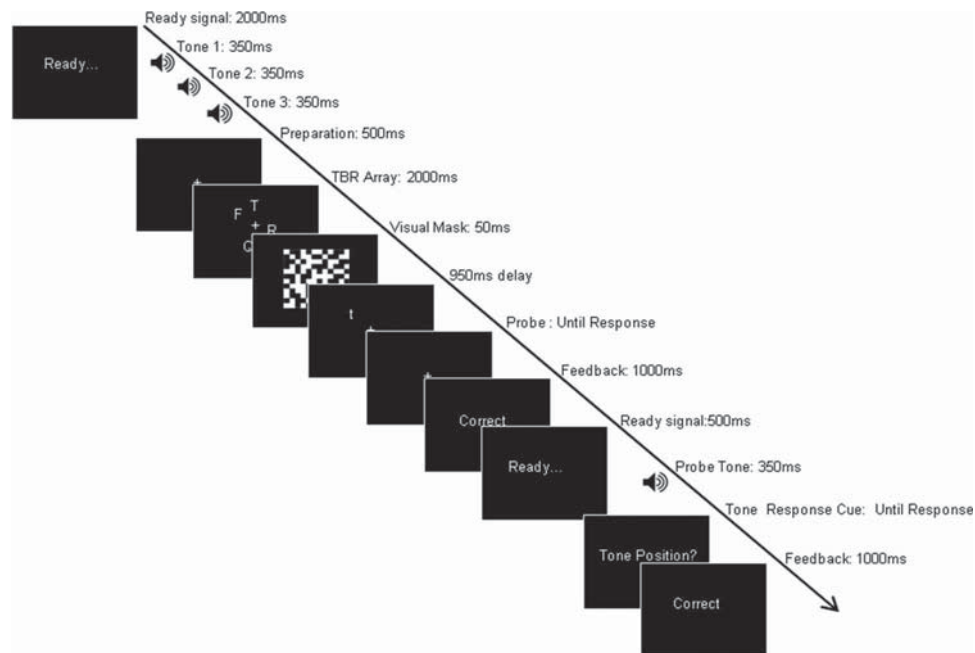


Figure 1. Schematic illustration of a single trial in the load condition. Trials in the control condition were similar except that the string of tones presented at the start of the trial, along with the tone presented at the end of the trial, were of the same pitch. Following the presentation of the probe tone a digit (between 1 and 3) appeared at the centre of the screen, and participants had to make a simple key press corresponding to the number presented. The example depicted on this figure is that of a recombined probe (both consonant and location were presented in the to-be-remembered array but not together). Probe consonants were always in lower-case form.

response in the tone task was measured were included in the analysis. In order to use meaningful performance data on the tone task, participants scoring more than 65% errors (i.e., at or below chance level) on the tone task were not subjected to statistical analyses. This resulted in the removal of data from 5 participants. Finally, 1 participant was removed from statistical analyses for

performance across the verbal-spatial task falling outside of 2 standard deviations of the mean. The percentage of errors in the load task (as a function of probe type) is presented in Table 1. The results are organized in two parts. First and foremost, we focus on the binding effect (defined as the difference in performance between intact and recombined probe conditions) as a function of memory load. We also report, for completeness, an analysis of performance on the negative probe conditions in the Appendix.

Table 1. Descriptive statistics displaying the mean accuracy for the load task as a function of probe type

<i>Probe</i>	<i>M</i>	<i>SE</i>
Intact	51.45	0.03
Recombined	53.26	0.02
Both-features-new	50.63	0.02
New-letter	51.04	0.03
New-location	50.00	0.02

Note: Mean accuracy = % incorrect. *SE* = standard error of the mean.

The effect of load on binding

Errors. The percentage of errors was subjected to a 2 (load vs. no load) \times 2 (intact vs. recombined) analysis of variance (ANOVA) for repeated measures, which indicated no significant main effect of load, $F(1, 39) = 1.10$, $MSE = 161.60$, $p = .30$, $\eta_p^2 = .03$; a significant binding effect, $F(1, 39) = 4.89$, $MSE = 296.65$, $\eta_p^2 = .11$; and no

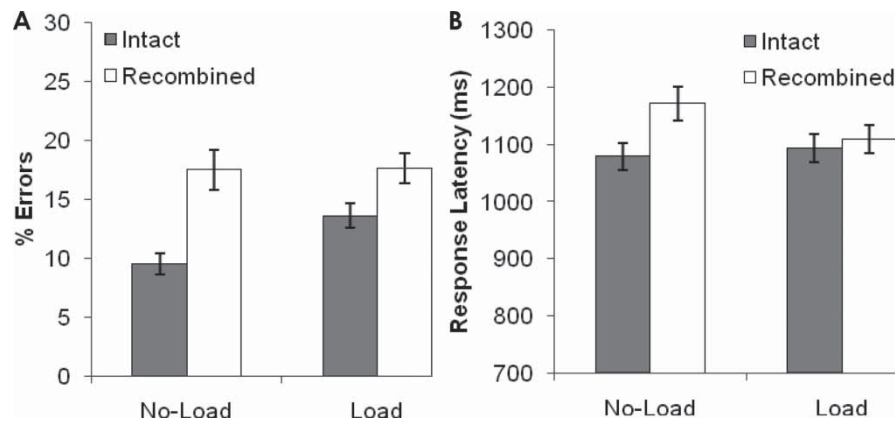


Figure 2. The effect of attentional load on binding. Mean percentage of errors (Panel A) and mean median response time (RT; Panel B) for intact and recombined probes in the control and load conditions. Error bars represent one standard error of the mean.

interaction between these factors, $F(1, 39) = 1.55$, $MSE = 100.13$, $p = .22$, $\eta_p^2 = .04$ (see Figure 2, Panel A).

Planned comparisons testing our a priori hypothesis of a reduction of binding in the presence of a load were carried out and revealed a significant binding effect in the control condition, $F(1, 39) = 5.37$, $MSE = 238.11$, $p < .05$, $\eta_p^2 = .12$; but not in the load condition, $F(1, 39) = 2.07$, $MSE = 158.67$, $p = .16$, $\eta_p^2 = .05$. The data therefore suggest a removal of binding under a memory load.

Response latencies. Intact and recombined mean median response latency measures (for correct responses only) were subjected to a 2 (load vs. no load) \times 2 (intact vs. recombined) ANOVA for repeated measures. The analysis indicated no significant main effect of load, $F(1, 39) < 1$; a significant binding effect, $F(1, 39) = 7.11$, $MSE = 16,296.56$, $p < .05$, $\eta_p^2 = .15$; and finally a significant interaction between factors, $F(1, 39) = 4.68$, $MSE = 12,922.02$, $p < .05$, $\eta_p^2 = .11$. Planned comparisons indicated a significant binding effect in the control condition,

$F(1, 39) = 10.95$, $MSE = 15,698.42$, $p < .01$, $\eta_p^2 = .22$; but not in the load condition, $F(1, 39) < 1$. The results therefore corroborate the error data in indicating a removal of binding under concurrent load (see Panel B of Figure 2).¹

Discussion

The experiment reported in this paper investigated whether verbal-spatial binding in WM involves general attentional resources. The impetus for establishing the role of attention in the binding process was twofold. Firstly, attentional resources are stipulated as critical for binding by the EB component of the working memory model (Baddeley, 2000). Secondly, indirect evidence suggests that attention may be implicated in location binding processes. For example, an imaging study investigating verbal-spatial binding (Prabhakaran et al., 2000) noted that binding to location activated right frontal regions, also implicated in central executive functioning. In addition, Elsley and Parmentier (2009) demonstrated that the binding of shapes and locations can be eradicated under

¹ In order to demonstrate the effect of binding on overall performance, the data were subjected to a 2 (load vs. no-load) \times 2 (intact vs. recombined) multivariate analysis of variance (MANOVA) for repeated measures with accuracy (% errors) and response latencies as dependent variables. The analysis indicated no significant main effect of load, $F(2, 38) < 1$; a significant binding effect, $F(2, 38) = 4.03$, $p < .05$, Wilks's lambda = .83, $\eta_p^2 = .18$; and finally a significant interaction between factors, $F(2, 38) = 3.25$, $p < .05$, Wilks's lambda = .85, $\eta_p^2 = .15$.

sufficient concurrent memory load. Until now, the contribution of attentional resources to verbal-spatial binding had not been directly assessed in a behavioural study. Using a single probe change detection task adapted from Prabhakaran et al. (2000) with a concurrent memory load (the maintenance of the pitch order of a string of three pure tones) we found that binding between letters and locations was eradicated under concurrent memory load conditions. Taken together these findings suggest that there may be a common general mechanism for binding to location, which is dependent on the availability of attentional resources.

The finding of the negative impact of a concurrent load on verbal-spatial binding stands in contrast to findings reported in the literature for object-feature binding (as opposed to location binding), which previously has been found to be immune to manipulations of general attention (e.g., Allen, Baddeley, & Hitch, 2006). Allen et al. carried out a series of experiments in order to identify conditions under which attentional resources were critical to the binding of two visual features (object-feature binding) in WM and concluded that such a binding process was not dependent on attentional resources. Their task required participants to hold in memory the colour, the shape, or both the colour and shape bindings of four stimuli presented simultaneously and to judge a single probe item accordingly. Their results indicated that participants remembered the bindings between shapes and colours at no extra cost relative to the harder of the two single features and that three concurrent tasks taxing attentional resources (counting backwards in ones, near span recall of a string of digits, and counting backwards in threes) failed to disrupt performance differentially in the binding condition and the single feature conditions. The authors concluded that the binding of colour and shape features does not draw upon attentional resources any more than the maintenance of individual visual features.

Taken together, the finding that object-feature binding is not impacted by a concurrent mental load (Allen et al., 2009) while the binding of letters to locations (the present study) and shapes

to locations (Elsley & Parmentier, 2009) is, may indicate a dissociation in processes supporting object-feature binding and location binding—while the former may occur relatively automatically (with no additional recruitment of attentional resources), the latter may not. Under the working memory model architecture (Baddeley, 2000), the distinction may reflect the need to bind across distinct specialized subsystems, with visuospatial binding involving the visuospatial sketchpad subsystem (the visual cache and the inner scribe, respectively; Logie, 1995) and verbal-spatial binding involving the phonological loop and the visuospatial sketch pad (and perhaps in that case, the EB). Under this hypothesis, attentional resources would only be mobilized when binding is implemented across the WM's slave systems. This contention is undermined by an experiment we conducted to compare the effect of a concurrent memory load on object-feature binding and location binding (Elsley & Parmentier, 2009, Experiment 2), however. Using the same paradigm as that in the present study, we compared binding for shape and locations to binding for shapes and colours and found that the concurrent retention of a string of monosyllabic words disrupted both types of binding to the same degree. This finding suggests that binding, at least in the recognition paradigm we used, recruits general attentional resources (the central executive in the working memory's framework).

One possible explanation for the difference in findings between our study and that of Allen et al. (2006) lies in the choice of concurrent task. Our concurrent memory load required pitch memory (without phonological or spatial codes) while our primary task required the maintenance of phonological and spatial codes. However, Allen et al. (2006) used concurrent tasks that required the maintenance of phonological codes. It is possible that their secondary task interfered specifically with the maintenance of their individual visual features (e.g., geometric shapes and colours), if one assumes that these features can be encoded verbally. If binding is not supported by the maintenance of a new composite representation held independently from its constituent

features (*representational* view of binding, as implied by the EB account), but relies instead on the transient associative links between independently held features (*associative* view of binding, as suggested, for example, by Ruchkin, Grafman, Cameron, & Berndt, 2003), then damaging the association between features would be of no consequence if the maintenance of one of the features has already been damaged to the point of recognition failure. In other words, if Features A and B yield the creation of a new composite representation C, then interfering with the maintenance of A or B would be of no consequence for the maintenance of C. If, however, binding simply reflects an associative link between A and B, then any damage to one of the features would affect binding. In sum, if Allen et al.'s (2006) visual features were encoded verbally, binding was associative (and not representational), and their secondary tasks interfered with the processing of their visual features, then the absence of effect of attentional manipulation that they reported may be explained. This contention remains hypothetical, however, and it is worth pointing out that the finding that articulatory suppression has little effect on performance in visuospatial tasks (e.g., Luck & Vogel, 1997) challenges it.

The associative view of binding, as opposed to the representational one prescribed by the EB, has received increasing support from recent studies reporting an asymmetrical relationship between features of an object. For example, Olson and Marshuetz (2005) found that the processing of visual features yields involuntary binding to their location. In addition, using a measure of binding based on the comparison of intact and recombined visual (shape) and spatial (location) features, Elsley and Parmentier (2007) compared conditions where participants attended either to the shape features only or to the location features only of a display comprising three irregular shapes in different locations. The findings indicated that the processing of shapes resulted in their involuntary binding to location, while the reverse was not observed. Jiang, Olson, and Chun (2000) demonstrated a similar asymmetry and asserted that visual features are bound to positions

located on a spatial configuration that is formed prior to the processing of the constituent features of that configuration (see Maybery et al., in press, for evidence of the asymmetry between phonology and location in the auditory domain).

Finally, it is possible that the discrepancy between Allen et al.'s (2006) study and ours related to the functional difference in the type of binding measured. Participants in Allen et al.'s (2006) study were explicitly instructed to bind by virtue of being required to endorse intact probes and reject recombined probes as lures, while in the present study participants were not explicitly instructed to maintain bindings. In that sense, our measure of binding may reflect a combination of automatic and controlled binding (to use broad terms) while Allen et al. put the stress on voluntary, controlled binding. Such a difference is unlikely to account for the discrepancy in findings, however. Indeed, because following this logic, one would have to conclude that a secondary task depleting general attentional resources would impair binding less when it is most probably controlled (i.e., more effortful) and more when possible automatic or implicit mechanisms are at play.

In sum, the present results suggest that the binding of visually presented verbal and spatial information can be disrupted by limiting attentional resources by way of a concurrent memory load, at least in the recognition paradigm used here.

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APPENDIX

The effect of load on negative probe performance

Errors. Negative probe error data were subjected to a 2 (load vs. no load) \times 3 (negative probe) ANOVA for repeated measures, which indicated a significant main effect of load, $F(1, 39) = 4.66$, $MSE = 181.13$, $p < .05$, $\eta_p^2 = .11$, whereby performance was superior in the control condition ($M = 87.71$, $SE = 1.42$) relative to the load condition ($M = 83.96$, $SE = 1.70$); a significant main effect of negative probe, $F(2, 78) = 27.33$, $MSE = 11,168.25$, $p < .001$, $\eta_p^2 = .41$; and no interaction between these factors, $F(2, 78) < 1$ (see Table A1).

Further analyses indicated superior performance in the both-features-new condition relative to the new-location condition, $F(1, 39) = 73.14$, $MSE = 107.36$, $p < .001$, $\eta_p^2 = .65$, and relative to the new letter condition, $F(1, 39) = 13.25$, $MSE = 92.27$, $p < .001$, $\eta_p^2 = .25$; as well as superior performance in the new-letter condition relative to the new-location condition, $F(1, 39) = 12.10$, $MSE = 237.80$, $p < .001$, $\eta_p^2 = .24$. In sum, the data show that, *ceteris paribus*, a change in consonant was more salient than a change in location, suggesting that consonants may be the dominant feature of the consonant-location pairs in this task.

Response latencies. Mean median response latencies for correct responses were subject to a 2 (load vs. no load) \times 3 (negative

Table A1. Descriptive statistics displaying the mean percentage of errors and mean median response latency measures for the negative probe conditions as a function of load

Probe	Control condition				Load condition			
	% error		Response latency (ms)		% error		Response latency (ms)	
	M	SE	M	SE	M	SE	M	SE
Both-features-new	3.85	1.10	1005.15	32.39	6.06	1.73	1039.36	38.04
New-letter	10.10	2.12	1102.29	39.21	15.44	2.82	1130.46	46.04
New-location	22.92	3.13	1210.33	58.75	26.62	2.88	1105.59	49.27

Note: SE = standard error of the mean.

probe) ANOVA for repeated measures, which indicated no significant main effect of load, $F(1, 39) < 1$; a significant main effect of negative probe, $F(2, 78) = 13.87$, $MSE = 27,873.48$, $p < .001$, $\eta_p^2 = .26$; and finally a significant interaction between factors, $F(2, 78) = 6.21$, $MSE = 19,864.03$, $p < .01$, $\eta_p^2 = .14$. No significant difference was observed between new-letter and new-location conditions, $F(1, 39) = 2.44$, $MSE = 14,192.36$, $p = .13$, $\eta_p^2 = .06$, while the both-features-new condition yielded faster responses than the new-letter condition, $F(1, 39) = 13.60$, $MSE = 13,030.73$, $p < .001$, $\eta_p^2 = .26$; and the new-location condition, $F(1, 39) = 25.25$, $MSE = 14,586.13$, $p < .001$, $\eta_p^2 = .39$.

Further analyses assessed the interaction between negative probe and load. The data indicated no significant impact of

load on the both-features-new condition, $F(1, 39) < 1$; no significant main effect of load on the new-letter condition, $F(1, 39) < 1$; but a nearly significant main effect of load in the new-location condition, $F(1, 39) = 2.86$, $MSE = 76,777.47$, $p = .09$, $\eta_p^2 = .07$. Thus, the interaction was driven by a nearly significant improvement in performance in the new-location condition under concurrent load. In sum, in the no-load condition, performance was poorest when participants had to reject an old consonant in a new location, supporting the contention that the consonants constituted the dominant feature in this task. However, under a concurrent memory load, the consonants' dominance appeared to diminish.