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Properties of Perceptual Motor After-Effects in Visuo-Spatial Tasks

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ABSTRACT

A series of experiments were conducted with the general theme and aim of exploring some of the yet to be determined properties of perceptual motor processing after-effects in visuo-spatial tasks. Using a variety paradigms, procedures and methods of analysis, numerous factors of interest were manipulated and examined to determine their implications related to how we process, store, make decisions and execute task requirements when presented with both relevant and irrelevant visuo-spatial information.

Experiment 1 investigated how distractor-generated response retrieval occurs; either via ‘inherent’ processing of high association strength links, or the application of task assignment rules (i.e., response selection determinants) for both visible and masked primes. Results indicated that visible prime distractors involved both response retrieval determinants; the inherent response being more highly activated and inhibited. Masked data also indicated that both retrieval determinants were involved, though not unequivocally.

Experiment 2 was concerned with the information storage and retrieval processing; namely, an episodic storage via indirect retrieval hypothesis was tested and supported. This experiment was unique in that it relied on a newly discovered inhibitory after-effect (Error Protection) to indicate indirect retrieval and episodic storage. It was also the first replication of this new inhibitory after-effect.

Experiment 3 aimed to determine whether relevant and irrelevant stimulus object features bind to each other and to their associated responses during perceptual processing in visuo-spatial tasks. Strong evidence of location (relevant) to response binding was observed in most cases; weak evidence of identity (irrelevant) to response binding was also observed in some instances.

Experiment 4 also examined feature binding, but in a different way. A cueing procedure allowed testing for whether the detrimental performance impact of binding violations could be modulated if the knowledge of the upcoming violation was given in advance. Although the cue information was used, data indicated that advanced knowledge of an impending violation did not reduce the violation’s latency increasing impact.

In sum, the combined findings from these Experiments extended upon previous related research, delineated some yet to be discovered properties of cognition and human information processing in the visuo-spatial field, and provided some needed first replications.

KEY WORDS: Spatial Negative Priming, Visuo-spatial Tasks, Masking, Free-choice, Object Feature/Response Binding, Episodic Storage/Retrieval, Distractor Processing Error Protection, Cueing.

CO-AUTHORSHIP

This dissertation contains material from manuscripts under review for publication (chapters 2, 3, 4 and 5). All experimental data presented were collected, analyzed and interpreted to be the original work of Ben Kajaste, co-authored by Dr. Eric Buckolz.

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LIST OF ABBREVIATIONS

Abbreviation	Long Form
1:M………..	One-to-Many (location-to-response mappings)
A…………..	Activation (related to responses)
CO…………	Control (trial)
Con………..	Congruent (response)
CR…………	Control Response
D or d……..	Distractor
D1………….	Distractor 1 (prime/matching)
DA…………	Distractor Absent
DP………....	Distractor Present
DR………....	Distractor Response (related to error protection)
DRR……….	Distractor Response Repeat (trial)
EP………….	Error Protection
ER…………	Execution Resistant/Resistance
I……………	Inhibited/Inhibition
IAE………..	Inhibitory After Effect
Incon………	Incongruent (response)
IR………….	Ignored Repetition (trial)
ISI………….	Inter-Stimulus-Interval
L1-L7……..	Location # (bar markers)
L-R………..	Location-Response (assignments)
M:1………..	Many-to-one (location-to-response mappings)
NCE……….	Negative Compatibility Effect
NP…………	Negative Priming
RSI………..	Response-Stimulus-Interval
RT…………	Reaction Time
S1-R1……..	Stimulus 1 – Response 1 (prime)
S2-R2……..	Stimulus 2 – Response 2 (probe)
S-R………..	Stimulus-Response (mapping/assignment/rule)
SNP………..	Spatial Negative Priming (effect)
SOA……….	Stimulus Onset Asynchrony
T or t……….	Target
T1………….	Target 1 (prime/matching)
T2………….	Target 2 (probe/mismatching)
TR…………	Target Repeat (trial)
TT………….	Trial Type

CHAPTER 1

Introduction & Overview

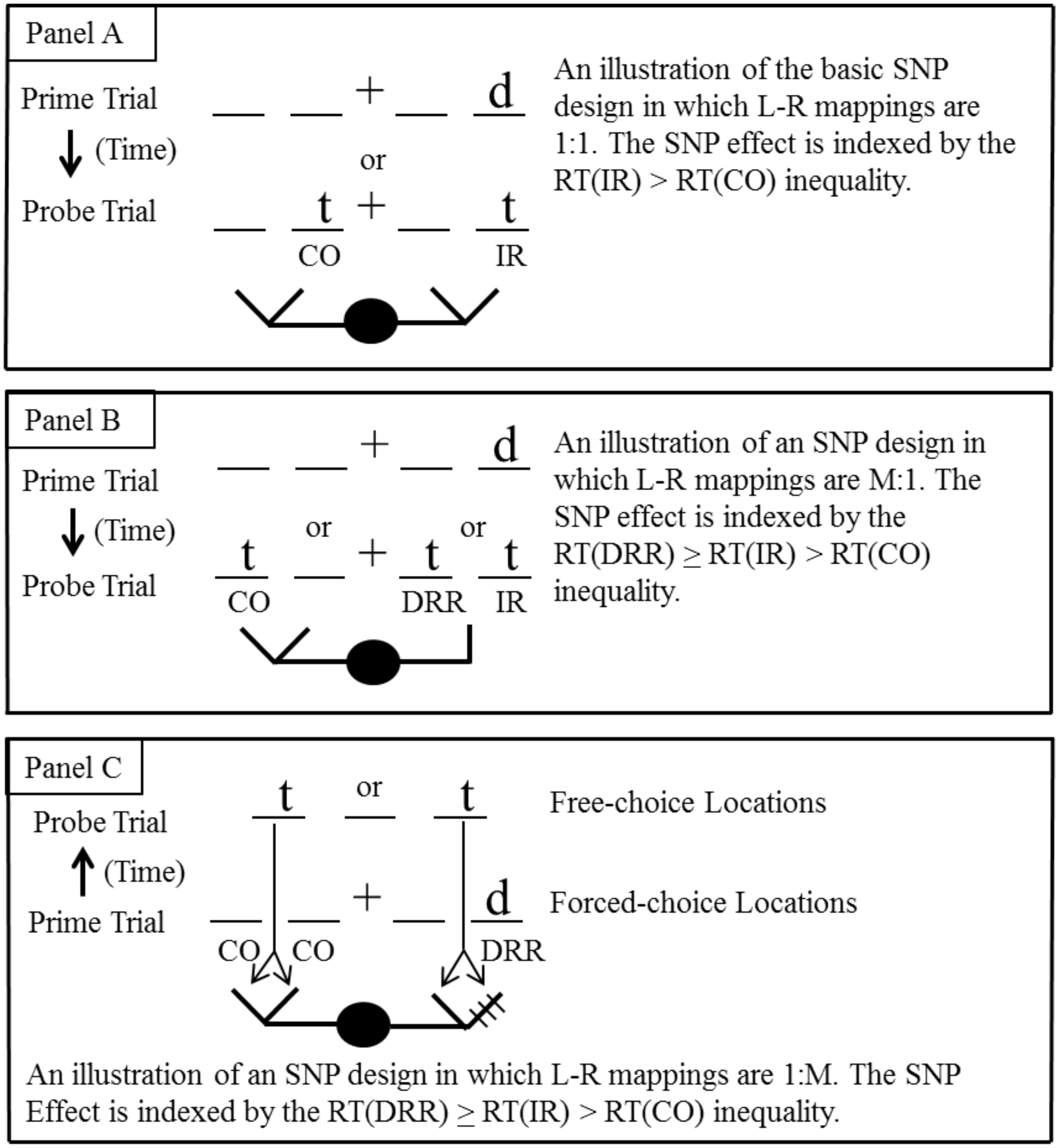
The major aim of this section is to facilitate the understanding of the four Experiments reported in this thesis through the provision of various Schemata, and by setting out in general terms the main goals pursued herein.

The fundamental procedures used in the series of Experiments reported here involved the study of sequential effects (or lack thereof), whereby earlier processing demonstrates an ability to influence current, related processing. It follows that sequential effects, evident for some time within the study of cognition (e.g., Fitts & Posner, 1967; Keele, 1972), bring memory into play, as prior processing must be stored so that it is available for retrieval and so for involvement during current processing. The examination of sequential effects is informative not only in its own right (i.e., sequential effects exist and should be expected and/or accounted for in efforts to understand human information processing) but, perhaps more importantly, because they reveal other processing characteristics (i.e., those characteristics that produce and shape their existence).

Perhaps the most studied sequential effect over the past 20 years or so has been the ‘negative priming (NP)’ phenomenon (e.g., D’Angelo, Thomson, Tipper, & Milliken, 2016; Frings, Schneider, & Fox, 2015; Neill, 2007; Tipper, 2001). Framed generally, the NP effect reflects the sequential processing impact observed when a former to-be-ignored, distractor event (prime trial) later assumes the status of being the relevant target event (probe trial). The later impacts of prime trial distractor processing are referred to as ‘inhibitory after-effects’ (e.g., Buckolz, Stoddart, Edgar, & Khan, 2014) and are observed both when the relevant target feature is its identity or its location. Because it was the lesser studied of the two, our interest here focused solely on the latter where events were delivered visually (i.e., a visuo-spatial task).

There are four distractor generated after-effects in visuo-spatial tasks (i.e., Buckolz et al., 2014), all of which will be encountered in the Experiments recounted here and of which will be highlighted in this section. The most commonly studied inhibitory after-effect in visuo-spatial tasks is the spatial negative priming (SNP) effect. An SNP effect is deemed to be present when reaction time (RT) for a target-occupied probe location is significantly longer when this location had recently contained the (prime) distractor (i.e., ignored-repetition probe trial [IR]), relative to when it had been unoccupied on the prime trial (i.e., control trial [CO]). The most basic task for demonstrating the SNP effect is set out in Schematic 1, Panel A. Modifications to this basic procedure are seen in Schematic 1, Panels B and C, where many-to-one (M:1 [forced-choice]) and one-to-many (1:M [free-choice]) location response assignments are included, respectively. These location-response mappings allow us to use the prime distractor response on the probe trial, without also using the prime distractor location (i.e., distractor response repeat [DRR] trials). In turn, the contrasting the latencies for the DRR, Control and ignored-repetition (IR) trials allows us to determine the locus of the SNP effect. Most typically, RT(DRR) = RT(IR) > RT(CO), indicating that it is the use of the prime distractor location's related response on the IR probe trial that causes the SNP phenomenon (e.g., Buckolz, Goldfarb, Khan, 2004; Fitzgeorge & Buckolz 2008; Guy, Buckolz, & Khan, 2006).

At this point, we briefly outline our preferred view as to the processing afforded distractor-occupied locations in visuo-spatial tasks, partly to illustrate some of the main



An illustration of the basic SNP design in which L-R mappings are 1:1. The SNP effect is indexed by the RT(IR) > RT(CO) inequality.

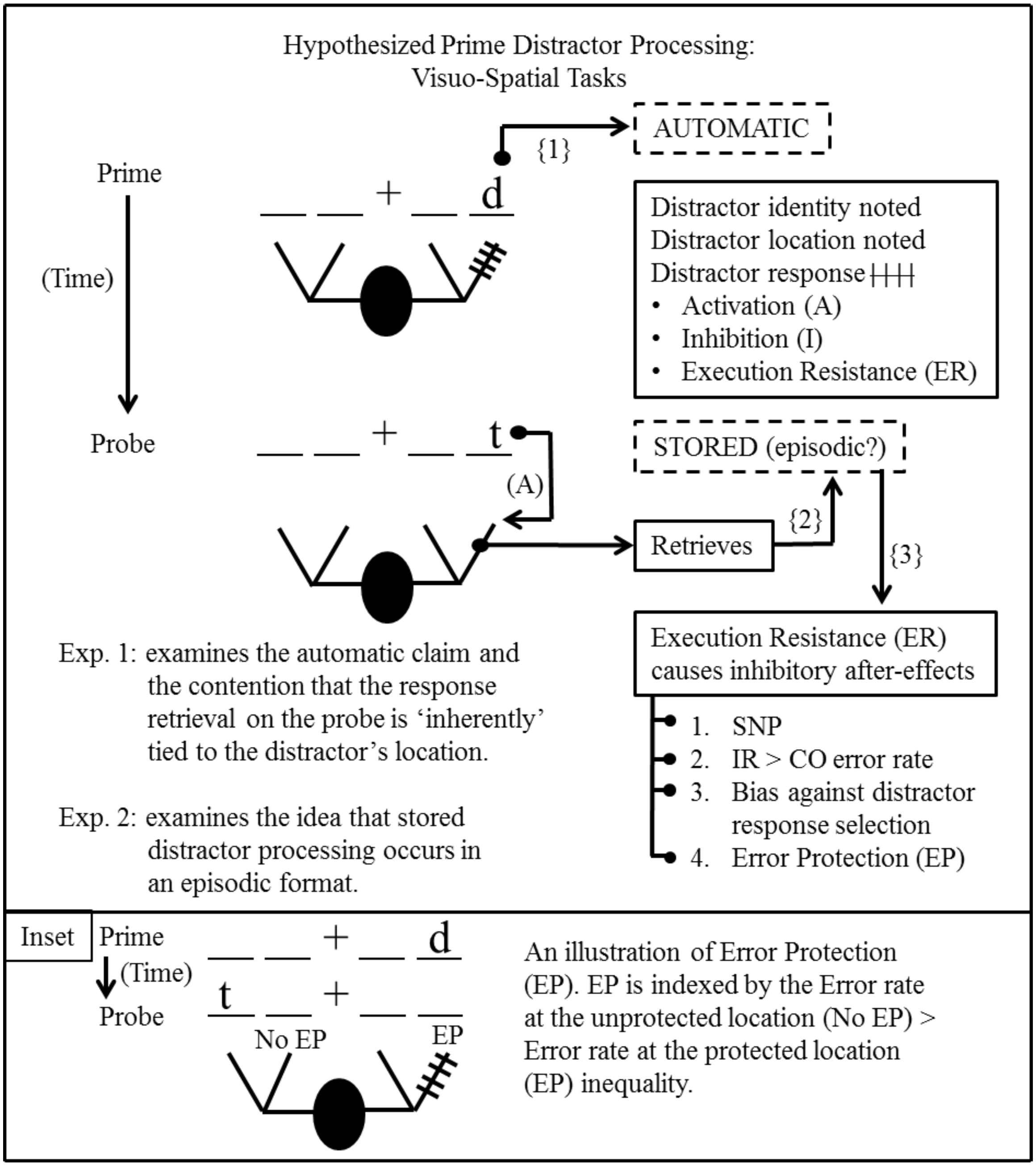
An illustration of an SNP design in which L-R mappings are M:1. The SNP effect is indexed by the RT(DRR) ≥ RT(IR) > RT(CO) inequality.

An illustration of an SNP design in which L-R mappings are 1:M. The SNP Effect is indexed by the RT(DRR) ≥ RT(IR) > RT(CO) inequality.

Schematic 1. Illustrations of various Spatial Negative Priming (SNP) paradigms. L-R = Location-to-Response Mappings; 1:1 = one-to-one (forced-choice), M:1 = many-to-one, 1:M = one-to-many (free-choice). RT = Reaction Time, d = distractor, t = target, IR = Ignored-repetition trial (probe target appears at the location formerly occupied by the prime distractor [forced-choice]), CO = Control trial (probe target appears at a location which is unrelated to prime distractor's location and/or response [free and/or forced choice]), DRR = Distractor Response Repeat trial (probe target appears at a location which causes the forced [M:1] or freely selected [1:M] re-execution of the prime distractor associated response.

aims in this dissertation (e.g., Buckolz, Stoddart, Edgar, & Khan, 2014) [see Schematic 2]. The processing of the to-be-ignored prime distractor event is done automatically, and includes the identification of the distractor's identity and its location, extending to the retrieval of the location's linked response, which then undergoes activation and subsequent inhibition. The latter causes the prime distractor location response to become 'execution resistant (ER)' for a period of time. This processing is then stored.

It is the ER feature of the prime distractor response that produces the four inhibitory after-effects observed when the prime distractor's response is involved on the probe trial. For example, on ignored-repetition trials the required use of the prime distractor response necessitates overriding its (retrieved) ER property. When successful, this overriding takes time, delaying ignored-repetition reactions and so generating the SNP phenomenon. When ER override is not successful, an error results, usually causing more experiment-wise errors on ignored-repetition than on control trials. Thirdly, on free-choice probe trials (Schematic 1, Panel C), when subjects freely select the prime distractor response, it similarly comes with an elevated reaction time due to ER. Additionally, the prime distractor response is chosen significantly less often than the control response, again, owing to the repelling impact of ER related to the former output. The fourth inhibitory after-effect is that of error protection (EP). When the probe target does not appear at the prime distractor's location, and an error is made, control responses are used significantly more often than former prime distractor responses (Schematic 2, inset). Presumably, the ER aspect of the prime distractor response protects it against erroneous use.



Schematic 2. Illustrations of hypothesized prime distractor processing and error protection in visuo-spatial tasks. SNP = Spatial Negative Priming, IR = Ignored Repetition (trial), CO = Control (trial), d = distractor, t =target.

Turning now to the research reported in this exposition, the first two Experiments dealt with some residual uncertainty associated with our foregoing account of prime distractor processing.

Experiment 1: there is little disagreement that the prime distractor-occupied location causes response retrieval; what was unclear was the rule utilized to determine which response is retrieved. The lack of clarity here arises because a location can, theoretically, have two different attached responses. One has been deemed ‘inherent’ (O’Connor & Neill, 2010), and exists either because of extensive practice and/or because of genetic endowment, while the other arises due to the location-response (L-R) assignments employed in the task. Because the prime distractor event was held to be automatically processed, and because L-R mappings do not technically apply to the prime distractor, the assumption has been that it is the ‘inherent’ response that is retrieved. O’Connor and Neill showed this was not true for masked (phenomenally invisible) prime distractors in an identity rather than location task. Experiment 1 aimed to determine which of the retrieval rules (‘inherent’ vs. ‘S-R’) is utilized in visuo-spatial tasks, for both visible and phenomenally invisible tasks. It turns out that both are used, and so prior models of prime distractor processing for visuo-spatial tasks, such as our own, must be modified on this account.

Experiment 2: the claim that prime distractor processing is stored brought with it the question as to its storage format (Schematic 2). Specifically, we tested the possibility that visually processed items are stored ‘episodically’. The fundamental notion of episodic storage is that as processing proceeds, both relevant (targets) and irrelevant (distractors) aspects of a visual display temporarily bind and so are stored together. The existence of episodic storage predicts that we should be able to ‘indirectly’ retrieve prime distractor processing by stimulating the retrieval of the prime target processing only (on the probe). The major aim of Experiment 2 tested this possibility. To do this, it was necessary to use the ‘error protection’ rather than the traditional SNP effect to track instances of prime distractor retrieval/processing. This afforded the opportunity to provide the first replication of error protection existence as an inhibitory after-effect (Buckolz, Stoddart, Edgar, & Khan, 2014) [Schematic 2, Inset].

Finally, the procedure in Experiment 2 enabled us to resolve another aspect of uncertainty related to prime distractor processing. Specifically, we could determine whether prime distractor processing could be retrieved ‘directly’ when the prime and probe distractor identities matched, independent of whether the distractor object reassumed its prime location or not.

All three of the issues addressed were responded to in the affirmative.

Experiment 3: Experiments 3 and 4 departed from the first two Experiments reported in this thesis in that they examined after-effects produced by prime trial targets rather than prime trial distractors, in order examine the notion of ‘binding’ in visuo-spatial tasks. The concept of binding emanated from the view that the perceptual analysis of visual objects involved the independent identification of its identity features (i.e., colour, shape, size, orientation etc.), which then had to re-integrated (bound) to form a representation of the object, which could then be recognized. The re-assembled object identity features were deemed to be stored as ‘object files’ (Hommel, 2007). Indications were that in visuo-identity tasks, non-identity object features, such as the object’s location and/or its assigned response, could also bind with each other and/or with the identity object features during processing. When this occurred, the stored processing was labeled as an ‘event’ file.

With Experiment 3, we examined whether the prime target’s response did bind with the relevant (i.e., location) and/or irrelevant (i.e., shape) features of the prime target during their processing, using a visuo-spatial negative priming task. The use of both forced-choice and free-choice prime and probe trials (Schematic 1) allowed us to determine whether self-selected and imposed responses exhibited binding in a similar way. Free-choice trials were further separated into within-hand versus between-hand finger response competitions, since these two have exhibited different SNP results in the past, to see whether either of these would be the more ideal to use when looking for response binding.

In terms of some of the main findings produced by Experiment 3, freely selected but not imposed prime responses exhibited binding with the prime target’s location, but virtually not at all to the prime target object’s identity (irrelevant). This was revealed for the within-hand and between-hand free-choice probe trials. The forced-choice probe trials revealed virtually no evidence of response binding. These findings are perhaps the first demonstration of target responses binding to the target’s location in visuo-spatial tasks, and provide some direction as to the procedures that should be employed within future work examining response binding in location tasks.

Experiment 4: this Experiment was genuinely exploratory in nature because its procedure was largely based on speculation. The issue addressed arose from the fact that it is difficult to detect the presence of binding by contrasting the reaction times of those instances held to be free of binding violations with those where binding violations have been procedurally induced. Binding violations are set aside with a time cost and so are associated with comparatively longer reaction times. The problem is that binding violations occur when part of the prime trial is repeated, and so reaction time can be reduced on this account, a reduction which would oppose reaction time slowing resulting from resolving the binding violation. The net latency effect of these opposing forces is unknown and so makes conclusions regarding binding risky (this was why Experiment 3 used free-choice probe trials so that we could rely on response selection frequencies as a means of measuring binding presence).

With Experiment 4, we used a different procedure from those in the past whereby reaction time results might be used to detect binding. Basically, using a visuo-spatial negative priming format, we included a pre-cue that validly forecast an upcoming response-location binding violation on some probe trials. Our conjecture was that if response-location binding exists, and if the delays caused by this violation can be set aside when the binding is validly cued, the reaction time difference between violation-free and actual violation trials should be reduced when the pre-cue is provided, relative to when it is not. This did not occur. If we assume based upon Experiment 3 that response-location binding occurs in visuo-spatial tasks, the current result indicates that the delays caused by this binding cannot be offset when the individual knows that the violation is imminent.

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CHAPTER 2

Distractor-occupied Prime Locations Retrieve Inherently-related and Task-assigned Responses in Visuo-spatial Tasks

Introduction

The fundamental interest of this investigation was to further examine the processing associated with to-be-ignored (irrelevant) distractor events, particularly for visuo-spatial tasks where the target's location is its relevant feature. Because distractor events are processed in spite of intentions/instruction not to do so (see D'Angelo, Thomson, Tipper, & Milliken, 2016; Frings, Schneider, & Fox, 2015 for recent reviews), and because they are processed even when they are rendered phenomenally invisible by successful masking, distractor processing is held to be automatic (e.g., Eimer & Schlaghecken, 1998; Eriksen , Coles, Morris, & O'Hara, 1985; Fitzgeorge, Buckolz, & Khan, 2011; Klapp & Hinckley, 2002; Schlaghecken, Rowley, Sembi, Simmons, & Whitcomb, 2007). Furthermore, based upon EEG and EMG recordings, (Coles, Gratton, Bashore, Eriksen, & Donchin, 1985; Eriksen et al.1985; de Jonge, Liang, & Lauber, 1994; Valle-Inclan & Redondo, 1998) and some behavioral data with visuo-spatial tasks (e.g., Buckolz, Goldfarb, & Khan, 2004; Buckolz, Edgar, et al., 2012; Buckolz, Lok, et al., 2015; Fitzgeorge, Buckolz, & Khan, 2011; Guy, Buckolz & Khan, 2006), this automatic distractor processing can extend to the retrieval of any stored response to which it has become related. The more specific question addressed here is, what governs the response(s) retrieved by a distractor event in visuo-spatial tasks (i.e., what are the 'response retrieval determinants' for distractors)?

O’Connor and Neill (2010) considered two retrieval alternatives that will be examined in this report as well. One was deemed to be the result of ‘inherent’ processing, whereby the distractor event has a strong association with a particular response and so automatically retrieves it upon its presentation (i.e., a high level of distractor-response compatibility degree). The second alternative put forward by O’Connor and Neill was that distractor events invoke the application of the task-assigned stimulus-response (S-R) mappings. Hence, the response retrieved by the distractor was the one that would have been appropriate had the distractor event been a relevant target stimulus (hereafter referred to as, ‘S-R rule-based’ retrieval). O’Connor and Neill set out to determine which of these two ‘response retrieval determinants’ was functional, choosing a negative compatibility effect (NCE) design to do so, which restricted their examination of response retrieval determinants to masked distractors only.

The Negative Compatibility Effect (NCE) and its Basic Task Design

Using a visuo-identity arrow classification task which they largely popularized, Schlaghecken, Eimer and colleagues (Eimer & Schlaghecken, 1998, 2002; Schlaghecken & Eimer, 2004; Schlaghecken, Rowley, Sembi, Simmons, & Whitcomb, 2007), along with some other researchers (e.g., Klapp & Hinckley, 2002; Sumner, 2007), generated a phenomenon that was labeled the ‘negative compatibility effect (NCE)’. In the seminal NCE task design, trials were presented in sequential pairs; first the ‘prime’ and then the ‘probe’, with double arrow (<< or >>) heads serving as either a distractor event (prime) or an imperative stimulus (probe). Arrow events were delivered at the center of a screen display, pointing to the left or to the right (<< or >>). Prime trial arrow presentations did not require a response; rather they were briefly presented (16 msec. or so) and were then masked, either immediately after prime arrow offset, or after a small acceptable delay (<33 msec. or so). The mask consisted of superimposing a pair of overlapping double arrow heads on the original prime display for about 100 msec. The probe trial then followed the prime trial by various delays (i.e., stimulus onset asynchrony [SOA]) and contained either a single arrow head (<< or >>; forced-choice probe trial) [e.g., Schlaghecken, Klapp, & Maylor, 2009] or a double arrow head pointing in opposite directions (<<>>: free-choice probe trial) [e.g., Klapp & Hinkley, 2002; Schlaghecken & Eimer, 2004]. Probe trial events were not masked.

The forced-choice probe trials stipulated a single required response. The stimulus-response assignments for the probe trials were deemed to be spatially compatible; right pointing arrows required a finger response positioned on a keyboard button to the right of midline, and vice versa. With the free-choice probe trials, either manual response was permissible and subjects could freely select between them.

The results usually reported with the compatible S-R mappings and forced-choice probe trials were that probe RT was significantly shorter when the prime-probe arrows pointed in the same direction compared to when they pointed in opposite directions. This held as long as the SOA duration was comparatively short; however, this latency pattern was reversed when the SOA duration was sufficiently lengthened, revealing the negative compatibility effect (NCE). Analogously, this RT configuration was also evident with free-choice probe trials. When subjects freely chose the probe response pointed to by the prime arrow, RT was faster and then slower as the SOA duration went from shorter to longer, respectively (NCE). Additionally, at the longer SOA, there was a significant bias against choosing the response pointed to by the prime arrow.

Ultimately, a competitive explanation for the NCE phenomenon relied solely upon the involvement of ‘inherent’ response retrieval (Schlaghecken et al, 2007). Masked prime distractor arrows were deemed to automatically retrieve their highly associated, spatially compatible responses which, after a short period of activation, subsequently underwent automatic (mask-induced) self-inhibition. When the SOA was sufficiently long to allow the activation-inhibition sequence to be completed, which was then stored, the forced or freely chosen use of the prime retrieved response on the probe trial was delayed, due to the time needed to set aside a persistent after-effect tied to prime response (self) inhibition. This same prime response inhibition persistence feature would cause its selection to be avoided on free-choice trials, and so would account for the observed bias against its probe selection (e.g., Schlaghecken & Eimer, 2004).

O’Connor and Neill (2010) challenged this NCE explanation, noting that the foregoing result pattern could also have resulted if the response retrieved by the masked prime distractor had been achieved by implementing the task ‘S-R assignment rule’, since this response, and the one retrieved via inherent processing, would be the same with compatible S-R mappings. Hence, identifying which response had been retrieved on the probe would not allow one to discern which response retrieval determinant was responsible for its retrieval. Accordingly, O’Connor and Neill undertook an experiment to disentangle the ‘S-R rule-based’ and the ‘inherent processing’ response retrieval determinants possibly associated with (masked) distractor processing (utilizing an NCE design).

O'Connor and Neill Experiment (2010)

O'Connor and Neill (2010) reasoned that it would be possible to disentangle the two, distractor-related response retrieval determinants by including an S-R assignment rule condition that involved incompatible (arrow-response) mappings with an NCE design (e.g., >> arrows, use left-hand finger press). With the incompatible S-R mapping, the two response retrieval determinants will retrieve different responses; inherent processing will retrieve its highly associated response, while application of the S-R assignment rule will retrieve the incompatible (newly assigned) response. The procedure then is to first identify which prime response had been retrieved, and then to work backwards to isolate which of the two response retrieval determinants would had to have been active in order for the response retrieved to have occurred.

Recall that completing the first step in the process (retrieved response identification) rests upon the assumption that the retrieved output would be been activated to the extent that it would subsequently undergo inhibition (e.g., Schlaghecken et al., 2007), which would then render this response resistant to future execution for a finite period of time. Consequently, when the response actually retrieved by the prime distractor event is later utilized on the probe trial (imposed use, or freely chosen) [longer SOAs], it can be identified in that it will have a comparatively slower RT (i.e., time is needed to override its execution resistant property) and/or, in the case of free-choice probe trials, it may also be associated with a bias against its selection, again owing to its execution resistant feature (Fitzgeorge et al., 2011). The probe response exhibiting these characteristics is the response deemed to have been retrieved by the distractor on the prime trial. This identified response will then reveal which of the two retrieval determinants was responsible for its retrieval.

We interject here to stipulate two caveats when identifying a prime retrieved response in the foregoing manner: (1) it does not exclude the possibility that multiple responses were retrieved by the prime distractor, with one dominating in the sense that it is more highly activated and inhibited than the others (e.g., by way of a preview, RT differentials may point to one response while the response selection frequencies may point to multiple retrievals on free-choice trials) , and, (2) either the RT or the response selection preference dependent variable can identify a retrieved response on free-choice probe trials.

In brief, O'Connor and Neill (2010) used a basic NCE task with masked (no response) prime trials and non-masked probe trials that were either of the forced-choice or free-choice trial type. Their prime-probe SOA durations were either 27 msec. (short) or 240 msec. (long) and they used S-R assignment rules that involved either compatible or incompatible (i.e., arrow points right, left response required) mappings. With respect to terminology, prime distractor retrieved responses for incompatible mapping conditions that were consistent with the S-R mapping rule in effect were deemed to be 'congruent'(Con); otherwise, they were defined as 'incongruent' (Incon [inherent processing]). So, to be clear, congruent and incongruent response labels are established by the prime distractor location/processing. For forced-choice compatible mapping conditions, prime distractor retrieved responses were termed Ignored-repetition trials (IR); the alternate response on the same side of fixation being a Control (CO) trial. With respect to Free-choice compatible mapping conditions, prime distractor retrieved responses were deemed Distractor Response Repeat trials (DRR), with the alternate response on the same side of fixation also being a Control (CO) trial. These terms were used in the compatible mapping conditions because they are analogous to the traditional SNP terms (i.e., Fitzgeorge et al., 2011) and procedures, also in order to differentiate between compatible and incompatible mappings conditions.

The most critical claim made by O'Connor and Neill (2010), related to our current interests, was based upon data from incompatible S-R mapping condition at the longer SOA, involving free-choice probe trials. Because the 'congruent' response produced the numerically slower RT and the lower selection rate, O'Connor and Neill concluded that masked distractor primes retrieved their related responses by applying the task's S-R mapping rule, and not through inherent distractor processing as earlier proposed by some in explaining the NCE phenomenon (e.g., Schlaghecken et al., 2007). This conclusion has several potential implications of note.

First, if correct, the conclusion would dictate a revision to the account of how masked distractors are processed regarding response retrieval (i.e., excludes inherent retrieval) and, by inference, would necessitate a modification to the explanation for the NCE itself.

Second, this conclusion should be viewed with a little caution. One reason for this is that the free-choice selection frequency and RT results (i.e., incompatible mappings, 240 msec. SOA), used in part by O'Connor and Neill (2010) to justify the 'S-R rule-based' contention, were significant only when using a more lenient ANOVA *p-value* of 0.1 (but see the accompanying forced-choice data).

The other reason for a little skepticism concerning the view that (masked) distractor events retrieve responses ‘solely’ on the basis of S-R assignment rules is more theoretical in nature (O’Connor & Neill, 2010), and actually feeds into the aims developed for the present investigation. The argument begins with recognizing that the tasks used and the data acquired by O’Connor and Neill do not to rule out the possibility that masked prime distractors also retrieve their inherent responses, even though such responses may be processed differently than the S-R rule-based responses so that they do not influence probe performance (e.g., inherently retrieved responses may be less activated and so less inhibited, or they may be set aside by S-R association rules; see Henson, Eckstein, Waszak, Frings, & Horner [2014] regarding the latter option).

Continuing with the skepticism theme, the claim that distractors retrieve responses exclusively on the basis of S-R rule-based assignments would mean either that automatic inherent processing of distractors does not occur, or that this processing does happen at times, but can be prevented during the application of low compatible S-R mappings in this particular instance. Concern arises because these options appear to be out of step with some prior reports, albeit these reports that dealt with the processing of non-masked, visually evident distractors.

For example, in a visuo-identity Simon task (Simon, 1969) where a target’s spatial information is irrelevant, RT for incompatible ‘spatial-response’ mappings is significantly longer than the RT for compatible spatial assignments (i.e., the Simon effect). The latency slowing on the incompatible trials (e.g., target on left side, response on right side, of midline) has been attributed to the ‘inherent’ processing associated with the irrelevant spatial location of the target, which retrieves its spatially compatible (inherent) response (Buckolz, Mandich, & Polatjko, 2002; DeJong, Liang, & Lauber, 1994; Proctor, Lu, & van Zandt, 1992; Valle-Inclan & Redondo, 1998). This response then interferes with (i.e., delays) the correct response. There are two related points here with the Simon task. One is that there were no task S-R assignments that would have caused the retrieval of the location-related responses; leaving inherent response retrieval to accomplish this. The other point is that the ‘inherent’ location processing leading to the retrieval of its spatially compatible response was not set aside in Simon tasks under competition from low compatible S-R assignments.

So, to this point, there are indications with identity-based tasks that distractors retrieve responses based upon an application of the task S-R assignment rules when they are masked (i.e., phenomenally invisible; O’Connell & Neill, 2010), but that this changes to distractors retrieving responses to which they are inherently attached when the distractors are visible. Our interests here center on location-based tasks. Accordingly, the question that arises from all of this is whether task S-R mapping rules (compatible or incompatible S-R assignments) or inherent processing, or both, control response retrieval for non-masked visible distractor events in location tasks (the study of masked prime distractors is of a lesser interest here). Examining this question served as the main aim of the current investigation. To do this, we selected a procedure typically employed to produce the spatial negative priming (SNP) effect (e.g., Fitzgeorge, Buckolz, & Khan, 2011).

The Spatial Negative Priming (SNP) Task

With the SNP design of interest here, trials are presented in sequential pairs; first the ‘prime’, and then the ‘probe’. Target and/or distractor events arise at centrally positioned locations on the prime and probe trials, and subjects are required to respond with the manual response linked to the location occupied by the target, should one appear. Typically, the location-response (L-R) assignments have been spatially compatible. With forced-choice probe trials (1:1 location-response assignments), RTs are significantly longer when the probe target appears at the location that held the prime distractor (i.e., ignored-repetition trial [IR]) than when it arises at an unoccupied prime location (i.e., control trial [CO]). This RT(IR) > RT(CO) latency inequality is one index of the SNP effect (e.g., Buckolz, Boulougouris, & Khan, 2002; Neill, Terry, & Valdes, 1994).

One view is that the SNP effect is due to the use of the prime distractor location's related response (i.e., response locus) on the probe trial. This much is indicated by the fact that when the prime distractor's output, but not its location, is used on the probe trial, whether it is imposed (forced-choice, 2:1 location-to-response assignments trials) [Buckolz, Edgar, Kajaste, Lok, & Khan, 2012; Guy, Buckolz, & Khan, 2006] or is self-selected (free-choice trials) [Buckolz, Lok, Kajaste, Edgar, & Khan, 2015; Fitzgeorge et al., 2011], an SNP effect, nonetheless, emerges. Going along with this SNP response locus account was the assumption that the visible prime distractor location's related response was 'inherently' retrieved, activated (e.g., Buckolz et al., 2012; Fitzgeorge et al., 2011; Guy et al., 2006), and then subsequently inhibited, and, as a result, became resistant to future execution. This prime distractor event processing was then stored. When retrieved on the probe for use, the execution resistance feature of the now required prime distractor response then slowed its forced or freely-selected probe trial use, and created the observed response bias against itself selection on free-choice trials (e.g., Fitzgeorge et al., 2011).

In any event, the assumption that prime distractor locations induce inherent processing as the means by which their related responses are retrieved will have to be repudiated if the results of O'Connor and Neill (2010) are replicated here for visible distractors in a spatial task.

Current Study Aims

To recapitulate, our main aims here were to determine whether distractor processing and the responses they retrieve are guided by the task S-R assignment rules or by inherent processing in visuo-spatial tasks, or both, and to learn if the answer depends upon whether the distractor event is visible or is phenomenally invisible. To do this, we employed an SNP design similar to one used by Fitzgeorge et al. (2011) that included six possible event locations; four designated forced-choice and two free-choice (probe trial only) experiences (see Schematic 1). Prime trials were masked or non-masked (between-subjects), and the location-response assignments for the forced-choice designated locations were spatially compatible or incompatible (within-subjects).

Our most pressing interest was to see whether the retrieved response for visible prime distractors, identified by free-choice probe trials for the incompatible location-response mappings, pointed to inherent processing (as earlier presumed) or to S-R rule application (or both) as the basis for retrieval. On the lesser issue of replication, we will be able to see if masked prime distractors in location tasks are processed (Fitzgeorge et al., 2011), and whether the processing of such distractors solely incorporate S-R assignment rules as the basis for response retrieval (O'Connor & Neill, 2010).

There is a final theoretical point of importance, which is that the interpretation given by O'Connor and Neill (2010) to their findings rested upon the assumption that only one of the two response retrieval alternatives (i.e., inherent processing and S-R assignment rule application) functions at a time. The caution we have at this time is that this assumption may not hold for visuo-spatial tasks; it is conceivable that a forced-choice distractor location in this study can simultaneously initiate multiple response retrieval mechanisms, via inherent processing, and by implementing the S-R assignment rule. Theoretically, both of these responses would be activated and then inhibited. This could occur to equal, or to unequal, levels for the retrieved congruent and incongruent responses. If equally processed, congruent and incongruent responses would exhibit comparable relative RT and selection frequency values on free-choice probe trials. Unequal processing would see either the S-R rule-based output, or the inherent response, show evidence of distractor-induced retrieval, possibly the case with O'Connor and Neill,

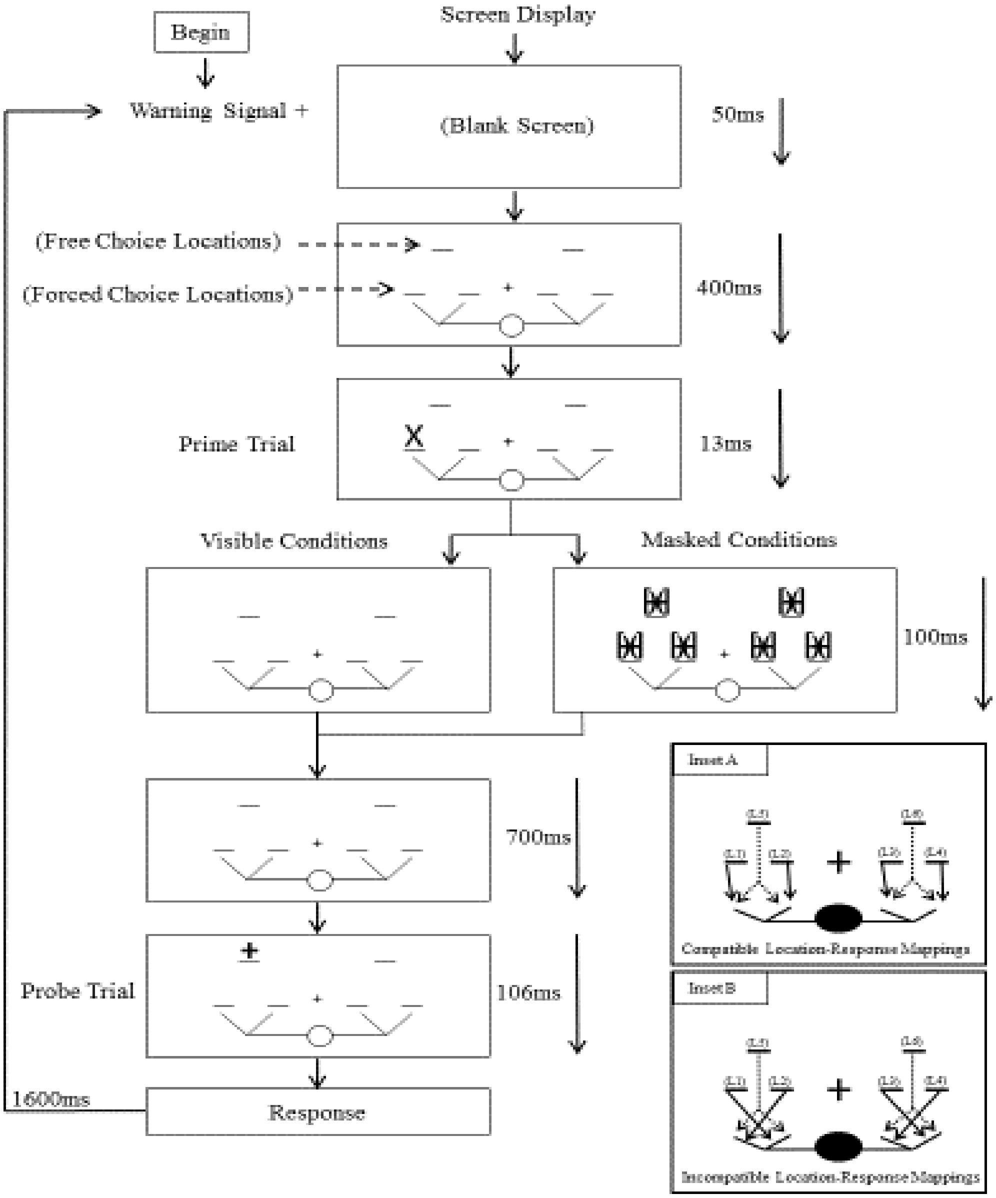
METHOD

Participants

Eighteen undergraduate students (12 males, 6 females), from the faculty of Health Sciences at Western University participated in this study. The age range of participants was 20-25 years and all reported normal or corrected to normal vision. Participants were unaware of the purpose of the study.

Apparatus

Participants were seated at a desk in a dimly lit room 200cm from a 61cm (24 inch) computer monitor which contained the visual display for the experiment. On each trial, the display was presented on a black background. The display consisted of a white fixation cross in the center of the screen measuring 0.5cm in length and 0.1cm in thickness for both its horizontal and vertical components. The cross was flanked by two white (forced-choice) horizontal location markers on each side (denoted L1-L4 from left to right) which had the same dimensions as the horizontal component of the fixation cross. The distance between the bar markers was 0.5cm as was the distance between the bar markers and the fixation cross which yielded a horizontal distance of 4.5cm and a horizontal visual angle of approximately 1.3 degrees. There were also two (free-choice) horizontal location bar markers positioned 1.5cm directly above and in between the forced-choice location markers on either side of the fixation cross. These free-choice location markers (denoted L5 and L6) served as within-hand finger response competitions and had the same dimensions as the forced-choice location markers except that they were yellow in colour. The vertical visual angle of this paradigm was approximately 0.5 degrees. To respond to the appearance of a target stimulus, participants sat in a chair at a desk with a standard computer keyboard affixed to it. Their forearms rested comfortably on the desktop with their middle and index fingers of each hand resting on the keyboard buttons “D”, “V”, “M” and “L” respectively. These keys were assigned to their spatially compatible forced-choice and free-choice bar marker locations. Forced-choice mappings were as follows: L1 = D, L2 = V, L3 = M and L4 = L; whereas free-choice mappings were: L5 = D or V and L6 = M or L (see Schematic 1, Inset A). When a target appeared at locations L1-L4 only the appropriate forced-choice response was accepted. When a target appeared at locations L5 or L6, participants were free to choose either of the two equally permissible associated responses. The prime distractor was always a bright green ‘X’ measuring 1cm in height by 0.5cm in width by 0.1cm in



Schematic 1. An illustration of a distractor-only prime to target-only probe trial sequence and presentation durations used in this experiment. Prime distractors were always a green X and could appear at any forced-choice location. Probe targets were always a green + (cross) and appeared equally often at all possible locations (free and forced choice locations). In the masked conditions, the mask was a unique green hashed image comprised of overlapping vertical, horizontal and diagonal lines. Inset A: a diagram depicting the compatible location-response mapping conditions used in this experiment. Inset B: a diagram depicting the incompatible location-response mapping conditions used in this experiment.

thickness and appeared equally often at all four of the forced-choice locations during an experimental session, but never at the free-choice locations. The probe target was always a bright green ‘+’ (plus symbol or cross) measuring 0.5cm in height by 0.5cm in width by 0.2cm in thickness which appeared at a forced-choice location 50% of the time and at free-choice location 50% of the time during an experimental session. When the probe target appeared at a forced-choice location, it did so equally often amongst the four forced-choice locations (L1-L4) during an experimental session. When the probe target appeared at a free-choice location it did so equally often between the two free-choice locations (L5 & L6) during an experimental session. For the masked conditions, the mask was a unique bright green hashed image comprised of overlapping vertical, horizontal and diagonal lines. It measured 1.1cm in height by 0.7cm in width and appeared simultaneously at each of the six locations in the paradigm during the masked conditions.

Procedure (pre-experimental)

A group of twelve participants (all different from those that undertook the main experimental sessions) undertook a pilot session designed to test the effectiveness of the masking procedure in maintaining the phenomenal invisibility of masked prime events.

The pilot session used single item trials and variable mask delays (0ms [80 trials] & 100ms [80 trials]) which were randomized within a session. Participants were instructed to respond as quickly and accurately as possible (using the same spatially compatible location-response mappings described above), while keeping errors minimal, any time they saw a green ‘X’ appear (dimensions described above, this was the same symbol that would later be used as the prime distractor in the experimental sessions). Trials commenced with a 50ms warning tone whose offset was followed by the appearance of the experimental display paradigm (described above) which remained on the screen for the duration of each trial. The target ‘X’ appeared 400ms after the onset of the paradigm and was displayed for 13ms. Following the offset of the ‘X’, one of two possibilities could occur. The first possibility (which occurred 50% of the time, randomly) was that the mask (described above) appeared for 100ms at all locations and then disappeared leaving only the empty paradigm until either a response was made or 1000ms had elapsed. The second possibility (which occurred the other 50% of the time, randomly) was that the empty paradigm remained on the screen for 100ms followed by the mask which appeared for 100ms and then disappeared leaving only the empty paradigm until either a response was made or 1000ms had elapsed at which point the paradigm disappeared and a 1600ms inter-trial interval was initiated, the offset which coincided with the onset of the next warning tone and commencement of the next trial. The target ‘X’ appeared equally often at each of the four, forced-choice location markers during the 160 (randomized) trial session. Participants were offered a break after 40 trials and could resume the session at their own discretion by pressing the space bar. Participants completed 10 practice trials prior to beginning the pilot session and had the opportunity to ask any questions to ensure the task requirements were understood.

Any trials that included button press errors, anticipations (reaction times less than 100ms) or insufficient vigilance (reaction times greater than 1000ms) were discarded and excluded from reaction time and response selection data analyses.

Procedure (experimental)

Participants (*n*=18) were randomly divided into two equal groups, one group received the visible experimental conditions, the other received the masked experimental conditions. Each experimental condition consisted of two sub-conditions; compatible location-response mappings and incompatible location-response mappings. Participants in each group (Visible & Masked) completed two experimental sessions in order beginning with the compatible location-response mappings sub-condition, then moving to the incompatible location-response mappings sub-condition. Each session took approximately 30 minutes to complete, no two sessions were completed on the same day and no more than two days elapsed between sessions. Each session consisted of 320 distractor-only primes → target-only probe trial pairs. Participants were automatically offered a break after every 32 trial pairs (e.g., 1 Block) and could resume the session at their own discretion by pressing the space bar. The prime distractor appeared equally often at all four forced-choice locations over the 320 trial pairs. The probe target could either appear at a forced choice location (50%) or at a free-choice location (50%), and appeared equally often at each possible location within each 50%. This resulted in 160 forced-choice probe trials of which 40 had the probe target appear at the former prime distractor location, and 40 of which had the probe target appear on the same side of fixation as the prime distractor but at the location that was unoccupied on the prime. The remaining 80 forced-choice trials were probes that appeared on the opposite side of fixation relative to the prime distractor occupied location and were of no current theoretical interest.

There were also 160 free-choice probe trials, 80 of which occurred on the same side of fixation as the prime distractor occupied location. The remaining 80 free-choice probe trials, which occurred on the other side of fixation relative to the prime distractor occupied location, were of no current theoretical interest.

Participants were instructed to respond as quickly and accurately as possible with the appropriate keypress (according to which location-response mapping condition they were in; compatible/incompatible) to all target events (‘+’) while keeping errors to a minimum and ignoring any distractor events (‘X’). In the case of a free-choice target event, participants were instructed to choose one of the two permissible responses, both being equally correct. Before beginning each experimental session, participants completed 10 practice trial pairs (per condition) and had the opportunity to ask any questions to ensure their understanding of the task requirements.

Any prime-probe trial pairs that included button press errors, anticipations (reaction times less than 100ms) or insufficient vigilance (reaction times greater than 1000ms) were discarded and excluded from reaction time and response selection data analyses.

Visible, Compatible

Trials were presented in pairs, first the prime, then the probe. All trials began with a blank (black) screen and a warning tone (50ms) whose offset was followed by the appearance of the display configuration paradigm (described above and depicted in Schematic 1) which remained on the screen for the duration of each trial pair. 400ms following the offset of the warning tone the prime distractor (‘X’) appeared at one of the four forced-choice locations for 13ms followed by an 800ms inter-stimulus-interval (ISI) of the empty paradigm. Coincident with the end of the ISI, the probe target (‘+’) appeared randomly at any one of the 6 available locations for 106ms. Following the offset of the probe target the empty paradigm remained on the screen until a response was executed or 1000ms had elapsed at which point the paradigm disappeared and a 1600ms inter-trial-interval was initiated whose offset coincided with the onset of the subsequent warning tone and commencement of the next trial sequence.

Visible, Incompatible

The details and trial sequence breakdown were identical to the visible compatible condition (above) with the only exception being the location-response mappings. In this incompatible condition, the mappings were flipped/crossed (see Schematic 1, Inset B). So now to respond to a target at L1 a participant would press the “V” key (in the compatible condition this required “D”), a response to L2 would now require the “D” key (previously “V”); L3 was now mapped onto “L” and L4 onto “M” (previously vice versa). Although the location-response mappings were now crossed, the permissible responses for the free-choice probe locations did not change; an appropriate response to L5 was still “D” or “V”, and an appropriate response to L6 was still “M” or “L”.

Masked, Compatible

This condition was identical to the visible compatible condition in all aspects except those aspects of the trial sequence related to the mask which were as follows. At the offset of the prime distractor the mask (as described above) appeared at all six locations for 100ms followed by a 700ms inter-stimulus-interval during which only the empty paradigm was displayed.

Masked, Incompatible

This condition was identical to the visible incompatible condition in all aspects except those aspects of the trial sequence related to the mask, which were identical to those of the masked compatible condition (above).

RESULTS & DISCUSSION

At the outset here, we decided to rely more heavily on free-choice than on forced-choice probe trial data to detect distractor event response retrieval determinants. Free-choice probe trials were ideal for exposing these determinants because they, themselves, functioned independently of these retrieval possibilities (i.e., free-choice trials were not constrained by a particular ‘S-R rule-based’ response choice, nor were they ‘inherently’ associated with one of the permissible responses, selectively). Furthermore, beyond the latency measures also available with forced-choice trials, free-choice trials have the advantage of providing an indication of probe trial response selection preference, which can be helpful in revealing distractor response retrieval mechanisms. In fact, probe RTs and response selection preference usually act together (i.e., slower RTs, lesser selection frequency) to reveal earlier response inhibition and so designate the response retrieved by a prime distractor (e.g., Fitzgeorge et al., 2011).

Furthermore, in keeping with the terminology of O’Connor and Neill (2010), responses related to the prime distractor location by S-R rule assignment are classified as ‘congruent’, while those tied to this location via inherent processing are categorized as ‘incongruent’ (incompatible mappings only).

The analyses of variance (ANOVA) utilized Response Type (congruent and incongruent for incompatible mappings; ignored-repetition [forced-choice], distractor response repeat [free-choice] and control for compatible assignments) and Blocks as their main factors. Mean within-subject RTs or response selection frequencies served as the dependent variables. The major motivation for deciding ad hoc to examine the data over Blocks was to determine whether there was any indication with the incompatible location-response assignments, that distractor processing incorporated S-R rule-based retrieval more so as practice with assignments continued.

Mean latency and selection percentage scores for the DRR vs. CO and congruent vs. incongruent free-choice probe trials, as a function of compatible and incompatible location-response mappings (respectively), non-masked and masked primes, and Blocks, are found in Tables 1 and 2, respectively. Table 3 contains the mean reaction time values for ignored-repetition vs. control trials and congruent vs. incongruent for the forced-choice probe trials over Blocks for compatible and incompatible assignments (respectively).

Visible (Non-Masked) Distractor Primes

Compatible Location-response Mappings

Free-choice Probe Trials

ANOVA calculations revealed that only the Response Type main effect approached significance, F(1, 8)= 4.02, *p*= 0.07, MSE= 5957 (Blocks, F[9, 72]= 1.19. *p*= 0.31, MSE= 2822; interaction, F<1). Consistent with previous reports, RT was slower when the prime distractor response (DRR) was freely chosen, relative to when a Control response (CO) was selected (i.e., 353 msec. vs. 330 msec.). Unexpectedly, however, the former prime distractor response (DRR) was not chosen significantly less often (.495) than the Control response (F<1) [Tables 1 & 2]. Seemingly, the prime distractor (DRR) response was more highly inhibited than the Control response, and so it took longer to override its greater execution resistance level, thereby raising its RT. Uncharacteristically, however, this relatively greater execution resistance did not cause a bias against choosing the former distractor response (DRR) on free-choice trials (Buckolz

Table 1

Mean Reaction Times (ms) for Free-Choice Probe Trials for the Visible and Masked Prime Conditions, and for Compatible and Incompatible Location-Response Mappings over Blocks.

Condition →	No Mask				Mask			
L-R →	Compatible		Incompatible		Compatible		Incompatible	
TT →	DRR	CO	Con	Incon	DRR	CO	Con	Incon
Blocks								
1.	372 (11) [0.00]	346 (11) [0.00]	388 (32) [0.00]	424 (29) [0.00]	380 (24) [0.00]	366 (21) [0.00]	477 (33) [0.00]	451 (24) [0.00]
2.	362 (16) [0.00]	334 (20) [0.00]	411 (23) [0.00]	442 (25) [0.00]	313 (22) [0.00]	339 (17) [0.00]	416 (18) [0.00]	425 (27) [0.00]
3.	353 (20) [0.00]	350 (14) [0.00]	427 (17) [0.00]	413 (14) [0.00]	325 (11) [0.00]	314 (18) [0.00]	415 (16) [0.00]	416 (21) [0.00]
4.	377 (28) [0.00]	328 (17) [0.00]	406 (31) [0.00]	416 (28) [0.00]	324 (20) [0.00]	312 (18) [0.00]	418 (29) [0.00]	408 (15) [0.00]
5.	339 (17) [0.00]	312 (17) [0.00]	380 (23) [0.00]	441 (24) [0.00]	312 (13) [0.00]	324 (21) [0.00]	395 (17) [0.00]	402 (18) [0.00]
6.	360 (28) [0.00]	340 (27) [0.00]	402 (34) [0.00]	425 (25) [0.00]	355 (20) [0.00]	318 (19) [0.00]	394 (21) [0.00]	407 (24) [0.00]
7.	364 (22) [0.00]	333 (15) [0.00]	379 (20) [0.00]	396 (27) [0.00]	326 (17) [0.00]	310 (15) [0.00]	404 (13) [0.00]	396 (18) [0.00]
8.	324 (28) [0.00]	321 (17) [0.00]	385 (22) [0.00]	396 (37) [0.00]	310 (10) [0.00]	294 (13) [0.00]	390 (16) [0.00]	398 (08) [0.00]
9.	335 (17) [0.00]	312 (18) [0.00]	405 (19) [0.00]	408 (23) [0.00]	310 (12) [0.00]	294 (09) [0.00]	368 (23) [0.00]	375 (15) [0.00]
10.	347 (31) [0.00]	323 (21) [0.00]	406 (20) [0.00]	421 (31) [0.00]	285 (11) [0.00]	292 (16) [0.00]	382 (21) [0.00]	408 (13) [0.00]
Mean	353 (5.3) [0.00]	330 (4.2) [0.00]	399 (4.9) [0.00]	418 (5.0) [0.00]	324 (8.3) [0.00]	316 (7.3) [0.00]	406 (9.4) [0.00]	409 (6.4) [0.00]

Notes. ( ) = standard error (ms); [ ] = button press error (%); L-R = Location–Response Mapping; TT = Trial Type; Blocks = each Block contained 32 randomized prime-probe trial pairs; DRR = Distractor Response Repeat; CO = Control; Con = Congruent Response; Incon = Incongruent Response.

Table 2

Response Selection Percentages for Free-Choice Probe Trials for the Visible and Masked Conditions, and for Compatible and Incompatible Location-Response Mappings over Blocks.

Condition →	No Mask				Mask			
L-R →	Compatible		Incompatible		Compatible		Incompatible	
TT →	DRR	CO	Con	Incon	DRR	CO	Con	Incon
Blocks								
1.	0.444	0.542	0.444	0.514	0.500	0.500	0.444	0.528
2.	0.542	0.444	0.500	0.486	0.486	0.514	0.514	0.486
3.	0.472	0.500	0.486	0.486	0.500	0.500	0.528	0.458
4.	0.500	0.500	0.514	0.486	0.500	0.500	0.514	0.472
5.	0.528	0.458	0.528	0.444	0.472	0.514	0.486	0.486
6.	0.514	0.472	0.486	0.500	0.486	0.514	0.486	0.514
7.	0.514	0.472	0.500	0.472	0.528	0.458	0.514	0.458
8.	0.417	0.569	0.542	0.444	0.486	0.514	0.472	0.528
9.	0.486	0.500	0.528	0.458	0.514	0.486	0.500	0.500
10.	0.458	0.528	0.514	0.431	0.500	0.500	0.472	0.500
Mean	0.488	0.499	0.504	0.472	0.497	0.500	0.493	0.493

Notes. L-R = Location–Response Mapping; TT = Trial Type; Blocks = each Block contained 32 randomized prime-probe trial pairs; DRR = Distractor Response Repeat; CO = Control; Con = Congruent Response; Incon = Incongruent Response.

et al., 2015; Fitzgeorge et al., 2011); both this response, and the Control response, were selected equally often. The reason for the dissociation between the normally inversely related RT size and the selection preference values for prime distractor responses chosen on the probe trial in this study is unclear; although it has been seen before for masked primes in visuo-identity tasks (e.g., O'Connor & Neill, 2010). While this dissociation is of theoretical interest if it persists under certain conditions (i.e., intentional disregard of execution resistance as a selection determinant, not so for execution override time), it is of no consequence to our main interest here. This is because with compatible location-response assignments, it is not possible to distinguish between S-R rule-based and inherent processing as distractor response retrieval determinants.

Forced-choice Probe Trials

ANOVA computations produced only a single significant effect; Response Type, F(1, 8)= 14.42, $p<0.01$, MSE= 871 (Blocks, F[9, 72]= 1.53, $p= .155$, MSE= 1728; interaction, F< 1) [Table 3]. Reaction time was significantly larger for ignored-repetition (IR) (371 msec.) than for Control (354 msec.) trials, revealing the traditional SNP effect for visuo-spatial tasks under these conditions (e.g., Buckolz, Boulougouris, & Khan, 2002; Neill, Terry, & Valdes, 1994).

Incompatible Location-response Mappings

Free-choice Probe Trials

The Response Type main factor was the only significant F-value produced by the ANOVA calculations, F(1, 8)= 5.70, $p <0.05$, MSE= 2965 (remaining Fs< 1). Mean reaction time durations were reliably slower when the inherent (Incongruent) response was selected (418 msec. vs. 399 msec.). While the incongruent

Table 3

Mean Reaction Times (ms) for Forced-Choice Probe Trials for the Visible and Masked Prime Conditions, and for Compatible and Incompatible Location-Response Mappings over Blocks.

Condition →	No Mask				Mask			
L-R →	Compatible		Incompatible		Compatible		Incompatible	
TT →	IR	CO	Con	Incon	IR	CO	Con	Incon
Blocks								
1.	374 (23) [0.01]	367 (20) [0.00]	532 (22) [0.02]	486 (32) [0.01]	372 (19) [0.00]	388 (21) [0.00]	475 (26) [0.01]	492 (31) [0.02]
2.	363 (15) [0.01]	367 (12) [0.01]	493 (31) [0.01]	505 (27) [0.02]	351 (19) [0.00]	360 (15) [0.00]	438 (21) [0.01]	429 (18) [0.01]
3.	377 (15) [0.01]	365 (12) [0.01]	446 (29) [0.01]	449 (32) [0.01]	361 (22) [0.01]	349 (13) [0.00]	422 (20) [0.01]	452 (14) [0.01]
4.	375 (18) [0.01]	365 (13) [0.00]	485 (30) [0.01]	454 (34) [0.01]	344 (21) [0.01]	344 (18) [0.00]	400 (21) [0.01]	421 (20) [0.01]
5.	394 (25) [0.01]	358 (16) [0.01]	434 (28) [0.01]	459 (32) [0.01]	351 (21) [0.00]	346 (22) [0.00]	409 (18) [0.00]	382 (27) [0.01]
6.	365 (19) [0.01]	352 (21) [0.01]	468 (36) [0.01]	458 (26) [0.01]	325 (19) [0.01]	340 (17) [0.00]	402 (23) [0.01]	397 (24) [0.01]
7.	382 (25) [0.00]	352 (21) [0.01]	454 (25) [0.01]	425 (31) [0.01]	378 (27) [0.00]	327 (15) [0.01]	381 (15) [0.01]	385 (15) [0.01]
8.	370 (14) [0.02]	335 (16) [0.01]	432 (27) [0.01]	436 (28) [0.01]	327 (11) [0.00]	324 (08) [0.00]	391 (14) [0.01]	394 (18) [0.01]
9.	359 (22) [0.01]	348 (19) [0.01]	458 (22) [0.01]	452 (33) [0.01]	307 (15) [0.01]	316 (15) [0.01]	383 (17) [0.01]	368 (19) [0.01]
10.	346 (19) [0.01]	326 (15) [0.01]	444 (15) [0.01]	422 (20) [0.01]	344 (12) [0.00]	336 (12) [0.01]	375 (17) [0.00]	391 (17) [0.01]
Mean	371 (4.2) [0.01]	354 (4.5) [0.01]	465 (9.9) [0.01]	455 (8.1) [0.01]	346 (6.9) [0.00]	343 (6.5) [0.00]	408 (9.7) [0.01]	411 (12) [0.01]

Notes. ( ) = standard error (ms); [ ] = button press error (%); L-R = Location–Response Mapping; TT = Trial Type; Blocks = each Block contained 32 randomized prime-probe trial pairs; IR = Ignored-repetition; CO = Control; Con = Congruent Response; Incon = Incongruent Response.

response was selected less often than the congruent options (i.e., .48 vs. .52), the ANOVA outcomes revealed that this difference was not significant, F(1, 8)= 1.35, *p*=0.28, MSE= 412) [remaining F-values < 1].

The free-choice latency data indicated that the inherent (Incongruent) response was either exclusively activated by the prime trial distractor event and then inhibited, or that it was selectively activated and inhibited to a greater degree than was the S-R rule-based response. Either would result in the incongruent response's significantly slower RT, and in its less frequent selection. Actually, the free-choice result pattern here may be more supportive of the latter option (i.e., multiple response retrieval), whereby both the congruent and incongruent responses are simultaneously retrieved by the prime distractor, but where the incongruent response is more highly activated and inhibited. This inhibition (execution resistance) differential is not sufficient to bias response selection against the incongruent response, but it is adequate to produce differential resistance override times, causing RT for the incongruent response to be elevated.

The equivalent response selection frequency findings observed here for congruent and incongruent responses are in line with Simon effect research, which indicates that the inherent processing of visible distractor locations is not set aside on incompatible location-response trials, perhaps because of its high degree of automation (e.g., de Jong, Liang, & Lauber, 1994; Lu & Proctor, 1995; Valle-Inclan & Redondo, 1998). Analogously, distractor-occupied locations in visuo-spatial tasks seem capable of invoking both S-R rule-based and inherent processing at the same time, each leading to response retrieval. If this is the case, it will require a modification to one explanation of the spatial negative priming (SNP) effect, which currently holds that prime distractor locations retrieve responses solely on the basis of inherent processing (e.g., Buckolz, Stoddart, et al., 2014; Fitzgeorge et al., 2011).

On the surface, the results here, when contrasted with the conclusion by O'Connor and Neill (2010) that retrieval with masked primes is solely achieved via S-R assignment rule application, suggest that visible and masked primes are processed differently. This suggestion is a tentative one, however. This is because while the determination by O'Connor and Neill that S-R mapping rules were involved in response retrieval is justifiable, it is not clear that their results, and tasks, allow the concurrent contention that inherent processing was absent during masked distractor processing.

Forced-choice Probe Trials

ANOVA results yielded a significant Blocks main effect, F(9, 72)= 4.53, $p<0.01$, MSE= 2753; however, neither Response Type, F(1, 8)= 1.92, $p= 0.20$, MSE= 2364, nor the interaction, F(9, 72)= 1.06, $p= 0.40$, MSE= 2058, achieved significance. Neman-Keuls tests applied to the Blocks factor revealed that mean latencies declined significantly after Block 2, but not thereafter. Numerically, probe RT was greater for the required use of the congruent response than when the incongruent response was required (i.e., 465 msec. vs. 455 msec.). Technically, however, this latency data is consistent with the free-choice findings, indicating that the S-R rule-based and the inherently related responses were concurrently retrieved by the prime distractor event.

Visible Distractor Primes: Further Discussion

The arrival of visible prime trial distractors in visuo-spatial tasks seem to induce multiple response retrievals through the involvement of two response selection determinants; one is by activating 'inherent' processing (incongruent response), and the other is by having the task’s S-R assignment rule somehow applied to its processing (congruent response). The consequences of this result pattern are that: (a) explanations for the spatial negative priming (SNP) effect which formerly attributed prime distractor response retrieval solely to ‘inherent’ processing (e.g., Buckolz et al., 2012, 2014; Fitzgeorge et al., 2011) need to be modified to include S-R assignment rules as a contributor to distractor response retrieval, and so to the SNP phenomenon. In the latter instance, we are consistent with O’Connor and Neill (2010) who studied masked primes, and, (b) it is at odds with the contention by O’Connor and Neill that distractor retrieved responses occur only on the basis of S-R rule-based processing. Bear in mind that O’Connor and Neill could not rule out response retrieval also occurring via inherent distractor processing and that they looked only at masked distractor primes in an identity task.

The manner by which S-R task assignment rules are incorporated into (prime) distractor processing is still to be determined. One option is that compatible S-R assignments are simply an instance of inherent processing, which is initiated when the distractor event appears. If this is correct, the involvement of incompatible S-R mapping assignments in prime distractor response retrieval would not take effect immediately upon task undertaking, but would evolve somewhat slowly, in concert with the new, incompatible S-R associations became more natural (i.e., with practice). A second option is that the S-R assignment rule is intentionally applied to the processing of the prime distractor (O’Connor & Neill, 2010), although it is not clear why this would occur. A third option is that as the warning signal foretells the impending delivery of a prime-probe trial pair, the individual focuses on the S-R mapping rule now held in working memory, in preparation for its enforcement during probe trial processing. Inadvertently, the S-R rule also gets applied to the processing of irrelevant (prime trial) events because relevant events that appear on the probe also appear on the prime, but as to-be-ignored distractors. This would be instituted almost immediately.

Our Blocks/Practice data seem to support the third option. The latency values declined significantly over practice for the incompatible mappings for the forced-choice probe trials, likely as the new location-response assignments became more strongly associated. However, this improvement in location-response association strength was not accompanied by evidence of the increased involvement of the S-R assignment rule in terms of controlling distractor response selection. For example, the lack of a significant Blocks x Response Type interaction for the incompatible assignment condition, for both the probe selection preference and the probe RT data, indicated that the likelihood of congruent response retrievals (i.e., S-R rule involvement) did not change over Blocks. Rather, the involvement of the task S-R assignment rule in generating response retrieval for visible prime distractor events seems to begin very early, perhaps the inadvertent consequence of a focus on the S-R rule needed to be applied on the probe trial.

Incidentally, reaction times did not decline with practice for the compatible location-response forced-choice mappings, perhaps indicative of their high degree of pre-experimental compatibility. Similarly, since the S-R assignment rules did not apply on free choice trials, no Blocks effect would be expected for the incompatible mapping condition on this account, and none was observed.

Masked Primes

Mask Success (pre-experimental pilot session)

We tested the effectiveness of our masking procedure via random mask delays (see Method section) of 0 msec. and 100ms following event (duration = 13ms) offset; at 0ms, response rate was <1%, while at the 100ms delay, individuals responded 98% of the time. Based on the aforementioned, the mask worked successfully in that the events remained phenomenally invisible.

Compatible Location-response Mapping

Free-choice Probe Trials.

The ANOVA calculations produced only two significant F-scores; Blocks, F(9, 72)= 5.08, $p< 0.01$, MSE= 1876, and Response Type, F(1, 8)= 14.59, $p<0.01$, MSE= 179. Newman-Keuls tests revealed that RTs significantly declined after Block 1, with no further reductions thereafter. More important, RTs were reliably slower when individuals selected the prime distractor associated response (DRR) on the probe compared to when the Control output was chosen (i.e., 324 msec. vs. 316 msec.).

With this significant Response Type main effect, we have evidence from the latency measure that masked distractor-occupied prime locations get processed. According to one view, the masked distractor event results in the activation and subsequent inhibition of its related response, which then becomes execution resistant. When this output is freely selected on the probe trial, its execution resistance must be set aside as part of its processing. This takes time and so its production time is delayed (e.g., Buckolz, Stoddart et al. 2014). This much is consistent with Fitzgeorge et al. (2011). Unlike Fitzgeorge et al., however, we did not observe a significant bias against choosing the prime distractor (DRR) response, which should have also been caused by the response's execution resistance. Rather, both prime distractor and Control responses were selected with equal frequency (50/50). If we accept the interpretation afforded the latency data, whatever the basis for the probe free-choice response selections, it ignored the greater execution resistance tied to the prime distractor location's response.

Forced-choice Probe Trials.

ANOVA computations produced only two significant F-values: Blocks, F(9, 72)= 4.00, $p< 0.01$, MSE= 1592, and the Blocks x Response Type interaction, F(9, 72)= 2.25, $p< 0.05$, MSE= 751 (Response Type, F< 1). Overall, the RTs for the ignored-repetition (IR) and control (CO) trials were statistically equivalent. The post-hoc Newman-Keuls tests applied to the interaction revealed that the RTs for these two trial types differed significantly ($p< 0.05$) only for Block 7 (i.e., IR 377 msec. vs. CO 326 msec.; SNP effect).

The absence of a significant spatial negative priming (SNP) effect provides no evidence that masked distractor-occupied prime locations are processed in visuo-spatial tasks. This is contrary to what Fitzgeorge et al. (2011) reported.

Incompatible Location-response Mappings

Free-choice Probe Trials.

The Blocks main effect was the only significant F-ratio revealed by the ANOVA computations using latency measures, F(9, 72)= 5.19, $p< 0.01$, MSE= 2053 (remaining F-values < 1). Newman-Keuls tests applied to the Blocks main effect indicated that probe reaction time size significantly declined after Block 1, and remained unchanged thereafter. Probe reaction time values were statistically equivalent for the congruent (Con) and incongruent (Incon) response selections (i.e., 406 msec. vs. 409

msec.). Additionally, these two responses were selected with the same frequency (.49 vs. .49) [Table 2].

There was, therefore, no evidence from these particular findings that masked prime distractors are processed in visuo-spatial tasks. However, since evidence of processing was observed with the masked compatible mappings condition (RT, free-choice), one could argue that masked distractor processing likely occurred for the incompatible location-response assignments as well. If so, masked prime distractor events seemingly involve both the task S-R assignment rules and inherent processing to concurrently retrieve their respective congruent and incongruent responses; hence their equal selections.

Forced-choice Probe Trials.

ANVOVA calculations showed that Blocks, F(9, 72)= 9.53, $p <$ 0.01, MSE= 2105), produced the only significant effect (Response Type, F< 1; interaction, F(9, 72)= 1.50, p=0.16, MSE= 987). Newman-Keuls tests revealed that RT decreased significantly after Block 1. A further latency decline occurred after Block 3, with values remaining stable thereafter.

The RT reductions with continuing practice likely reflected an increasing association strength with the new location-response mappings, although there may also be a contribution of getting used to the mask, given the practice effect observed with the free-choice trials.

The comparable RTs for the congruent (408 msec.) and incongruent (411 msec.) responses indicate either that the masked distractors were not processed, or that they were, and the distractor caused both congruent and incongruent responses to be retrieved, which were then comparably activated and inhibited.

GENERAL DISCUSSION

Cast in broad terms, the current report aimed to further our understanding of the processing afforded to-be-ignored distractor events, and, more particularly, our interest focused on the manner by which visible (and phenomenally invisible) distractors retrieve responses in visuo-spatial tasks.

Early reports (using visuo-identity tasks) generated a consensus that visible distractor events were processed automatically, to the point of retrieving responses with which they shared a strong association (i.e., ‘inherent’ processing). Illustrative of this response retrieval was the fact that distractor-related responses exhibited electrophysiological signs of activation (e.g., Coles, Gratton, Bashore, Eriksen, & Donchin, 1985; de Jonge, Liang, & Lauber, 1994; Eriksen, Coles, M. G., Morris, & O’Hara, 1985; Valle-Inclán, & Redondo, 1998), while distractors without experimental assigned responses, and/or those tied to non-conflict responses, failed to interfere with concurrent target processing (e.g., Herman, 1969; Hintzman, D. L., Carre, F. A., Eskridge, V. L., Owens, A. M., Shaff, S. S., and Sparks, M. E. (1972); also see Buckolz, E., O'Donnell, C., & McAuliffe, J. (1996). In some instances, the view was that these retrieved distractor responses went on to generate inhibitory after-effects, such as the spatial negative priming effect (Buckolz, Goldfarb, & Khan, 2004; Buckolz, Edgar, et al., 2012; Buckolz, Lok, et al., 2015; Fitzgeorge, Buckolz, & Khan, 2011; Guy, Buckolz & Khan, 2006) and the negative compatibility effect (e.g., Klapp & Hinkley, 2002;

Schlaghecken et al., 2007). Accordingly, explanations offered for these inhibitory after-effects included the idea that prime distractor events retrieved associated responses solely on the basis of ‘inherent’ (automatic) processing (e.g., Fitzgeorge et al., 2011; Guy et al., 2006).

O’Connor and Neill (2010) challenged this more or less conventional ‘inherent processing’ notion, proposing instead that distractor response retrieval was controlled exclusively by the inclusion of the task stimulus-response (S-R) mapping assignments into its processing (S-R rule-based retrieval). Looking only at masked distractors in an identity task, O’Connor and Neill claimed support for their proposal and so for the need to modify the NCE explanation on this account.

Distractors Can Retrieve Multiple Responses

The most informative results in this study arose with incompatible location-response mappings, visible prime distractors and free-choice probe trials. With this combination, the latency data pointed to distractor response retrieval generated by ‘inherent’ processing (i.e., incongruent response retrieval) while the selection probability values for these same responses were virtually identical. We took this pattern to indicate that the prime distractor event involved both the S-R assignment rule and inherent processing to result in the retrieval of both the congruent and incongruent responses (i.e., freely chosen equally). Furthermore, we reasoned that inherently retrieved (incongruent) responses were more highly activated and inhibited (A→I), causing them to be more slowly initiated (execution resistance override time); however, the inhibition difference between the responses was not sufficient to cause a response selection bias. With this same combination, but with the prime distractor masked, the response selection data again pointed to the concurrent retrieval of congruent and incongruent responses, although, in this case, there was no latency difference between these two outputs (i.e., no differential A→I).

The implications of these findings are reasonably clear. The caution raised by O'Connor and Neill (2010) in conjunction with masked distractors, that distractor processing incorporates the S-R assignment rule of the task and so retrieves responses on this basis, also applies to visible distractor events, typically used in the production of the spatial negative priming effect. Distinct from the contention by O'Connor and Neill, however, is the fact that the visible (and masked) distractors here also demonstrated the concurrent retrieval of responses on the basis on inherent processing. Future explanations of the SNP effect produced with visuo-spatial tasks should include this dual response retrieval generated by the prime trial distractor event. This may also be appropriate for masked primes as we saw here, and bearing in mind that the work of O'Connor and Neill could not rule out inherent response retrieval for their masked distractors.

How Does the S-R Assignment Rule Get Applied to Prime Distractor Processing?

In retrospect, the speculation that S-R rule-based retrieval would be 'intentionally' applied to the processing of (prime) distractor events while 'inherent' processing would be set aside at the same time (O'Connor & Neill, 2010), is counter intuitive, given the nature of the visuo-spatial task used in the current study, and the design of the NCE task employed by O'Connell and Neill (2010). In the first instance, there is no logical or functional benefit to 'volitionally' incorporating the S-R assignment rule as a basis for distractor response retrieval on forced-choice prime trials; after all, the S-R rules applied only to probe trial processing needs. As we proposed earlier, S-R assignment rules may inadvertently influence prime (distractor) processing because individuals are focusing on these assignments in advance of probe delivery.

In the second instance, ‘inherent’ prime trial distractor processing was procedurally induced with both the visuo-location task used in this investigation, and in the NCE task studied by O’Connor and Neill. This is because the same event (i.e., location or identity [>>]) served as both the prime distractor and the probe target events. Consider our location task as an illustrative example. Forced-choice locations were spatially aligned with the positions of the task response keyboard buttons and were assigned a fixed manual response, which was either spatially compatible (inherent links) or incompatible with event locations. Essentially, the front end of a compatible location-response link would occur and be triggered whenever it was occupied on the prime, and this happened whether the occupying event rendered the location a distractor or a target location. It would follow that inherent location processing extending to response retrieval would occur with distractor-occupied prime locations. Our point here is that this inherent (automatic) processing should not be prevented just because the task location-response assignments are rendered incompatible. This was in fact what we found in this study. The free-choice response selection bias data often indicated that inherent and S-R rule-based responses were both retrieved by the prime distractor location.

The preservation of distractor location-response inherent processing has also been demonstrated in Simon tasks, where target position is irrelevant (Lu & Proctor, 1995). On spatially incompatible trials, it was evident that the irrelevant location of the target stimulus had nonetheless generated the retrieval of its compatible (inherent) response. A similar case can be made for the Stroop task where the inherent processing tied to unwanted word naming occurs while individuals apply the S-R task rule of naming the colour in which a colour word is printed (Lu & Proctor, 1995).

Overall, it may be that (prime) distractor response retrieval is governed by unintentional processing, both for ‘inherent’ processing and for S-R assignment involvement.

Masked Prime Distractors in a Visuo-spatial Task

There are two aspects of the masked prime distractor findings here that were informative. One is that it provided the first support for the general finding of Fitzgeorge et al. (2011), indicating that phenomenally invisible distractor events in location tasks get processed. This manifestation here was, however, much more restricted (compatible mappings, free-choice probes, RT data) than in Fitzgeorge et al., perhaps because these authors masked distractor colour rather than distractor form, as done in this study. The second aspect of note is that visible and phenomenally invisible prime distractors were comparable in showing that distractors retrieve responses on the basis of inherent processing and S-R assignment rule involvement.

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CHAPTER 3

Episodic Storage and Retrieval in Visuo-spatial Tasks: Evidence of Indirect Retrieval

Introduction

There are still instances where the storage format attendant to processed information remains uncertain. We believe that one exemplar of such instances relates to visuo-spatial tasks, where the explicit salient feature of the target stimulus is its location (i.e., a location-response ‘ruled based’ connection). The format in which processed visual events in spatial tasks is retained can be tested using the spatial variant of the traditional negative priming task (SNP). With this SNP procedure, target and distractor events are presented singly or together on a sequential pair of trials; first the ‘prime’, then the ‘probe’, and the correct response is uniquely specified by the target’s spatial position and the response assigned thereto. The probe trials are then examined for ‘after-effects’ in the form of evidence showing that prime trial target and/or distractor processing exhibited an impact on related probe processing. The emergence of such ‘after-effects’ naturally relies on, and so attest to, the storage of prime processing representations, which persist for a period of time, at least as long as the prime-probe delay interval. More specifically, an examination of these ‘after-effects’ can identify which features of the visual prime objects have been stored, and, along with a consideration of the probe trial configurations that retrieved them (Schematic 1), will give us some insight into retrieval requirements, and into the format in which (prime trial) processing in visuo-spatial tasks is stored. To reiterate, the latter constitutes a major interest in this study.

	IR vs. CO Trials	
	Prime	T1 __ + __ D1
Probe Trial Configurations	[1]	__ __ + __ T1
	[2]	__ __ + __ T2
	[3]	__ __ + T1 __
	[4]	__ __ + T2 __
	[5]	__ D1 + __ T1
	[6]	__ D1 + __ T2
	[7]	__ D1 + T1 __
	[8]	__ D1 + T2 __

	TR vs. CO Trials	
	Prime	T1 __ + __ D1
Probe Trial Configurations	[9]	T1 __ + __ __
	[10]	T2 __ + __ __
	[11]	__ T1 + __ __
	[12]	__ T2 + __ __
	[13]	T1 __ + D1 __
	[14]	T2 __ + D1 __
	[15]	__ T1 + D1 __
	[16]	__ T2 + D1 __

Schematic 1. An illustration of the probe trial configurations (exemplars) that will be selectively used to examine the experimental objectives herein, displayed for when a repeated or changed probe target identity appears at the prime target location (location repeat), at the prime distractor location (ignored-repetition), or at a new (control) location. IR= ignored-repetition, TR= target repeat, which is defined with respect to the target stimulus only, whereby its location and/or identity are repeated, CO= control.

Notes.
T1 = Target 1 (green rectangle)
T2 = Target 2 (yellow cross)
D1 = Distractor 1 (red rectangle)

What follows is a depiction of the various procedural and theoretical issues that needed consideration in order to devise a protocol for assessing episodic storage in visuo-spatial tasks. We begin with a description of the probe trial ‘after-effects’ (outcomes) produced with the basic SNP task design, accompanied by one version as to the prime trial processing that gives rise to these after-effect outcomes.

After-effects in Visuo-spatial Negative Priming Tasks

After-effects are produced by both prime target and distractor events in visuo -spatial negative priming tasks. Their appearance testifies to the processing and retrieval of these events. For example, it is well established that repeating a prime target’s identity and its location on the probe trial in a visuo-spatial task facilitates reaction time (RT) relative to a control condition, where neither of these target features is repeated (e.g., Buckolz, Avramidis & Fitzgeorge, 2008; Fitzgeorge & Buckolz, 2008).

More complex though, is the fact that prime distractor processing in location tasks, such as the kind used in this study, generates four probe trial after-effect manifestations. To grasp the nature of these four after-effects, some position must be taken as to what processing prime distractors undergo. In this regard, we propose that prime distractor processing takes place automatically (and so contrary to instructions and intentions; Fitzgeorge, Buckolz, & Khan, 2011; Kajaste, Buckolz, & Perry, 2013), involves the identification of the distractor event (Haworth, Buckolz, & Kajaste, 2014), which then continues to the point where the location’s assigned response is activated and subsequently inhibited (to prevent its unintended initiation). This act of output inhibition causes the prime distractor response to become ‘execution resistant’ (ER) which opposes its future use, whether this use is required by the probe target or is self-selected on free choice trials (e.g., Buckolz, Lok, Kajaste, Edgar, & Khan, 2015; Fitzgeorge et al. 2011). Representations of prime distractor processing (i.e., distractor event files; Hommel, 2004) are stored for a period of time (i.e., up to 4-10 seconds in visual SNP tasks: Buckolz et al., 2008; Neill, Valdes, Terry, & Gorfein, 1992). The possible format for this storage is described shortly. When stored distractor representations are retrieved, they generate their 'inhibitory' after-effects (the term 'inhibitory' here is meant to delineate those after-effects which result from prime distractor processing, and does not mean to imply that these after-effects are necessarily detrimental to probe processing).

In particular, the 'execution resistance' property of stored prime distractor responses is held to be solely responsible for the inhibitory after-effect production in visual SNP tasks (e.g., see Buckolz, Stoddart, Edgar & Khan, 2014; but see Neill & Kleinsmith, 2016[1]). Delineating these four probe-trial inhibitory after-effects, we *first* have the visual spatial negative priming (SNP) phenomenon itself, reflecting the fact that probe trial target reactions are slower when the target appears at a location formerly occupied by a prime distractor (i.e., ignored-repetition [IR] trial), relative to when it arises at a previously unused location (i.e., control [CO] trial). The delayed responding for the ignored-repetition trials is thought to reflect the time needed to override the ER feature of the now required, former distractor response. *Second*, response selection errors are sometimes greater for ignored-repetition than for control trials. When this occurs (e.g., Buckolz et al., 2008; Fitzgeorge & Buckolz, 2008), it is due to the selection-repelling ER property of the prior distractor response which prevails, causing the individual to choose another (incorrect) response. *Third*, on free choice trials where there is more than one permissible response assigned to a location, individuals exhibit a significant bias against selecting a prior distractor response when it competes with a control response (e.g., Buckolz et al., 2015; Fitzgeorge et al., 2011). Again, this pattern is thought to be the consequence of the distractor response's ER repelling feature. *Finally*, on probe trials, prime distractor responses are used significantly less often in error than are control responses, suggestive of an error protection (EP) role for ER, when the prime distractor output is not required on the probe trial (Buckolz et al., 2014). As we detail later, part of the new methodology here for examining storage format in visuo-spatial tasks involved relying upon error protection rather than ignored-repetition trials to detect the retrieval of prime distractor processing.

Next, we speculate as to the format of stored prime trial representations.

Potential Storage Components Associated with Prime Trial Processing in Visual Spatial Negative Priming Tasks: Feature Binding and Episodic Storage

Feature Binding and Event Files. According to Hommel (2007; also see Hommel, 1998, 2004), the processing of prime target and distractor objects may well include the binding of their respective features (i.e., identities, locations, and/or assigned responses), which then constitute target and distractor 'event files' (Hommel, 2004), which are then stored. Evidence indicative of event file feature binding has come mostly from visuo-identity tasks. For example, prime target responses bind to the relevant (within event file) and irrelevant (between event files) features of presented prime objects. This is revealed by significant latency changes when the relevant or irrelevant prime identity features are later repeated on the probe trial (Hommel, 1998; Hommel, 2007; Hommel, Memelink, Zmigrod, & Colzato, 2014).

In contrast, feature binding for visuo-spatial tasks was initially examined for distractor event files. The results were mixed. Binding between the prime distractor's identity and its prime location was not observed for visual (Milliken, Tipper, Houghton, & Lupianez, 2000) or for tactile (Wesslein, Spence, Mast, & Frings, 2016) inputs; however, such binding was implicated with auditory prime events, where it was held responsible for auditory SNP production (e.g., Mayr, Hauke, & Buchner, 2009; Mayr, Buchner, Moller, & Hauke, 2011). On a positive note, Kajaste, Buckolz & Khan, (2016) recently reported that the prime target response exhibited binding with the prime target's relevant location feature in a visuo-location task (i.e., target event file). So, arguably, there is sufficient data to support including event files as one component of the format in which processed prime information in visuo-spatial tasks is stored. Episodic storage is a further retention component worthy of consideration.

Episodic Storage Format.

Some time ago, Neill and his colleagues (e.g., Neill, 1997, 2007; Neill et al.,1992), as well as others (e.g., Fox & de Fockert, 1998; Hintzman, 1984), proposed that visual (prime trial) processing is stored episodically. A distinguishing feature of episodic storage is that relevant and irrelevant (contextual) display features are retained together in the same episode (e.g., Fox & de Fockert; Neill, 1997). In the vernacular of Hommel (2004), target and distractor event files would be confined within the boundaries of a stored episode, existing either independently, or in some related manner. Presently, the latter is indicated. Although provisional, there is data which indicates that the features of target 'event files' can also bind; specifically, that the prime target response binds to the prime target's identity (Kajaste et al., 2016), and/or to its prime location (Frings &

Moller, 2010). Quite possibly, these between ‘event file’ bindings are the essence of an episode. If this is correct, we should see evidence of episodic storage for visuo-spatial tasks in this study (our primary aim).

The Probe Trial Configuration Requirements for Retrieving Stored Episodes.

In order to establish an effective procedure for testing episodic storage, it was, of course, necessary to have some idea as to how to retrieve these episodes through use of proper probe trial configurations. Once again, differences in this respect appeared for visuo-identity and visuo-spatial tasks.

For visuo-identity tasks, retrieval of stored prime episodes appeared to require that paired prime (encoding stage) and probe (retrieval stage) trial configurations match. Accordingly, testing for episodic storage involved the absence of some irrelevant prime trial component on the probe (i.e., reduced contextual similarity), which should disrupt prime information retrieval and so result in the lack of a negative priming effect. Successful examples of this contextual approach have been reported by Neill (1997) and Fox and deFockert (1998) using visuo-identity tasks. They showed, respectively, that changing the timing of distractor delivery relative to target appearance (simultaneous vs. delayed), or by altering the contrast degree between display objects and their background, prevented access to the stored prime representation (i.e., removed an identity negative priming effect). This prevention did not occur when these contextual manipulations between the prime and probe trials did not occur.

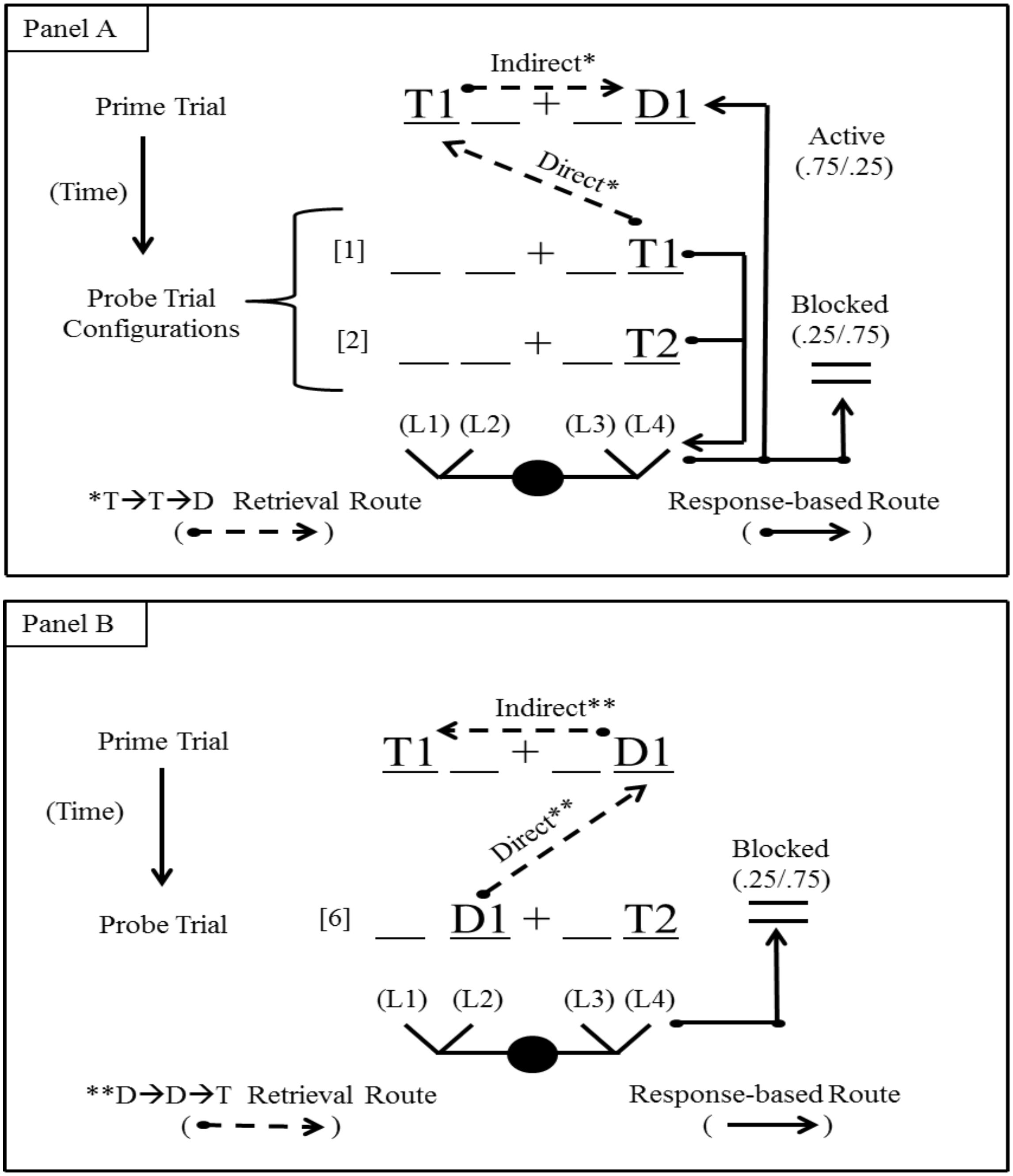
In contrast to identity tasks, contextual similarity manipulations did not seem to prevent the retrieval of stored prime representations in visuo-spatial tasks, putting an episodic storage format for such tasks in question. For example, when the prime trial contained both a target and a distractor while the probe trial lacked a probe distractor event (at a chance level or better) [Buckolz, Boulougouris, & Khan, 2002; Buckolz, Goldfarb & Khan, 2004; Guy, Buckolz, & Pratt, 2004], or when the prime contained a single distractor event that was followed by a probe trial containing both a target and a distractor (e.g., Buckolz et al., 2014; Fitzgeorge & Buckolz, 2008), an SNP effect (i.e., prime retrieval) persisted. Further, distractor-only primes which were followed by target-only probes also do not result in prime retrieval prevention (e.g., Buckolz et al., 2014; Guy et al., 2004; Milliken et al., 2000; also see Buckolz et al., 2008; Neill et al., 1994). To the extent that these latter manipulations constituted a contextual similarity reduction, we again see that it had no retrieval impact in a location task.

Neill (1997) proposed that the foregoing null effects of contextual similarity variations on SNP did not necessarily undermine the existence of episodic storage for location tasks. Rather, Neill posited that these null effects possibly revealed the existence of different retrieval requirements for stored prime episodes for location versus identity tasks. Neill posited that contextually dissimilar prime-probe paired trials could nonetheless result in retrieval as long as they shared highly ‘salient’ features, a position later endorsed by Moller, Mayr, and Buchner (2013) and embraced by Frings and Moller (2010). It would follow that in the past visuo-spatial SNP tasks cited above, the probe target and/or distractor objects in visuo-spatial tasks were sufficiently ‘salient’ that they ‘directly retrieved’ their ‘event files’. An assumption to this effect was made here; that is, that the retrieval of prime event files can be achieved in visuo-spatial tasks as long as one feature in the probe configuration matches one feature embedded in the stored event files.

The Major Aim Here: Testing a Different Prediction of Episodic Storage

The foregoing theorizing by Neill (1997) leads to a new procedure for testing a different prediction of episodic storage (as we view it) than has been examined in the past (e.g., Neill et al., 1992). The basic protocol was to have a target-only probe trial (see Schematic 1) follow a target-plus-distractor prime, where the prime-probe target identities matched. Theoretically, the probe target should ‘directly’ contact only the stored prime target event file, resulting in its retrieval (i.e., ‘direct [object] retrieval’). Upon showing evidence that this target retrieval did take place, episodic storage would predict that we should see evidence of the concurrent ‘indirect’ retrieval of the prime distractor event file, whether this arises because of inter event-file feature binding, or is due to some other means of connection. As Hintzman (1984) put it, more can be retrieved than is contained in the probe trial (i.e., “associative recall”; our episodic retrieval) [also see Mayr & Buchner, 2014]. In this study, we will then test for a target → distractor indirect retrieval route using the T→T→D combined route (Schematic 2, Panel A) to establish the existence of episodic storage (objective 1). Note, throughout, our reference to retrieval ‘routes’ refers to ‘processing routes’ and not to anatomical pathways.

It is clear that our test of episodic storage here requires that we be able to identify the retrieval routes, so far identified as ‘direct’ and ‘indirect’, which are likely implicated by our various prime-probe trial configuration combinations. Unfortunately, the spatial negative priming task has a third possible retrieval route (i.e., the ‘response-based’ route) that makes this identification of direct and indirect retrieval routes impossible on some probe trials. Next, we delineate the three envisioned retrieval routes. Then we explain how the involvement of the response-based route, and its confounding of route



Schematic 2. Illustrations of the target→target→distractor (T→T→D) [Panel A] and distractor→distractor→target (D→D→T) [Panel B] processing retrieval routes

Notes. For Panels A & B:
.75/.25 = .75(probe distractor present)/.25(probe distractor absent)
.25/.75 = .25(probe distractor present)/.75(probe distractor absent)
T1 = Target 1 (green rectangle)
T2 = Target 2 (yellow cross)
D1 = Distractor 1 (red rectangle)
L1-L4 = Location markers on screen from left to right
[ ] = Probe trial configuration number

identification, were set aside so that the SNP procedure could be employed in this study to examine episodic storage.

Four Processing Retrieval Routes Involved with the Visual Spatial Negative Priming (SNP) Protocol.

With the prototypical visual spatial negative priming (SNP) procedure, we hypothesize that at least four retrieval routes can be active at any time. These routes are illustrated in Schematic 2 (Panels A & B) for target-only, ignored-repetition trials. They consist of (1) a 'response-based' route, held to be triggered (and so distractor representation retrieval achieved) whenever the prime distractor response is reactivated by the probe target's position, such as on ignored-repetition or distractor-response repeat trials (where the prime distractor response is involved but not its location) [e.g., Buckolz et al., 2012; Fitzgeorge et al., 2011; Guy, Buckolz, & Khan, 2006], (2) a 'direct' (object-based) route which is activated by what subjects 'see' on the probe trial, triggered when prime and probe object identities (fully) match (i.e., T →T, D→D; dashed lines; Schematic 2, panel A & B) [Haworth et al., 2014], (3) 'indirect' (episodic) retrieval routes that are set in motion upon the 'direct' retrieval of either the prime target or distractor object (i.e., T→D & D→T processing routes), and, (4) combined 'direct' and 'indirect' pathways (i.e., T→T→D, D→D→T; see Figure 2). It is these combined pathways that we envision implicating with our procedural manipulations in this study, and which form the basis for detecting episodic storage.

We are most particularly interested in examining the T→T→D pathway in isolation (i.e., prime trial distractor event file retrieval). To do this, we must, of course, eliminate the involvement of pathways that would confound the route responsible for prime distractor event file retrieval (i.e., both for target-only probes [response-based route], and for target-plus-distractor probe trials (direct object-based, and/or response-based routes) [Schematic 2].

The D→D→T processing route can be avoided through the use of target-only probe trials. The involvement of the response-based can be prevented/avoided in two ways, which are outlined in the next two sections.

Error Protection as an Index of Prime Distractor Retrieval in a Visual SNP task

Recall that the inhibition of the prime distractor-related response renders this response ‘execution resistant’ (i.e., to future use). This feature, when retrieved with the distractor event file, results in former distractor-related responses being used significantly less often in error compared to their control response counterparts (which lack the execution resistance feature) on probe trials (Buckolz et al., 2014). Incidentally, this ‘error protection’ after-effect is reminiscent of the selection bias against choosing former distractor responses on free-choice probe trials (e.g., Buckolz et al, 2015; Fitzgeorge et al., 2011), presumably owing to the execution resistance characteristic of these responses.

In any event, the important procedural point here is that when ‘error protection’ is used to replace the SNP effect itself as the means of identifying the occurrence of stored prime distractor processing retrieval, it automatically excludes the involvement of ignored-repetition trials, and so, too, the response-based retrieval route. This is because the configurations used to assess error protection on probe trials requires that the prime distractor location be unoccupied on the probe. Instead, the probe target appears either at the prime target location (target-repeat trial), or at a new (control trial) location. This leaves the retrieval of prime distractor event files, and the resulting generation of error protection evidence, attributable solely to the T→T→D retrieval route for target-only probe trials (e.g., Schematic 1, configurations [9]-[12]).

Using the .25[distractor present]/.75[distractor absent] Probe Distractor Probability Ratio (Experiment 1B).

The second method of preventing the involvement of the response-based retrieval route on probe trials here entailed having a distractor appear randomly on only 25% of the probe trials administered (i.e.; .25[distractor present]/.75[distractor absent]). This maneuver (Buckolz et al., 2012; Fitzgeorge & Buckolz, 2008, Haworth et al, 2014) somehow eliminates the typical latency delay produced by ignored-repetition trials (i.e., no SNP effect), provided they are preceded by primes that contain both a target and a distractor as will be the case here (Guy, Buckolz, & Fitzgeorge, 2007). Possibly, the low incidence of probe trials with distractors causes a blocking of the response-based retrieval pathway (Fitzgeorge & Buckolz, 2008; Haworth et al., 2014; also see Guy et al., 2004), which then prevents stored distractor event file retrieval on (target only) ignored-repetition probe trials.

Accordingly, utilizing the .25/.75 probe distractor frequency ratio allowed us to address several issues. First, we could determine whether matching prime-probe distractor identities allowed the probe distractor to directly and independently retrieve stored distractor-event files; even if the probe distractor's location, along with the target's identity, changed between prime-probe trial pairs (see Schematic 2, Panel B, configuration [6]). Second, if this uncertainty is resolved in the affirmative, it would support the assumption made here that a prime event file could be retrieved directly by repeating a single item on the probe which is contained in a stored prime event file (distractor identity in this case). It also would permit us to interpret certain results as revealing the 'indirect' retrieval of prime target event files (i.e., D→D→T) on the probe trial. If observed, it would support episodic storage. Third, relatedly, the indirect retrieval of the prime distractor event file (T→T→D) could also materialize on Control and Target Repeat trials, possibly replicating Experiment 1A in this regard and pointing to episodic storage.

Fourth, we were able to test the possibility that the elimination of the SNP effect via the .25 (probe distractor present)/.75 (probe distractor absent) procedure in the past may have been signaling the absence of episodic storage (indirect retrieval) in visuo-spatial tasks. In theory, a functioning target → distractor indirect retrieval route (T→T→D) should have provided a retrieved prime distractor event file, otherwise lost by the blocking of the response-based route. This would have prevented the observed absence of the SNP effect. Since this did not occur, it may well be that we will see no evidence of a T→T→D indirect retrieval pathway in both Experiments 1A and 1B, unsupportive of episodic storage in visuo-spatial tasks. Alternately, this indirect retrieval pathway may exist; however, the retrieved prime distractor event files may not participate in ignored-repetition trial processing for whatever reason. We will test this possibility here by looking to see whether error protection (distractor event file retrieval) is evident when the SNP effect is not evident in Experiment 1B.

Returning to Feature Binding: Evidence of Feature Binding Within a Target Event File in This Study?

As indicated just above, a major aim in this study is to test for a possible T→T→D retrieval pathway, indicative of episodic storage. The procedure to do this begins with the requirement that we first verify, through latency differentials, that the retrieval of prime target event files has taken place on certain probe trials.

Identifying instances of stored target event file retrieval (T→T) will also automatically test for the existence of prime target feature binding (i.e., target identity and its location) in a visual location task. For example, changing the prime target's identity and repeating its location, and vice versa (Schematic 1, [10] & [11]), would violate any identity-location binding established on the prime. Overcoming such violations presumably comes with a time cost, and so would elevate probe target reaction time. Possibly, though, this latency increase would be opposed by any facilitation benefit resulting from the repeated prime target feature. When the benefit outweighs the time costs, the reactions for partial feature repeats (Configurations [10], [11]) will be less than those for a baseline control condition, where no feature repetition occurs (Schematic 1, Configuration [12]). However; when the reverse holds, latencies for partial repetitions will exceed those of baseline, revealing target identity-location binding. The important point here is that both of these benefit and cost latency effects rely on the retrieval of stored prime target processing; hence, either of the ordinal relationships between reactions for partial feature repeats and complete feature changes, reflects stored target representation retrieval. We adhere to this interpretation in this study.

A Summary of Study Aims

The findings generated here by two experiments (Exp. 1A, .75 [probe distractor present]/.25[probe distractor absent]; Exp. 1B, [.25/.75]) will yield findings that comment on three issues of major interest. *First* and foremost is the question of whether processing in visuo-spatial tasks is stored episodically. For the first time, we will test episodic storage by looking for ‘indirect’ distractor event file retrieval (i.e., via T→T→D), while error protection will be employed for the first time as the main index of distractor event file retrieval. *Second,* we will determine whether a probe distractor can directly retrieve the prime distractor event file when the prime-probe distractor identities match (and the prime-probe target identities mismatch). *Third,* we hope to confirm the existence of an error protection inhibitory after-effect associated with prime trial distractor processing in location tasks (Buckolz et al., 2014). On a more incidental note, data will be available which will permit us to see whether the lack of a spatial negative priming effect observed with target-only probes in the .25(probe distractor present/.75(probe distractor absent) probability ratio condition coincides with a possible absence of episodic storage evidence. However, if episodic storage is indicated i.e., significant error protection), it could mean that the retrieved distractor event file did not participate in probe trial processing. Further, we will look to see whether the identity and location/response features of the prime target undergo binding in visuo-spatial tasks.

METHOD

Experiment 1A (.75[probe distractor present/.25[probe distractor absent])

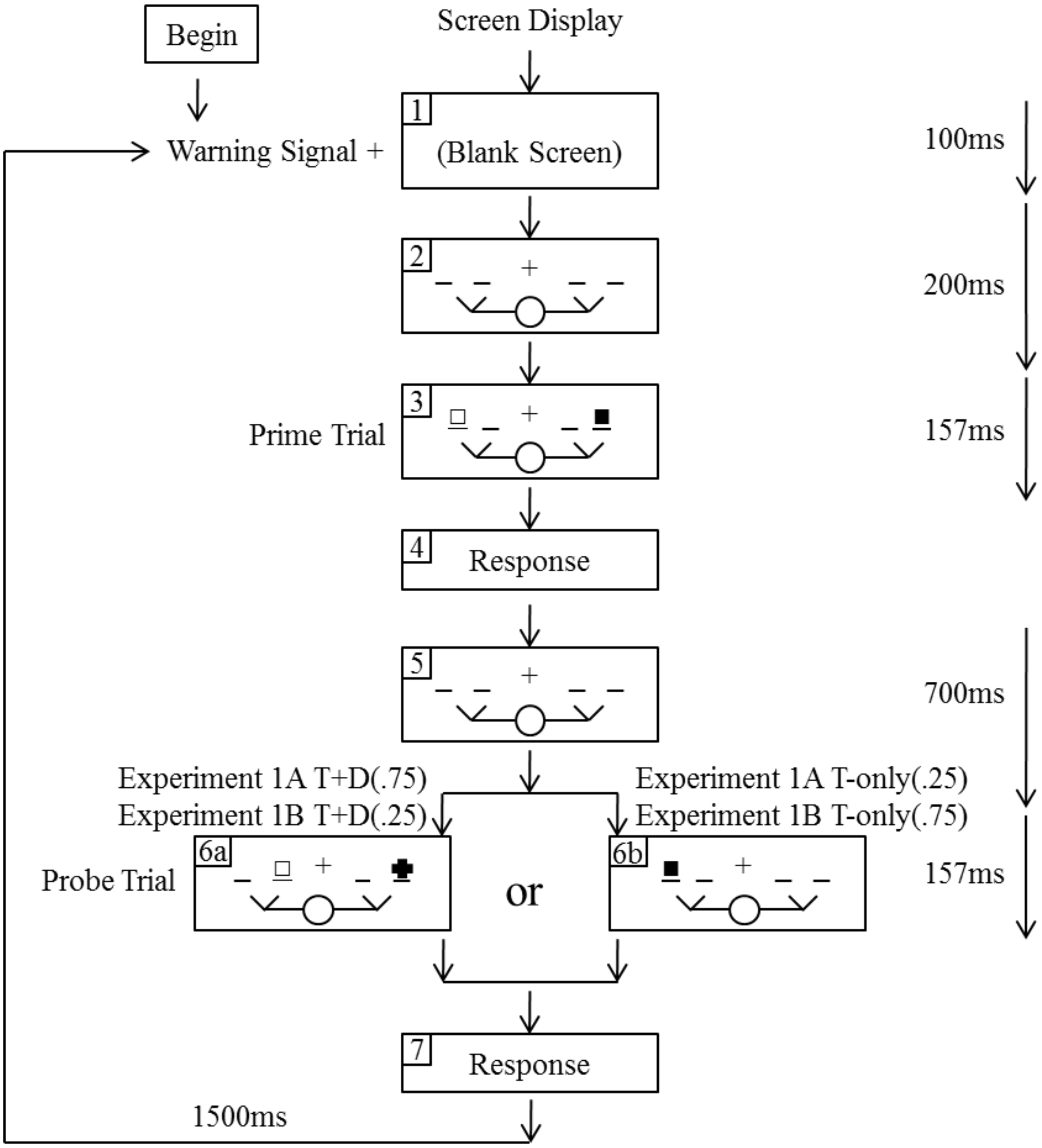
Objectives. Foremost, this study tested the possibility that representations of prime trial processing are stored episodically. The approach was to generate the ‘direct’ retrieval of the prime target on the probe trial, and then to look for evidence of the concurrent and ‘indirect’ retrieval of the prime distractor event file. Evidence of this indirect distractor file retrieval (i.e., T→T→D) signaled episodic storage and was indexed using error protection (Buckolz et al., 2014) rather than the more typical spatial negative priming (SNP) effect to index the retrieval of stored prime distractor information. Confirming the existence of error protection as a consequence of prime distractor processing and looking into the presence of within file feature binding (e.g., Hommel, 1998) serve as lesser aims.

Participants. Forty university students (14 males and 26 females) ranging in age from 20-25 years, with normal or corrected-to-normal vision engaged in this study.

Apparatus. Participants were seated at a desk in a dimly lit room 200 cm from a 61cm (24 inch) computer monitor that contained the visual display for the experiment. On each trial, a white fixation cross (0.9 cm in length, 0.1 cm in thickness, for both horizontal and vertical components) appeared against a black background, flanked by two white horizontal bar marker locations on either side that had identical dimensions to the horizontal component of the fixation cross. A distance of 0.5 cm separated the bar markers (denoted L1-L4 from left to right) from each other and from the fixation cross, producing a horizontal display distance of 7 cm (visual angle of approximately 2 degrees). In order to respond to the appearance of a target stimulus, participants positioned their forearms on either side of a computer keyboard that was fastened to the desktop while resting the middle and index fingers of each hand comfortably on keyboard buttons “D”, “V”, “M” and “L”, respectively. These keys were assigned to their spatially compatible bar marker locations (L1, L2, L3, and L4). Responses were achieved through finger flexion which depressed the appropriate keyboard button, terminating the RT interval.

Procedure (see Figure 3 throughout). Participants undertook a visual spatial negative priming (SNP) task where trials were presented in pairs; first the 'prime', and then the 'probe'. The prime trial always (100%) contained a target (green rectangle) plus a distractor (red rectangle) object (both measuring 0.9 cm wide x 2 cm high), while the probe trial could also contain a target plus a distractor (i.e. distractor present, 75% [Expt. 1A]) or a target by itself (distractor absent, 25% [Expt. 1A]). The prime distractor's identity remained unaltered throughout, while that for the prime target could either be repeated or changed (yellow cross) on the probe. This occurred in a blocked fashion, randomly counterbalanced among subjects. This probe target identity manipulation allowed us to index stored target representation retrieval using the RT(target identity repeat) < RT(target identity change) metric, and, along with a repetition or change in target location, allowed this measurement to occur both with and without a feature binding possibility. Further, target representation retrieval can be examined for ignored-repetition trials (e.g., Configurations [1] & [2], Schematic 1) and so test episodic storage in this way.

The probe trial distractor probability ratio in Expt. 1A was .75(distractor present probe)/.25 (distractor absent probe), presumably leaving the distractor response retrieval pathway intact (Buckolz et al., 2012; Fitzgeorge et al., 2008), while yielding 288 target-plus-distractor and 96 target-only probe trials (complete trial sequence = 384 trial pairs). For each of these two probe trial types, distractor and/or target objects appeared equally often at all locations; resulting in 72 ignored-repetition (IR), 72 target location repeat (TR) and 96 control (CO), trials. The remaining prime-probe trial combinations (n= 144) did not contribute to the aims of this experiment and so were not analyzed (but are



Schematic 3. Illustration of a prime-probe trial sequence and presentation durations for Experiments 1A (75[probe distractor present]/.25 [probe distractor absent]) and 1B (.25 [probe distractor present]/.75 [probe distractor absent]). Target events could be either a green rectangle (dark rectangle in figure) or a yellow cross (dark cross in figure); only the former could appear on the prime trial, while either target could arise on the probe trial. When a distractor appeared (100% on the prime, 75% or 25% on the probe), it was always a red rectangle (light rectangle in figure). Panel 6a represents a target-plus-distractor (T+D), target location repeat trial. Panel 6b represents a target-only (T-only) ignored-repetition trial.

presented in Table A1 in Appendix A). Participants completed two counterbalanced trial sequences on separate days; one where the probe target identity was repeated and one where it was changed. The order of trial pair delivery was randomized within each series so that no participant had the same order twice, or the same order as any other participant.

A trial sequence commenced with a warning tone (100ms), whose offset was followed by the appearance of the fixation cross and four location bar markers which remained on the screen for the duration of each trial pair. The prime trial objects (target and distractor) appeared simultaneously 0.1cm above any two of the four location markers 200ms after onset of the cross and bar markers and remained visible for 157ms (e.g., Milliken et al., 2000). A correct prime trial response initiated a 700ms inter-stimulus interval (ISI) whose termination coincided with the probe trial presentation which lasted for 157ms. A correct probe trial response initiated the disappearance of the cross and bar markers and the onset of a 1500ms inter-trial interval which terminated with the onset of the next warning tone, which began the presentation of the next trial pair. An incorrect response on either the prime or the probe trial resulted in the display remaining static until the mistake was corrected. Trial pairs that contained errors were recorded but were not used in reaction time analyses. Participants were automatically offered a rest break after completion of every 100 trial pairs. Trials resumed when participants pressed the space bar at their discretion.

Before beginning the experimental phase, participants were instructed that (a) they were to respond to any target event with the appropriate key press as quickly and as accurately as possible while ignoring any distractor event should one be present, (b) they were to avoid button press errors and responding before target arrival (i.e., anticipations),

(c) trials would be presented in pairs, and, (d) a distractor would appear on the probe trial three times more often than not (analogous to the usual SNP procedure in producing the SNP effect).

Before undertaking the critical portion of the experiment participants completed approximately 10-15 prime-probe practice trials and had the opportunity to ask any questions to ensure their understanding of the task requirements.

Experiment 1B (.25[probe distractor present/.75[probe distractor absent])

Objectives. In addition to the aims described earlier for Experiment 1A, (i.e., episodic storage in visuo-spatial tasks), the current experiment set out to determine whether a probe distractor whose identity matched that of the prime trial, independently retrieves stored distractor event file representations even when they change their prime locations on the probe (allowed by the use of changing prime-probe target identities; Schematic 2, Panel B, Configuration [6]). As well, the success rate of a probe distractor ratio of .25(distractor present)/.75(distractor absent) in preventing the appearance of spatial negative priming will again be tested (Haworth et al., 2014).

Participants. Fifty-eight university individuals (ranging in ages from 20-25 years), with normal or corrected-to-normal vision participated in this experiment (29 males, 29 females).

Apparatus. Same as in Experiment 1A.

Procedure. The procedure was identical to that of Experiment 1A, with the following exceptions. The probe distractor ratio was .25(distractor present/.75 (distractor absent), giving rise to 144 target-plus-distractor, and 432 target-only trials (total = 576). Within the 576 trials, there were 132 ignored-repetition, 132 target location repeat, and

240 control trials. The remaining prime-probe combinations (72 trials) had no theoretical consequences for our immediate interests and so were not retained for analyses.

RESULTS & DISCUSSION

Unless otherwise noted, all analyses of variance will use Probe Target Identity (repeat, change) and Probe Target Location (repeat, change) as the main within-subject factors, and with mean individual reaction times, or probe trial error selection frequencies, serving as the dependent variables. Reaction times less than 100ms (anticipations) or greater than 1000ms (insufficient vigilance), as well as those produced whenever a prime-probe trial pair contained a button press error, were excluded from the reaction time analyses.

Evidence that the prime trial target identity has been retrieved on the probe will be primarily indexed as the difference between probe RTs for repeated versus changed prime target identities.

Experiment 1A (.75[probe distractor present]/.25[probe distractor absent)

The basic aim of Experiment 1A was to look for evidence of episodic storage in visuo-spatial tasks. Episodic storage would be indicated if the ‘direct’ retrieval of the prime target event file was accompanied by the ‘indirect’ retrieval (T→T→D) of the prime distractor event file.

Probe Targets Appearing at the Prime Distractor (Ignored-repetition Trial), or at a New (Control Trial), Location

Reaction Times

Target-only (distractor absent) Probe Trials. Probe Target Location was the only significant effect yielded by the ANOVA, F(1,39)= 15.98, p< 0.01, MSE= 187. Reactions were reliably slower when the probe target appeared at the prime distractor position rather than at a new location (456 ms vs. 447 ms), revealing a significant spatial negative priming (SNP) effect. The effect was evident whether prime-probe target identities were repeated (9 msec.) or changed (8 msec.) [Table 1: configurations [1] vs. [3]; [2] vs. [4], respectively].

The lack of a reliable Probe Target Identity main effect, F(1, 39)= 1.12, p= 0.30, MSE= 1328, along with its non-significant interaction (F<1), provided no evidence that the prime target event file had been retrieved; equivalent reaction time differences for repeated versus changed probe target identities were observed for ignored repetition and control trials (Table 1: configurations [1] vs. [2] and/or [3] vs. [4]). This failed retrieval of stored prime target event files on ignored-repetition trials, which nonetheless resulted in the retrieval of the prime distractor event file (SNP; response-based route), is notable because it argues against 'indirect' D→D→T retrieval. This finding is contrary to the existence of episodic storage in visuo-spatial tasks and possibly to Frings and Moller (2010), who felt that a probe distractor did 'indirectly' retrieve aspects of the stored prime target file (see General Discussion).

Target-plus-distractor Probe Trials. When the probe trial contained a target and a distractor (whose identity always matched that of the prime trial), significant Probe Target Location, F(1, 39)= 39.03, p < 0.01, MSE= 132), and Probe Target Identity, F(1, 39)= 11.16, p < 0.01, MSE= 1243, main effects were qualified by

Table 1

Mean Reaction Times (ms) and Error Protection as a Function of Probe Distractor Probability Ratio (Exp.1A: .75[probe distractor present]/.25[probe distractor absent], Exp.1B: .25[probe distractor present]/.75[probe distractor absent]) and Probe Trial Configuration (Configuration Exemplars of Ignored Repetition and Control Trials).

		Probe Distractor Probability Ratio			
Prime Exemplar	→ T1 __ + __ D1	Experiment 1A .75(DP)/.25(DA) n=40		Experiment 1B .25(DP)/.75(DA) n=28	
Probe Trial Configuration Exemplars	↓	Reaction Time (ms)	EP CR/DR	Reaction Time (ms)	EP CR/DR
[1]	__ __ + __ T1	453 (8.1) [8.1]	N/A	436 (8.3) [11.5]	N/A
[2]	__ __ + __ T2	458 (7.5) [6.0]	N/A	448 (6.7) [7.9]	N/A
[3]	__ __ + T1 __	444 (8.4) [5.8]	0.020/0.014	433 (7.7) [10.3]	0.027/0.016*
[4]	__ __ + T2 __	450 (7.6) [5.1]	0.018/0.014	445 (6.7) [8.9]	0.019/0.016
[5]	__ D1 + __ T1	476 (8.3) [7.0]	N/A	469 (9.8) [10.6]	N/A
[6]	__ D1 + __ T2	490 (8.1) [7.2]	N/A	501 (10.2) [8.9]	N/A
[7]	__ D1 + T1 __	460 (7.7) [6.8]	N/A	464 (11.5) [10.3]	N/A
[8]	__ D1 + T2 __	483 (8.0) [6.8]	N/A	485 (9.3) [10.1]	N/A
SNP (IR-CO) T-only Probes	[1]-[3] [2]-[4]	T1 = 09* T2 = 08*		T1 = 03 T2 = 03	
SNP (IR-CO) T+D Probes	[5]-[7] [6]-[8]	T1 = 16* T2 = 07*		T1 = 05 T2 = 16*	

Notes. T1 = Target 1 (green rectangle), T2 = Target 2 (yellow cross), D1 = Distractor 1 (red rectangle), IR = Ignored Repetition Trial ([1], [2], [5], [6]), CO = Control Trial ([3], [4], [7], [8]), SNP = Spatial Negative Priming (IR-CO), DP = Distractor Present, DA = Distractor Absent, EP = Error Protection, CR = Control Response, DR = Distractor Response, N/A = Not Applicable (EP cannot be measured). ( ) = standard error (ms); [ ] = button press error percent. *$p<0.05$.

their reliable interaction, F(1, 39)= 6.32, $\underline{p}$= 0.02, MSE= 114 (see Table 1). Newman-Keuls tests ($\underline{p}$< 0.05) applied to the interaction revealed that RTs were significantly faster when prime-probe target identities were repeated, a difference that was greater for Control (23 msec.; configurations [7] vs. [8]) than for ignored-repetition (14 msec.; configurations [5] vs. [6]) trials. Unlike the T-only probes, the SNP phenomenon was significantly greater when the prime-probe target identities were repeated (16 msec.; [5], [7]) as opposed to when they changed (7 msec.; [6] vs. [8]).

Because the route responsible for prime trial distractor event file retrieval with target-plus-distractor probe trials is uncertain we can say nothing unequivocal from this data about episodic storage (e.g., Schematic 2; i.e., the response-based route, the ‘direct’ object-based route [for matching prime-probe target or distractor identities], or the ‘indirect’ retrieval pathways [D→D→T, T→T→D]). However, two minor points can be made.

One point is that along with the target-only probe data noted above, we have assurance that the procedure used here does produce an SNP effect. Hence, looking ahead, we can more confidently attribute any removal of an SNP effect in Experiment 1B, which would otherwise be present, to its .25(probe distractor present)/.75(probe distractor absent) probe distractor ratio manipulation (Fitzgeorge et al., 2008).

The second point is more speculative and relates to probe configuration retrieval effectiveness. The retrieval of the prime target event file may be more consistent from trial to trial when a matching probe target identity is accompanied by a distractor, whose identity is the same as that of the prime distractor. This possibility was suggested by the fact that the facilitation effect observed (i.e., latency difference between target identity repeat vs. identity change) was larger with the probe distractor present rather than absent (i.e., 19 msec. vs. 6 msec., respectively; Table 1, Exp. 1A). This elevated facilitation effect might have happened simply because of the probe distractor's assistance in retrieving the prime target event file (i.e., assistance to the retrieval effect of the matching probe target). If so, a D→D→T indirect retrieval route would be indicated, as would episodic storage. Alternately, prime target retrieval might have been better with the probe distractor present because both of the prime event identities re-appeared on the probe. In the latter instance, there seems to be no need that prime and probe event locations also be repeated for a retrieval benefit to arise.

Error Protection

Target-only Probe Trials. It was technically possible to test for error protection evidence for configurations [3] & [4] in Table 1. The general notion here is that the 'direct' retrieval of the prime target event file could 'indirectly' retrieve the prime distractor event file (i.e., T→T→D), which would be manifested by the appearance of error protection data. This would hold for configuration [3]. However, according to the earlier latency results, the prime target event file was not retrieved on the probe trial for configuration [3], thereby obviating a T→T→D retrieval of the prime distractor event file, and so the basis for error protection. As predicted, a significant error protection effect was not present. In this way, one could argue for the existence of episodic storage in visuo-spatial tasks, albeit on a null effect basis.

Looking at configuration [4], retrieval of the prime distractor event file was again not anticipated. This is because the probe trial makeup for this configuration presumably lacked a basis for inducing prime trial event file retrieval (i.e., repeated target location and/or identity). Once more, the predicted lack of a significant error protection effect was observed and so, again, these findings at least do not contradict the possibility of episodic storage.

The error protection data for configurations [3] and [4] may be instructive in another way. While not significant for either configuration; numerically, the data were consistent with an error protection effect (i.e., former prime distractor responses were used less often in error than were the control responses (i.e., averaged; 0.019 [control response] vs. 0. 014 [former distractor response]). That is, prime distractor event file retrieval may have been occurring to some extent even though, according to the assumption here, there was no 'event' basis for this retrieval. This leaves open the possibility that stored prime trial representations were retrieved in this study partially on the basis of 'contextual' prime-probe trial attributes (e. g., temporal contiguity of a pair of trials, bar markers for event positioning that remained on the display screen from prime to probe trial, etc.). Seemingly, contextually-based retrieval on its own is not consistent enough to generate 'significant' error protection data. Therefore, any significant error protection data that does emerge in this study could be ultimately attributed to the episodic storage of prime event file retrieval.

Target-plus-distractor Probe Trials. These trials were not appropriate for testing error protection.

Probe Targets Appearing at Prime Target (Target-repeat Trial) or at New (Control Trial) Locations

Reaction Times

About Interpreting the Probe Configuration Latency Data Within This Section. Ultimately, the major contribution of the data in this section was to detect the presence of a T→T→D indirect retrieval pathway, and so attest to the episodic storage of processed events in a visuo-spatial task. The approach taken was to identify which of the target-only probe configurations (Table 2, configurations [9]-[11]) achieved prime target event file retrieval, and then determine whether the configurations so identified also showed evidence of the concurrent and 'indirect' retrieval of stored prime distractor event files (i.e., episodic retrieval/storage). Notably, we used the 'error protection' after-effect (Buckolz et al., 2014) to index the 'indirect' retrieval of the prime distractor event file because its calculation avoids the confounding involvement of the response-based retrieval route, unlike the case for the more traditionally used SNP effect. Error protection evidence would point to the existence of a T→T→D indirect retrieval route, and hence to episodic storage in visuo-spatial tasks.

It bears reiterating that the interpretation of the latency data for some of the probe configurations examined here (i.e., Table 2: configurations [10], [11], [14], [15]) is constrained by the fact that they may incorporate opposing reaction time influences. That is, there may be a facilitation effect resulting from the repetition of some feature of the prime target (e.g., identity, location), which could be countered by a slowing influence due to the changed feature, per se. Delays could also result from the time needed to resolve a feature binding violation brought on by partial repeat/change of prime target features on the probe trial (e.g., Hommel, 1998, 2007; Mayr et al., 2011). On a positive note, the claimed involvement of either or both of these two latency factors for a particular probe configuration requires, and so signals, prime target retrieval. On the

Table 2

Mean Reaction Times (ms) and Error Protection as a Function of Probe Distractor Probability Ratio (Exp.1A: .75[probe distractor present]/.25[probe distractor absent], Exp.1B: .25[probe distractor present]/.75[probe distractor absent]) and Probe Trial Configuration (Configuration Exemplars of Target Repetition and Control Trials).

		Probe Distractor Probability Ratio			
Prime Exemplar	→ T1 __ + __ D1	Experiment 1A .75(DP)/.25(DA) n=40		Experiment 1B .25(DP)/.75(DA) n=28	
Probe Trial Configuration Exemplars	↓	Reaction Time (ms)	EP CR/DR	Reaction Time (ms)	EP CR/DR
[9]	T1 __ + __ __	425 (6.5) [3.5]	0.013/0.005*	411 (7.3) [7.1]	0.009/0.005*
[10]	T2 __ + __ __	444 (6.8) [5.1]	0.016/0.014	426 (6.3) [6.8]	0.010/0.005*
[11]	__ T1 + __ __	444 (8.4) [5.8]	0.020/0.014	433 (7.7) [10.3]	0.027/0.016*
[12]	__ T2 + __ __	450 (7.6) [5.1]	0.018/0.014	445 (6.7) [8.9]	0.019/0.016
[13]	T1 __ + D1 __	450 (7.1) [3.5]	0.009/0.013	442 (7.8) [8.0]	0.012/0.012
[14]	T2 __ + D1 __	481 (8.0) [5.5]	0.019/0.015	480 (8.5) [8.3]	0.007/0.016
[15]	__ T1 + D1 __	460 (7.7) [6.8]	N/A	464 (11.5) [10.3]	N/A
[16]	__ T2 + D1 __	483 (8.0) [6.8]	N/A	485 (9.3) [10.1]	N/A
Target Retrieval T-only Probes	[9]-[10] [11]-[12]	-19* -06		-15* -12*	
Target Retrieval T+D Probes	[13]-[14] [15]-[16]	-31* -23*		-38* -21*	

Notes. T1 = Target 1 (green rectangle), T2 = Target 2 (yellow cross), D1 = Distractor 1 (red rectangle), TR = Target Repeat Trial ([9], [10], [13], [14]), CO = Control Trial ([11], [12], [15], [16]; identical to Table 1 [3], [4], [7], [8]), DP = Distractor Present, DA = Distractor Absent, EP = Error Protection, CR = Control Response, DR = Distractor Response, N/A = Not Applicable (EP cannot be measured). ( ) = standard error (ms); [ ] = button press error percent. *$p<0.05$.

negative side, it is not always possible to stipulate with certainty which of these two factors is actually involved for a particular probe configuration. For example, probe configurations [10] and [11] both theoretically involved the two opposing latency factors. When their reaction times are compared to a baseline configuration (i.e., [12]) that repeats nothing from the prime, so that neither a binding violation nor a latency benefit were involved (e.g., Mayr et al., 2011), the ordinal latency relationship will depend upon the relative latency potency of the two factors. Configuration [10] and [11] reaction times significantly slower than that for configuration [12] would clearly signal the involvement of target feature binding; however, a reversal of this order would be unclear as to whether feature binding exists or not.

Target-only Probe Trials. Significant Probe Target Location, $F(1, 39)= 13.21$, $\underline{p} < 0.01$, $MSE= 482$, and Probe Target Identity, $F(1, 39)= 6.12$, $\underline{p} = 0.02$, $MSE= 1108$, main effects entered into a significant interaction, $F(1, 39)= 7.48$, $\underline{p} < 0.01$, $MSE= 216$. Applied Newman-Keuls tests ($p< 0.05$) revealed that the RT for configuration [9] was significantly faster than the RTs for the remaining configurations ([10] - [12]). These latencies did not differ reliably from one another (Table 2). Noting that configurations [9] and [12] are free of feature binding influences, their RT difference is a clear indication that probe configuration [9] resulted in the ‘direct’ retrieval of the stored target event file, which manifested itself by hastening the same target processing now required on the probe trial. This retrieval is corroborated by the fact that probe RT is significantly faster when the prime target identity is repeated rather than changed when the prime location is also repeated (configuration [9] vs. [10]).

No definitive evidence of target feature binding (identity and location) was present (i.e., RTs for configurations [10] or [11] vs. [12] were equivalent). However, one might speculate that the longer RT for configuration [11] than for configuration [9] might be due to the added time needed to accommodate a binding violation (i.e., repeating prime target identity at a new probe location [11]). In this view, when a target’s location, but not its identity, is changed on the probe trial, processing is slowed not because of the location change, per se, but because the change causes a feature binding violation.

Target-plus-distractor Probe Trials. Again, significant Probe Target Location, F(1, 39)= 4.60, p = 0.04, MSE= 384, and Probe Target Identity, F(1, 39)= 26.54, p < 0.01, MSE= 1085, main effects were qualified by their reliable interaction, F(1, 39)= 4.05, p= 0.05, MSE= 155. From one perspective, the Newman-Keuls test applied to this interaction revealed that the RTs for configurations [13] and [15] were significantly faster than the RT for configuration [16] (Table 2). As with the target-only probe trials, the faster RT for configuration [13] (repeat both prime target identity and location) than for configuration [16] (repeat neither), where target feature binding violations are excluded for both, is unequivocal in showing that the retrieval of the prime target event file had been achieved with probe configuration [13].

From a second perspective, the Newman-Keuls test also indicated that repeating the prime target identity on the probe trial produced significantly faster latencies (455 msec.) than when target identity changed (482 msec.) [Table 2]. This difference was significant whether the prime location had been repeated or changed on the probe in both cases, but was significantly greater when the prime target location was also reused (i.e., 31 msec. vs. 23 msec.; Table 2, configurations [13] vs. [14] and [15] vs. [16], respectively). There are two things that need to be highlighted here. The first is that these data reinforce the claim that the prime target was retrieved with probe trial configuration [13], and now extends this claim to configuration [15].

The second point is that the data may indicate a target identity-target location prime trial binding. In this latter regard, when prime target identity was repeated on the probe trial, its latency was 10 msec. slower if it appeared at a new probe location than if it arose at its prime location. This RT difference was not due to the location change, per se, as a location change did not change RT when the prime target identity changed (481 msec. vs. 483 msec.). Hence, the slower RT seen when the prime target was repeated at a new probe location might have reflected the time cost for a target identity-location binding violation (about 10 msec.).

Having speculated on the matter above, we hasten to point out that, technically, we did not determine whether feature binding within an event file, between a prime target identity and its location, actually took place in this study. More definitive evidence of a prime target identity-prime target location binding would have seen reactions for configurations [14] and [15], where a binding violation was possible, exceed the reaction observed for the baseline configuration ([16]) [Table 2] where binding was not possible. This did not occur.

Looking forward, we highlight the fact that configuration [13] could not be used to look for evidence of episodic storage. This is because the route responsible for the retrieval of a prime distractor event file is ambiguous for this configuration (i.e., the T→T→D ‘indirect’ route; or a matching probe distractor, ‘direct’ route). However, both configurations [13] and [14] could be employed, as we did later, to look for evidence supporting the existence of error protection afforded prime distractor responses (Buckolz et al., 2014).

Error Protection

According to Buckolz et al. (2014), evidence of error protection requires, and so reveals, the retrieval of prime distractor event files. Hence, support for episodic storage of prime trial processing would see those probe configurations that showed evidence of prime target event file retrieval (RT data), also showing evidence of error protection, likely mediated by a T→T→D ‘indirect’ retrieval route that provided access to the prime distractor event file (Schematic 2).

Target-only Probe Trials. Error protection was significant for configuration [9] (pr. = 0.5 [prime distractor response] vs. pr. = 1.3 [control response]), t(39)= 2.15, p < 0.05, SDD= 0.017, but not for configurations [10]-[12] (*p*-values ranged from 0.13 to 0.61) [Table 2]. Thus, the only probe configuration that showed RT evidence of prime target event file retrieval ([9]), provoked by its matching of the prime target’s identity and its location, was also the only configuration that showed evidence of having concurrently retrieved the stored prime distractor event file. This is consistent with the operation of a T→T→D indirect retrieval route, and so with the episodic storage in visual location tasks (Schematic 2).

Notably, for configurations [9] and [10] in Experiments 1A and 1B, the chance of committing a control response selection error (CR, Table 2) on the probe was double that for choosing the former prime distractor response in error (DR, Table 2). Accordingly, control response selection error probabilities were calculated by dividing the number of control response selection errors in half. A similar accommodation was made by Buckolz et al. (2014).

Target-plus-distractor Probe Trials. Configurations [13] and [14] did not allow for an unconfounded test of a T→T→D indirect retrieval route for the prime distractor event file. So, with these configurations, we were simply looking to verify the existence of error protection. However, significant error protection effects (t-tests [df= 39], *p*-values > 0.15) did not arise (Table 2).

Experiment 1B (.25[probe distractor present]/.75[probe distractor absent])

Experiment 1B had three basic objectives. The first was to re-visit the episodic storage matters addressed in Experiment 1A, with the hope of replicating the findings of shared conditions (i.e., T→T→D indirect route). Second, Experiment 1B was particularly suited for investigating the question of whether a probe distractor matching the identity of the prime distractor does, on its own, retrieve stored prime distractor event files ('direct' distractor object retrieval route). Third, confirmation of this possibility (along with the blocking of the response-based retrieval route), would permit an assessment of whether a distractor→target 'indirect' retrieval pathway exists with some of the probe configurations (D→D→T). If so, it would support episodic storage in visuo-spatial tasks.

Probe Targets Appearing at the Prime Distractor (Ignored-repetition Trial), or at a New (Control Trial), Location

Reaction Times

Target-only Probe Trials. In keeping with Haworth et al. (2014), our ANOVA calculations revealed a significant Probe Trial Location main effect, F(1, 57)= 44.85, p< 0.01), MSE= 96, indicating that the .25(probe distractor present)/.75(probe distractor absent) distractor manipulation had failed to cause the response-based retrieval route to be blocked (i.e., SNP removed) for the collective of individuals studied in this experiment. Accordingly, we followed the lead of Haworth et al., by identifying those subjects that produced SNP values that were either negative or less than 9 msec. positive (i.e., approximately 2 times the standard error for all positive SNP values originally obtained, minus the related SNP mean), arguably holding that these individuals had successively blocked the response-based route. Twenty-eight participants met these criteria (48% of the original participant pool), about the same proportion as that reported by Haworth et al.

An ANOVA was then calculated using these 28 identified individuals. Probe Target Identity produced the only significant effect, F(1, 27)= 5.35, p= 0.03, MSE= 492. Reaction time was reliably shorter when the prime-probe target identities matched rather than mismatched (Table 1: configurations [1] & [3] vs. [2] & [4]); 436 msec. vs. 446 msec.), both for ignored-repetition and control trials. This indicates that the stored prime target event file was retrieved, presumably being responsible for the hastened reaction time observed when the prime target identity remained unchanged on the probe.

Notably, the non-significant Probe Trial Location main effect (2 msec.), F(1, 27)= 1.34, p= 0. 26, MSE= 40, reflected the failed retrieval of the stored prime distractor event file, thereby accounting for the absence of a spatial negative priming (SNP) effect on the target-only probe trials. This is consistent with the blocking of the response-based retrieval route for these individuals (Schematic 2, Panel A), brought on by the .25(probe distractor present)/.75(probe distractor absent) manipulation (Fitzgeorge et al., 2008; Haworth et al., 2014).

It is notable that we see that the prime target event file was retrieved by configuration [1] (Table 1), yet it did not result in an SNP effect (configurations [1] vs. [3]). Hence, no T→T→D 'indirect' distractor file retrieval was indicated. Alternately, a T→T→D retrieval pathway does exist; however, a prime distractor event file retrieved in this way does not influence ignored-repetition processing.

Target-plus-distractor Probe Trials. The major outcomes of the ANOVA calculation were that the Probe Target Identity, $F(1, 27)= 34.00$ $p< 0.01$, $MSE= 592$, and the Probe Target Location, $F(1, 27)= 6.92$, $p = 0.01$, $MSE= 449$, factors generated significant main effects, which did not interact, $F(1, 27) = 3.85$, $p= 0.06$, $MSE= 242$. Respectively (Table 1), reactions were significantly faster when the prime-probe target identities were repeated (466 msec.) rather than changed (493 msec.), and slower reactions were evident when the prime distractor location was re-occupied by the probe target (485 msec., ignored-repetition trial) versus when the target showed up at a location unused on the prime (474 msec., control trial) [i.e., an SNP effect= 11 msec.].

Related to a main objective of Experiment 1B was the restoration of the SNP effect for configuration [6] (16 msec.), where the prime distractor identity, but not the prime target identity, was repeated. When the prime-probe target identities again mismatched, but where the probe lacked a distractor object, no SNP effect (retrieval) was observed (3 msec.; configuration [2]). Hence, the presence of an SNP effect in configuration [6] indicates that its identity-matching probe distractor directly retrieved the stored prime distractor event file, even when the probe distractor appeared at a new probe location. Similar claims to this effect in the past were premature because in that work, the prime and probe target and distractor object identities both matched (e.g., Fitzgeorge et al., 2008; Haworth et al., 2014). Hence, it was unclear as to whether repeating prime distractor identity on the probe generated distractor event file retrieval on its own or, whether distractor retrieval arose because of a combined retrieval impact of the two probe objects whose identities matched those used on the prime (i.e., configuration [5]). The result here (i.e., configuration [6]) supported the former option.

Relatedly, the notion that probe distractors must appear at their prime locations to induce retrieval in location tasks seems untenable (e.g., Frings & Moller, 2010). Rather, contact with stored prime information may require only that the identity of a single probe (e.g., distractor) object matches one that is stored in the event file/episode.

Finally, as with the .75/.25 probe distractor probability ratio, we again see that stored prime target event files were retrieved with both ignored-repetition and control trials, and that the benefit of this retrieval (facilitation size) when prime and probe target identities matched was more than twice that produced for target-only probe trials (Table 1, Exp. 1B, 27 msec. vs. 10 msec.). These findings might reflect the involvement of a D→D→T indirect retrieval route which increases the consistency of prime target event file retrieval and so hastens perceptual target recognition more often.

Error Protection

Target-only Probes. With configuration [3], where there was latency evidence that the prime target had been retrieved on the probe trial, there was a concurrent indication of error protection (Table 1, Exp. 1B). Control responses were employed significantly more often in error on the probe trial than was the case for former prime distractor response ($t[27]=3.85$, $p<0.01$). These findings are indicative of the ‘indirect’ retrieval of the prime distractor event file (i.e., T→T→D retrieval route), and so support the existence of episodic storage in visuo-spatial processing tasks.

At this point we turn to another aim of this study which was to look into why some individuals manifest SNP removal when operating with the .25[probe distractor present], .75[probe distractor absent] ratio, while others do not (Haworth et al., 2014; Exp. 1B here). The proposal in this regard was that those who exhibited SNP removal did not store their processing episodically. Hence, when the response-based retrieval route is blocked, they have no alternative way to retrieve prime distractor event file; hence, no SNP effect occurs. This possibility was not supported here. Subjects who exhibited the ability to prevent the SNP phenomenon, nonetheless showed evidence that they stored prime trial processing in an episodic fashion. There was RT evidence earlier that the prime target was retrieved on the ignored-repetition trials (e.g., configuration [1], Table 1). Given the existence of episodic storage, and so of a T→T→D retrieval pathway, the prime distractor event file should have been retrieved with configuration [1], and SNP should have been produced. This was not the case. If one accepts that the prime distractor event file was, in fact, retrieved with configuration [1], it would follow that SNP prevention can occur post-retrieval, as well as being the consequence of failed retrieval (Hommel, 2007).

It would follow, too, that ‘indirectly’ retrieved prime distractor event files (T→T→D) do not impact ignored-repetition trial processing. Therefore, episodic storage (T→T→D) does not play a role in SNP production, and so differences in this regard do not explain why SNP is preserved for some individuals but not in others when a .25/.75 probe distractor probability imbalance is employed. Applying this view to those who manifest an SNP effect with this probability imbalance, it would mean that they are unable to block the response-based route.

Target-plus-distractor Probes. These configurations ([5]-[8]) were unsuitable for examining error protection on the probe trials.

Probe Targets Appearing at Prime Target (Target-repeat Trial) or at New (Control Trial) Locations

Reaction Times

Target-only Probes. ANOVA outcomes revealed significant Probe Target Identity, F(1, 27)= 6.66, p= 0.02, MSE= 747, and Probe Target Location, F(1, 27)= 30.90, p< 0.01, MSE= 386, main effects which did not interact, F(1, 27)= 0.50, p= 0.49 MSE = 152. Reaction times were shorter when prime-probe target identities matched (422 msec. vs. 436 msec.) and when target location was repeated (418 msec. vs. 439 msec.). This RT pattern indicates that the retrieval of stored prime target event file had occurred with configurations [9], [10], and [11] (Table 2). Thus, they were suitable for subsequent testing for concurrent error protection (episodic storage) evidence.

Further, the lesser latencies observed for configurations [10] and [11] relative to configuration [12] showed no evidence of a within event file feature binding between the prime target's identity and its prime location.

Target-plus-distractor Probes. ANOVA calculations again revealed significant Probe Target Identity, F(1, 27)= 30.62, p< 0.01, MSE= 808, and Probe Target Location, F(1, 27)= 4.55, p= 0.04, MSE= 1101, main effects, together with their reliable interaction, F(1, 27)= 5.30, p= 0.03, MSE= 400. The cell means for this analysis are found in Table 2, Exp. 1B. Numerically, reactions were faster when prime-probe target identities matched (453ms vs. 483ms) and when prime target position was repeated on the probe (461ms vs. 474ms). Newman-Keuls tests applied to the interaction showed that all pair-wise comparisons had significantly different RTs with the exception of the [14] vs. [16] configurations contrast, where the location was repeated/changed (respectively), while the target identity was the same (but was different from that of the prime).

What we can say with some certainty is that the RT differential for configurations [13] and [16] indicates that stored prime target event file was retrieved with configuration [13], but we cannot stipulate the retrieval route(s) that achieved this retrieval (Schematic 2). Definitive interpretations of the remaining configuration contrasts is impossible because of the multiplicity of factors involved (e.g., RT for [14] could be influenced by binding, target identity change, and/or a D→D→T indirect retrieval). As with the .75/.25 probe distractor probability imbalance section, none of these configurations ([13]-[16]) can be used to test for T→T→D indirect retrieval (storage), although [13] and [14] can be used to look for evidence of error protection.

There is, however, an indication in this RT data that points, albeit tentatively, to the occurrence of the ‘indirect’ retrieval of the prime target (i.e., a D→D→T route), and so to episodic storage (Table 2). Specifically, when the probe target appears alone, the probe RT difference between when the prime target’s identity is repeated versus when it is changed (i.e., [9] – [10], Table 2; 19 msec./15 msec. for Exps. 1A and 1B, respectively), is about doubled in size on average, when the probe target is accompanied by a distractor, whose identity matched that of the prime (i.e., [13] - [14], Table 2; 31 msec./38 msec. for Exps. 1A and 1B, respectively). This magnification of the probe RT difference between a target identity repeat versus an identity change could reflect the workings of an ‘indirect’ retrieval of the prime target’s identity (i.e., D→D→T), and so support episodic storage. When the prime-probe target identities matched, the ‘direct’ retrieval of the prime target (T→T) would be supplemented by its ‘indirect’ retrieval (D→D→T). These complementary retrievals could reduce target recognition time and so facilitate overall target repeat RT (this may take the form of reducing the delaying effect simply owing to the presence of a probe distractor). Alternately, when the prime-probe target identities mismatched, the ‘indirect’ retrieval of the prime target’s identity by the probe distractor could interfere with the recognition of the now different probe target identity. So, the presence of a matching probe distractor identity can produce facilitative or interference effects, which operate to cause larger RT differences between repetitions versus changes in the prime target’s identity on the probe; an outcome that is, therefore, consistent with episodic storage.

Error Protection

Target-only Probes. Significant error protection data was obtained for configurations [9], [10], and [11] (Table 2, Exp. 1B); former prime distractor responses were used significantly less often in error than were the control responses on the probe trials (the t-values for these configurations were; ts [27] = 2.82, 2.72, 3.85, respectively, *ps* <0.01).

The latency data indicated that the prime target event file was retrieved for configurations [9] and [11]. Presumably, this retrieval triggered the ‘indirect’ (T→T→D) retrieval of the prime distractor event file, which was then responsible for the error protection findings. In these findings, we again have evidence of episodic storage in visuo-spatial processing.

To reconcile the evidence of error protection for configuration [10], we would have to assume that the prime target event file was retrieved because of the re-use of the prime target's location on the probe.

Target-plus-distractor Probes. T-tests for probe configurations [13] and [14], contrasting the probabilities of using the probe control and the former prime response in error on the probe (Table 2), were non-significant, ts (27) = 0.01 and 1.30, respectively, (ps > 0.21). There was no reliable bias against choosing the prime distractor response in error on the probe trial. This absence of error protection when a probe distractor is present replicates Experiment 1A.

GENERAL DISCUSSION

Error Protection: A Prime Distractor Inhibitory After-effect

We did see evidence of an error protection inhibitory after-effect on target-only probe trials where former prime distractor responses were used significantly less often in error on the probe trial than were control responses, confirming the existence of this inhibitory after-effect reported by Buckolz et al. (2014). The presence of an error protection after-effect logically follows from the contention that former distractor responses resist future execution on a probe trial, which is held to be responsible for the other inhibitory after-effects observed in visuo-spatial tasks (i.e., the SNP effect, the selection bias against former distractor responses on free choice probe trials, etc.) [e.g., Buckolz et al.; Fitzgeorge et al., 2011]. It would follow, too, that error protection supports a response locus for the spatial negative priming effect (e.g., Buckolz et al.).

It appears that error protection manifestation is not inevitable, a property also exhibited by the other inhibitory after-effects which are a consequence of prime distractor processing. In some instances, after-effect absence is deliberately engineered (Exp. 1B; Fitzgeorge & Buckolz, 2008) while in other cases, it happens unexpectedly (i.e., greater probe trial button-press errors for ignored-repetition than for control trials is not inevitably observed; e.g., Buckolz et al., 2008; Fitzgeorge et al., 2011; Milliken et al., 2000). In the unexpected category, the error protection evidence obtained here with the target-only target repeat probe trials failed to materialize when the target was accompanied by a distractor (Experiments 1A and 1B; but see Buckolz, et al.). While no readily apparent explanation for this finding presents itself, we can likely rule out a retrieval failure. This is because prime distractor representation retrieval would have been stimulated on the probe target-plus-distractor trials by the T→T→D ‘indirect’ retrieval route (target-only probe trials, see below) and ‘directly’, by the presence of a matching probe distractor (established in Experiment 1B). The question then becomes why the execution resistance feature of the retrieved prime distractor response did not exert any control over probe response selection, when a distractor object was present?

In any case, the findings here alert us to the need to identify those task contexts in which an error protection after-effect is likely to show up or not. In this vein, experimental efforts going forward might look to see whether error protection is also an inhibitory after-effect related to distractor processing with other sensory systems (i.e., auditory, tactile), and then possibly use a procedure similar to the one employed here to determine whether the episodic storage format applies to these sensory systems.

Actually, related to the foregoing possibility, Mayr and Buchner (2014) have reported that the processing of auditory events in an identity task is stored episodically. Of note, their index of episodic storage existence was based upon evidence of the ‘indirect’ retrieval of prime trial events, the same logic utilized to detect episodic retrieval in this investigation. Specifically, Mayr and Buchner found that probe trial errors were significantly more likely to involve the prime target response than a control response on ignored-repetition trials. Presumably, a probe target, whose identity matched that of the prime distractor, retrieved this event, which then ‘indirectly’ retrieved the prime target event file (i.e., T→D→T). This added retrieval impetus resulted in the prime target response being employed more often in error than a probe control response. In any event, the format used for storing processed material may well be the same, irrespective of modality.

On a cautionary note, however, looking back at the possibility of error protection for auditory and/or tactile distractors, error protection might not be forthcoming because their inhibitory after-effects are not caused by response inhibition (e.g., Mayr et al., 2014; Wesslein et al., 2016), which is the proposed basis for error protection (Buckolz et al., 2014). However, it would be interesting to find error protection for auditory and/or tactile processing because it would suggest that the distractor-related responses undergo inhibition, contrary to speculation (e.g., Mayr et al.; Wesslein et al.). Furthermore, it would indicate that response inhibition does not delay responding on ignored-repetition trials because the use of prime distractor responses on ignored-repetition trials has been shown to be unrelated to SNP production in these modalities (e.g., Mayr et al.; Wesslein et al.).

Episodic Storage in Visuo-spatial Tasks

Our view of the storage of processed information in visuo-spatial tasks is that relevant target features and irrelevant distractor features bind together within their respective event files (Hommel et al., 2014). These relevant and irrelevant event files are then stored in a connected fashion, perhaps as a consequence of between event-file binding (Kajaste et al., 2016), a fundamental property of episodic storage.

It is possible to retrieve target and distractor event files ‘directly’, through the repetition of target and/or distractor identities on the probe trial. When this demonstrably occurs, we should see the concurrent, ‘indirect’ retrieval of the other event file. We tested this ‘indirect’ retrieval prediction of an episodic storage format (Hintzman, 1984; Neill et al., 1992). Specifically, we focused on inducing the direct retrieval of the prime target event file, then looking for evidence of the concomitant retrieval of the prime distractor event file (i.e., a T→T→D ‘indirect’ retrieval route; Schematic 2, Panel A).

Present Study: Evidence of Episodic Storage.

(a) Evidence of ‘Indirect’ Prime Target Retrieval (D→D→T). Overall, the latency data in this study revealed that a target-only probe trial can ‘directly’ retrieve the prime target event file provided their identities matched, and this can occur whether the prime-probe trial location is repeated or changed (exception: Exp. 1A, configurations [1] vs. [2] and [3] vs. [4]).

When the probe trials contained both a target and a distractor, the RT benefit of repeating the prime target’s identity on the probe was larger than was the case when the repeated prime target appeared alone on the probe trial (e.g., Tables 1 & 2, Exp. 1A & 1B). This might reflect ‘indirect’ (D→D→T) prime target retrieval. The presence of a probe distractor whose identity matched that of the prime could directly retrieve the prime distractor event file, which indirectly retrieves the prime target file. When the direct and indirect retrievals point to the same required response, RT may be hastened beyond that which occurs with the direct retrieval pathway only. Taking the results here, and those of Frings and Moller (2010) at face value, a D→D→T indirect retrieval direction is viable, a result that supports episodic storage in visuo-spatial tasks.

(b) Evidence of 'Indirect' Prime Distractor Retrieval.

The current findings supported the existence of T→T→D indirect retrieval, indicative of episodic storage in visuo-spatial tasks. When the prime target location was repeated (target-repeat) or changed (control) on target-only probe trials, and the latency evidence demonstrated prime target retrieval had occurred, evidence of concurrent distractor event file retrieval was inevitably observed via error protection data (Exp. 1A - configuration [9]; Exp. 1B – configurations [9], [10], [11]). These results pointed to episodic storage.

It is perhaps instructive that probe configurations which generated neither significant evidence of prime target retrieval, nor significant error protection evidence, nonetheless had numerical probability imbalances that were often in the direction indicative of some 'error protection' impact happening on these probe trials (e.g., Exp. 1A – configurations [3], [4], [10], [11], [12] and [14]; Exp. 1B – configurations [4] and [12]). If we agree that 'error protection' reflects the retrieval of the prime distractor event file, these numerical error protection data lead to the possibility that stored prime trial representations are retrieved based on probe trial features other than the relationship between the 'events' contained in the prime-probe trial presentations. Possibly, retrieval of the prime trial takes place to some degree simply because of the contiguity of the prime-probe trial appearances and/or because of irrelevant contextual features, such as occurs for visual identity tasks (e.g., background similarity; Fox & de Fockert, 1998). Stored prime trial representation retrieval on the basis of irrelevant contextual features is in line with episodic storage in visuo-spatial tasks. Notably, though, this retrieval source by itself is not consistent enough within or between subjects to produce significant error protection results (i.e., prime distractor event file retrieval). In contrast, the addition of matching prime-probe target event features appears to have an independent prime target retrieval impact that results in significant error protection effects, presumably owing to a T→T→D indirect retrieval pathway that retrieves the prime distractor event file. This is consistent with episodic storage. Overall, we have evidence here of T→T→D and D→D→T retrieval, indicative of bi-directional ‘indirect’ retrieval, both of which point to episodic storage. Apparently, we can independently generate the retrieval of either target or distractor event files which, in turn, can induce the retrieval of the other.

Past Studies: Evidence of Episodic Storage. Studies reported by Neill et al. (1992) and Frings and Moller (2010) have purported to show evidence of episodic storage in visuo-spatial tasks. If this assertion is accepted, the present data represent a novel method of replicating this earlier conclusion. If there are some reservations about the clarity of these previous findings, which we highlight below, then the current investigation could be seen as lending some initial credibility to the idea that visuo-spatial processing is stored episodically.

(a) Neill et al. (1992). It is not obvious to us why the procedure utilized by

Neill et al. (1992) necessarily leads to the stipulation that visuo-spatial processing is stored episodically. These authors varied the time from the onset of the warning signal to the arrival of the target stimulus (500 msec. vs. 4000 msec.) and allowed these (fore-period) durations to vary randomly between prime and probe trial pairs (Exp. 1). The intent was to vary the temporal discriminability among stored representations. The idea was that if prime information is stored episodically, retrieval (SNP size) would be best when the stored episodes were most distinguishable temporally, which was presumed to be greatest with the 4000 msec./500 msec. fore-period pairing (i.e., the prior stored representations were farthest way while the current representations were placed most closely [500 msec.] to the current probe trial). Predictably, the largest SNP value occurred with the 4000 msec./500 msec. condition; however, it was not reported whether this SNP size differed significantly from the remaining three possible fore-period combinations. Furthermore, on a theoretical point, it is not evident why enhanced temporal distinction among stored representations would not also assist non-episodically stored processing. Overall, the basis for claiming that episodic storage applies to visuo-spatial processing on the basis of the Neill et al. study is, in our view, tentative.

Incidentally, another way of viewing the Neill et al. (1992) protocol was that it altered prime-probe contextual similarity (Fox & deFockert, 1998), provided that task timing is part of a stored episode. If so, mismatching the fore-period durations between prime and probe trials would degrade their contextual similarity, thereby preventing the retrieval of the retained prime representation by the probe trial. Reflective of this retrieval breakdown, and so of the lack of episodic storage, would be the absence of the SNP phenomenon on fore-period mismatch trials. This did not occur. Average SNP magnitude was significant and about the same whether the prime-probe fore period lengths matched (23 msec.) or mismatched (26 msec.). This is consistent with past work showing that contextual dissimilarity does not prevent retrieval in visuo-spatial tasks (e.g., Buckolz et al., 2008; Guy et al., 2004).

In any event, we reiterate that we tested a different prediction of episodic storage (i.e., ‘indirect’ retrieval) than the prediction examined by Neill et al. (1992). On this account, the current study can be viewed as providing some novel data indicative of episodic storage of processing in visuo-spatial tasks

(b) Frings and Moller (2010). Frings and Moller (2010) presented findings that apparently pointed to ‘indirect’ retrieval of prime target features (D→D→T) and so to the episodic storage of visuo-spatial processing. There are, however, several procedural features in their study that rendered their conclusion of indirect binding tentative.

Frings and Moller (2010) had the probe distractor either re-appear at the location it occupied on the prime trial (i.e., distractor location-repeat trial) or at a new probe location (i.e., distractor-location change trial). The tacit assumption was that prime distractor event file retrieval would occur when the prime-probe distractor locations matched, but not when the locations mismatched. Moreover, a further presumption was that the probe target played no role in the ultimate retrieval of the prime distractor event file (more on these assumptions later).

The findings were interesting. Probe target RT was significantly faster for the distractor location-repeat than for the distractor location-change trials when the prime target response had to be repeated on the probe (i.e., target-repeat trial), but not when the needed probe response changed (i.e., when the probe target arose at a new location). Frings and Moller reasoned that the re-occupation of the prime distractor position on distractor location-repeat trials triggered the retrieval of the stored target event file, whose response had become bound to the prime distractor location during prime processing. This being so, it would attest to the presence of a distractor→target 'indirect' retrieval route (Schematic 2, Panel B), whose outcome somehow facilitated RT when the retrieved response matched the required probe output.

To reiterate, a number of the procedural features employed by Frings and Moller (2010), along with some of their associated assumptions and related theoretical explanations, render an unequivocal episodic storage interpretation of their findings difficult. The reasons for these assertions are highlighted next.

First, in the critical probe trial contrasts, significantly faster target RTs may have evolved on distractor-repeat trials because on these occasions, the locations of the prime and probe distractor and target locations matched, while on the comparator control trials, prime-probe object location placements were not a complete match of the prime locations; hence, their relatively longer latency. This complete location repeat feature difference, and not an indirect (D→D→T) retrieval route (Schematic 2), as claimed, may have been responsible for the RT facilitation produced on distractor location repeat trials.

Second, in a theoretical vein, it is not clear how the proposed (episodic) link between the prime target response and the prime distractor location would cause a facilitation of target-response repeat reactions on probe distractor location-repeat trials, as Moller and Frings proposed. Recall that on the critical probe trial configuration, the prime events retained their respective locations on the probe and were presented simultaneously. Presumably then, the probe events would begin their respective processing together; both to retrieve their stored event files with the probe target leading directly to correct response selection, while the retrieval of the prime distractor's event file would trigger the D→D→T retrieval route, indirectly retrieving the to-be-required response. The question is how the latter serves as a backdrop to hasten probe target response selection/production by the probe target? It would seem unlikely that the probe target response activation resulting from the D→D→T indirect pathway would precede that produced by a direct target-driven response activation, especially given the high degree of compatibility for the location-to-response mappings used.

Third, the merits of the tacit assumption made by Frings and Moller, that probe distractors arising at new locations had no/lesser retrieval impact (i.e., their distractor location-change trials), is questionable. Frings and Moller did not directly test for prime distractor retrieval and so were not able to verify this assumption. There is evidence, however, that a probe distractor whose identity matches that of the prime, and which appears at a new probe location, can generate the retrieval of stored prime distractor representations (Exp. 1B here; Fitzgeorge et al., 2008; Haworth et al., 2014).

Fourth, there is, too, the idea that distractor-occupied locations activate their assigned responses, which can then compete with the target-activated response (i.e., a response conflict [e.g., Fitzgeorge et al., 2011; Buckolz et al., 2015]). The question arises as to whether differences in response conflict strength, perhaps being less for distractor location-repeat trials, could have contributed to faster RTs for the critical probe configurations, rather than this facilitation being solely due to 'indirect' D→D→T retrieval?

Fifth, as the authors pointed out, when prime event identities changed on the probe, they were only partial changes (i.e., one object feature was retained, one was altered). This occurred for both probe target and distractor events simultaneously. It is not clear how this manipulation affected their findings relative to what would be found if total object identity changes had been employed. However, it does mean that identity feature binding was potentially involved on all identity change trials, distinct from our current study.

The Probe Trial Distractor: Direct Retrieval of the Prime Trial Distractor Event File

Two findings in this study concurred in showing that a probe distractor, whose identity matched that of the prime distractor event, can 'directly' access stored distractor processing. This occurs even when a prime distractor's location is changed, in contrast to the supposition of Frings and Moller (2010).

The more definitive of these two results revealed that the absence of an SNP effect observed on target-only probe trials in Experiment 1B, when the prime-probe target identities mismatched, was restored when this probe target was accompanied by a distractor, whose identity matched that of the prime (Table 1, Exp. 1B, configurations [2] vs. [6]). The presence of the SNP effect attests to the retrieval of prime distractor event file solely by the (identity matching) probe distractor.

The second result supportive of the direct' retrieval of the prime distractor event file is more equivocal. The data and the argument in this case come from revisiting the preceding section where the existence of a D→D→T 'indirect' retrieval pathway was posited, based on the fact that the latency benefits of repeating the prime target's identity was enhanced when it was accompanied by a distractor, relative to when it was not. This facilitation augmentation could have occurred because the probe distractor ‘directly’ retrieved the prime distractor’s stored representation (Exp. 1B), which in turn triggered a D→D→T ‘indirect’ retrieval route that accessed the prime target. This could have added to prime target retrieval consistency in response to the probe configuration, and so to the greater target facilitation effects when a probe distractor was present.

On the Success of the .25(distractor present)/.75(distractor absent) Procedure in Preventing Spatial Negative Priming

Approximately 50% of the individuals in this investigation eliminated the SNP effect in the .25 (probe distractor present)/.75 (probe distractor absent) probability ratio condition, mimicking the SNP effect removal rate reported by Haworth et al. (2014). It is far from clear as to why the .25/.75 probe distractor ratio eliminated the SNP phenomenon for some, but not for others.

One intriguing option is that the .25/.75 probe distractor ratio causes the response-based retrieval route to be blocked in virtually all individuals, while the presence/absence of episodic storage determines whether SNP manifestation or absence occurs. In theory, the continued manifestation of SNP with the .25/.75 ratio might reflect the presence of the episodic storage of prime trial processing because it provides an alternative route (i.e., T→T→D) to the (now blocked) response-based pathway for accessing prime distractor event files. This would account for the persistence of the SNP phenomenon in some individuals. Alternately, without episodic storage, no replacement for retrieving the prime distractor event file would be present when the response-based route had been blocked, resulting in SNP removal (on target-only probe trials).

This explanation is not embraced by the present data, however. Participants who did not show an SNP effect with the .25/.75 distractor ratio (Table 1, Exp. 1B, configurations [1] & [2]), nonetheless exhibited evidence of episodic storage in their error protection data (i.e., T→T→D indirect retrieval: for target-repeat and control trials - Table 2, Exp. 1B, configurations [9] through [11]). Further, there was also evidence that target event files were retrieved (i.e., a possible trigger for T→T→D indirect retrieval route) on ignored-repetition trials, where SNP was absent (Table 1, Exp. 1B, configurations [1] vs. [2] and [3] vs. [4]). So, SNP absence occurs in individuals where episodic storage is indicated. Contrary to our previous conjecture, episodic storage plays no role in SNP preservation with the .25/.75 probe distractor probability ratio.

A related point to make here is that the prime distractor event files retrieved by a T→T→D indirect retrieval pathway are not a replacement for those brought forward by the response-based route (Schematic 2), in that these files do not seem to participate in ignored-repetition trial processing (i.e., no SNP). Possibly, for there to be a time cost associated with the later use of the prime distractor's assigned response (SNP effect), this response, and its related event file, must be externally activated on an ignored-repetition probe trial, in this instance by the location occupied by the probe target (i.e., the response-based route).

Finally, the possibility that the T→T→D indirect retrieval route is also blocked in response to the .25/.75 probe distractor ratio condition is unlikely. This is because this T→T→D retrieval route is active in producing the error protection evidence seen on control trials, and/or when the prime target location is repeated on the probe. Both of these trial types occur randomly, along with the ignored-repetition trials. It is unlikely that the T→T→D indirect route could somehow be blocked selectively for unpredictable ignored-repetition trials.

Feature Binding: Prime-trial Target Processing

While the current feature binding results were not central to the main objectives of this study they, nonetheless, warranted some comments. The findings provided mixed indications as to whether target identity and its location/response undergo binding within their event file in a visuo-spatial task.

On the negative side, the more classic index of feature binding revealed that the latency values for the probe trial configurations that potentially involved target feature binding violations (i.e., one feature of the target is repeated, the other not; see Table 2; configurations [10], [11], [14], [15]) were either less than or equal to the latencies produced in a comparator condition, where binding violation possibilities were absent (i.e., configurations [12], [16]). This held whether the probe target appeared alone or with a distractor. Firm evidence of target feature binding would have seen the latencies for the probe violation configurations exceed those of the baseline configurations, indicative that the time needed to deal with the binding violation exceeded any reaction facilitation resulting from a repetition of one of the prime trial target features. The caution here with this ‘partial repeat’ method of detecting target feature binding is that this binding may have occurred; however, the time cost of its violation may have been less than the RT benefit of a partial feature replication, thereby obscuring feature binding.

Also in the negative category, some past work has revealed that repeating the prime target’s identity produced comparable RTs whether the prime location changed or was repeated (i.e., no identity-location binding), even when the prime response was repeated in both cases (Buckolz et al., 2015; Fitzgeorge et al., 2011).

On an affirmative note, we did find in this study that retaining the prime target's identity while changing its location significantly increased probe trial target latency, relative to when the prime target's location was also repeated. The probe RT slowing might reflect a binding of the prime target identity with its location and/or response, and that when this binding was violated on the probe (i.e., prime target location/response changed), overcoming these possible violations slowed target RT. Notably, when the prime target's identity changed, it frequently had the same latency whether the prime target's location was repeated or not. This suggests that the RT increase seen when the prime target's identity was repeated, but its location changed, was not simply due to this location change. This would be consistent with a prime trial target identity-location/response binding, which influenced probe target latency.

A number of other past feature binding results bear a brief mention. One is that the latency cost/benefit ordinal relationship of 'binding violations' and 'partial feature repeats' may be modality specific to some extent. Contrary to the visual events used here, auditory prime targets appear to bind to their respective locations in a spatial task. Reaction times for configurations involving feature binding violations exceeded those produced by a baseline condition, absent of binding violations and of target feature repeats. Seemingly, binding violation costs must have exceeded any target feature repeat benefits to register a binding occurrence (e.g., Mayr et al., 2009; Mayr, Moller, & Buchner, 2014; Moller, Mayr, & Buchner, 2013, 2015). However, even here, one must be cautious, as there are instances where the ordinal relationship between RT binding violation costs and target feature repeat benefits is the same (e.g., Mayr et al., 2011, 2014, Exp. 1; Moller et al., 2013), as seen here for visuo-spatial tasks.

A second point is that there is some symmetry to the fact that feature binding for (prime) distractor events is also modality specific; prime distractor identity and its location do not bind for visual (Milliken, Tipper, & Weaver, 1994; Milliken et al., 2000) or for tactile (e.g., Frings, Mast, & Spence, 2014) processing; however, distractor identity-location binding has been ratified for auditory distractors in spatial tasks (Moller et al., 2013, 2015; Mayr et al., 2009; 2014). It is curious that those (distractor) events that are spatially coded (visual, tactile) [Frings et al.] do not seem to bind to their locations, while auditory events, which are not spatially coded, do. Possibly, efficient spatial coding of newly arriving visual or tactile events is best achieved in the absence of stored spatial bindings, or in the presence of weaker location bindings, which prevent feature binding manifestation.

A final point is that an improved procedure for assessing feature binding in location tasks may be to use free-choice (probe) response selection trials to index feature binding because they avoid the cost (binding violation)/benefit (feature repeat) confrontation inherent in latency measures (Hommel, 2007).

Summary of Conclusions

The findings here warrant the following conclusions: (1) visually processed information in a spatial task is stored in an episodic fashion, and it is likely that retrieval within an episode is bi-directional (i.e., T→T→D & D→D→T), (2) the prime distractor event file can be retrieved ‘directly’ by a probe distractor whose identity matches that of the prime (D→D), even when the prime-probe locations are different, (3) for the first time, the existence of an error protection feature associated with prime distractor-related responses (Buckolz et al., 2014) was replicated, (4) the .25(probe distractor present)/.75(probe distractor absent) distractor probability ratio, again only eliminated the spatial negative priming (SNP) effect for about 50% of the subjects studied (Haworth et al., 2014); we learned that SNP absence, when it occurred, was not the result of the absence of episodic storage, and, (5) sporadic support was seen in support of the prime target event binding to its prime location and/or response.

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FOOTNOTE

Footnote 1. Contrary to the viewpoint embraced in this study, Neill and Kleinsmith (2016) have concluded that the prime distractor's location, and not its related response, is the source of the delay on ignored-repetition trials, and hence is the cause of the visual spatial negative priming (SNP) effect. We believe that this conclusion does not apply to the visual SNP task as structured here, and as employed in the prior work pointing to the prime distractor's response as the visual SNP locus (e.g., Buckolz et al., 2012; Buckolz, et al., 2015; Fitzgeorge & Buckolz, 2008; Fitzgeorge et al., 2011). A proper accounting as to why this is the case is beyond the scope of this footnote. Suffice it to say that one cluster of factors giving rise to the disconnection of the Neill and Kleinsmith study is procedural in nature. The current study, along with past work, has used centrally positioned event locations (i.e., central SNP task) to avoid the confounding engendered when peripheral locations are employed (i.e., 'orientation inhibition', and perhaps more precisely a 'net inhibitory vector' confounds distractor response inhibition after-effects: Fitzgeorge & Buckolz, 2009; Klein, Christie, & Morris, 2005). Neill and Kleismith used peripheral event locations. Additionally, with visual central SNP tasks, the SNP phenomenon is removed when 100% distractor-free probe trials are used (Buckolz et al., 2002; Guy et al., 2004; Tipper, Brehaut, & Driver, 1990: also see Fitzgeorge et al., 2011; Haworth et al., 2014). Neill and Kleinsmith utilized 100% distractor-free probe trials. Finally, other procedures used by Neill and Kleinsmith that may have mitigated against finding a response locus for visual SNP is that their degree of location-response compatibility was too low; this issue was not addressed in the manuscript, and is difficult to determine on the basis of the Methods description. Moreover, the trials used to calculate a location locus included a response conflict component, not contained in the respective control trials (or in the response locus trials). This might have contributed to, or fully caused, the location locus that Neill and Kleinsmith reported.

CHAPTER 4

Freely Selected and Forced Responses Bind with Target Object Location in a Visuo-spatial Task

Introduction

The features that define a visual object's identity (e.g., size, shape, colour, orientation etc.), along with any non-identity features of this same object (e.g., object location), are held to be processed automatically (Hawkins, 1969; Treisman, 1969) and in a distributed fashion (e.g., Hommel, 2007), that is, at separately located neural analyzers. Accordingly, the outcomes emanating from these distributed feature analyses must be re-united or re-integrated in order to construct an accurate representation of the externally delivered visual object. This re-integration can be conceived of as a 'binding' of the object feature representations into an 'object' file, which is then stored for a period of time (Hommel, 2004). In a number of extensive reports, Hommel and his colleagues concluded that responses executed in the presence of a visual target object bind in one way or another to its object file, thereby creating an 'event' file (Hommel, 1998, 2004, 2007; Hommel, Memelink, Zmigrod, and Colzato, 2014).

Response Binding with Visuo-identity Processing

Evidence indicative of existence of event files (i.e., response binding) has come largely from visual-identity tasks, where one or all of the features of a target event dictate correct response selection at some point during the experimental task (see Henson, Eckstein, Waszak, Frings, & Horner, 2014 for a review).

Although somewhat more complex, the protocol employed by Hommel et al. (2014) does contain the essential aspects of many of the tasks utilized to study response binding in visual-identity tasks. In this study, two stimulus dimensions, colour (green, red) and shape (horizontal, vertical lines), were crossed to form four distinct stimulus events. The feature-response mapping rules were such that the vertical line and the colour green were assigned to the left-hand finger response while the horizontal line, and the colour red, required the use of the right-hand finger response.

A typical trial sequence commenced with a warning signal, followed by a double-headed arrow that cued one of the two possible experimental responses (i.e., left-hand vs. right-hand finger button press) [R1]. This response was then to be executed immediately upon the detection of a ‘trigger’ stimulus (S1), which could be any one of the four stimulus events (i.e., the identity features of S1 were irrelevant). Following the correct initiation of R1, a reaction stimulus (S2) appeared which, again, could be any one of the four stimulus events. The relevant feature of S2 (colour or shape), which was conveyed to the subject by inserting this information before or after S1 within the trial sequence, then dictated which of the two finger responses should be executed (R2).

With this procedure, it was possible test for S1-R1 binding by determining whether the RTs for instances where violations of presumed binding had occurred significantly exceed those found when S1-R1 binding remained appropriate for, and/or was avoided by, S2 processing. Consider by way of an example, the scenario where the relevant identity feature of S2 (say colour) happens to match the colour of S1 (i.e., both green), noting that this occurs both when the irrelevant ‘form’ component of S2 is the same or different from the ‘form’ used with S1. With this S1-S2 colour matching, the required response dictated by the S2 ‘feature-response’ assignment rule, and that retrieved via S1-R1 binding, could be the same (response repeat) or different (response change). Hommel et al. (2014) found that reaction time was significantly longer when the

R1 response changed (binding violation) relative to when it was repeated. Presumably, S1-R1 binding hastened the retrieval of the required response when the cued response had to be repeated, while this same binding-related response retrieval would interfere with the production of a response change, because it would violate the original S1-R1 binding. In a similar vein, when the S1-S2 inputs differed with respect to the relevant stimulus feature (e.g., S1 green, S2 red), reactions were slower when the cued response was retained as opposed to changed. Again, the comparatively slower latency would be due to a violation of S1-R1 binding, and the need to execute the same response to a different input.

Notably, the impact that the manipulation (repeat/change) of the relevant stimulus features had on RT was not affected by whether the accompanying irrelevant feature was the same or different for S1 and S2. This gives the appearance that response binding was selective, involving relevant but not irrelevant S1 features. This notion was set aside, however, by the fact that the binding results were similar whether the stipulation of the relevant S2 feature occurred before or after S1. In the latter case, response binding could not have been influenced by feature relevance knowledge, suggesting that the binding of the cued response to S1 features was non-selective. The fact that this presumed irrelevant feature binding did not manifest itself in the S2 latency data prompted Hommel et al. (2014) to suggest that this failed manifestation occurred because of retrieval prevention; only feature bindings relevant to current processing are retrieved by S2.

By way of a preview, this distinction between response binding ‘formation’ and response binding ‘manifestation’ is a broad theme that is maintained in the present investigation, as we identify and later discuss more specific questions of current interest.

Response Binding with Visuo-spatial Processing: Task and Aims

Below, we have presented the major aims of the current study in a cascading fashion, beginning at this point with the stipulation that our global interest is to initiate the examination of response binding during visuo-spatial processing, where the declared salient feature of a designated target event with respect to response selection is its location.

Turning now to one of the specific intentions of the present investigation, the notable aspect of the findings obtained by Hommel et al. (2014) was that the responses shown to exhibit binding to S1 features were pre-determined (also seen in past work; Hommel, 1998, 2007). The question that arose was whether response binding occurred only when R1 was readied in advance of S1? This possibility was rendered unlikely for visuo-identity tasks when Moeller, Pfister, Kunde, & Frings (2016) extended prior work by showing that uncertain R1 responses, determined by forced-choice disjunctive S1-R1 trials, also bound to S1 features (both relevant and irrelevant). Even here, however, the fact that S1 uniquely defined the required response might have maintained a binding imperative. Accordingly, we fundamentally set out here to determine whether freely selected R1 responses, deemed to be less tied to S1 object features, would bind to their relevant (location) and irrelevant (stimulus identity) dimensions (i.e., non-selective binding). The data will be available to do the same for forced-choice R1 response bindings. Due to its lesser interest here, these findings are presented and discussed in Appendix B.

To accomplish this and other aims, we utilized a modified task previously employed to study spatial negative priming (Buckolz, Lok, Kajaste, Edgar, & Khan, 2015; Fitzgeorge, Buckolz, & Khan, 2011). The essentials of this task are as follows. Seven centrally positioned presentation locations appeared on a computer screen arranged in two horizontal rows of 4 and 3 bar markers, with the latter situated above the former (see Schematic 1, Inset). The lower row of 4 of bar marker locations (L1-L4, left to right) were forced-choice locations that were each mapped onto spatially compatible keyboard finger-press responses. The upper row of 3 bar markers (L5-L7) were dedicated free-choice locations, each assigned two permissible finger-press responses; L5 and L7 were assigned the 3rd digit and index fingers of the left and right hands, respectively (within-hand finger competitions), while L6 was mapped onto the index fingers (between-hand finger competitions). Subjects responded with the response assigned to the object-occupied location, irrespective of its identity (i.e., green rectangle or yellow cross).

Trials were presented in pairs: first S1 (prime), then S2 (probe), with the stimulus object occurring at any of the seven locations for both trials within a pair. This gave rise to four trial type Combinations: free choice → free choice (Combination 1), free choice → forced choice (Combination 2); forced choice →free choice (Combination 3; Hommel, 2007, Exp. 2), and, forced choice → forced choice (Combination 4). These trial type Combinations varied unpredictably within a trial series.

Most important here is that Combinations 1 and 2 allowed us to learn whether freely selected R1 responses bind to S1 identity (irrelevant) and/or to its location (relevant), and whether the manifestation of these bindings differ for free-choice (Combination 1) versus forced-choice (Combination 2) S2 trial types. During the course of making the case that this latter possibility is plausible and so is an important measurement concern (see Hommel, 2007), we can delineate how we intend to measure response binding in this study.

S1-R1 Response Binding Manifestation in Visuo-spatial Tasks

Free-choice S2-R2 trials. To begin with, response bindings can, in theory, manifest themselves in response selection preference (when given the choice) and latency values; both of these measures are available with free-choice, but not with forced-choice (RT only), S2-R2 trials. Notably, too, binding may, depending upon the task, be prevented from its normal manifestation in one of these dependent variables, giving free-choice S2-R2 trials a binding detection advantage. Now imagine that S1-R1 response-location binding has occurred, it should manifest itself with the manipulation of S1 location in the following manner on free-choice trials. When the S1 location is repeated, retrieved binding should expedite R1 response re-activation, while inducing its selection. Accordingly, we should see a strong selection bias toward repeating R1, accompanied by a latency that is shorter than when R1 is not repeated. Further contributing to this latency difference might be the fact that changing R1 is slowed because one would first have to inhibit the R1 repeat urge and/or because an R1 change would incur a binding violation which may take time to override. In contrast, when the S1 location is changed on a subsequent trial, there could be a concomitant urge to also change the R1 response (e.g., see Hommel, 2007, Fig. 3) simply because when you change one component of a response binding (i.e., location), there is a concomitant urge to change the other (i.e., response). It could also be argued that repeating R1 when the S1 location changes would involve a time consuming S1-R1 binding violation, whose avoidance is encouraged by the urge to change R1. Hence, with a location change, we should see a significant tendency to change the R1 response, whose latency is shorter than when a repeat of the R1 response happens to be chosen.

If R1 also binds to the (irrelevant) identity of S1, when changing or repeating S1 identity in opposition to location changes or repeats, the S1 identity manipulation should affect RT and selection data found when location and identity changes match. For instance, if the location is repeated RTs ought to be slower and response selection repeats reduced when the target object's identity is changed relative to when it has been repeated. The same would hold if location is changed. This result pattern will not materialize, of course, if the binding with irrelevant S1 identity features are not retrieved on S2-R2 trials, as Hommel et al. (2014) proposed occurs with visuo-identity tasks. Nonetheless, we speculate that it is possible with visuo-spatial tasks that both relevant and irrelevant bindings are retrieved on an S2-R2 trial, where the relevant (location) binding dominates to control response selection. This would naturally prevent the manifestation of an R1-object identity binding in the selection data. However, this binding could still appear in the latency results; hence, one advantage of free-choice S2-R2 trials. Notably, the selective appearance of R1-S1 identity binding in one dependent variable in this study, but not in the other, would signal that the mechanism responsible for manifestation prevention is post-retrieval.

Forced-choice S2-R2 Trials. In addition to being restricted to only providing latency/error data, another related shortcoming of forced-choice trials is that evidence of S1-R1 response binding requires an assumption that may not be met. Specifically, response binding is held to be present when the RT delay caused by changing one aspect of the presumed S1-R1 binding (i.e., partial repeat trial) exceeds the RT value observed when all or no features of the S1-R1 trial are repeated on the S2-R2 trial. This manner of indexing S1-R1 response binding assumes that the latency cost of changing an S1object feature exceeds any benefit of repeating an S1 feature. This requirement, if unmet, will generate false negatives regarding response binding existence.

In sum, it is by no means inevitable that response binding detection will be comparable for free-choice and forced-choice S2-R2 trials in visuo-spatial tasks. While these two S2-R2 trial types have been used with some detection success in visuo-identity tasks (e.g., Hommel, 1998, 2007; Moeller et al., 2016), their response binding evidence has not been contrasted within the same study, which will be the case with its consideration here. While the foregoing related mostly to free-choice response binding (S1-R1, Combinations 1 & 2), the same response binding manifestation question will be examined for forced-choice S1-R1 binding as well (Combinations, 3 & 4).

S2-R2 Free-choice Trials: More on Response Binding Manifestation in Visuo -spatial Tasks (Hand Condition Type: Between-hand vs. Within-hand Finger Competitions). The use of S2-R2 free-choice trials in visuo-spatial tasks brings with it a manifestation issue of its own, which requires that it be accommodated in this study as well. Specifically, within-hand and between-hand free-choice finger response competitions on S2-R2 trials do not always provide results leading to a similar conclusion. For example, when S1-R1 processing includes a designated distractor event, and when subjects must freely choose between the distractor-related (S1-R1 trial) response and a control response (i.e., uninvolved during S1-R1 [prime] processing), they showed a significant bias against selecting the (inhibited) distractor output for within-hand free-choice finger competitions. Presumably, this result pattern reflected the fact that recently inhibited distractor responses become ‘execution resistant’, which opposes their future use (e.g., Buckolz et al., 2015; Fitzgeorge et al., 2011). This execution resistance feature was not manifested; however, with the between-hand S2-R2 finger competitions. For these competitions, Fitzgeorge et al. (2011) discovered that subjects largely based their between-hand R2 finger selections using a top-down strategy of ‘hand dominance’, ignoring the inhibition status of the free-choice response options, tending to choose the dominant hand finger significantly more often. The point to be made here is that a hand dominance strategy for self-selected between-hand free-choice trials could similarly prevent the manifestation of S1-R1 binding over response R2 control in visuo-spatial tasks. As a result, the findings obtained here will be examined separately for within-hand and between-hand free-choice S2-R2 trials to determine if future work should maintain this distinction.

Overall, then, the foremost aim here was to look for evidence showing that freely-selected R1 responses exhibit binding to relevant (location) and irrelevant (identity) S1 object features on S1-R1 trials in a visuo-spatial task. In order to properly test this possibility, it was essential that we consider the matter of response binding manifestation. In particular, whether it would be impacted by S2-R2 free-choice versus forced-choice trials, and whether it would be affected by within-hand versus between-hand free-choice finger competitions (Combinations 1 & 2). Forced-choice S1-R1 response binding data was automatically available with our procedure, and while these results were not without potential value, they were of a lesser interest at this time and so their consideration was largely limited to Appendix B (Combinations 3 & 4).

METHOD

Participants

Twenty-four undergraduate students (11 males, 13 females), from the Faculty of Health Sciences at Western University participated in this study. The age range of participants was 20-25 years and all reported normal or corrected to normal vision. Participants were unaware of the purpose of the study.

Apparatus

Participants were seated at a desk in a dimly lit room 200cm from a 61cm (24 inch) computer monitor which contained the visual display for the experiment. On each trial, the display was presented on a black background. The display consisted of a white fixation cross in the center of the screen measuring 0.5cm in length and 0.1cm in thickness for both its horizontal and vertical components. The cross was flanked by two white (forced-choice) horizontal location markers on each side (denoted L1-L4 from left to right). The distance between the bar markers was 0.5cm as was the distance between the bar markers and the fixation cross which yielded a horizontal display distance of 4.5cm and a horizontal visual angle of approximately 1.3 degrees. There were also three (free-choice) horizontal location bar markers positioned in a row 1.5cm above the forced-choice location markers and fixation cross. These location markers (denoted L5-L7 from left to right) were arranged so that L5 and L7 were 1.5cm above and in between L1 & L2, and L3 & L4 respectively. These (L5 and L7) served as within-hand response competition locations. The upper middle location marker (L6) was positioned 1.5cm directly above the horizontal component of the fixation cross; this location was used for between-hand response competitions. The upper row of (free-choice) location makers were separated from each other by a distance of 1cm. The vertical visual angle of this paradigm was approximately 0.5 degrees.

To respond to the appearance of a target stimulus, participants sat in a chair at a desk with a standard computer keyboard affixed to it. Their forearms rested comfortably on the desktop with their middle and index finger of each hand resting on the keyboard buttons “Q”, “W”, “O” and “P” respectively. These keys were assigned to their spatially compatible forced-choice and free-choice bar marker locations. Forced-choice mappings were as follows: L1 = Q, L2 = W, L3 = O and L4 = P. Free-choice mappings were: L5 = Q or W, L6 = W or O and L7 = O or P (see Schematic 1, inset). When a target (S1 or S2) appeared at locations L1-L4 only the appropriate forced-choice response (R1 or R2) was permitted. When S1 or S2 appeared at locations L5-L7 participants were ‘free’ to choose either of the two equally permissible, spatially compatible responses. Prime targets (S1) were always (100%) green rectangles 1cm in height by 0.4cm in width and appeared equally often 0.1cm above all seven locations. Probe targets (S2) could either be a green rectangle (50%) with identical dimensions to that of the prime target (S1), or a yellow cross (50%) 0.4cm (height) by 0.4cm (width) and 0.2cm (thickness); both appeared equally often 0.1cm above all seven locations during an experimental session.

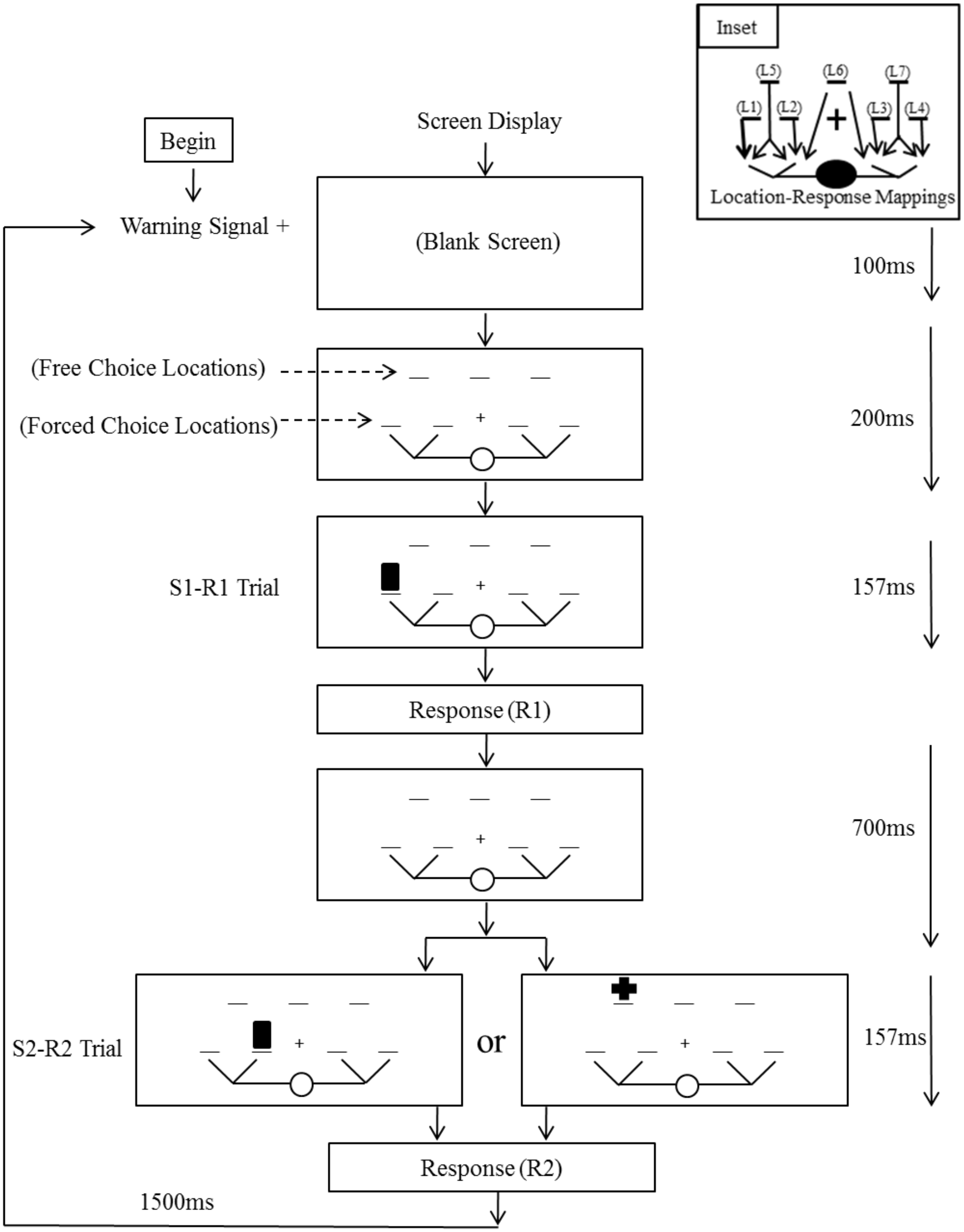
Procedure

Trials were presented in pairs, first the prime (S1-R1), then the probe (S2-R2). All trials began with a blank (black) screen and a warning tone (100ms) whose offset was followed by the appearance of the display configuration (described above and shown in Schematic 1) which remained on the screen for the duration of each trial pair. 200ms after the onset of the display configuration S1 (green rectangle [100%]) appeared alone at any one of the seven locations and remained on the screen for 157ms. A correct R1 initiated a 700ms response-stimulus-interval (RSI) whose offset coincided with the appearance of S2 (green rectangle [50%] or yellow cross [50%]) which was displayed for 157ms again at any one of the seven locations. A correct R2 initiated a 1500ms inter-trial interval whose termination coincided with the next warning tone and the beginning of the next S1-R1/S2-R2 sequence.

Participants were automatically offered a break after every 100 trial pairs. Participants determined when to resume the trial after a break by pressing the space bar; they could also press the escape key to institute a break at any time.

Participants were instructed to respond to the appearance of any target event (S1 or S2) on the prime (S1-R1) or probe (S2-R2) by depressing the associated keyboard button as quickly and accurately as possible while keeping button press errors and anticipations minimal. In the case of a target (S1 or S2) appearing at a free-choice location, participants were instructed to choose one of the two appropriate responses based on the aforementioned location-response mappings, both being equally correct. Before beginning the experimental session, participants completed 15 practice S1-R1/S2-R2 pairs and had the opportunity to ask any questions to ensure the task requirements were understood.

Participants completed three experimental sessions each consisting of 392 randomized S1-R1/S2-R2 trial pairs (1176 total). No two experimental sessions were conducted on the same day and no two sessions were separated by more than two days. Having S1’s and S2’s that appeared equally often at all locations (forced-choice and free-choice), resulted in four combinations for analysis (S1-R1 → S2-R2) 1. Free-



Schematic 1. An illustration of a target-only S1-R1 to target-only S2-R2 trial sequence and presentation durations used in this experiment. S1-R1 targets were always a green rectangle (dark rectangle in figure) and could appear at any location (free or forced choice). S2-R2 targets were either also a green rectangle (dark rectangle in figure [50%]) or a yellow cross (dark cross in figure [50%]) and also appeared equally often at all possible locations (free and forced choice locations). Inset: a diagram depicting the location-response mappings used in this experiment.

choice → Free-choice, 2. Free-choice → Forced-choice, 3. Forced-choice → Free-choice and 4. Forced-choice → Forced-choice. These four combinations also resulted in unique trial type frequencies within each combination per session (see Appendix B, Table B1 for full breakdown).

Combination 1. The free-choice → free-choice combination contained 72 trial pairs (of the 392 [per session]) including 16 within-hand S1-R1 → within-hand S2-R2 competitions where S1's location was repeated, 8 S2-R2's of which also repeated S1's identity, 8 of which did not; 8 between-hand S1-R1 → between-hand S2-R2 competitions where S1's location was repeated, 4 S2-R2's of which also repeated S1's identity, 4 of which did not; 16 within-hand S1-R1 → within-hand S2-R2 competitions where S1's location was not repeated, 8 S2-R2's of which repeated S1's identity, 8 of which did not; 16 within-hand S1-R1 → between-hand S2-R2 competitions where S1's location was not repeated, 8 S2-R2's of which repeated S1's identity, 8 of which did not and; 16 between-hand S1-R1 → within-hand S2-R2 competitions where S1's location was not repeated, 8 S2-R2's of which repeated S1's identity, 8 of which did not.

Combination 2. The free-choice → forced-choice combination also contained 96 trials (of the 392 [per session]) including (all with respect to the S1's identity and location) 32 within-hand competitions (on S1-R1), 16 S2-R2's of which repeated S1's identity, 16 of which did not (during these trials participants could be forced to re-execute their freely selected response from S1-R1 on S2-R2); 16 between-hand competitions (on S1-R1) 8 S2-R2's of which repeated S1's identity, 8 of which did not (again, during these trials participants could be forced to re-execute their freely selected response from S1-R1 on S2-R2); 32 within-hand competitions (on S1-R1), 16 S2-R2's of which repeated S1's identity, 16 of which did not (these S2-R2 trials occurred at locations that made re-execution of R1 impossible) and; 16 between-hand competitions (on S1-R1) 8 S2-R2's of which repeated S1's identity, 8 of which did not, all of which also occurred at locations that made re-execution of R1 impossible.

Combination 3. The forced-choice → free-choice combination contained 96 (of the 392) trial pairs including (all with respect to S1's identity and location) 24 repeat identity only trials (16 within-hand and 8 between-hand competitions [on S2-R2]) where it was possible to repeat R1; 24 trials (16 within-hand and 8 between-hand competitions [on S2-R2]) where neither S1's identity nor its location was repeated but it was possible to repeat R1; 24 trials (16 within-hand and 8 between-hand competitions [on S2-R2]) in which only S1's identity was repeated but at a location that made the correct re-execution of R1 impossible and; 24 trials matching the previous description the only difference being S1's identity was not repeated on S2-R2.

Combination 4. The forced-choice → forced-choice combination contained 128 (of the 392) trial pairs per session including (all with respect to the S1's identity and location) 16 identity and location repetition trials; 16 location (only) repetition trials; 48 identity (only) repetition trials and; 48 trials in which neither S1's identity nor its location was repeated (on S2-R2).

Any S1-R1/S2-R2 trial pairs that included button press errors, anticipations (reaction times less than 100ms) or insufficient vigilance (reaction times greater than 1000ms) were discarded and excluded from reaction time and response selection data analyses.

RESULTS & DISCUSSION

Combination 1

(Free-choice S1-R1 [prime] to Free-choice S2-R2 [probe] Trial Sequence)

R2 response selection probability (repeat/change) constituted the major dependent variable employed to detect R1 response binding to S1's identity (irrelevant) and/or to its location (relevant). The associated latency results were also examined in a supplemental capacity, primarily to see whether they supported or challenged the response binding conclusions generated by the response selection probability results. Furthermore, results were examined separately for between-hand and within-hand free-choice S2-R2 trials, partly because it provides the option for a more direct comparison of our findings with those already reported (i.e., usually between-hand; e.g., Hommel, 2004, 2007), and partly because these two hand conditions have shown different free-choice after-effect findings in some past spatial negative priming work (e.g., Fitzgeorge et al., 2011), and may do so with respect to response binding.

Hence, the analyses of variance (ANOVA) calculations were carried out separately for within-hand and between-hand S2-R2 free-choice trials (where appropriate), and were further subdivided as to whether the S1 location had changed or had been repeated on the S2 trial. Response Choice (2: repeat, change) and Selection Category (2 of these 4: repeat S1 identity and location {1}, repeat S1 location only {2}, repeat S1 identity only {3}, repeat neither S1 identity nor location {4}), along with Sessions (3), served as the main factors. The data were presented over Sessions throughout as an exploratory examination of result stability.

Between-hand Finger Response Competitions (R2)

Results

S1 (Prime) Location Repeated for S2-R2 (Probe) Trial

R2 Response Selection. In this (2 x 2 x 3) ANOVA, the two Selection Categories are S1 identity repeated {1} or changed {2} (Table 1; Fig. 1). The Response Choice, F(1, 69)= 1526, $p< 0.01$, MSE= 0.036, and Sessions, F(2, 69)= 4.25, $p< 0.02$, MSE= 0.002, main effects produced the only significant F-values. The magnitude of R2 response repeat preference was not modulated by whether the S1 object's identity was repeated (.94, {1} or not (.92, {2}) [Response Choice x Selection Category interaction; F(1, 69)= 1.19, $p= 0.28$, MSE= 0.022] (Figure 1).

R2 Reaction Time. Response Choice, F(1, 162)= 43.64, $p< 0.01$, MSE= 4139, and the Response Choice by Selection Category interaction, F(1, 162)= 3.87, $p= 0.05$, MSE= 4139, yielded the only significant effects (Table 1). The interaction emerged because, when averaged over Sessions (F<1), RT was significantly faster for repeated than for alternated R1 responses overall (i.e., 432 msec. vs. 523 msec.); however, this difference was reliably larger when the S1 identity was repeated (119 msec.), relative to when it had been changed (62 msec.) [Table 1].

S1 Location Changed on S2-R2 Trial

R2 Response Selection. In this ANOVA, the two Selection Categories ({3}, {4}, Table 1) again had S1 identity repeated or changed, but this time when the S1 location had been changed. No significant F-values were recorded, although the Response Choice main effect approached significance, F(1, 13)= 3.30, $p= 0.09$, MSE= 0.303. There was, overall, a numerical difference in favour of choosing to repeat R1 (i.e., .50 [repeat] vs. .18 [change]); however, this difference varied inconsistently in size and direction over Sessions, and over S1 identity repeats or changes (Fig. 2) [Response Choice x Selection Category x Sessions interaction, F(2, 13)= 2.23, *p*= 0.14, MSE= 0.120]. Hence, there was no formal evidence that R1 bound to S1 location or identity.

R2 Reaction Times. The ANOVA calculations produced no significant effects. With the exception of the Sessions main effect, F(2, 45)= 1.39, *p*= 0.26, MSE= 7599, all F-values were less than one. Nonetheless, a visual inspection of the latency data (Table 1) revealed a pattern whereby when the S1 object changed locations on the next trial, RT was slower when the R1 was repeated rather than changed (508 msec. vs. 485 msec.). This held whether the S1 identity was repeated or not.

Interim Discussion (Between-hand)

The S2-R2 free-choice data for the between-hand finger competitions clearly revealed that self-chosen R1 responses did bind to the object-occupied location that preceded their selection and execution; however, evidence that points to these responses concurrently binding to the irrelevant identity of S1 is inconsistent. Indicative of the formation of an R1 response S1 location binding was the fact that when the S1 object location was repeated on the S2-R2 trial, there was a highly significant preference for also repeating R1 (Fig. 1), which was initiated reliably faster than when a change in R1 was decided upon. Furthermore, this latency imbalance was reversed when the S1 object location changed; reactions were reliably slower when individuals chose to repeat rather than change the R1 response (Table 1; {3}, {4}). In this latter case, choosing to repeat the R1 response when the S1 object’s location had changed would have violated the existing response-location binding. Assuming that response binding violations come with a time cost (i.e., binding override time), this would explain the longer R2 response repetition RTs when the S1 location changed. As well, or instead of, it is also possible that changing one component of response-location binding (location) causes an urge to change the other (response). Inhibiting this urge would cause the slower R1 repeat latency. The merit of this latter proposal at this point is circumspect, however, because, unexpectedly, changing the S1 location did not enhance the probability of a change in free-choice response selection (Fig. 2).

The data patterns described in the preceding paragraph remained essentially unaltered whether the S1 object's identity was repeated or not on the S2-R2 trial (Table 1; {1}, {3} vs. {2}, {4}: Fig. 1). On this basis, freely chosen R1 responses did not show evidence of binding to the irrelevant identity of the S1 object.

There was, nonetheless, at least a subtle indication of an R1 response-object identity binding in some aspects of the latency results. When the S1 location was repeated, the RT difference between repeating vs. changing the R1 response was significantly smaller when the S1 object's identity changed (440 msec. vs. 502 msec. [62], Table 1{2}) relative to when it was repeated (424 msec. vs. 543 msec. [119], Table 1{1}). These size disparities were due to the R1 'change' RTs. They were faster when the S1 object had also changed (502 msec.), rather than if it had been repeated (543 msec.). The faster RT could represent the latency benefit of an R1-object identity binding leading to a faster retrieval of response involved in the change, while the slower RT could reflect the time cost of violating this binding (i.e., repeat identity/change response). The same argument could be made to explain the slower RT when the R1 response was repeated when S1 identity changed (440 msec.), relative to when it was repeated (424 msec.).

Table 1

Mean S2-R2 Reaction Times (ms) for Combination 1 (Free-choice [S1-R1] → Free-choice [S2-R2] trials) for Within-hand and Between-hand R2 competitions over Sessions as a function of Selection Category and Response (R2) Choice.

Selection Category	Repeat Location Repeat Identity {1}		Repeat Location Change Identity {2}		Change Location Repeat Identity {3}		Change Location Change Identity {4}	
R2 Choice	Repeat	Change	Repeat	Change	Repeat	Change	Repeat	Change
				Between-hand R2 Trials				
Session 1	437 (12.9) [0.03]	508 (7.5) [0.03]	438 (8.5) [0.04]	503 (31.4) [0.04]	506 (26.8) [0.04]	492 (31.5) [0.04]	535 (43.3) [0.05]	488 (11.8) [0.05]
Session 2	418 (9.3) [0.00]	526 (50.8) [0.00]	444 (12.0) [0.00]	523 (55.7) [0.00]	511 (47.6) [0.02]	537 (29.1) [0.02]	506 (24.5) [0.02]	508 (11.5) [0.02]
Session 3	418 (10.3) [0.01]	594 (85.8) [0.01]	437 (9.1) [0.01]	481 (33.1) [0.01]	498 (35.5) [0.02]	425 (29.2) [0.02]	467 (37.5) [0.01]	440 (14.4) [0.01]
Means	424 (10.8) [0.01]	543 (48.0) [0.01]	440 (9.9) [0.03]	502 (40.1) [0.03]	505 (36.6) [0.03]	485 (29.9) [0.03]	503 (35.1) [0.03]	479 (12.6) [0.03]
				Within-hand R2 Trials				
Session 1	443 (12.7) [0.01]	467 (32.7) [0.01]	453 (9.2) [0.02]	420 (15.9) [0.02]	441 (21.6) [0.00]	444 (19.3) [0.00]	520 (40.6) [0.03]	454 (14.6) [0.03]
Session 2	434 (11.7) [0.00]	309 (52.3) [0.00]	437 (10.2) [0.01]	412 (29.0) [0.01]	482 (45.6) [0.01]	456 (15.8) [0.01]	470 (55.5) [0.02]	454 (14.9) [0.02]
Session 3	417 (8.9) [0.01]	408 (19.1) [0.01]	424 (9.6) [0.01]	455 (35.2) [0.01]	484 (36.2) [0.01]	455 (15.4) [0.01]	487 (27.7) [0.02]	454 (12.3) [0.02]
Means	431 (11.1) [0.01]	395 (34.7) [0.01]	438 (9.7) [0.01]	429 (26.7) [0.01]	469 (34.5) [0.01]	452 (16.6) [0.01]	492 (41.3) [0.02]	454 (13.9) [0.02]

Notes. ( ) = standard error (ms); [ ] = button press error (%).
See Figures 1-4 for associated Response Choice selection percentage data.
Trial Pair: [S1-R1] = first trial, [S2-R2] = second trial.

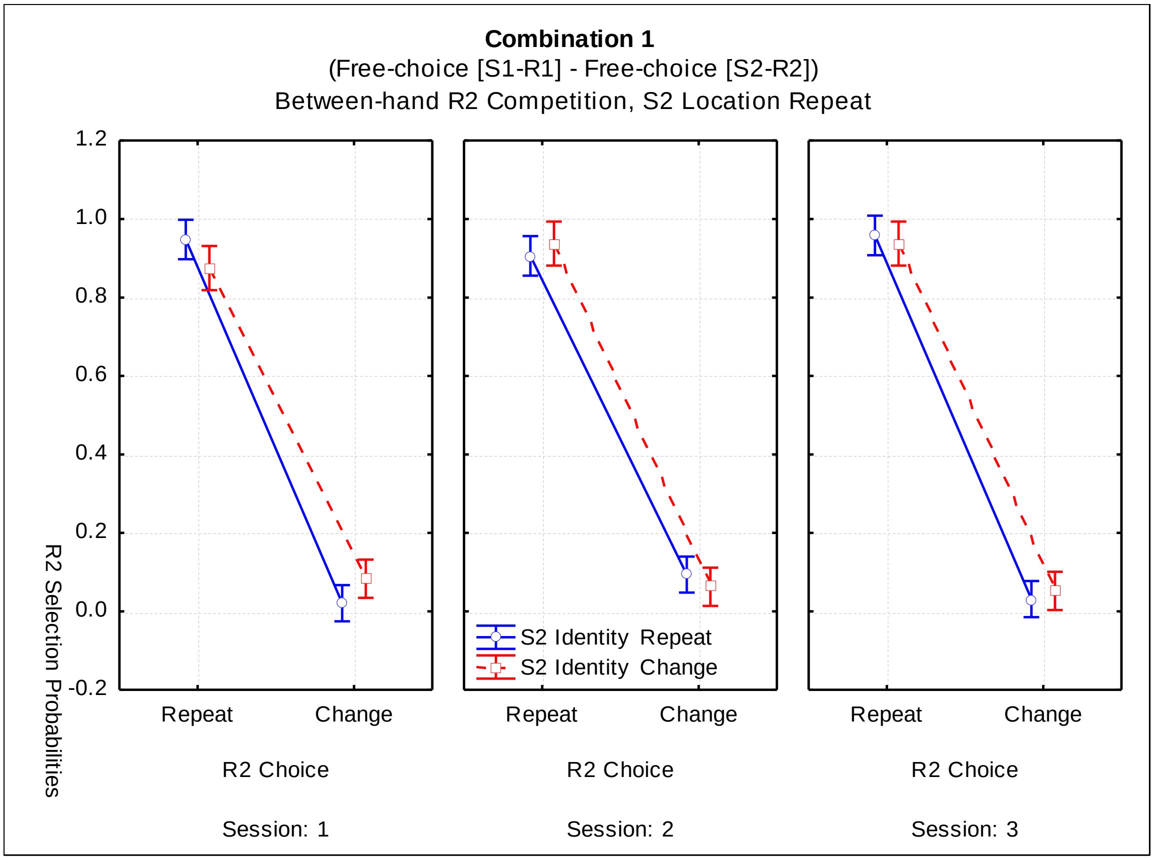


Figure 1. Combination 1 (Free-choice S1-R1 to Free-choice S2-R2 trial sequence): R2 selection percentages for Between-hand Free-choice R2 competitions when S1's location was repeated (on the S2-R2 trial), as a function of Response Choice (repeat or change R1 on the S2-R2 trial), Selection Category (S1's identity was either repeated or changed on the S2-R2 trial), and Sessions (392 S1-R1/S2-R2 trial pairs per session).

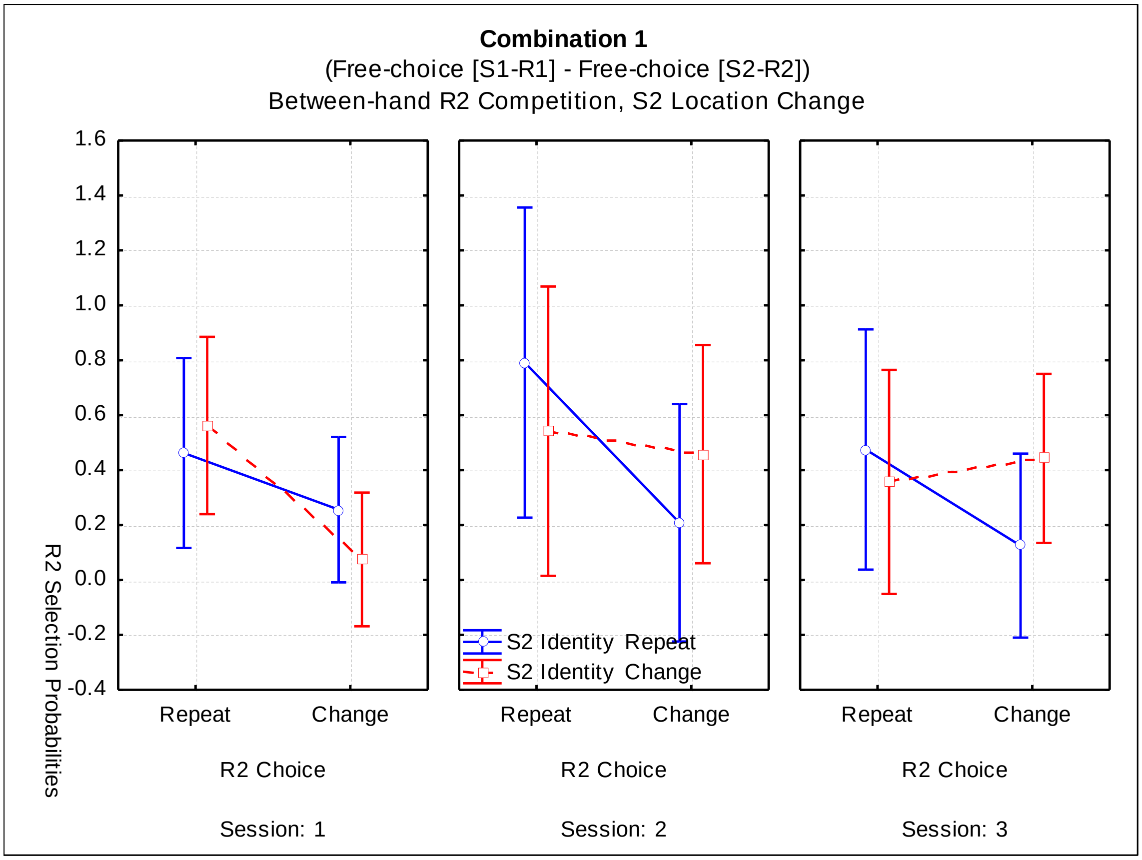


Figure 2. Combination 1 (Free-choice S1-R1 to Free-choice S2-R2 trial sequence): R2 selection percentages for Between-hand Free-choice R2 competitions when S1's location changed (on the S2-R2 trial), as a function of Response Choice (repeat or change R1 on the S2-R2 trial), Selection Category (S1's identity was either repeated or changed on the S2-R2 trial), and Sessions (392 S1-R1/S2-R2 trial pairs per session).

Within-hand Finger Response Probe Trial Competitions

Results

S1 (Prime) Location Repeated for S2-R2 (Probe) Trial

R2 Response Selection. The Response Choice (2: repeat vs. change) x Selection Category (2: varied) x Sessions (3) ANOVA used the Selection Categories that repeated the S1 object's location, while the S1 identity could vary (Table 1; {1}, {2}; Fig. 3). Response Choice generated the only significant effect, F(1, 69)= 4170, $p< 0.01$, MSE= 0.014. When the S1 object's location was repeated, there was a large and significant tendency to re-select the just-executed R1 response, whether the S1 identity was repeated (.95) or not (.96).

R2 Reaction Time. The ANOVA calculations yielded a significant Sessions main effect, F(2, 168)= 4.00, $p= 0.02$, MSE= 3507, along with two significant interactions: Sessions x Response Choice, F(2, 168)= 5.64, $p< 0.01$, MSE= 3507, and a three-way interaction, F(2, 168)= 3.53, $p= 0.03$, MSE= 3507).

A visual inspection of the latencies for the location repeat conditions (Table 1;{1}, {2}) reveals a disorderly change in the RT differences between response repeats and response changes over Sessions. Hence, these RT findings are of little assistance with regard to the main aims in this study.

S1 Location Changed on S2-R2 Trial

R2 Response Selection. The ANOVA compared the two Selection Categories where the S1 object location was not repeated ({3}, {4}), while the S1 identity varied. Only the Selection Category, F(1, 69)= 4.11, $p< 0.05$, MSE=0.002, and the Response Choice, F(1, 69)= 546.39, $p < 0.01$, MSE=0.092, main effects produced significant F-values (interaction, and Sessions, Fs<1). Individuals demonstrated a strong inclination to change the R1 response on the S2-R2 trial, whether the S1 identity was repeated (.92) or changed (.89) [Fig.4].

R2 Trial Reaction Time. The ANOVA produced no significant F-ratios, all of which were less than one, with the exception of the Response Choice main effect, which approached significance, F(1, 160)= 2.95, *p*= 0.09, MSE= 6368 (Table 1). In this instance, reactions were numerically slower when the S1-R1 response was repeated rather than when it had been changed (481msec. vs. 453 msec.; Table 1), both when the S1 object's identity was repeated or changed.

Interim Discussion (Within-hand)

Freely chosen R1 responses did bind to the relevant S1-R1 object-occupied location that prompted their selection; however, evidence of a concurrent binding with the S1 objects (irrelevant) identity was only indicated intermittently.

The link between the S1-R1 response and the S1 object's location was nicely illustrated by the synergy between object location and response selection repeat or change on the S2-R2 trials (Figs. 3 & 4). When the S1 object's location was re-used, the selected response followed suit (Fig. 3); while a change in location brought with it a significant and strong bias to also change the chosen response (Fig. 4). The presence of an S1-R1 response-location binding would account for this response selection pattern in that a location repeat would retrieve the S1-R1 response, thereby generating its use. We speculate that changing the S1-R1 location produces the urge to also change the R1 response because if one aspect of the response-location binding is altered (i.e., location), there is a tendency to change the other (i.e., response). Supportive of this tendency is the fact that RT was numerically (non-significant) faster for response changes than for repeats, when the S1-R1 location changed (Table 1; {3}, {4}). Also, motivating a response change could be an aversion on the part of individuals to violating an S1-R1 location-response binding. This binding violation aversion would be accomplished by not repeating the R1 response when the S1 target's location had changed.

Importantly, there was no indication that freely selected R2 responses were chosen on the basis of repeating the just-executed S1-R1 response (i.e., a 'response recency' selection determinant). The use of a response recency bias would have been problematic because it would have either confounded (location repeat) or opposed (location change) the control that response binding might have had over S2-R2 output selection. Looking at the location change data, where the 'response recency' and 'response binding' selection determinants would have urged response repeats versus response changes, respectively, revealed a large inclination by subjects to do the latter (Fig. 4). Assuming that this absence of a recency strategy extends to when the S1 object location is repeated, the conclusion that a 'response-object location' S1-R1 binding was responsible for the free-choice S2-R2 response selections observed here is defensible (Fig. 3).

There was no evidence in the response selection data pointing to a 'response-object identity' binding. The response selection bias levels seen when S1 object location and identity were both repeated or changed (homogenous conditions) were unaltered when these two object features were repeated or changed in opposition to one another (i.e., heterogenous conditions: repeat location/change identity; change location/repeat identity). With the heterogeneous conditions, a functioning response-target identity binding should have reduced the response selection biases observed with the homogeneous conditions. For example, when the S1 object location changed, a repeat of the S1 object identity would have opposed a change the R1 response. To the extent that this opposition gained control of S2-R2 response selection, the R1 response would been repeated; causing a reduction in the response change rate. This did not occur (Fig. 4).

Finally, we do note that when the S1 object’s location changed, repeating the R1 response had an RT that was longer when the S1 identity also changed (492 msec., Table 1{4}), relative to when it was repeated (469 msec., Table 1 {3}). This might indicate a response-object identity binding, which adds to the location-based urge to change the R1 response. Overcoming this additive urge may be more time consuming to achieve. Hence, the slower RT when the response is repeated.

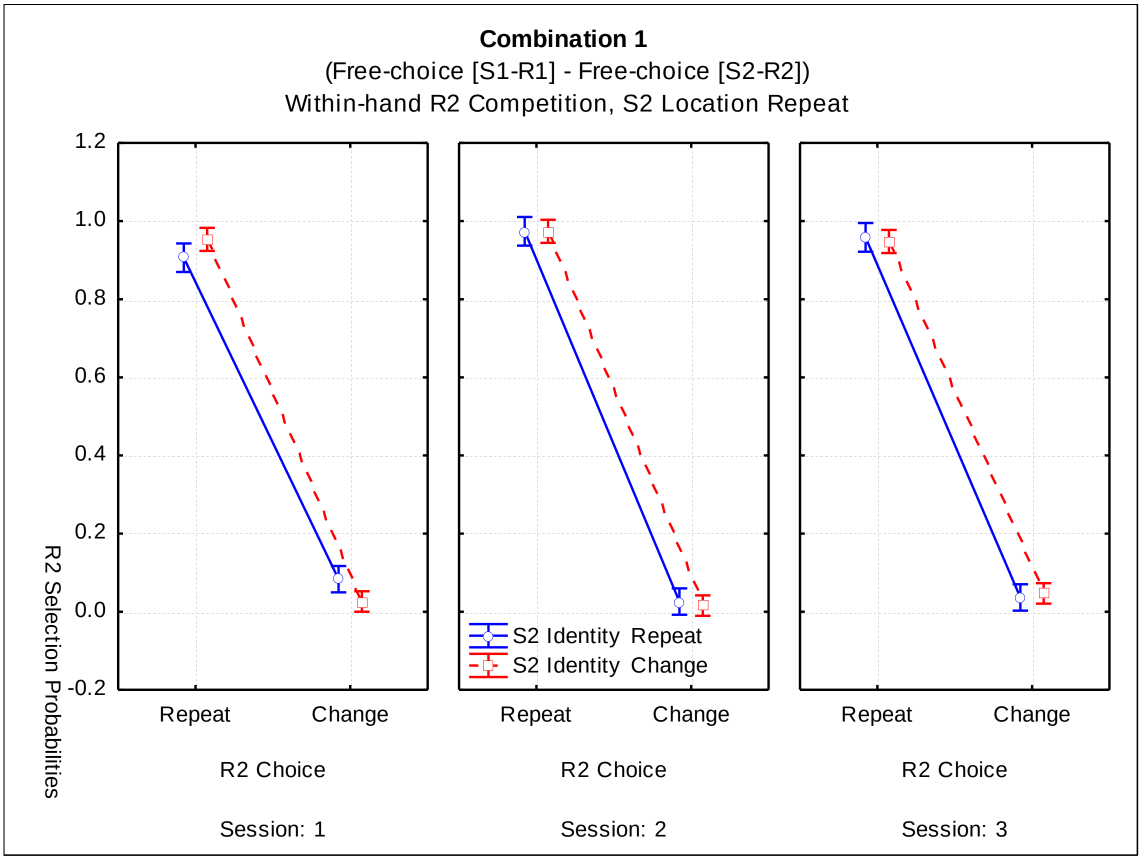


Figure 3. Combination 1 (Free-choice S1-R1 to Free-choice S2-R2 trial sequence): R2 selection percentages for Within-hand Free-choice R2 competitions when S1's location was repeated (on the S2-R2 trial), as a function of Response Choice (repeat or change R1 on the S2-R2 trial), Selection Category (S1's identity was either repeated or changed on the S2-R2 trial), and Sessions (392 S1-R1/S2-R2 trial pairs per session).

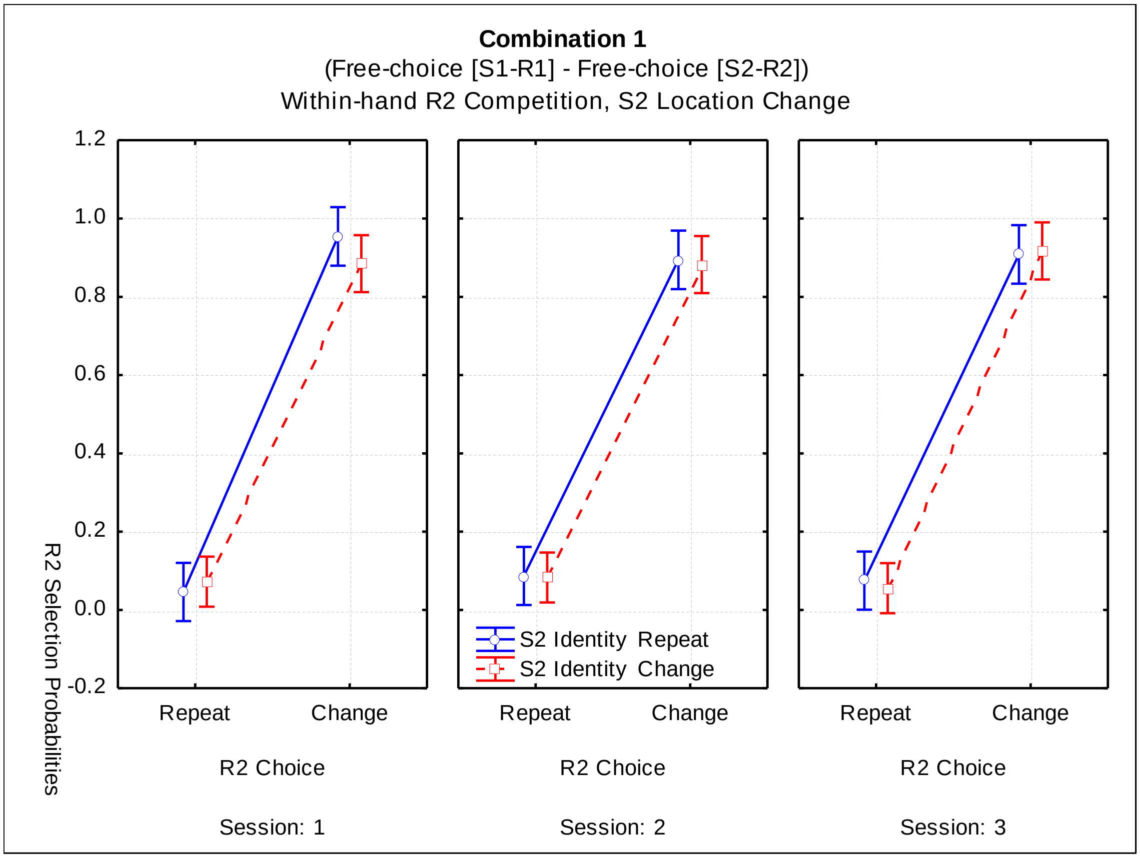


Figure 4. Combination 1 (Free-choice S1-R1 to Free-choice S2-R2 trial sequence): R2 selection percentages for Within-hand Free-choice R2 competitions when S1's location changed (on the S2-R2 trial), as a function of Response Choice (repeat or change R1 on the S2-R2 trial), Selection Category (S1's identity was either repeated or changed on the S2-R2 trial), and Sessions (392 S1-R1/S2-R2 trial pairs per session).

Combination 1 Summary (Free-choice Prime to Free-choice Probe Trial Sequence)

Four inferences are in order here. *First,* in visuo-spatial tasks, freely chosen (S1-R1) manual responses bind to the relevant object-occupied location that permitted their selections. This 'response-location' binding then exerted a powerful control over subsequent free-choice response selections, manifested both when the preceding trial location was repeated (within-hand & between-hand finger response competitions), and when it was changed (with-hand only competitions) on S2-R2 trials. Typically, the latencies associated with these free-choice response selections were in step with the actual response selections themselves (exception; Table 1, within-hand, {1} & {3}) in pointing to a response-object location binding.

Second, there were some sporadic, albeit non-significant, instances in the free-choice response selection latency patterns that indicated that the S1-R1 response did bind to the S1 object's identity, a binding whose existence was not concurrently revealed in the S1-R1 response choices (Figs. 3 & 4). Two things here: one is that this pattern suggests the binding manifestation prevention occurs post-retrieval on S2-R2. The other is that seemingly, an object-identity response binding can produce time-influencing response 'urges' that do not usually culminate in response selections. Extending this thought, it would mean contending that the impact of repeating or changing the S1 object's identity was not restricted to reducing or lengthening perceptual processing, respectively, as usually presumed. Rather, the latency pattern was such it revealed an influence of S1 identity repeats/changes upon unrequited response urges (distinct from actual response selections). For example, repeating the S1 object identity lead to a latency increase when the location and the chosen response had changed.

Third, the probe response selection data remained virtually unchanged over Sessions (exception: between-hand, location change), while variations in the latency data over practice were unsystematic. Perhaps the most notable aspect of this finding is that the continued exposure to the irrelevant object identities showed no indication that 'response-object target identity' binding strength increased. Alternately, if binding strength does increase with practice, the increase does not change its manifestation in the dependent variables used here.

Fourth, the within-hand and between-hand free-choice data, both with regard to response selection probabilities and latencies, yielded comparable binding-related conclusions when the S1-R1 location was repeated, but the conclusions differed when the S1 location changed. It may be that between-hand free-choice trials are less suitable for examining the existence of response bindings in visuo-spatial tasks. This is because the manifestation of response bindings may be modified or prevented for between-hand competitions because of the intentional use of other response selection determinants, peculiar to between-hand trials, such as a preference for choosing the dominant hand finger response (Fitzgeorge et al., 2011). This occurrence would then serve as an exemplar in visuo-spatial tasks that bindings do not 'inflexibly' control response selection (Henson et al., 2014).

Combination 2

(Free-choice [S1-R1] to Forced-choice [S2-R2] Trial Sequence)

Results

S1 Object Location Change

S2-R2 Reaction Time. The Response Choice (2: repeat/change) x Selection Category (2: S1 identity repeat/change) x Sessions (3) ANOVA produced no significant main effects; however, the Sessions x Selection Category interaction did achieve significance, F(2, 141) = 3.24, p=0.04, MSE=1362 (Table 2). Post hoc analysis of this interaction indicated that it was due to the fact that the RT difference for R1 response repeats vs. response changes was only significant for Session 1, when the S1 object identity was repeated (475 msec. vs. 484 msec., Table 2).

Interim Discussion

The binding of freely-selected responses to the location occupied by the S1-R1 object which we saw evidence of with the free-choice S2-R2 trials with Combination 1, was not manifested when the S2-R2 response was imposed by a randomly imposed forced-choice trial.

By way of an explanation, we are mindful that the S1-R1 target's location changed on the next trial throughout Combination 2 which should have produced the inclination to also change the R1 response on the S2-R2 trials (see Combination 1). Reflective of this response change urge, RTs should have been slower when the forced R2 response was a repeat of that chosen on the S1-R1 trial (especially when the S1 object's identity also changed). This predicted RT differential did not occur (Table 2) and so the response-location binding known to have occurred on the free-choice S1-R1 trials (Combination 1) did not exert the forecast results. One line of conjecture here is that responses that are uniquely determined by an object-occupied S2-R2 location in visuo-spatial tasks may simply dominate S2-R2 response selection, setting aside any competitors such as those that might emanate from response-object location binding.

Table 2

Mean S2-R2 Reaction Times (ms) for Combination 2 (Free-choice [S1-R1] → Forced-choice [S2-R2] trials) over Sessions as a function of Selection Category and Response (R2) Required.

Selection Category	Change Location Repeat Identity {3}		Change Location Change Identity {4}	
R2 Required	Repeat	Change	Repeat	Change
Session 1	475 (11.8) [0.07]	484 (12.8) [0.07]	475 (11.1) [0.11]	472 (9.9) [0.11]
Session 2	455 (10.6) [0.06]	457 (10.0) [0.06]	464 (12.6) [0.04]	462 (10.6) [0.04]
Session 3	441 (9.3) [0.04]	439 (8.5) [0.04]	453 (9.5) [0.04]	453 (8.3) [0.04]
Means	457 (6.3) [0.06]	460 (6.4) [0.06]	464 (6.6) [0.06]	462 (5.7) [0.06]

Notes. ( ) = standard error (ms); [ ] = button press error (%).
Trial Pair: [S1-R1] = first trial, [S2-R2] = second trial.

Combinations 3 and 4

(Forced-choice S1-R1 trials; see Appendix B)

Summary

There was confirmation that forced-choice responses bind with the location inhabited by the S1-R1 object in visuo-spatial tasks. This verification was, however, a conditional one; materializing for within-hand free-choice finger competitions (both RT & response selection data); but not for the between-hand free choice, nor for the forced-choice, S2-R2 trials. Furthermore, binding between the forced-choice response and the S1 object's identity was not statistically supported, but it was selectively indicated, numerically, by the within-hand free-choice latency data (i.e., repeated responses were faster if the S1 object's identity was also repeated).

GENERAL DISCUSSION

Overview of the Current Findings

As a cautionary note, bear in mind that the response binding as studied in this investigation included in the visual display containing a known relevant object feature (i.e., location) that controlled the selection and execution of the response to which it could potentially bind. In contrast, the early seminal work that employed visuo-identity processing/tasks examined the binding associated with predetermined responses. This meant that response binding was studied involving display features that were known to be irrelevant at the time the response binding took place (S1-R1) [and for binding to object features that would be relevant in the future, when uncertain forced-choice responses would be required on the S2-R2 trial] (e.g., Hommel, 1998, 2007). It is not clear if the response binding to a display feature known to be relevant at the time the binding occurs differs from that when relevance is applicable only to a future trial, in the sense that the impact on response binding manifestation differs. Nonetheless, this response binding distinction should be born in mind when comparisons are made between our findings and those of some of the past visuo-identity tasks.

The results of the present experimentation support the notion that response binding is likely a pervasive phenomenon, extending beyond the pre-cued responses and the visual-identity tasks mostly studied in the past (e.g., Hommel, 1998, 2007; Hommel et al., 2014; but see Moeller et al., 2016). Response binding occurs in visuo-spatial tasks and for responses that are not known in advance. While response binding was also seen for forced-choice S2-R2 trials (Appendix B), more notable in this latter regard was the fact that freely-chosen responses on S1-R1 trials exhibited binding to the relevant visual display feature (i.e., location) that was present at the time of response selection/execution. There was some question about free-choice responses binding because these responses may be less tied to the location that permitted their selection as these locations have more than one response assigned to them. Possibly, too, the self-selection act itself may distance the response from the S1-R1 location in the subject’s view. If so, the strength of the link between a response and a particular location may be inconsequential with respect to whether binding will occur or not, consistent with automatic binding (e.g., Hommel et al., 2014).

Throughout, evidence of S1-R1 responses binding to irrelevant display features (i.e., object identity) was not strong; being limited to the latency data, and even here, the RT differences pointing to this binding were typically non-significant. A liberal interpretation of these findings would be consistent with the idea that response binding in visuo-spatial tasks may be indiscriminant, as Hommel et al. (2014) proposed for visuo-identity processing. As well, it would indicate that irrelevant response binding in visuo-spatial tasks is not prevented by the concurrent binding of this response to the salient S1-R1 object feature. Since this same object feature (i.e., location) will also be relevant on the next S2-R2 trial, the binding with an irrelevant object feature was not done here in the event that the irrelevant S1-R1 feature might become relevant on the S2-R2, a possibility implied by Henson et al. (2014).

On a minor note, it is likely that the object's identity, although unnecessary for correct response selection, was automatically processed during S1-R1 processing (Graboi, 1971; Hawkins 1969) and so it was certainly possible that it could have bound to the S1-R1 response. Since automatic processing of this type extends to response retrieval (e.g., Eriksen, Coles, Morris, & O'Hare, 1985; Valle-Inclan & Redondo, 1998), the S2-R2 object's identity could have retrieved its related response and so caused the response interference effects proposed in the Results and Discussion sections earlier.

We saw that the manifestation of S1-R1 response binding in this study was impacted by a few of the measurement and design facets utilized in this experiment, which make their consideration for future work looking into response binding with visuo-spatial processing almost obligatory. Explicitly: (a) response binding evidence was observed for free-choice but not with forced-choice S2-R2 trials, and this included the binding with relevant and irrelevant S1-R1 object features, (b) even within the free-choice trials manifestation differences were evident; response binding was most consistently apparent in the 'within-hand' free-choice RT and response selection data

(S2-R2), while with the between-hand free-choice results only sporadically replicated the within-hand data, (c) evidence that response binds with irrelevant object identity during S1-R1 processing was manifested only in RT data, and then only weakly, and, (d) for the most part, much of the clear evidence of response binding remained invariant over continued exposure to the task.

Below, we consider the foregoing generalities in a little more detail, adding implications where appropriate.

Free-choice Hand Condition Type (within-hand, between-hand): A Response Binding Manifestation Issue, Somewhat.

At the outset here, we speculated that between-hand and within-hand free-choice finger competitions might differ findings with regard to response binding existence and manifestation, likely being absent in the former, but present in the latter. This concern arose from some past spatial negative priming work using the physical design employed in this study, where, on occasion, subjects had to choose between a just-inhibited S1-R1 distractor-related manual response and a control response, which was uninvolved on the preceding S1-R1 trial. Individuals exhibited a significant inclination to select against the distractor-related response, but this tendency showed up for within-hand but not for between-hand free-choice finger competition. Buckolz, Lok, et al., 2015; Fitzgeorge et al., 2011). With further analysis, Fitzgeorge et al. discovered that with the between-hand competitions, subjects typically invoked a Hand Dominance selection determinant so that the dominant hand finger was likely to be selected, irrespective of its inhibitory status. Naturally, the implementation of this selection determinant would eliminate the selection pattern seen with the within-hand free-choice trials (i.e., distractor response avoidance).

So, for the present study, the question was whether a Hand Dominance strategy would prevail over the competitive efforts of response binding to control action selection during between-hand S2-R2 contests, and so conceal binding existence. We obtained a conditional answer to this possibility. Between-hand and within-hand free-choice trials produced supportive response binding results (i.e., selection data) when the S1-R1 object's location was repeated on the next trial. However, when the S1-R1 object's location changed, within-hand selection data continued to point to S1-R1 response location binding (Fig. 4), while the between-hand response selection data became somewhat chaotic, for whatever reason (Figs. 2). It may be that response-location binding control over S2-R2 selection is strong if the location is repeated, and so the response-location binding is evident (Fig. 1). However, the control that response-location binding has over S2-R2 response choice while present, may be lessened when the S1-R1 object location changes. This reduction in response selection potency control is exposed by the between-hand finger competitions where other competing response selection determinants are perhaps more likely to come forcefully into play (e.g., dominant hand strategy). In any event, whatever the reason for the discordant response binding selection effects for between-hand and within-hand for the S2-R2 free-choice trials (on occasion), this discrepancy indicates that it would be prudent to include within-hand free-choice responses when testing response binding effects in visuo-spatial tasks.

It is, of course, curious that response binding in visuo-identity tasks is consistently manifested with between-hand free-choice S2-R2 trials (Hommel, 2007; Moeller et al., 2016). It may be that when the location features of both the task responses (left/right of midline; see Hommel, 2007) and the task objects are relevant to response selection, as in our study and in past work (Fitzgeorge et al., 2011), that response selection strategies like Hand Dominance (a spatial response distinction) are more likely to be invoked.

When the S2-R2 Trials Were of the Forced-choice Type

Combinations 1 and 3 revealed evidence of S1-R1response-location binding for both free-choice and forced-choice trials, when the S2-R2 trials were of the free-choice variety; however, evidence of these location bindings for the freely-chosen and forced-choice responses was absent when the S2-R2 trials were of the forced-choice type (Combinations 2 & 4). It is not certain why forced-choice trials mask the presence of S1-R1 response binding in visuo-spatial tasks, but it seems that they pose a manifestation risk. In any event, one possibility for the masking is that when location is the relevant feature of an object, location forcefully controls response selection (seen with free-choice trials, Combination 1). In the case of forced-trials, response control occurs on the basis of the location-response assignments of the experiment (i.e., task instructions). Possibly, too, free-choice and forced-choice S2-R2 trials invoke different task sets. This would preclude the participation of other response selection determinants such as response-location binding (Combinations 2 & 4).

When/How Does Manifestation Prevention Occur for Irrelevant Response Bindings?

Hommel et al. (2014) concluded that pre-cued responses in a visuo-identity task bind automatically and indiscriminately to display features that are irrelevant at the time that the binding takes place. It followed that the failed manifestation of irrelevant response-identity binding on test trials (S2-R2) was the consequence of their failed retrieval. Our results suggest that for visuo-spatial tasks, the failed manifestation of an actual response-object identity binding can occur post retrieval.

This proposal arises from the fact that while evidence of a ‘response-object identity’ binding was not revealed in the S2-R2 free-choice response selection findings (manifestation absent), it was evident occasionally in the latency values for these same choices (albeit usually non-significant). It follows that a ‘response-object identity’ binding had to have been retrieved in order to exert an influence on the RT data; however, it failed to participate in response selection. This post retrieval manifestation prevention in this case is likely owing to the dominant effect that the relevant response-location binding’ has over irrelevant response bindings in controlling S2-R2 response selection in visuo-spatial tasks. Hommel et al. (2014) have made this same suggestion for visuo-identity tasks, but the control of relevant over irrelevant response bindings is exercised at the retrieval level.

Features of the S1-R1 Visual Display Need Not Be Repeated for Response-Location Binding Effects to be Felt on S2-R2 Trials

Response-location binding is a powerful S2-R2 response selection determinant on free-choice trials in visuo-spatial tasks. The important point here is that this response choice control was also evident when the S1 object location and identity changed. In this instance, there was large and significant tendency for individuals to also change their chosen response, whose reactions were faster than when the response was repeated (within-hand, free-choice trials). We have argued that this result pattern was the consequence of an S1-R1 response location binding, despite the fact that nothing from the visual display had been repeated. Specifically, we suggested that the tendency to change the S1-R1 response when the location had changed reflected the fact that if you change one component of the response-location binding, there is an inclination to change the other (i.e., response). Alternately, or as well, efforts to use a bound S1-R1 response from a changed S1 location would be resisted, because it would violate an existing response-location binding. Changing the S1-R1 response would avoid a binding violation. Furthermore, both of these ‘binding violation aversion’ scenarios would require overriding the urge to change the S1-R1 response when a decision was made to repeat the response, and so would account for the latter’s elevated RT as we saw.

Actually, evidence of a ‘binding violation aversion’, which allows for response binding effects to exert an influence even when S1-R1 display aspects are not repeated on an S2-R2 trial are evident in response selection data obtained with visuo-identity tasks that have employed S2-R2 free-choice trials. Hommel (2007) reported a tendency for individuals to change the S1-R1 response even when irrelevant locations were changed from one trial to the next. Later, Moeller et al. (2016), had both a visual target and an auditory distractor appear on an S1-R1 (prime) trial. Only a distractor appeared on the S2-R2 (probe) free-choice trial, where subjects choose either of two permissible manual responses. When the distractor identities matched between trials, individuals exhibited a significant bias toward repeating the prime response, which was done more quickly than when the S1-R1 output was changed. This established the existence of a response-distractor identity binding. More pertinent here is that when the distractor identities mismatched (i.e., so no S1-R1 response binding was implicated on the S2-R2 trial on that account), individuals showed a significant inclination to change the S1-R1 response, which was done more quickly than repeating it. As we claimed for our own comparable results, when the S1-R1 object identity changed on the S2-R2 trials, it may have brought into play an aversion to a binding violation, which would be resolved by not repeating the S1-R1 response, as observed.

Finally, the ‘binding violation avoidance’ notion as expressed above would imply that the retrieval of S1-R1 response binding would be retrieved at the time that response urges are generated/considered on S2-R2 trials.

Little Changed with Sessions (Practice)

With one exception (i.e., Combination 1; within-hand, location repeat, RT data), the Sessions main effect, and its interactions with Selection Category and Response Choice, proved to be non-significant; both for the latency and response selection results. Any significant effects reflected non-orderly changes in S2-R2 performance, which were difficult to interpret.

More impressive was the stability of the S2-R2 data, especially when it was examined as a function of variations in the relevant location feature of the S1 object (e.g., Figs. 1, 3, 4, & 6). Note, too, that this stability arose in a context where the forced-choice and free-choice trials appeared randomly over the S1-R1and S2-R2 trials, as did S1-R1 object location and identity changes and repeats. The early and then persistent use of S1-R1 response-location binding as an S2-R2 response selection determinant is in line with a degree of automaticity of this behaviour (Hommel et al., 2014). As well, it may be noteworthy that continued exposure to irrelevant object identities did not enhance response-identity binding, or it did, but that it had no altered impact on S2-R2 response selection.

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CHAPTER 5

Detecting Target Identity – Location/Response Binding in Visuo-spatial Tasks Using A Cueing Procedure: An Exploratory Study

Introduction

Evidence that the retrieval of earlier stored processing (prime trial) can influence current processing (probe trial) [i.e., sequential effects] has been available for some time in a variety of forms; including the fact that previously incorrect predictions decrease the RT benefit of a current correct prediction (e.g., Geller, 1974), that latency facilitation occurs for repeated target identities and/or their responses (e.g., Keele, 1969), and the existence of a number of inhibitory after-effect phenomena (i.e., such as negative priming, and the negative compatibility and inhibition of return effects: e.g., Tipper, 2001; Schlaghecken, Fowley, Sembi, Simmons, & Whitcomb, 2007). The examination of sequential effects is worthwhile because, depending on the task context in which they are observed, they can reveal the presence of various processing characteristics or properties. For example, there is a sequential processing impact observed when there is a change in the status of an object's identity and/or response when going from being 'irrelevant' on the prime trial to being 'relevant' on the probe trial. The RT for this status change is significantly longer than when the same relevant processing does not undergo a status change. Notably, this holds whether the prime distractor is visible (non-masked) or phenomenally invisible (masked) [Fitzgeorge, Buckolz, & Khan, 2011; Schlaghecken et al., 2007]. Seemingly, distractor events are processed automatically, in spite of intentions/instructions not to do so. This processing is then stored, and when later retrieved with the presentation of the probe trial, can interfere with related processing (i.e., the negative priming effect; Neill, Terry & Valdes, 1994; Tipper, 2001).

There is yet another sequential effect which, along with the processing characteristic that it reveals (i.e., binding; Hommel, 2007), is of specific interest in this study. In this case, partial repetitions of the prime trial S-R processing on the probe trial in a visual identity task (i.e., repeat stimulus identity, change the response or repeat the response, change stimulus identity) are accompanied by RT elevations relative when the S-R prime processing is entirely repeated, or entirely changed on the probe. Hommel (e.g., 2004; 2007), along with colleagues (e.g., Hommel, Memelink, Zmigrod, & Colzato, 2014), have interpreted such findings to indicate that executed (prime) responses bind to their sponsoring target's identity dimensions (e.g., shape, size, colour etc.) and/or to their non-identity features (e.g., location, related response), both when they are relevant or irrelevant to response selection. It follows too from the RT results that overcoming binding violations on the probe trial (i.e., partial repetition probes) comes at a time cost; hence, the shorter latencies for the non-violation conditions (complete change, complete repeat of the prime S-R processing).

Recently, Kajaste and Buckolz (2017) extended the earlier binding results produced with visual identity tasks to visual location-based tasks, where the relevant feature of the designated target object determining response selection is its spatial position. Specifically, Kajaste and Buckolz demonstrated that during the course of prime trial processing, the selected response binds to the relevant location occupied by the prime target object and, less consistently, to the irrelevant target's identity. Actually, a target's identity is indirectly relevant in location tasks in that it is needed to identity the pertinent location for response selection; hence, a target's identity needs to be fully processed. This thorough processing enhances the likelihood that the prime target's identity binds with some aspect of prime target processing in location tasks, and so we pursued this possibility here. Specifically, we examined the possibility that the prime target's identity binds to its location, and/or to its location and response as a collective.

To accomplish this goal, we used a procedure that generated four Conditions, formed by which prime trial features were repeated/changed on the probe trial: [1] repeat neither target identity, location, nor response, [2] change target identity, repeat target location and response, [3] repeat target identity, change target location and response, [4] repeat target identity, location, and response. Conditions [1] and [4] did not involve potential binding violations while Conditions [2] and [3] did. Typically, binding is held to be revealed when the RTs for Conditions deemed to include binding violations (e.g., [2], [3]) exceed the latencies produced by Conditions where binding violations have been avoided (e.g., [1], [4]). However, this approach to binding detection is not ideal (Kajaste & Buckolz, 2017). The point of concern can be illustrated by considering the comparisons between Conditions [2] and [3] with Condition [4]. With Conditions [2] and [3], the slowing effect of actual binding violations may be offset or fully countered by repeating the prime target's identity or its location and response, for Conditions [3] and [2], respectively. As a result of opposing latency effects of a prime feature repeat and a binding violation, the outcome could be that the latencies for Conditions [2] and [3], where binding violation slowing actually occurred, are shorter than for Condition [1]. This would give rise to the faulty conclusion that binding had not occurred during prime trial processing. In the same way, one could argue that slower RTs for the partial feature repeats in Conditions [2] and [3] relative to RTs for Condition [4], arose because of the complete prime trial feature replication in Condition [4], and not because of binding violations in Conditions [2] and [3].

We reasoned that one way to avoid the aforementioned interpretation confounding involved with RT comparisons among Conditions [1] – [4], and so allow latency differences to reflect binding existence of the kind studied here would be to introduce both uninformative and informative cues between prime and probe trial pairs. Latencies following an uninformative cue (a ‘question mark’), typical of past work, would establish baseline RT differences among the four Conditions that would be reflective of their processing demand differences, including whether a binding violation was involved or not. An informative cue (i.e., the numbers 1-4) would signal the likely target location (with 75% accuracy), and so the response needed, on a forthcoming probe trial. Also of note is the fact that whether the prime target identity was repeated or changed on a paired probe trial was fixed (i.e., 100%). Consequently, while the informative cue did not relate to predicting probe trial target identity, it did forecast when a binding violation would occur on an impending probe trial (Conditions [2], [3]).

With respect to binding detection (target identity to its location/response), the rationale was that if binding did in fact occur for Conditions [2] and [3], and if cueing its impending occurrence on the upcoming probe trial could reduce/eliminate processing delays associated with binding violations, we would see a reduction in RT differences between binding violation and non-binding violation Conditions for the validly cued Conditions (i.e., [1] vs. [3] and [2] vs. [4]), relative to the uninformative RT differences for these same Condition contrasts. In other words, the RT impact of a valid cue, relative to an uninformative cue, should interact with Conditions, being greater when binding violations had occurred. Naturally, the reason for the absence of such an interaction would be unclear; reflecting either that prime binding had not occurred or, that it had, but is resistant to cue modulation. Note that paired Conditions selected for contrast were chosen on the basis of the fact that the cue forecast a location/response repeat ([2], [4]) or a location/response change ([1], [3]).

Actually, there is another aspect to the possibility that validly cueing an impending binding violation could reduce or eliminate the latency impact of unexpected violations that is worthwhile highlighting. It has to do with the recognition that the consequences of prime trial binding to future processing in which they participate are mixed; being ‘beneficial’ in reducing RT size when prime and probe processing demands fully match, but ‘detrimental’ when earlier binding is violated (i.e., partial prime repetition). This maladaptive feature of cognition, which runs counter to the notion that we are evolving into a state of intelligent processing design, has been seen before. For example, consider the phenomenon of negative priming in general (e.g., D’Angelo, Thomson, Tipper, & Milliken, 2016; Frings, Schneider, & Fox; 2015) and spatial negative priming (SNP) in particular (e.g., Fitzgeorge, Buckolz, & Khan, 2011). An SNP effect is observed when the RT for a current (probe) target is significantly greater when it arises at a location formerly occupied by a to-be-ignored distractor, relative to when it occurs at a spatial position that was previously (prime) empty. So, when an irrelevant location (i.e., distractor-occupied) becomes relevant (i.e., target-occupied), target RT is interfered with. Interestingly, the negative influence reflected in the SNP phenomenon can be prevented in a number of ways, including cueing the use of the prime distractor response on the probe trial (e.g., Buckolz, Boulougouris & Khan, 2002; Buckolz, Edgar, Kajaste, Lok, & Khan, 2012; Fitzgeorge & Buckolz, 2008). It will be interesting to determine whether this same interference prevention is possible with prime trial binding.

To be clear, then, while an important objective here was to look for binding between the prime target's identity and its location/response, of equal importance was to determine whether the cue method to be employed here was suitable for detecting such binding.

Finally, for the sake of convenience, we modified and utilized existing programs to control our procedure. With these programs, Probe Trial Content (either a target + distractor or a target alone) and Probe Trial Content Probabilities (the relative frequencies of these two probe types being .75/.25 or .25/.75 [between-subjects]) were two factors that were manipulated, which generated four distinct 'contextual environments' within each we could examine the relationship between Conditions ([1] – [4]) and Cue Type (valid, uninformative, [invalid]). We had no a priori basis for predicting an impact for these contextual environments, other than to note that they can influence spatial negative priming results (e.g., Fitzgeorge et al., 2008).

METHOD

Participants

Forty-two undergraduate students (22 males, 20 females) participated in this experiment. Participants ages ranged from 19-23 years and all reported normal or corrected to normal vision.

Apparatus

Participants were seated at a desk in a dimly lit room 200cm from a 61cm (24 inch) computer monitor which contained the visual display for the experiment. On each trial, a white fixation cross (0.9cm in width and height, 0.1cm thickness) appeared against a black background flanked by two white horizontal bar markers on each side which had the same dimensions as the horizontal component of the fixation cross. The bar markers (denoted L1-L4 from left to right) were separated from each other and the fixation cross by a distance 0.5cm. This produced a horizontal display distance of 6.5cm which resulted in a visual angle of 1.9 degrees.

In order to respond to the appearance of a target stimulus, participants sat with their forearms resting comfortably on the desk with their hands resting on a standard computer keyboard and their middle and index fingers of each hand resting on the keys "D", "V", "M" and "L". Each of these keys corresponded spatially to a location bar marker on the screen in the visual display (from left to right, respectively). Responses were achieved via finger flexion which depressed the appropriate key and terminated the response interval.

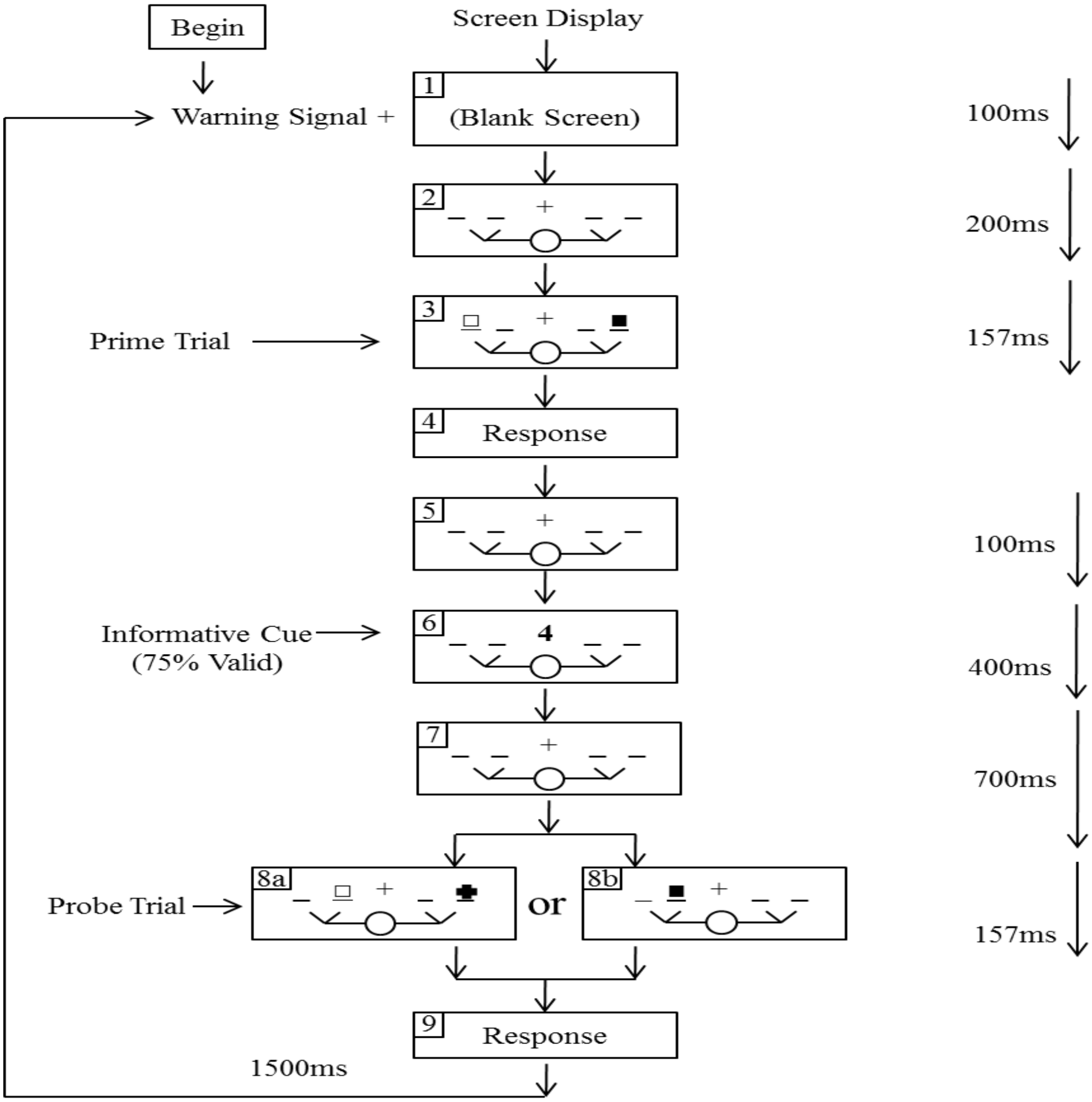
Procedure

Participants undertook a modified visual spatial negative priming (SNP) task where trials were presented in pairs; first the 'prime', and then the 'probe'. The prime trial always contained a target (green rectangle) and a distractor (red rectangle) object (both measuring 0.9 cm wide x 2 cm high), while the probe trial could contain a target and a distractor (distractor present) or a target by itself (distractor absent). The prime distractor's identity remained unaltered throughout, while that for the prime target could either be repeated (green rectangle) or changed (yellow cross) on the probe. Participants (*n*=42) were randomly assigned to one of four experimental groups. With group 1 (*n*=12), the experimental condition was characterized by the .75/.25 probe distractor probability ratio (.75 distractor present / .25 distractor absent) along with a matching (relative to the prime target's identity) probe target (identity repeat). In group 2 (*n*=11) a .25/.75 probe distractor probability ratio was utilized (.25 present / .75 absent) along with a matching probe target (identity repeat). For group 3 (*n*=10), the experimental manipulation was a .75/.25 probe distractor probability along with a mismatching (relative to the prime target's identity) probe target (identity change). Group 4 (*n*=9) undertook a .25/.75 probe distractor probability manipulation along with a mismatching probe target (identity change). Participants in the .75/.25 conditions (groups 1 &3) completed 2688 randomized trial pairs over 6 sessions with each session lasting approximately 35 minutes. Participants in the .25/.75 conditions (groups 2 & 4) completed 2880 randomized trial pairs over 6 sessions, each lasting approximately 35 minutes. Participants completed a maximum of one session per day, with no more than one day in between any two sessions. The discrepancy in the number of trials was due to the different trial frequencies associated with the .75/.25 and .25/.75 probe distractor probability manipulations. A complete breakdown of trial type and frequencies for both probe distractor probability conditions can be found in Appendix C.

A trial sequence commenced with a blank screen and an audible warning tone which lasted for 100ms. This was followed by the appearance of the display paradigm (described above and illustrated in Schematic 1) which remained on the screen for the duration of the trial pair. 200ms after the appearance of the paradigm, the prime trial objects (target and distractor) appeared at any two of the four possible locations and remained on the screen for 157ms. A correct response on the prime trial resulted in the screen remaining empty for 100ms, after which the cue (number 1, 2, 3, 4 or ‘?’) appeared in place of the fixation cross and remained on the screen for 400ms. This cue was informative in that it predicted the location of the upcoming probe target with 75% accuracy (i.e., cue “1” = 75% chance that the probe target appears at the first location from left [L1]), except in the case of the ‘?’ cue, which meant the probe target could appear at any one of the four possible locations with all locations being equiprobable. Following the offset of the cue there was a 700ms intra-trial-interval during which the paradigm remained empty. Next, the probe trial objects (target-only, or target-plus-distractor) appeared for 157ms. At the offset of the probe trial the empty paradigm remained on the screen until a response was made or 1000ms had elapsed, at which point the screen went black and a 1500ms inter-trial-interval commenced, whose offset was followed by the next warning tone and the beginning of the next trial pair sequence.

Trial pairs that contained errors (button press, anticipations [RT<100ms] or insufficient vigilance [RT>1000ms]) were recorded but were not used in reaction time analyses. Participants were automatically offered a rest break after completion of every 100 trial pairs. Trials resumed when participants pressed the space bar at their discretion.

Before beginning the experimental phase, participants were instructed that (a) they were to respond to any target event with the appropriate key press as quickly and as accurately as possible while ignoring any distractor event should one be present, (b) they were to avoid button press errors and responding before target arrival (i.e., anticipations), (c) trials would be presented in pairs with a cue appearing in between each prime-probe pair, (d) a distractor would appear on the probe trial 75% of the time or 25%



Schematic 1. An illustration of a prime-probe trial sequence and presentation durations for the Experiment 4. Target events could be either a green rectangle (dark rectangle in figure) or a yellow cross (dark cross in figure); only the former could appear on the prime trial, while either target could arise on the probe trial depending on Condition. When a distractor appeared (100% on the prime, 75% or 25% on the probe respectively, depending on Probe Distractor Probability Condition), it was always a red rectangle (light rectangle in Figure). Panel 6 represents a 75% valid cue that replaced the fixation cross for 400ms between the prime and probe. The number(s) displayed in the cue corresponded spatially to the location bar markers from left to right (i.e. cue ‘1’ = L1 [first location from left]) and represented, with 75% validity, the likelihood that the probe target would appear at that location. Panel 8a represents a target-plus-distractor probe (T+D) that was validly cued, with target location repeated and target identity changed [2]. Panel 8b represents a target-only probe (T-only) that was invalidly cued, with target location changed and target identity repeated [3].

of the time (depending on which Group they were in), and, (e) the cue represented, with 75% accuracy, the location that the upcoming probe target would appear at, except in the case of the ‘?’ cue, which meant that the probe target could appear at any of the 4 locations (all equally likely).

Before undertaking the critical portion of the experiment participants completed approximately 10-15 prime-probe practice trial pairs and had the opportunity to ask any questions to ensure their understanding of the task requirements.

RESULTS & DISCUSSION

Individual mean reaction times were utilized for all analyses of variance (ANOVA). Condition Type ([1] vs. [3] or [2] vs. [4]) and Cue Type (valid cue or uninformative cue) served as the main factors, and two ANOVAs were calculated for each of our four contextual environments (.75/.25, T+D; .75/.25, T-only; .25/.75, T+D; .25/.75, T-only). The cell means for these computations are found in Tables 1 and 2. Recall that the paired Conditions chosen for comparison in each ANOVA were selected on the basis that one contained a binding violation potential, the other did not; and that both have the same cue information, that is, whether a repeat or change in the prime target location and response was forecast. Further, the two Conditions used in an ANOVA differed with respect to whether the prime target identity was repeated or changed, a factor that would have to be considered for the interpretation of Condition RT differences. Because target identity repeat or change was entirely predictable, it was uncertain as to what impact this target identity manipulation would have on RT.

Table 1

Mean reaction times (ms) of Critical Conditions for the .75/.25 Probe Distractor Probability Ratio (.75 probe distractor present /.25 probe distractor absent) as a function of Probe Type (Target plus Distractor and Target-only), and Cue Type (Uninformative, Valid [75%] and Invalid [25%]).

.75/.25 Probe Distractor Probability Ratio						
Probe	Target plus Distractor			Target-only		
Cue	Valid	Uninformative	Invalid	Valid	Uninformative	Invalid
Condition						
[1]	430	481	512	400	454	499
	(18.5)	(12.8)	(12.6)	(18.9)	(14.3)	(13.5)
	{4.8}	{5.6}	{11.0}	{5.7}	{14.0}	{11.3}
[3]	397	455	493	380	442	481
	(17.6)	(11.3)	(10.3)	(16.4)	(9.4)	(11.3)
	{6.0}	{10.2}	{13.7}	{6.8}	{16.0}	{12.8}
Effect [1]-[3]	33	26	19	20	12	18
[2]	434	475	515	403	455	491
	(13.8)	(11.2)	(11.3)	(16.0)	(14.2)	(11.6)
	{4.9}	{6.9}	{9.4}	{4.8}	{5.0}	{8.9}
[4]	402	447	483	383	431	465
	(13.2)	(11.9)	(11.3)	(13.0)	(10.5)	(10.1)
	{5.5}	{7.1}	{15.3}	{6.6}	{7.6}	{11.3}
Effect [2]-[4]	32	28	32	20	24	26

Notes. ( ) = standard error (ms); { } = button press error %. * $p < 0.05$. Conditions (all relative to prime target): [1] = change probe target identity, location and response, [2] = change probe target identity, repeat location and response, [3] = repeat probe target identity, change location and response, [4] = repeat probe target identity, location and response.

Table 2

Mean reaction times (ms) of Critical Conditions for the .25/.75 Probe Distractor Probability Ratio (.25 probe distractor present /.75 probe distractor absent) as a function of Probe Type (Target plus Distractor and Target-only), and Cue Type (Uninformative, Valid [75%] and Invalid [25%]).

.25/.75 Probe Distractor Probability Ratio						
Probe	Target plus Distractor			Target-only		
Cue	Valid	Uninformative	Invalid	Valid	Uninformative	Invalid
Condition						
[1]	447	480	517	404	452	482
	(14.6)	(14.0)	(16.4)	(12.5)	(11.6)	(13.1)
	{7.9}	{8.3}	{13.2}	{5.9}	{14.9}	{13.4}
[3]	426	459	505	392	448	482
	(23.8)	(14.4)	(17.0)	(24.0)	(15.0	(11.9)
	{4.5}	{9.5}	{12.9}	{6.0}	{16.2}	{14.4}
Effect [1]-[3]	21	21	12	12	4	0
[2]	450	489	509	401	443	464
	(12.1)	(14.8)	(14.3)	(9.7)	(10.4)	(12.9)
	{6.0}	{5.1}	{12.5}	{4.7}	{6.2}	{9.3}
[4]	413	460	490	377	432	454
	(19.4)	(16.1)	(16.7)	(18.3)	(16.5)	(11.0)
	{3.4}	{8.3}	{13.3}	{4.8}	{6.6}	{15.9}
Effect [2]-[4]	37	29	19	24	11	10

Notes. ( ) = standard error (ms); { } = button press error %. * $p < 0.05$. Condition (all relative to prime target): [1] = change probe target identity, location and response, [2] = change probe target identity, repeat location and response, [3] = repeat probe target identity, change location and response, [4] = repeat probe target identity, location and response.

In any event, the reasoning was that the RT differences between Conditions following an uninformative cue would establish a baseline value that would reflect all of the processing differences between the Conditions, whatever these may be. When an informative cue turned out to be valid, its only differential impact on the two Conditions involved would be to predict a forthcoming binding violation. If a binding violation time cost had been present with the uninformative cue trials, and if the time cost of a binding violation can be reduced or eliminated when it is validly cued, we should see a greater RT impact of this cue on the binding violation Condition, resulting in a reduced latency difference between Conditions in the valid cue instance, relative to when an uninformative cue had been used (i.e., a Condition Type x Cue Type interaction).

The pattern of significance was the same for all eight ANOVAs; throughout, the Cue Type main effect produced significant F-ratios (ranging from 11.59 to 84.22, *p*-values all < .009), while no significant F-ratios were produced by the Condition Type main effect (ranging from 0.06 to 2.76, *p*-values ranging from 0.13 to 0.81), nor its interaction with Cue Type (all F-ratios were 1 or less). Apparently, the contextual environments included in this study do not differentially influence target identity-location/response binding.

These ANOVA outcomes clearly demonstrated that individuals used the informative cue information as probe RTs were significantly faster following valid than uninformative cues (409 msec. vs. 457 msec., respectively [Tables 1 & 2]). This latency benefit was not selective to Condition Type; however, revealed by the failed Cue Type by Condition Type interactions. Collectively, it follows that the cue information provided was used to prepare the likely required probe response, and/or to process the probe target at a particular spatial position, but not to influence any latency impact of binding violations. Otherwise, valid cue RT benefits should have been larger for Conditions with binding violations than for those without. This was not the case. So, either 'target identity-location/response' binding does not occur during prime trial processing, or it does, but its latency elevating impact (upon binding violation) cannot be reduced or removed when the individual knows that an impending probe binding violation is likely.

If we provisionally interpret our findings as indicating that prime target identity does not bind with its location and/or its response in a location task, it would be consistent with results from spatial negative priming tasks which have shown that RT is delayed for ignored-repetition trials (i.e., SNP effect), whether the probe target's identity matches that of the prime distractor or not (e.g., Milliken, Tipper, Houghton, & Lupianez, 2000). So, whether a prime 'distractor-location/response binding violation occurs (identity mismatch) or not (identity match), a significant slowing for ignored-repetition trials is observed. The only difference in this study is that it seems that prime target identities do not bind to their location and/or responses either. Actually, a failure of prime target or distractor identities to bind to their locations or responses is less surprising given that these identities randomly appear at all locations during a trial series. Perhaps this circumstance acts to prevent identity bindings?

As it turns out, the non-significant Condition Type main effects here are somewhat puzzling; partly because the numerical RT differences between paired Conditions are quite large (Table 1), and partly because an examination of Newman-Keuls tests applied to the Trial Type by Condition Type interactions revealed significant RT differences between compared Conditions. The latency significance pattern revealed by the Newman-Keuls tests was such that RTs were significantly faster when the prime target identity was repeated, as opposed to when it was changed, on the probe trial. This held despite the fact that target identity repetitions or changes were entirely predictable, and despite the fact that identity repetition occurred in a Condition with a binding violation in one instance ([3]). Seemingly, we cannot cue away the RT benefit of repeating a target's identity on sequential trials, and, the latency facilitation owing to a repetition of the target's prime identity seems to override any RT delays owing to a concurrent binding violation, should one exist.

Another series of ANOVAs were executed, identical to those above, with the only difference being that the invalid cue reaction time data was now included in the Cue Type factor. These eight ANOVAs yielded the same pattern of significance (or lack there of). The Cue Type main effect was significant in all analyses, with F-ratios ranging from 31.79 to 68.40 (p-values all < 0.001). The Condition Type main effect (F-ratios ranged from 0.01 to 2.90, p-values all > 0.12) as well as the Condition Type x Cue Type interaction (F-ratios ranging from 0.03 to 1.03 and p-values all > 0.38) both failed to achieve significance.

GENERAL DISCUSSION

We set out to determine whether prime target identities in visuo-spatial tasks bind to their locations and responses, using a new procedure that relied on the latency effects of uninformative and informative cues between Conditions that differed principally with respect to whether they involved a binding violation or not. Paired Conditions selected for comparison were chosen on this basis. Reaction time differences among Conditions following uninformative cues reflected processing duration discrepancies brought on by any disparate processing requirements. An informative cue forecast the likely target location and response on a forthcoming probe trial, as well as predicting the upcoming binding violation in the Conditions where a violation was possible. If a binding violation existed and contributed to RT following uninformative cues, and if a valid cue reduced or eliminated this latency influence, RT differences between binding violation and non-violation Conditions should be less for valid cue than for uninformative trials.

This did not occur. The RT differences between Conditions were unaltered by a valid cue. Either a target's identity does not bind to its location and response or, it does, but the slowing impact of a binding violation cannot be offset when its occurrence is expected. In any event, the cue procedure employed here is unsuitable for detecting target identity -location/response binding existence in visuo-spatial tasks.

On a lesser note, we did replicate a classic cue effect whereby RT(valid cue) < RT(uninformative cue) < RT(invalid cue), reflective of a benefit-cost impact of informative cueing and indicating that our subjects used the cue information provided (e.g., Geller, 1974; 1975). Additionally, we did see that delays encountered when target identity changes occur on successive prime-probe trials could not be removed when they were fully predictable; their related RTs were still significantly slower than for predictable target identity repeats.

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CHAPTER 6

General Overview of the Major Conclusions Derived from the Current Experimentation

New Conclusions

1. In visuo-spatial tasks, responses become linked to a location on the basis of a high location-response association strength, often resulting from extensive practice (i.e., inherent responses), and/or on the basis of the location-response assignment rules (L-R responses) for the task at hand. Contrary to existing notions of prime distractor processing in visuo-spatial tasks, we learned here that visual prime distractors retrieve not only inherently related outputs but also task-assigned responses, even though the location-response task assignments do not apply to distractor processing. When these responses differ (one is usually required, the other not), they compete with one another before rendering their net inhibitory after-effect on future processing (Experiment 1).

2. The multiple retrieval of location-attached responses also occurs when the prime distractor event is phenomenally invisible (i.e., successfully masked), indicating that such processing is performed automatically (Experiment 1).

3. Processing in visuo-spatial tasks is stored in an episodic fashion. That is, relevant target and irrelevant distractor processing outcomes are retained in a connected fashion. This was revealed here when evidence of distractor processing was retrieved ‘indirectly’, by ‘directly’ generating the retrieval of only prime target information through probe trial configuration control (Experiment 2).

4. In visuo-spatial tasks, it is possible to directly retrieve stored prime trial distractor processing by having the prime and probe trial distractor identities match (Experiment 2).

5. With a visuo-spatial task, uncertain prime responses, whether freely chosen or imposed on forced-choice trials, bind to the relevant feature of the prime target; its location. In contrast, there was only minimal (latency) evidence suggesting that prime target responses also bind to the (irrelevant) identity of the target itself. On a procedural note, response binding was not observed with the forced-choice probe trials; however, binding was clearly evident for the free-choice probe trials, but only when the response choice involved fingers on the same hand (Experiment 3).

6. Interestingly, it appears that individuals act to prevent binding violations from happening on free-choice probe trials. For example, when the prime target location changed on the probe, there was a tendency to also change (rather than repeat) the prime response on free-choice trials (Experiment 3).

7. As expected, when evidence of response binding was present in certain conditions, it remained observable throughout the experiment, showing no change with extended experience with the task. This is consistent with response binding, as seen here, as being a more or less automatic outcome of stimulus-response processing in visuo-spatial tasks (Experiment 3).

8. We did not see evidence that foreknowledge of an impending response-location binding violation attenuates or removes the latency elevation impact attendant to handling such violations. The hope was that pre-cuing response-location binding

violations would provide a method of detecting the presence of response-location binding using ‘latency’ results (Experiment 4).

First Time Replications

Not that long ago, the importance of result replication between studies to the sound advancement of what is claimed to be ‘knowledge’ was underscored by researchers who reported that attempts to repeat prior findings published in quality journals, using the same methods and researchers in some cases, were only successful about 40% of the time (e.g., see Aarts, Anderson, Anderson et al., 2015). The message here is that result replication is not a frivolous component of later experimental efforts, but is essential to the determination of what is ultimately deemed to be ‘factual’, and should be viewed as such. In this vein, we highlight some of the data/conclusion replications emanating in this report.

1. To our knowledge, the masking results here represent the first replication of the view that phenomenally invisible prime distractor events in visuo-spatial tasks are processed, and that they produce inhibitory after-effects similar to those generated by visible prime distractors (Fitzgeorge, Buckolz, & Khan, 2011). Also, we again see evidence of automatic prime distractor processing. And, of note, the relevant identity feature in the Fitzgeorge et al. study was colour, while in the present work it was shape. This modestly increases the generalizability of visuo-spatial task masking (Experiment 1).

2. We duplicated the existence of ‘error protection as a beneficial consequence of prime trial distractor processing (Buckolz, Stoddart, et al., 2014). Protected prime

distractor responses were used erroneously less often than unprotected control responses on probe trials (Experiment 2).

3. Procedurally, we again saw that reducing the likelihood of a distractor appearing on a probe trial (0.25) eliminated the spatial negative priming effect in only about 50% of the individuals tested (Haworth et al., 2014), contrary to earlier findings (Fitzgeorge et al., 2008). Consequently, this method of intentionally removing the SNP effect must be done on an individual basis (Experiment 2).

Replication Shortcomings

The other side of the coin from the above section is clearly the instances in which previous findings were not replicated in the current experimentation. That being said, it should be borne in mind when interpreting this section that most of these instances of failed replications are, in fact, only the second or third time that such experimentation has been undertaken that even contained the possibility of replicating some of the previous findings. So, it should be noted that further work is still required in this area to determine the stability and replicability (or lack there of) of the following instances where result replication was not achieved.

In Experiment 1 we failed to replicate O'Connor & Neill (2010) in showing that the rule-based retrieval determinant was solely responsible for retrieval. This was expected because their results run counter to most theories of distractor processing, especially those for visuo-spatial tasks. We also unexpectedly did not replicate Fitzgeorge et al., (2011) in finding probe response selection percentage imbalances in both masked and visible conditions for compatible L-R mappings. Lastly, we did not find an SNP effect for visible, forced-choice compatible mappings contrary again to Fitzgeorge et al., (2011); this was also unexpected. Reasons for the aforementioned are detailed in Chapter 2.

Experiment 2 showed a failure to replicate Fitzgeorge & Buckolz (2008) in having the .25/.75 probe distractor probability manipulation remove the SNP effect in 100% of participants however, we were consistent with Haworth et al., (2014) in that the manipulation removed the effect in roughly 50% of participants. We also unexpectedly failed to find restoration of the SNP effect in the .25/.75 condition with a matching probe target, this is contrary to both Fitzgeorge & Buckolz (2008) and Haworth et al., (2014). Although we did replicate the newly discovered Error Protection inhibitory after-effect in this experiment, we did not observe it in all instances where it was possible to be found. This is contrary to Buckolz et al., (2014), although it should be noted that the prime trial configurations were different between the two experiments (i.e., T-only or D-only vs. T+D). Details of the aforementioned can be found in Chapter 3.

Experiment 3 failed to replicate the findings of Fitzgeorge et al., (2011) and Buckolz, E., Lok, M., Kajaste, B., Edgar, C., & Khan, M. (2015) on forced-choice (prime) to free-choice (probe) trials in that we found no ‘hand dominance’ effects, participants didn’t prefer to repeat their prime responses when given the choice on the probe, and when they did choose to repeat their responses, they were slower to do so. Details regarding the above can be found in Chapter 4 and Appendix B.

Experiment 4 was so unique and exploratory that it had virtually no opportunities for replication (or lack there of).

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APPENDIX A

Chapter 3 Supplemental Material

Table A1

Mean Reaction Times (ms) and Error Protection as a Function of Probe Distractor Probability Ratio (Exp.1A: .75[probe distractor present]/.25[probe distractor absent], Exp.1B: .25[probe distractor present]/.75[probe distractor absent]) and Probe Trial Configuration (Configuration Exemplars of Non-Critical Trials Only).

		Probe Distractor Probability Ratio			
Prime Exemplar	→ T1 __ + __ D1	.75(DP)/.25(DA) n=40 Experiment 1A		.25(DP)/.75(DA) n=28 Experiment 1B	
Probe Trial Configuration Exemplars	↓	Reaction Time (ms)	EP CR/DR	Reaction Time (ms)	EP CR/DR
[17]	__ T1 + __ D1	459 (7.6) [5.5]	N/A	453 (8.6) [9.4]	N/A
[18]	__ T2 + __ D1	478 (8.4) [5.4]	N/A	482 (8.3) [7.7]	N/A
[19]	D1 __ + T1 __	463 (8.2) [5.5]	N/A	461 (10.1) [11.8]	N/A
[20]	D1 __ + T2 __	480 (8.0) [7.0]	N/A	486 (8.2) [8.9]	N/A
[21]	T1 __ + __ D1	441 (6.6) [3.5]	N/A	424 (7.3) [7.7]	N/A
[22]	T2 __ + __ D1	464 (7.9) [4.3]	N/A	461 (8.2) [8.0]	N/A
[23]	D1 __ + __ T1	476 (8.7) [7.1]	N/A	478 (11.7) [10.7]	N/A
[24]	D1 __ + __ T2	485 (8.4) [8.2]	N/A	494 (8.6) [11.0]	N/A

Notes. T1 = Target 1 (green rectangle), T2 = Target 2 (yellow cross), D1 = Distractor 1 (red rectangle), DP = Distractor Present, DA = Distractor Absent, EP = Error Protection, CR = Control Response, DR = Distractor Response, N/A = Not Applicable (EP cannot be measured). ( ) = standard error (ms); [ ] = button press error percent.

Table A2

Mean Reaction Times (ms) and Error Protection as a Function of Probe Distractor Probability Ratio (for Exp.1B: .25[probe distractor present]/.75[probe distractor absent)] and Probe Trial Configuration for Those Subjects (n=30) Not Showing SNP Removal (Configuration Exemplars of All Trial Types; Configurations [17]-[24] Were Non-Critical Trial Types).

		Probe Distractor Probability Ratio	
Prime Exemplar	→ T1 __ + __ D1	Experiment 1B .25(DP)/.75(DA) n=30	
Probe Trial Exemplars	↓	Reaction Time (ms)	EP CR/DR
[1]	__ __ + __ T1	453 (8.2) [11.0]	N/A
[2]	__ __ + __ T2	452 (7.9) [10.8]	N/A
[3]	__ __ + T1 __	436 (8.1) [8.1]	0.019/0.014*
[4]	__ __ + T2 __	439 (7.5) [8.8]	0.020/0.016
[5]	__ D1 + __ T1	478 (9.2) [10.4]	N/A
[6]	__ D1 + __ T2	499 (9.5) [13.6]	N/A
[7]	__ D1 + T1 __	465 (8.1) [7.4]	N/A
[8]	__ D1 + T2 __	483 (8.3) [9.4]	N/A
[9]	T1 __ + __ __	418 (7.1) [6.0]	0.008/0.005
[10]	T2 __ + __ __	429 (6.7) [6.6]	0.010/0.008
[11]	__ T1 + __ __	436 (8.1) [8.1]	0.019/0.014*
[12]	__ T2 + __ __	439 (7.5) [8.8]	0.020/0.016
[13]	T1 __ + D1 __	449 (7.6) [6.3]	0.007/0.004
[14]	T2 __ + D1 __	484 (8.1) [10.1]	0.018/0.017
[15]	__ T1 + D1 __	465 (8.1) [7.4]	N/A
[16]	__ T2 + D1 __	483 (8.3) [9.4]	N/A
[17]	__ T1 + __ D1	456 (8.6) [7.5]	N/A
[18]	__ T2 + __ D1	477 (8.8) [11.3]	N/A
[19]	D1 __ + T1 __	463 (8.8) [7.4]	N/A
[20]	D1 __ + T2 __	480 (9.3) [10.6]	N/A
[21]	T1 __ + __ D1	431 (16.4) [4.2]	N/A
[22]	T2 __ + __ D1	469 (9.6) [5.6]	N/A
[23]	D1 __ + __ T1	475 (9.2) [8.3]	N/A
[24]	D1 __ + __ T2	497 (10.8) [12.2]	N/A

SNP (IR-CO)	[1]-[3]	T1 = 17*	Target Retrieval	[9]-[10]	-11*
T-only Probes	[2]-[4]	T2 = 13*	T-only Probes	[11]-[12]	-03
SNP (IR-CO)	[5]-[7]	T1 = 13*	Target Retrieval	[13]-[14]	-35*
T+D Probes	[6]-[8]	T2 = 16*	T+D Probes	[15]-[16]	-18*

Notes. T1 = Target 1 (green rectangle), T2 = Target 2 (yellow cross), D1 = Distractor 1 (red rectangle), SNP = Spatial Negative Priming, DP = Distractor Present, DA = Distractor Absent, EP = Error Protection, CR = Control Response, DR = Distractor Response, N/A = Not Applicable (EP cannot be measured). ( ) = standard error (ms); [ ] = button press error percent. **p*<0.05.

APPENDIX B

Chapter 4 Supplemental Material

Table B1

Trial frequency breakdown for one experimental Session (392 trials)

	S1-R1 (competition)	S2-R2 (competition)	S2 Identity	S2 Location	Trials per Session
1.	Forced	Forced	Repeated	Repeated	16
2.	Forced	Forced	Repeated	Changed	48
3.	Forced	Forced	Changed	Repeated	16
4.	Forced	Forced	Changed	Changed	48
5.	Forced	Free (w)	Repeated	Changed	16
6.	Forced	Free (b)	Repeated	Changed	8
7.	Forced	Free (w)	Changed	Changed	16
8.	Forced	Free (b)	Changed	Changed	8
9.	Forced	Free (w)	Repeated	Changed	16
10.	Forced	Free (b)	Repeated	Changed	8
11.	Forced	Free (w)	Changed	Changed	16
12.	Forced	Free (b)	Changed	Changed	8
13.	Free (w)	Forced	Repeated	Changed	16
14.	Free (w)	Forced	Changed	Changed	16
15.	Free (b)	Forced	Repeated	Changed	8
16.	Free (b)	Forced	Changed	Changed	8
17.	Free (w)	Forced	Repeated	Changed	16
18.	Free (w)	Forced	Changed	Changed	16
19.	Free (b)	Forced	Repeated	Changed	8
20.	Free (b)	Forced	Changed	Changed	8
21.	Free (w)	Free (w)	Repeated	Repeated	8
22.	Free (w)	Free (w)	Changed	Repeated	8
23.	Free (b)	Free (b)	Repeated	Repeated	4
24.	Free (b)	Free (b)	Changed	Repeated	4
25.	Free (w)	Free (w)	Repeated	Changed	8
26.	Free (w)	Free (w)	Changed	Changed	8
27.	Free (w)	Free (b)	Repeated	Changed	8
28.	Free (w)	Free (b)	Changed	Changed	8
29	Free (b)	Free (w)	Repeated	Changed	8
30.	Free (b)	Free (w)	Changed	Changed	8

Note. (w) = Within-hand response competition, (b) = Between-hand response competition.

Combination 3

(Forced-choice [S1-R1] to Free-choice [S2-R2] Sequence)

Unlike Combination 1, the forced-choice to free-choice trial sequence of Combination 3 has been used before (e.g., Buckolz, Lok, et al., 2015; Fitzgeorge et al., 2011), although not all have employed visuo-spatial tasks (e.g., visuo-identity, Hommel, 2007). With Combination 3, the S1 object's location changed on every S2-R2 trial, as was the case with Combination 2.

Accordingly, with a response-location binding in effect, we should see evidence of an inclination to change the forced R1 response on the upcoming free-choice trial (see Combination 1). If the forced R1 response also binds to the S1-R1 object identity, we should see a reduction in the free-choice responses that reflect an R1 change when the S1 object identity repeats, rather than when the identity changes.

Between-hand Finger Response Competitions (R2)

Results

S1 Object Location Changed for S2-R2 Trials

R2 Response Selection. The Response Choice (2: repeat/change) x Selection Category (2: S1 identity repeat/change) x Sessions (3) ANOVA calculations produced no significant F-values (*p-values* ranged from 0.18 to 0.95) [Figure B1]).

R2 Reaction Time. The ANOVA yielded no significant effects; however, the Sessions main effect, F(2, 63)= 2.65, *p*= 0.08, MSE= 20178, and the Sessions x Response Choice, F(2, 63)= 2. 47, *p*= 0.09, MSE= 3019, and the Selection Category x Response Choice, F(1, 63)= 3.33, *p*= 0.07, MSE= 2261, interactions all approached statistical significance (Table B2).

Discussion (Between-hand)

Technically, there was no evidence that an imposed S1-R1 response binds to the location occupied by the imperative object or to the object's (irrelevant) identity. There was a lack of an overall tendency to change the S1-R1 response on the free-choice trial, thereby providing no evidence a response-location binding (Fig. B1).

Nonetheless, the visual inspection of the response selection probabilities in Figure B1 is suggestive of a response-object identity binding developing later in practice. By Session 3, subjects freely chose to more often repeat than to change the S1-R1 response when the object's identity was repeated, and vice versa. Relatedly, these response repeats had shorter latencies than response changes when S1 identity repeated (i.e., 473 msec. vs. 491 msec.; Table B2, Session 3, {3}), the reverse being the case when S1 identity changed. This is consistent with an S1-R1 response-object identity binding, whereby a repeated S1 identity resulted in an urge to also repeat the R1 response, and vice versa.

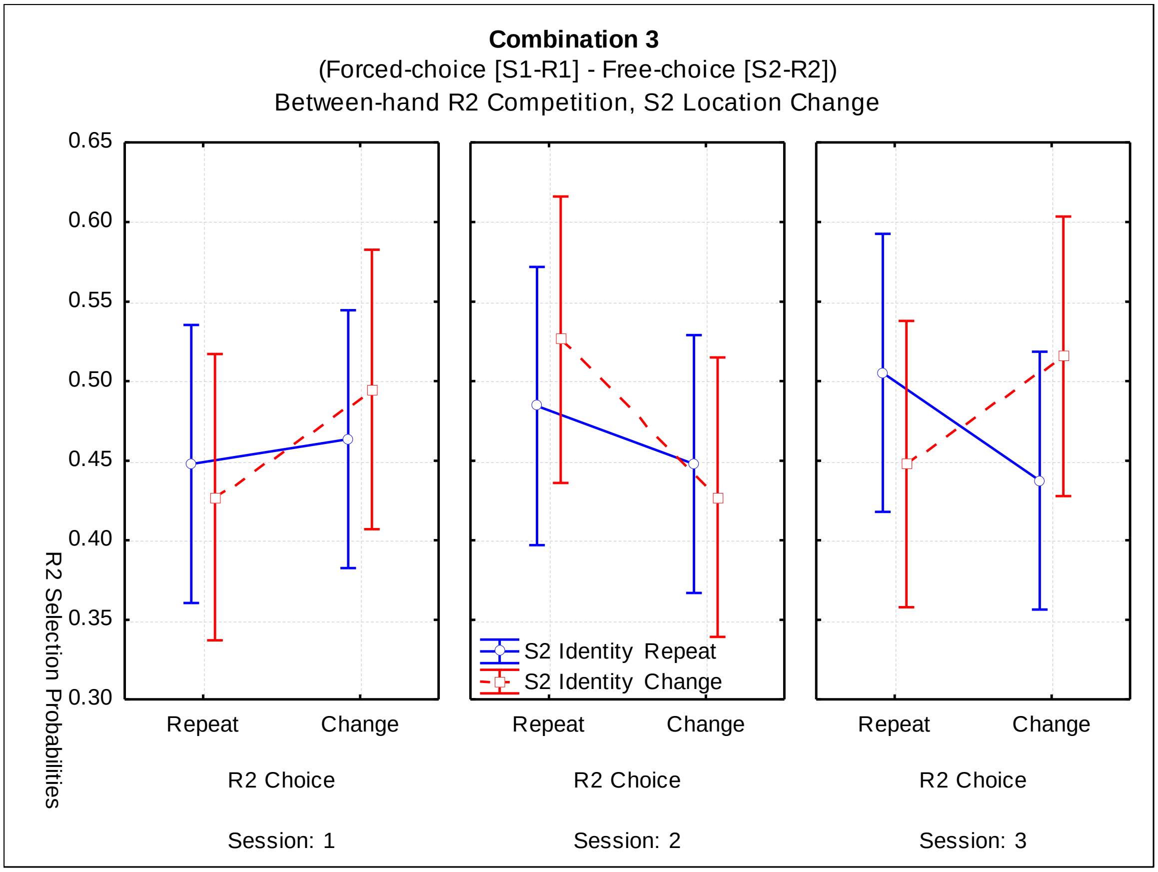


Figure B1. Combination 3 (Forced-choice S1-R1 to Free-choice S2-R2 trial sequence): R2 selection percentages for Between-hand Free-choice response competitions when S1's location changed on the S2-R2 trial, as a function of Response Choice (repeat or change R1 on the S2-R2 trial), Selection Category (S1's identity was either repeated or changed on the S2-R2 trial), and Sessions (392 S1-R1/S2-R2 trial pairs per session).

Table B2

Mean S2-R2 Reaction Times (ms) for Combination 3 (Forced-choice [S1-R1] → Free-choice [S2-R2] trials) for Within-hand and Between-hand R2 competitions over Sessions as a function of Selection Category and Response (R2) Choice.

Selection Category	Change Location Repeat Identity {3}		Change Location Change Identity {4}	
R2 Choice	Repeat	Change	Repeat	Change
		Between-hand R2 Trials		
Session 1	516 (20.1) [0.09]	507 (14.3) [0.09]	560 (19.9) [0.08]	518 (20.5) [0.08]
Session 2	499 (17.5) [0.07]	500 (15.7) [0.07]	512 (20.0) [0.05]	492 (19.1) [0.05]
Session 3	473 (12.2) [0.06]	491 (17.5) [0.06]	472 (13.5) [0.04]	483 (14.9) [0.04]
Means	496 (9.9) [0.07]	499 (9.1) [0.07]	514 (11.2) [0.05]	498 (10.6) [0.05]
		Within-hand R2 Trials		
Session 1	483 (16.8) [0.05]	463 (16.9) [0.05]	488 (16.8) [0.05]	464 (14.5) [0.05]
Session 2	470 (14.4) [0.05]	464 (14.6) [0.05]	486 (15.5) [0.04]	465 (14.7) [0.04]
Session 3	456 (12.8) [0.03]	436 (11.8) [0.03]	474 (11.7) [0.04]	444 (12.4) [0.04]
Means	469 (8.5) [0.04]	454 (8.4) [0.04]	483 (8.5) [0.04]	458 (8.0) [0.04]

Notes. ( ) = standard error (ms); [ ] = button press error (%).
See Figures B1 and B2 for associated Response Choice selection percentage data.
Trial Pair: [S1-R1] = first trial, [S2-R2] = second trial.

Within-hand Finger Response Competitions (R2)

Results

S1 Object Location Changed for S2-R2 Trials

R2 Response Selection. Another Response Choice (2: repeat/change) x Selection Category (2: S1 identity repeat/change) x Sessions (3) ANOVA was calculated. Response Choice produced the only significant effect, F(1, 69)= 8.03, $p < 0.01$, MSE= 0.014, revealing that subjects showed a (numerically small) tendency (.50 vs. .46) to change their response on S2-R2 trials, independent of whether the S1-R1 target object's identity was repeated or changed (Fig. B2).

R2 Reaction Time. The ANOVA calculated here produced significant Selection Category, F(1, 69)= 5.65, $p<0.05$, MSE= 892, and Response Choice, F(1, 69)= 41.89, $p<0.01$, MSE= 698, main effects (Table B2). Their interaction fell just short of being reliable, F(1, 69)= 2.67, $p=0.10$, MSE= 709. Overall, reaction time was reliably shorter when the S1 object identity was repeated (461 msec. vs. 471 msec.), and when the decision was taken to change the
R1 response on the S2-R2 trial (456 msec. vs. 476 msec.).

Discussion (Within-hand)

Looking at the response selection data, there was evidence that binding took place between the forced-choice S1-R1 response and the object-occupied location itself, but not with the S1 object's identity. Individuals chose to change the R1 response significantly more often than they did to repeat it (Fig. B2), and these changes were achieved significantly faster than were response repeats (Table B2). Presumably, changing one aspect of an S1-R1 response-location binding (i.e., location in this case) brings with it an urge to change the other component (i.e., response) [Combination 1]. Contrary to the involvement of an R1 response-object identity binding, the degree of this response selection bias was not altered by whether the S1's object identity was repeated or changed (Fig. B2).

There was, again, however, the indication of an 'S1-R1 response-object identity' binding that influences reaction time. Reaction time for a repeated response was reduced when the prime object identity was repeated (469 msec.), compared to when it was changed (483 msec.) [Table B2]. This could reflect an S1-R1 response-object identity binding, where a repeated object would retrieve the S1-R1 response and so produce some degree of facilitation for its production.

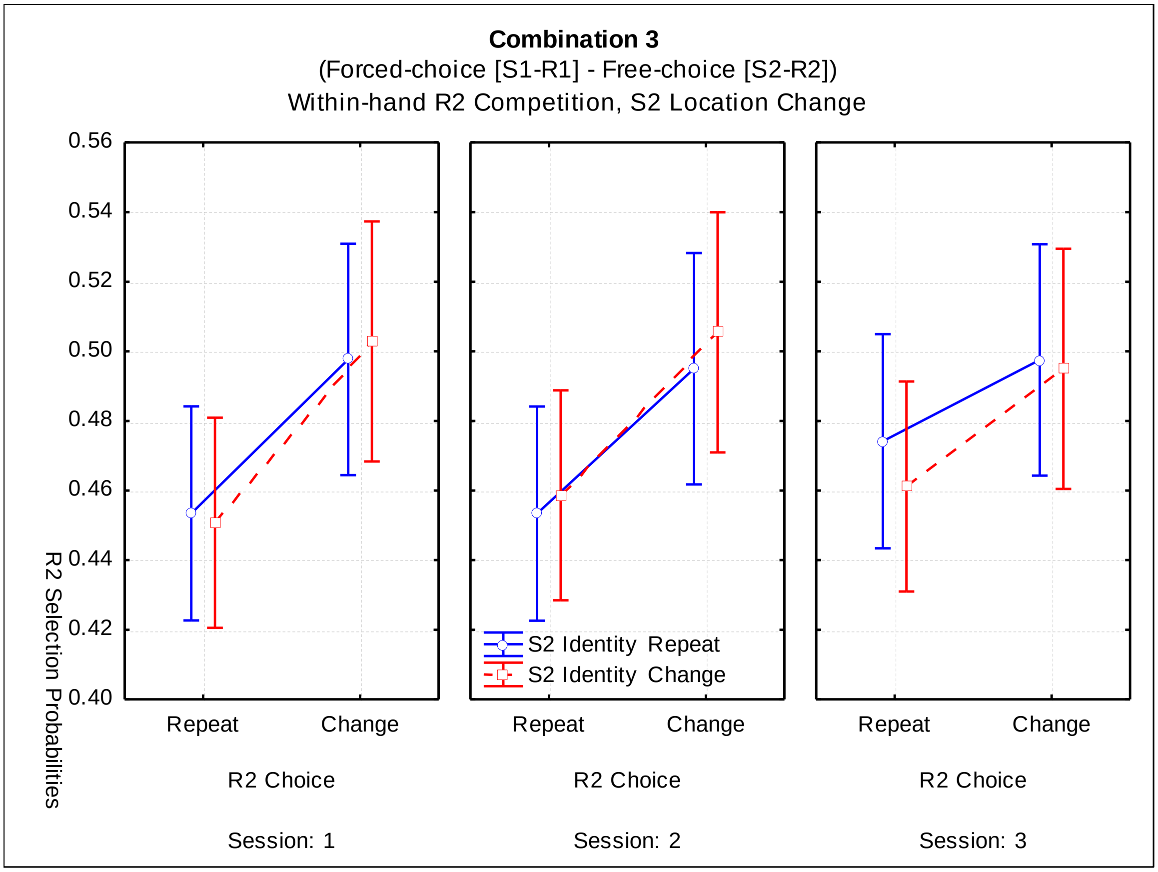


Figure B2. Combination 3 (Forced-choice S1-R1 to Free-choice S2-R2 trial sequence): R2 selection percentages for Within-hand Free-choice response competitions when S1's location changed on the S2-R2 trial, as a function of Response Choice (repeat or change R1 on the S2-R2 trial), Selection Category (S1's identity was either repeated or changed on the S2-R2 trial), and Sessions (392 S1-R1/S2-R2 trial pairs per session).

Combination 4

(Forced-choice [S1-R1] to Forced-choice [S2-R2] Trial Sequence)

Results

S2-R2 Reaction Time. The Combination 4 trial sequence yielded four (S2-R2) Selection Categories; {1} repeat object location & identity, {2} repeat object location only, {3} change object location, repeat object identity, and, {4} repeat nothing (see Table 4). Note, S1-R1 trial responses were also either repeated ({1}, {2}) or changed ({3}, {4}). Selection Categories {2} and {3} each involved one change in the S1-R1 object features (identity or location), and so both involved a violation of any existing response binding with target dimensions. Presumably, overcoming the need to violate an existing S1-R1 binding should take time and so delay RT, relative to when such violations are avoided ({4}). Such bindings and their violations would see the S2-R2 RTs for Categories {2} and/or {3} exceed that of Category {4}. Other ordinal RT relationships among the four Selection Categories would be uninterpretable from a binding perspective (i.e., binding could have occurred yet not be manifested because identity feature repeat benefits outweigh binding violation costs).

We calculated an ANOVA with Selection Category (4) and Sessions (3) serving as the main factors (Table 4). Selection Category produced the only significant F-value, F(3, 207)= 35.92, p<0.01, MSE= 371. Newman-Keuls tests (p< 0.05) revealed that all pair-wise Selection Category comparisons were significant. Reaction times were fastest and slowest when all S1-R1 features were repeated (RT= 423 msec.) or changed (RT= 455 msec.), respectively; with the partial repeat Selection Category RTs falling between these latency extremes (RTs = 436 msec. {2}, 446 msec. {3}).

Discussion

The reliably faster latencies for the two partial-repeat Selection Categories, compared to the Selection Category where nothing was repeated, presents no evidence that forced-choice S1-R1 responses binding to the target's identity.

Table B3

Mean S2-R2 Reaction Times (ms) for Combination 4 (Forced-choice [S1-R1] → Forced-choice [S2-R2] trials) over Sessions as a function of Selection Category and Response (R2) Required.

Selection Category	Repeat Location Repeat Identity {1}		Repeat Location Change Identity {2}		Change Location Repeat Identity {3}		Change Location Change Identity {4}	
R2 Required	Repeat	N/A	Repeat	N/A	N/A	Change	N/A	Change
Session 1	431		448			457		463
	(8.8)		(11.3)			(12.0)		(12.8)
	[0.09]		[0.08]			[0.14]		[0.11]
Session 2	424		438			447		457
	(9.9)		(9.7)			(12.5)		(13.5)
	[0.06]		[0.05]			[0.08]		[0.10]
Session 3	415		422			435		444
	(9.3)		(9.9)			(9.6)		(10.4)
	[0.05]		[0.05]			[0.08]		[0.07]
Means	423		436			446		455
	(5.4)		(6.0)			(6.6)		(7.1)
	[0.06]		[0.06]			[0.10]		[0.09]

Notes. ( ) = standard error (ms); [ ] = button press error (%).
Trial Pair: [S1-R1] = first trial, [S2-R2] = second trial.

APPENDIX C

Chapter 5 Supplemental Material

Table C1

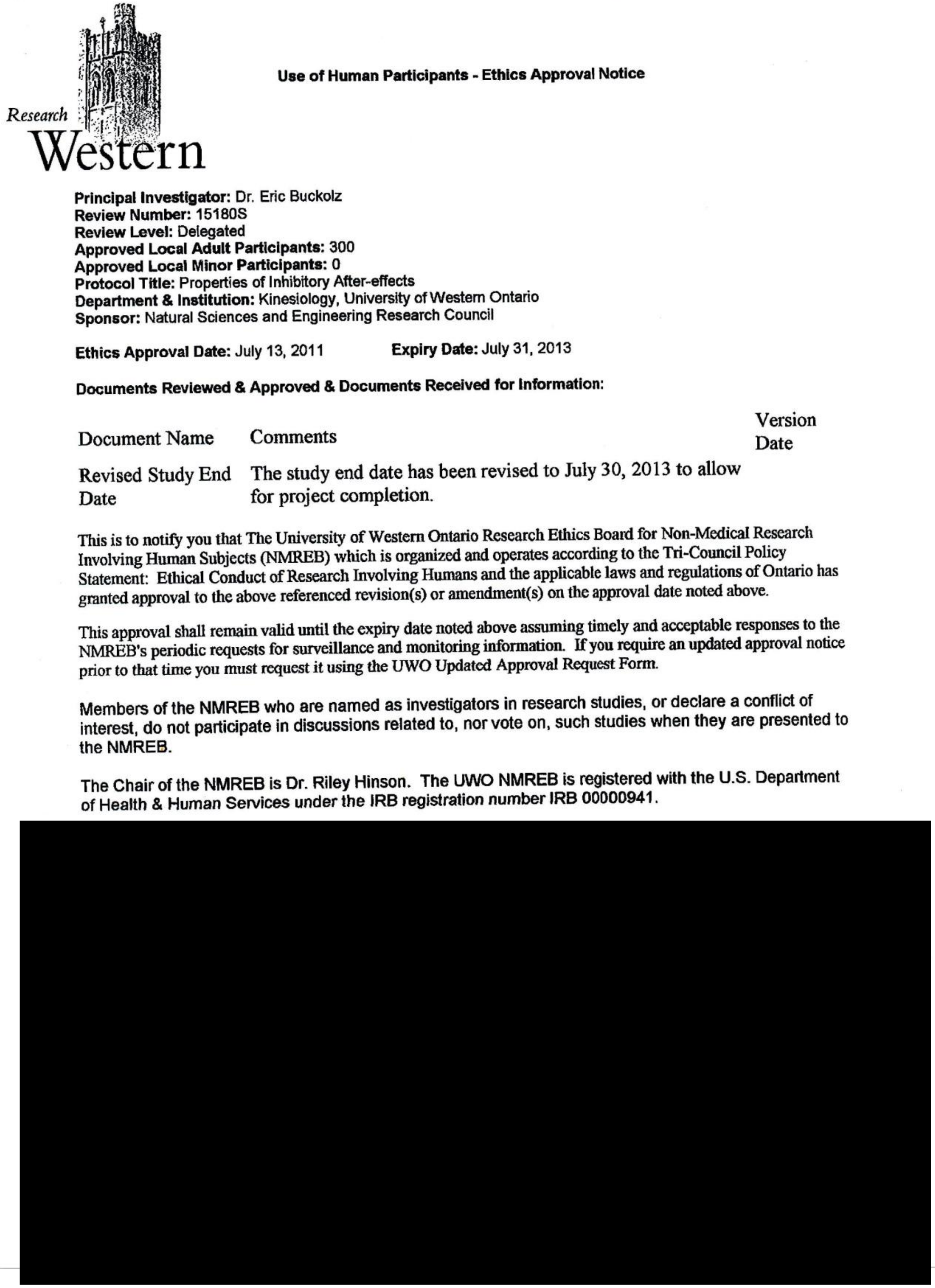
Trial Type frequency breakdown for Experiment 4.

Cue	Probe	Condition		PDP Ratio	
		PTI Repeat	PTI Change	.75/.25	.25/.75
Uninformative	T+D	Non-Critical	Non-Critical	192	96
Uninformative	T+D	[4]	[2]	48	24
Uninformative	T+D	[3]	[1]	48	24
Uninformative	T-only	Non-Critical	Non-Critical	24	108
Uninformative	T-only	[4]	[2]	24	108
Uninformative	T-only	[3]	[1]	48	216
Valid (75%)	T+D	Non-Critical	Non-Critical	864	96
Valid (75%)	T+D	[4]	[2]	216	24
Valid (75%)	T+D	[3]	[1]	216	24
Valid (75%)	T-only	Non-Critical	Non-Critical	108	396
Valid (75%)	T-only	[4]	[2]	108	396
Valid (75%)	T-only	[3]	[1]	216	792
Invalid (25%)	T+D	Non-Critical	Non-Critical	336	336
Invalid (25%)	T+D	[4]	[2]	48	48
Invalid (25%)	T+D	[3]	[1]	48	48
Invalid (25%)	T-only	Non-Critical	Non-Critical	36	36
Invalid (25%)	T-only	[4]	[2]	36	36
Invalid (25%)	T-only	[3]	[1]	72	72
				Total = 2688	Total = 2880

Notes. PDP Ratio = Probe Distractor Probability Ratio (.75[Probe Distractor Present]/.25[Probe Distractor Absent] or .25[Probe Distractor Present]/.75[Probe Distractor Absent]); T+D = Target-plus-distractor; T-only = Target-only; PTI = Probe Target Identity; Condition (all relative to prime target): [1] = change probe target identity, location and response, [2] = change probe target identity, repeat location and response, [3] = repeat probe target identity, change location and response, [4] = repeat probe target identity, location and response. The Probe Target Identity (repeat or change) was a blocked/between subject's factor, so the total trials for PTI Repeat Conditions would be 2688 (.75/.25) and 2880 (.25/.75); the total trials for the PTI Change Conditions would also be 2688 (.75/.25) and 2880 (.25/.75) respectively.

APPENDIX D

The University of Western Ontario Research Ethics Board of Approval Notices



Research Western

Use of Human Participants - Ethics Approval Notice

Principal Investigator: Dr. Eric Buckolz
Review Number: 15180S
Review Level: Delegated
Approved Local Adult Participants: 300
Approved Local Minor Participants: 0
Protocol Title: Properties of Inhibitory After-effects
Department & Institution: Kinesiology, University of Western Ontario
Sponsor: Natural Sciences and Engineering Research Council

Ethics Approval Date: July 13, 2011 **Expiry Date:** July 31, 2013

Documents Reviewed & Approved & Documents Received for Information:

Document Name	Comments	Version Date
Revised Study End Date	The study end date has been revised to July 30, 2013 to allow for project completion.	

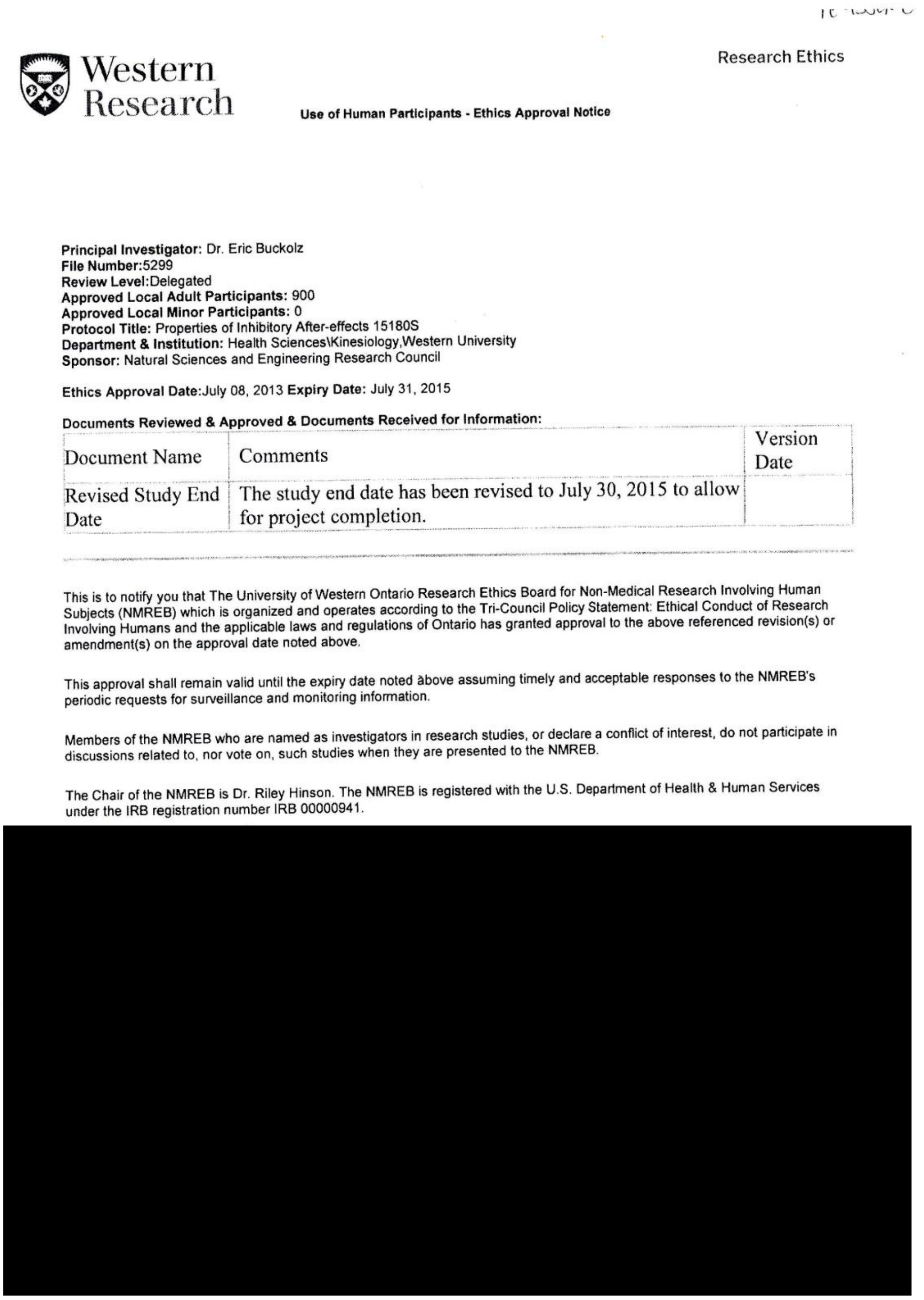
This is to notify you that The University of Western Ontario Research Ethics Board for Non-Medical Research Involving Human Subjects (NMREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the applicable laws and regulations of Ontario has granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above.

This approval shall remain valid until the expiry date noted above assuming timely and acceptable responses to the NMREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request Form.

Members of the NMREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussions related to, nor vote on, such studies when they are presented to the NMREB.

The Chair of the NMREB is Dr. Riley Hinson. The UWO NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

[redacted]



[illegible]

Western Research

Research Ethics

Use of Human Participants - Ethics Approval Notice

Principal Investigator: Dr. Eric Buckolz
File Number:5299
Review Level: Delegated
Approved Local Adult Participants: 900
Approved Local Minor Participants: 0
Protocol Title: Properties of Inhibitory After-effects 15180S
Department & Institution: Health Sciences\Kinesiology,Western University
Sponsor: Natural Sciences and Engineering Research Council

Ethics Approval Date: July 08, 2013 **Expiry Date:** July 31, 2015

Documents Reviewed & Approved & Documents Received for Information:

Document Name	Comments	Version Date
Revised Study End Date	The study end date has been revised to July 30, 2015 to allow for project completion.	

This is to notify you that The University of Western Ontario Research Ethics Board for Non-Medical Research Involving Human Subjects (NMREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the applicable laws and regulations of Ontario has granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above.

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The Chair of the NMREB is Dr. Riley Hinson. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

[redacted]

APPENDIX E

Participant Documents

Letter of Information

Project Title

Properties of Inhibitory After-effects.

Introduction

You are being invited to participate in a research study. The purpose of this letter is to provide you with the information you need to render an informed participation decision.

Purpose of the Study

The purpose of the study is to extend our understanding of the aspects of cognitive ‘inhibitory after-effects’, which refers to those occasions where a current act of inhibition results in interference effects (i.e. delayed response time, error production etc.) on future processing in which the previously inhibited events play a role.

Basic Procedures

If you agree to participate, you will be asked to respond as quickly and as accurately as possible to visual stimuli presented on a computer screen while concurrently ignoring distractor events that may also be present. You will respond to the spatial location and/or to the identity of the stipulated target stimuli by pressing designated computer keyboard buttons. Accuracy and reaction times associated with your manual button press responses will be recorded and analyzed.

Participation requires you to attend up to 6 testing sessions of approximately forty minutes each in laboratories. Normally these sessions will occur within 10 days of each other. Specific laboratory testing times will be arranged by you in consultation with the experimenter (Ben Kajaste).

Risks Associated with Participation

There are no known or reasonably anticipated risks associated with participation in this experiment.

Benefits

No personal benefits will necessarily follow from your participation. However, it is possible that any discoveries that advance our understanding of inhibitory after-effects as a result of your participation may be viewed as beneficial.

Confidentiality

Efforts will be made to ensure that your data cannot be linked to you by anyone other than the experimenter. Code numbers assigned to your data files will not identify you directly but will be linked to your name on a master sheet kept by the experimenter on a password protected computer. Once experimentation has been completed the master sheet will be destroyed. Henceforth it will be impossible to associate any particular data with your identity.

Any publications that may arise from the data collected will not identify you personally. The data files will be retained for five years in the event a publication does not arise, or for five years after 'on-line' publication and then deleted.

Participation

Participation in this study is voluntary. You may refuse to participate or withdraw from the study at any time without penalty. If you withdraw, any data collected to that point will be deleted and will not be used in the study.

Debriefing

Once all of the data collection has been completed, you may contact the experimenter by for an explanation of the purpose of the study along with the preliminary findings obtained. A debriefing session will also take place in class once all of the data have been collected. At that time information dealing with your participation will be discussed (i.e. study purpose, group results and their preliminary interpretation etc.).

Contact Information

If you have any questions about this study you may contact Dr. Eric Buckolz or Ben Kajaste

If you have any questions about the conduct of this study or your rights as a research participant, you may contact the Office of Research Ethics at The University of Western Ontario.

You do not waive any legal rights by signing the consent form.

This letter is yours to keep.

Research Consent Form

Project Title: Properties of Perceptual Motor After-effects

I agree to allow the data I produce during the laboratory experiment for this class (Kin 4409 or Kin 4482) to be used for research purposes. I understand that any publication resulting from this data will not identify me personally.

I have read the Letter of Information, have had the nature of the study explained to me and have had all questions answered to my satisfaction. I agree to participate.

Research Participant (print): ____

Participant Signature: ____

Date: ____

Person Obtaining Informed Consent (print): ________________________________

Signature: ____

Date: ____

CURRICULUM VITAE

SECTION I
Personal Information

NAME: Benjamin John Kajaste

WORK ADDRESS: Thames Hall, School of Kinesiology, Western University, London, Ontario, Canada N6A 3K7

SECTION II
Education

POSTSECONDARY EDUCATION AND DEGREES:

Western University
London, Ontario, Canada
Doctor of Philosophy, Kinesiology
Supervisor: Dr. Eric Buckolz
2018

Western University
London, Ontario, Canada
Master of Arts, Kinesiology
Supervisor: Dr. Eric Buckolz
2011

Western University
London, Ontario, Canada
Bachelor of Education, Intermediate/Senior, Physical & Health Education and Geography
2009

Western University
London, Ontario, Canada
Bachelor of Arts, Honours Specialization Kinesiology
Minor in Geography
2008

HONOURS AND AWARDS

FHS Graduate Conference Travel Award
November 2016, $170

Western Graduate Research Scholarship
September 2014, $14 268

Kinesiology Graduate Travel Award
May 2014, $500

FHS Graduate Conference Travel Award
November 2013, $500

Western Graduate Research Scholarship
September 2013, $14 268

Global Opportunities Award
April 2013, $1 000

FHS Graduate Conference Travel Award
November 2012, $500

Western Graduate Research Scholarship
September 2012, $14 268

Western Graduate Research Scholarship
September 2011, $14 268

Western Graduate Research Scholarship
September 2010, $5 258

Western Graduate Research Scholarship
September 2009, $5 258

Western Scholarship of Distinction Award
September 2004, $1 500

SECTION III
Publications & Presentations

REFEREED PUBLICATIONS

2018

Kajaste, B., & Buckolz, E. (2018). Detecting Target Identity—Location/Response Binding in Visuo-spatial Tasks Using a Cueing Procedure: An Exploratory Study. *Psychology*, *9*(04), 691.

Kajaste, B., & Buckolz, E. (2018). *Distractor-occupied prime locations retrieve inherently-related and task-assigned responses in visuo-spatial tasks*. Manuscript submitted for publication.

Kajaste, B., & Buckolz, E. (2018). *Episodic storage and retrieval in visuo-spatial tasks: evidence of indirect retrieval*. Manuscript submitted for publication.

Kajaste, B., & Buckolz, E. (2018). *Freely selected and forced responses bind with target object location in a visuo-spatial task*. Manuscript submitted for publication.

2014

Buckolz, E., Lok, M., **Kajaste, B**., Edgar, C., & Khan, M. (2014). The preservation of response inhibition after-effects in a location-based spatial negative priming task: Younger versus older adults. *Psychological Research.*

Haworth, P., Buckolz, E., & **Kajaste, B**. (2014). The role of probe-trial distractors in the production/removal of the spatial negative priming effect. *Journal of Cognitive Psychology.*

2012

Buckolz, E., Edgar, C., **Kajaste, B**., Lok, M., & Khan, M. (2012a). Inhibited prime-trial distractor responses solely produce the visual spatial negative priming effect. *Attention, Perception, & Psychophysics, 74,* 1632–1643.

2011

Buckolz, E., Edgar, C., **Kajaste, B**., Lok, M., & Khan, M. (2011). Blocking memory retrieval as a means for eliminating the spatial negative priming (SNP) effect: Preventing response-based information retrieval. *Journal of Sport & Exercise Psychology, 33 Suppl.,* 58-59.

Buckolz, E., **Kajaste, B**., Edgar, C., Lok, M., & Khan, M. (2011). Do centrally presented stimulations cause orientation inhibition? *Journal of Sport & Exercise Psychology, 33 Suppl*., 58.

Buckolz, E., Lok, M., Edgar, C., **Kajaste, B**., & Khan, M. (2011). Response inhibition in the elderly: Evidence for preservation. *Journal of Sport & Exercise Psychology, 33 Suppl.,* 57-58.

CONFERENCE PRESENTATIONS AND POSTERS

2016

Kajaste, B., Buckolz, E., & Khan, M., (2016, October). *Evidence of Episodic Storage Processing in a Visuo-spatial Task.* Poster presented at the Canadian Society for Psychomotor Learning & Sport Psychology Conference, Waterloo, Ontario.

Kajaste, B., Buckolz, E., & Khan, M., (2016, October). *Freely Selected & Forced Responses Quickly Bind to the Target Location, But Not to the Target Identity, That Activates Them in a Visuo-spatial Task.* Poster presented at the Canadian

Society for Psychomotor Learning & Sport Psychology Conference, Waterloo, Ontario.

2013

Kajaste, B., Buckolz, E., Haworth, P., & Perry, J., (2013, October). *Automatic Processing is Both Inevitable & Flexible.* Poster presented at the Canadian Society for Psychomotor Learning & Sport Psychology Conference, Kelowna, British Columbia.

Haworth, P., Buckolz, E., & **Kajaste, B.** (2013, October). *The Role of Probe-trial Distractors in the Production/Removal of the Spatial Negative Priming Effect.* Poster presented at the Canadian Society for Psychomotor Learning & Sport Psychology Conference, Kelowna, British Columbia.

2012

Buckolz, E., Stoddart, A., **Kajaste, B**., Edgar, C., & Haworth, P. (2012, November). *The influence of practice on response inhibition and its inhibitory after-effects in visual, location-based tasks.* Poster presented the Canadian Society for Psychomotor Learning & Sport Psychology Conference, Halifax, Nova Scotia.

Stoddart, A., Buckolz, E., **Kajaste, B**., Edgar, C., & Haworth, P. (2012, November). *Protection against response selection errors: Is this the benefit produced by inhibitory after-effects caused by response inhibition?* Poster presented at the Canadian Society for Psychomotor Learning & Sport Psychology Conference, Halifax, Nova Scotia.

2011

Buckolz, E., Edgar, C., **Kajaste, B.,** Lok, M., & Kahn, M. (2011, June). *Blocking memory retrieval as a means for eliminating the spatial negative priming (SNP) effect: Preventing response-based information retrieval.* Poster presented at the North American Society for the Psychology of Sport and Physical Activity Conference, Burlington, Vermont.

Buckolz, E., **Kajaste, B.,** Lok, M., Edgar, C., & Khan, M. (2011, June). *Do centrally presented stimulations cause orientation inhibition?* Poster presented at the North American Society for the Psychology of Sport and Physical Activity Conference, Burlington, Vermont.

Buckolz, E., Lok, M., Edgar, C., **Kajaste, B.,** & Khan, M. (2011, June). *Response inhibition in the elderly: Evidence of preservation.* Lecture presented at the North American Society for the Psychology of Sport and Physical Activity Conference, Burlington, Vermont.

SECTION IV

Related Work Experience & Professional Development

ADDITIONAL RESEARCH EXPERIENCE

2017	*Research Assistant & Lab Coordinator, Western University* Contact: Dr. Eric Buckolz, Ph.D.
2016	*Research Assistant & Lab Coordinator, Western University* Contact: Dr. Eric Buckolz, Ph.D.
2015	*Research Assistant & Lab Coordinator, Western University* Contact: Dr. Eric Buckolz, Ph.D.
2014	*Research Assistant & Lab Coordinator, Western University* Contact: Dr. Eric Buckolz, Ph.D.
2013	*Research Assistant & Lab Coordinator, Western University* Contact: Dr. Eric Buckolz, Ph.D.
2012	*Research Assistant & Lab Coordinator, Western University* Contact: Dr. Eric Buckolz, Ph.D.
2011	*Research Assistant & Lab Coordinator, Western University* Contact: Dr. Eric Buckolz, Ph.D.
2010	*Research Assistant & Lab Coordinator, Western University* Contact: Dr. Eric Buckolz, Ph.D.

TEACHING EXPERIENCE

Graduate Teaching Assistant Positions
Western University

Spring 2015	Course: Kinesiology 4409b - Strategies & Tactics in Sport Professor: Dr. Eric Buckolz (Approximately 80 students)
Fall 2014	Course: Kinesiology 2903q – Canoeing Professor: Dr. Glen Belfry (Approximately 35 students)
Spring 2014	Course: Kinesiology 4409b - Strategies & Tactics in Sport Professor: Dr. Eric Buckolz (Approximately 60 students)
Fall 2013	Course: Kinesiology 2903q – Canoeing Professor: Dr. Glen Belfry (Approximately 35 students)

Spring 2013	Course: Kinesiology 4474b – Physical Activity & Exercise Guidelines for Older Adults Professor: Dr. Liza Stathakostas (Approx. 80 students)
Fall 2012	Course: Kinesiology 2903q – Canoeing Professor: Dr. Glen Belfry (Approximately 35 students)
Spring 2012	Course: Kinesiology 4409b – Strategies & Tactics in Sport Professor: Dr. Eric Buckolz (Approximately 80 students)
Fall 2011	Course: Kinesiology 2903q – Canoeing Professor: Dr. Glen Belfry (Approximately 35 students)
Spring 2011	Course: Kinesiology 4409b – Strategies & Tactics in Sport Professor: Dr. Eric Buckolz (Approximately 80 students)
Fall 2010	Course: Kinesiology 2903q – Canoeing Professor: Dr. Glen Belfry (Approximately 35 students)
Spring 2010	Course: Kinesiology 1080B – Psycho-motor Behaviour Professor: Dr. Matthew Heath (Approx. 300 students)
Fall 2009	Course: Kinesiology 2903q – Canoeing Professor: Dr. Glen Belfry (Approximately 35 students)

SECTION V
Services & Societies

MEMBERSHIP IN ACADEMIC OR PROFESSIONAL SOCIETIES

2012-Present	Canadian Society for Psychomotor Learning and Sport Psychology
2011-Present	North American Society for the Psychology of Sport and Physical Activity
2009- Present	Society of Graduate Students
2008- Present	Ontario College of Teachers