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Inhibitory Control in Memory: Evidence for Negative Priming in Free Recall

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RUNNING HEAD: Inhibitory Control in Memory

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Abstract

Cognitive control mechanisms—such as inhibition—decrease the likelihood that goal-directed activity is ceded to irrelevant events. Here, we use the action of auditory distraction to show how retrieval from episodic long-term memory is affected by competitor inhibition. Typically, a sequence of to-be-ignored spoken distracters drawn from the same semantic category as a list of visually-presented to-be-recalled items impairs free recall performance. In line with competitor inhibition theory (Anderson, 2003), free recall was worse for items on a probe trial if they were a repeat of distracter items presented during the previous, prime, trial (Experiment 1). This effect was only produced when the distracters were dominant members of the same category as the to-be-recalled items on the prime. For prime trials in which distracters were low-dominant members of the to-be-remembered item category or were unrelated to that category—and hence not strong competitors for retrieval—positive priming was found (Experiments 2 & 3). These results are discussed in terms of inhibitory approaches to negative priming and memory retrieval.

Keywords: Inhibition, Distraction, Negative Priming, Semantic Relatedness, Free Recall

The notion that coherent cognitive functioning involves the inhibition of currently irrelevant or unwanted information has played a prominent role in explanations of a wide range of processes including perceptual selection (Tipper, 1985), reasoning and text processing (Dempster, 1991), language comprehension and production (Faust & Gernsbacher, 1996), retrieval from long-term semantic memory (Johnson & Anderson, 2004; Wentura & Frings, 2005) and from working memory (Hasher & Zacks, 1988). However, both the notion of cognitive inhibition and the situations in which it might be employed remain controversial (Gorfein & McLeod, 2007). The present article informs this debate by addressing the idea that attentional selectivity during free recall might be achieved in part through competitor inhibition (e.g., Anderson, 2003).

Previous work has demonstrated a semantic auditory distraction or *between-sequence semantic similarity effect* in the free recall of visually-presented items when they are accompanied by to-be-ignored auditory distracters (Beaman, 2004; Neely & LeCompte, 1999). A sequence of auditory distracters (e.g., “robin, sparrow, crow…etc.”) drawn from the same category as a concurrent list of visual to-be-recalled items (e.g., “peacock, cuckoo, kestrel…etc.”) produces more disruption to free recall of the visual items than categorically-unrelated auditory distracters (e.g., “apple, banana, pear….etc.”; Marsh, Hughes, & Jones, 2008). A plausible explanation for this impairment is that representations of auditory distracter items compete with similar representations of visual to-be-recalled items for retrieval. Of interest here is whether inhibitory processes are deployed in the face of such competition.

Consistent with this idea, there is evidence that even in the absence of distracters, inhibitory processes are employed as a form of cognitive control in episodic memory tasks. In a procedure known as the retrieval practice paradigm, participants learn a list of category-exemplar word pairs (e.g., Flower—Daisy; Insect—Ant) and then practice retrieval of half of the items in half of the categories. Using this procedure results in poorer recall in a later category-cued recall test for the unpracticed half of a category as compared with a matched half from a category in which none of the items were practiced, an empirical pattern referred to as retrieval-induced forgetting (RIF). Inhibition of the non-practiced half, it is argued, reduces the activation levels of the representations, impairing the later recall of those items when they then need to be retrieved (Anderson, Bjork, & Bjork, 1994). There are striking commonalities in these results to the semantic similarity effects observed in auditory distraction. For example, semantic auditory distraction effects in free recall are usually found only when the distracters are high in output-dominance, that is, when they are strongly related to the category-cue (e.g., Fruit-Apple; Marsh et al., 2008). RIF is also more pronounced when the non-practiced items are high output-dominant (Anderson et al., 1994; Bäuml, 1998).

These findings are consistent with the notion that, in both situations, distracters or non-practiced items that are high output-dominant are routinely inhibited but that there is no necessary requirement to apply inhibition to low output-dominant items because they are not strong competitors for retrieval. However, the only evidence to date for inhibition in semantic auditory distraction is somewhat indirect and relies upon a correlation observed between intrusion errors in a free recall protocol and poor performance on a working memory measure commonly supposed to reflect attentional control and inhibitory capability (Beaman, 2004). Here, it is useful to make reference to MacLeod's (2007) distinction between cognitive inhibition as a cause—which is hypothesized—and behavioral interference as an effect, which has already been empirically established (MacLeod, 2007, pp. 14-15).

Defining an effect as “inhibition” on the basis of behavioral interference effects risks circularity if the interference effects are themselves cited as evidence for inhibition (Klein & Taylor, 1994) and it is particularly problematic if alternative, non-inhibitory, explanations of the behavioral effect are available.

Accordingly, we refer to the behavioral data as “interference” and reserve the term “inhibition” for the hypothetical cause. Although other possible accounts will be considered, we proceed from the initial assumption that particular interference effects are the result of a particular type of inhibitory process and make predictions based upon this premise. This is in line with suggestions that, in the absence of an observable link between neural inhibition and particular interference effects, cognitive psychology may rely upon the power of converging evidence to inform debates about when behavioral interference can be ascribed to cognitive inhibition (Klein & Taylor, 1994, p. 146). As noted by Healey, Campbell, Hasher, and Ossher (2010), a distinguishing feature of inhibition is that it acts not upon the to-be-remembered item but upon the competitors. Accordingly, a more direct approach than taken by Beaman (2004), therefore, is to examine the hypothesis that if distracters undergo a process of inhibition there should be enduring consequences, over a relatively long time-scale, of that inhibition.

The notion that attempts to exclude semantic auditory distractors from the current memory set might have negative implications for their future processing—and, in so doing, potentially reveal the action of an inhibitory process—is inspired, in part, by the observed similarities between RIF and semantic auditory distraction. However, there are also differences between the consequences of RIF and directed forgetting and the effects of semantic auditory distraction. One notable difference between RIF and semantic auditory distraction is that in the former the act of practicing recall of the cued items is assumed to be the cause of poorer subsequent recall of the uncued items, which participants are never specifically told to ignore or inhibit (Anderson et al., 1994) whereas there is no explicit cue to “practice” recall of to-be-recalled lists in investigations of auditory distraction effects and participants are specifically instructed to ignore anything they might hear. Similarly, directed forgetting differs from semantic auditory distraction in that if the participant is re-exposed to the to-be-forgotten items prior to final recall, directed forgetting—which we take to be closely related to RIF—does not occur (Basden, Basden & Gargano, 1993; Bjork & Bjork, 1996).

It is not clear, given these methodological objections, whether an ongoing consequence of distracter inhibition can be established. The most obvious means of revealing the action of inhibition in semantic auditory distraction is to ask participants to ignore the distracter items initially and then test whether processing of those representations is impeded when they are re-presented as to-be-remembered items on a subsequent trial. This is also the procedure used to investigate possible inhibitory effects in perceptual selection: slowed responding to a target that was previously a to-be-ignored distracter—or “negative priming” (Tipper, 1985)—has often been taken to reflect inhibition of the distracter (for a review, see Tipper, 2001). However, this procedure necessarily involves re-presenting the to-be-ignored items in a way that, in past studies, often eliminated the directed forgetting effect for to-be-forgotten items (e.g., Basden et al., 1993). However, Bjork and Bjork (1996) also showed that when the task does not require access to the context of the original study episode, inhibition (i.e., an interference effect) for the to-be-forgotten items remains. Similarly, in the retrieval-practice paradigm, RIF has been shown to occur on implicit memory tests that re-present the original items (Perfect, Moulin, Conway & Perry, 2002) and it is possible to argue that the kind of inhibition considered here has more in common with RIF than with directed forgetting (for example, both involve strong semantic components).

Perhaps because of these complications, the negative priming approach is not typically applied to investigations of memory retrieval. Hughes and Jones (2003) nevertheless utilized it to test short-term memory for serial order, and found that re-presenting sequences as to-be-recalled lists that were previously presented as to-be-ignored distracter lists interfered with participants' memory for serial order. That is, if a list such as 8-4-9-2-1 was presented first as an auditory distracter on trial *n* and then as a visual to-be-recalled sequence on trial *n*+1, recall of the order of these digits was impaired on trial *n*+1 relative to a control condition where 8-4-9-2-1 had not previously been encountered. The negative priming effect reported by Hughes and Jones (2003) appears to stand in contrast to the "release from inhibition" (lack of directed forgetting) reported when to-be-forgotten items are re-presented (see Bjork, 1989). Perhaps an important difference between Hughes and Jones (2003) and the directed forgetting procedure is that the "re-presentation" of a sequence of items in Hughes and Jones' (2003) procedure is always contrasted with a condition in which the items were also repeated, although their position within the sequence differed from that previously experienced. So, "release from inhibition" may have occurred at the item level, but not at the level of the sequence.

Few studies other than that of Hughes and Jones (2003) have systematically examined the effect of actively ignoring a sequences of distracter—arguably the most common source of distraction in many environments (Beaman, 2005)—on future recall of those distracters. Extending this approach beyond the relatively narrow confines of short-term memory for serial order, here we use a category-exemplar free recall task to further test the possible involvement of inhibition in auditory distraction by measuring the impact of ignoring auditory distractors on their later recall. Based on the competitor inhibition approach, we predict that when lists ofto-be-remembered items are presented alongside semantically-related auditory distracters, the same distracters should be poorly recalled when they are immediately repeated, on the next trial, as to-be-remembered items. In line with Tipper's (2001) arguments concerning perceptual selectivity, we assume that competition exists between distracter and to-be-recalled lists. The consequences of any inhibition applied in the face of such competition, as in perceptual selectivity and RIF, may be relatively long-lasting for some of the competitors involved (Grison, Tipper, & Hewitt, 2007; Treisman & DeSchepper, 1996). In effect, if inhibition is implicated in the free recall of items under auditory distraction then negative priming (NP) should be found for to-be-recalled items that have recently been encountered as distractors. The exact timing of this process (whether it occurs during study, rehearsal, or test) is not examined here and does not materially affect the conclusions drawn.

Experiment 1

Method

Participants

Forty-two students at Cardiff University took part in the study. All reported normal or corrected-to-normal vision and normal hearing, and spoke English as their first language. They received course credit for their participation. Data for two participants was incomplete due to equipment failure, and they were excluded from the analysis.

Materials & Design

The experiment was run using *Superlab Pro* (Cedrus Corporation) software. Thirty words, taken from positions 1 to 30, were chosen from each of 54 semantic categories in the Van Overschelde, Rawson and Dunlosky (2004) category norm lists. Each participant received 54 trials comprising one list of 15 visually to-be-remembered words per trial. Half of these were designated as prime trials, and half as probe trials.

Prime trials. On prime trials, 15 auditorily-presented to-be-ignored words (distracters) were presented alongside the to-be-remembered items. To-be-remembered items were presented, one item at a time, on the computer screen in lower-case 72-point *Times* font on a white background at a rate of one every 1.5 s (750 ms on, with a 750 ms inter-stimulus interval; ISI). Auditory distracters were presented synchronously with visual to-be-remembered items at 65 dB(A) and at the same rate of one item every 1.5 s (750 ms on, with a 750 ms ISI). The distracters were digitally recorded in a male voice at an even-pitch and sampled with 16-bit resolution at a sampling rate of 44.1 KHz using *Sound Forge 5* software (Sonic Inc., Madison, WI, 2000). In 18 of these trials, the distracter lists were semantically-related to the to-be-remembered lists. To achieve this, items from odd ranked positions in the Van Overschelde et al. (2004) category norm lists were assigned to the to-be-remembered lists and items from even positions were assigned to the distracter lists (e.g., for the category "fruit", the to-be-remembered lists would be {apple [1], banana [3], pear [5] etc} and the distracters would be {orange [2], grape [4], peach [6] etc}). On the remaining prime trials, the auditory distracter items were drawn from a categories other than those from which the to-be-remembered items were drawn (e.g., if the to-be-remembered list was from the category "fruit", as above, the distracter list might be from the category "flowers", giving the items {daisy [2], lily [4], daffodil [6] etc}).

Within lists, all items were randomized with respect to their original ranked positions in the Van Overschelde et al (2004) norms. This random order was the same for all participants.

To-be-remembered category lists were also presented to participants in one of two orders (e.g., half the participants might have the category “fruit” as the basis for the to-be-remembered items on trial 1, and half might have the category “sport”). The presentation of distracters that were related or unrelated to these lists was counterbalanced across participants such that any given category was presented equally often in the presence of related distracters and unrelated distracters (resulting in four possible combinations across participants for trial 1: fruit (to-be-remembered)-fruit (to-be-ignored); fruit (to-be remembered)-sport (to-be-ignored); sport (to-be-remembered)-sport (to-be-ignored); sport (to-be-remembered)-fruit (to-be-ignored)).

Probe trials. A prime trial with auditory distracters accompanying the visual to-be-remembered list (27 of the 54 trials) was always immediately followed by a probe trial with no accompanying auditory distracters (the remaining 27 trials). The visually-presented list of to-be-remembered items on 18 of these probe trials exactly replicated the auditorily-presented list of distracter items from the preceding prime trial (ignored repetition trials). These ignored repetition probe trials always followed prime trials in which the auditory distracters and to-be-remembered lists were semantically-related.

On 9 probe trials that acted as a control condition, the to-be-remembered list comprised items were from a different category to the to-be-remembered list on the previous trial. They were instead taken from the same semantic category as the auditory distracters on the previous trial but were not a repetition of those distracters (see Figure 1). For these trials, the to-be-remembered items were drawn from the even positions of the semantic category previously heard as an auditory distracter. For example, if the distracters came from the odd positions of the category "animals" within the Van Overschelde et al. (2004) norms (dog[1], horse[3]…) then the to-be-remembered items on an unprimed "probe" trial would be cat[2], bear[4] and so on. Thus, the semantic categories—but not items—were repeated across prime and probe lists in all conditions. Pairs of trials were arranged such that there were no more than two pairs of trials from the same condition (no-repetition or ignored repetition) in a row. A schematic of the basic experimental design (which remained largely unchanged across all three experiments) is provided in Figure 1.

Figure 1 here please

Procedure

Participants were seated at a distance of approximately 60 cm from the PC monitor in a screened-off testing cubicle and wore headphones throughout the experiment. Participants began by reading standardized instructions explaining that they would be presented with lists of words to read and recall and they were told specifically that they would not be asked anything about any distracter words they might hear at any point during the experiment. They were given response booklets in which to recall as many words from each visually-presented list as possible (a grid was provided with space for the 15 words presented as to-be-remembered items on each trial).

The words in the to-be-remembered lists were presented one at a time on the computer screen and after all 15 words in the list had been presented, the computer displayed the prompt "recall" on the screen. Participants then had 30 s to write down on the response sheets, in any order, as many of the words as they could recall. After this 30 s recall period a tone in the headphones signaled the end of the trial. Pressing the space bar initiated presentation of the next list. One practice trial (in quiet) was given at the start of the experiment after which participants had the opportunity to ask any questions before the main trials began.

Results

Responses were scored according to a free recall criterion, an item was scored as correct regardless of its position and mean recall rates for each trial were calculated. As shown in Figure 2, the between-sequence semantic similarity effect previously reported (poorer recall in the related *vs.* unrelated speech condition in the prime trials) was replicated, and analysis shows the difference to be statistically significant, $t(39) = -5.56$; $CI_{.95} = -.058, -.027$, $p < .001$.

Of greater interest, analysis of the probe trials shows that items that were a repeat of the distracters on the prime trial were more poorly recalled than different exemplars of the same semantic category as the previous set of distracters (ignored repetition trials *vs.* no repetition on the probe trials), $t(39) = -4.11$; $CI_{.95} = -.044, -.015$, $p < .001$.

Figure 2 here please

Discussion

The results of Experiment 1 are, to our knowledge, novel in demonstrating a negative priming effect in free recall of multi-item lists and are also novel in showing cross-modal NP accruing to the visual re-presentation of items that were previously auditory distracters (but see Buchner, Zabal, & Mayr, 2003, for a demonstration of cross-modal NP on a categorization task). To-be-remembered lists comprising items that had been competitors for retrieval during the previous free recall trial were more poorly recalled than non-repeated lists. This is consistent with Hughes and Jones' (2003) data and is in line with the idea that competing irrelevant items are subject to inhibitory control so as to facilitate successful retrieval of the concurrent to-be-remembered items.

The results of Experiment 1, while consistent with past data and in line with predictions, nonetheless raise a number of questions. One question arises from the similarities and differences already highlighted between RIF, directed forgetting, and the present paradigm. From one standpoint, the results reported here are unexpected in view of the finding that, in the context of directed forgetting, re-presentation of the items from a to-be-forgotten list in a recognition memory test (sometimes as lures on that test) produces, in final recall test, performance equivalent to that for to-be-recalled items, an effect interpreted as "release from inhibition" (Bjork, 1989). The NP procedure adopted here necessitates re-presentation of the auditory distracters, albeit as to-be-recalled items in an immediate free recall test, not as items in a recognition memory test followed by a subsequent final recall. This procedural difference may be critical since release from inhibition might occur not as a simple result of re-presentation of the items, but because of their reappearance specifically within the context of a recognition test (Bjork & Bjork, 1996). Verde and Perfect (2011) review inconsistencies in the empirical findings from studies of RIF with recognition and argue for a "transfer-appropriate forgetting" framework, in which an interference effect only occurs upon re-exposure to the original context in which inhibition occurred (Perfect, Stark, Tree, Moulin, Ahmed, & Hutter, 2004). From this perspective, an interpolated recognition task might provide a sufficient shift in context (i.e., where *the items themselves* have appeared in a different context) to allow for release from inhibition in a final free recall task. In the current setting, however, there has been no such obvious shift in context from one trial to the next, which takes place only a few seconds later, participants are attempting to encode for future recall a visually-presented list that is only gradually revealed to them, one item at a time. Possibly also of importance, this procedure is repeated several times over, again contributing to the contextual similarity between prime and probe trials.

In contrast, a reason for expecting to see the results observed in Experiment 1 is that—as noted earlier—both RIF and the semantic auditory distraction effect (the difference between semantically related and unrelated distracters at prime) are moderated by the output dominance of the unpracticed items/auditory distracters, the strength of the relationship between these items and the parent category from which they are drawn (Anderson et al., 1994; Bäuml, 1998; Marsh et al., 2008). If this analogy between the two effects continues to hold, then one might also anticipate that negative priming will likewise be diminished if the output dominance of the auditory distracters is reduced.

This prediction is theoretically as well as empirically grounded and serves to distinguish between the competitor inhibition account and a particular form of retrieval-based interference account. A study by Treisman and DeSchepper (1996) showed, using a more standard NP design, that the negative priming of visually-presented nonsense shapes persists over long periods of time (up to a month). These results were interpreted in terms of implicit memory tokens, with action tags attached (ignore or attend). When a token is retrieved, the action tag attached is probably the most recent one (resulting, on average, in a negative priming effect that is only slowly diluted over time). This elegant and appealing account makes no direct reference to inhibition and is similar to other episodic retrieval accounts of NP (e.g., Neill & Valdes, 1992; Neill, 2007) which make equivalent assumptions that recall of the prime items includes recall of how the items were processed when last encountered and it is recall of this associated activity that impairs—or in the case of positive priming, facilitates—subsequent processing (Neill, 2007). Since recall of the auditory distracter items necessarily includes recall of the instruction to ignore or withhold a response from them, these accounts predict that the effects of negative priming should persist for any memory token to which an "ignore" action tag is attached (i.e., any previous auditory distracter).

In contrast, the competitor-inhibition account supposes that the relationship at prime between the to-be-ignored auditory distracters and the to-be-recalled lists is important. Representations of items that are high output-dominant exemplars of a taxonomic category (e.g., "banana", "orange", and "apple" for "Fruit") should compete more strongly with to-be-recalled items from the same category, and hence require more inhibition at prime, than items lower in output-dominance (e.g., "guava", "papaya", and "blackcurrant" for "Fruit"). The competitor inhibition account thus makes the prediction that such highly competitive items will be more disruptive to free recall on prime trials than auditory distractors from the same semantic category but low in output-dominance (as previously observed, Marsh et al., 2008, Experiment 4). However, it also makes the, as yet untested prediction that NP should also be greater for to-be-remembered items that were previously high output-dominant distracters than to-be-remembered items that were low output-dominant distracters.

Finally, Experiment 2 also provides a check on whether the negative priming effect observed in Experiment 1 was driven by a repetition of order information rather than item information *per se*. Since, in Experiment 1, the order of the items presented as distracters—not just the items themselves—was repeated when they later became to-be-remembered items, it is possible that, notwithstanding the free nature of the recall task, it is the order of the items (e.g., the sequential relations between irrelevant items), rather than the items themselves, that is inhibited. Hughes and Jones (2003) found that serial recall of visually-presented digits was poorer if the same sequence (same items, same order) was presented on the previous trial as an irrelevant auditory sequence and Beaman and Jones (1998) reported evidence that serial order of presentation might be used as a cue to support even nominally "free" recall (see also Bhatarah, Ward, & Tan, 2008; Ward, Tan, & Grenfell-Essam, 2010). To exclude the possibility that the NP effect of Experiment 1 represents merely a replication, in a different task, of the inhibition of order previously reported by Hughes and Jones (2003), in the ignored-repetition condition of Experiment 2, the serial order of the distracters on the prime trial and the serial order of those same items presented as to-be-remembered items on the probe trial differed.

Experiment 2

Method

Participants

Sixty-four students at Cardiff University took part in the study in exchange for course credit. All reported normal or corrected-to-normal vision and normal hearing and were native English speakers. None had participated in Experiment 1. Participants were randomly divided into two 32-participant groups, high output-dominant distracters or low output-dominant distracters.

Materials & Design

Eighteen of the pairs of category -exemplars used in Experiment 1 were used in Experiment 2. For each category, items from output positions 1-15 from the Van Overschelde et al. (2004) category-norms were the higher output-dominant set and items from output positions 16-30 were the lower output-dominant set.

Participants assigned to the high output-dominant distracter condition received lower output-dominant items as to-be-remembered lists and the higher-dominant items as distracters at prime, and then the high output-dominant items as to-be-remembered lists at probe. Participants assigned to the low output-dominant distracter condition received high output-dominant items as to-be-remembered lists and the lower output-dominant items as distracters at prime, and then the lower output-dominant items as to-be-remembered lists at probe.

For each group there were 36 trials. There were 9 control (no repetition) prime-probe pairs (18 trials in total) and 9 ignored repetition prime-probe pairs. In the ignored repetition condition, we re-randomized the order of the items within the lists for the probe trial, taking particular care to ensure that, having done so, items that were neighbors when presented as part of the distracter list were no longer neighbors when those same items were presented as part of the to-be-remembered list at prime. Other aspects of the method were the same as Experiment 1 . The order in which "related" and "unrelated" speech was presented in prime trials was counterbalanced by alternating related and unrelated speech with half the participants starting with related speech at prime and half with unrelated.

Results

Figure 3 (upper panel) displays the results of the auditory distraction manipulation on the prime trials. This figure shows that the semantic auditory distraction effect (unrelated *vs.* related prime trials) is found only when distracters are high output-dominant (thus replicating Marsh et al., 2008, Experiment 4). A 2 (Prime Type: Unrelated *vs.* Related) × 2 (Distracter Dominance: Low *vs.* High) Analysis of Variance (ANOVA) on the overall probability of correct recall confirmed a main effect of Prime Type, $F(1, 62) = 22.53$, $MSE = .001$, $\eta_p^2 = .27$, $p < .001$, and Distracter Dominance, $F(1, 62) = 5.36$, $MSE = .022$, $\eta_p^2 = .08$, $p = .024$. Of particular interest is the reliable interaction between Prime Type and Distracter Dominance, $F(1, 62) = 8.88$, $MSE = .001$, $\eta_p^2 = .13$, $p = .004$.

Simple effects analyses (LSD) revealed a significant difference between the unrelated and related prime trials when distracters were high output-dominant ($p < .001$; $CI_{.95} = -.07, -.03$) but not when they were low output-dominant ($p = .22$; $CI_{.95} = -.03, .01$), thus confirming a between-sequence semantic similarity effect only when the distracters were high output-dominant.

Figure 3 here please

A novel feature of the present results is that NP—worse performance on ignored repetition relative to no repetition conditions at probe—is only found when high and not low output-dominant to-be-remembered lists were distracters on the prime trial (Figure 3, lower panel, shows the results from the probe trials). Perhaps less surprisingly, high output-dominant to-be-remembered items also seem to have been more readily recalled across all conditions.

A 2 (Probe Type: No Repetition *vs.* Ignored Repetition) × 2 (Distracter Dominance: Low *vs.* High) ANOVA on the overall probability of correctly recalled items revealed no main effect of Probe Type, $F(1, 62) = .56$, $MSE = .001$, $\eta_p^2 = .01$, $p = .46$. There was a main effect of Distracter Dominance, $F(1, 62) = 37.18$, $MSE =$

.013, $\eta_p^2 = .36$, $p < .001$, and importantly a reliable interaction between Probe Type and Distracter Dominance, $F(1, 62) = 24.74$, $MSE = .001$, $\eta_p^2 = .29$, $p < .001$.Simple effects analyses (LSD) revealed significant differences between the ignored repetition and no repetition probe trials for the high output-dominant group ($p < .001$; $CI_{.95}$ = -.05, -.02) and the low output-dominant group ($p = .004$; $CI_{.95}$ = -.045, -.009) but, critically, these were in different directions (Figure 3, lower panel): Whereas NP emerged when high output-dominant distracters were re-presented as to-be-remembered lists, positive priming was produced when low output-dominant distracters were re-presented as to-be-remembered lists.

Discussion

The results of Experiment 2 indicate first that the NP effect found in Experiment 1 has little to do with repeating the order of the distracters when re-presenting them as to-be-remembered items. The order of the distracters and to-be-remembered items was changed between prime and probe and NP still arose. With regard to the primary goal of Experiment 2, the overall pattern of results supports the competitor inhibition approach: NP was only evident when the distracters were high output-dominant items and thus strong competitors for retrieval, consistent with the particular suggestion that only highly activated distracters are likely to compete with responding and therefore have to be inhibited (Malley & Strayer, 1995; Shiu & Kornblum, 1996; Strayer & Grison, 1999). Episodic retrieval-based theories, which assume that recall of the processing episode (the “ignore” tag) causes the NP effects observed (e.g., in Experiment 1), cannot account for these data.

Our particular implementation of the various conditions of Experiment 1 (see Figure 1) meant that in the ignored repetition condition there was a repetition across prime and probe of the category from which the to-be-remembered lists were drawn whereas this was not the case in the no-repetition condition. Thus, a relatively simple build-up of proactive interference (PI) explanation (Craik & Birtwhistle, 1971) of the “negative priming” results of Experiment 1 cannot be ruled out *a priori*. However, in Experiment 2, the comparison between low- and high-output dominant distracter conditions rules out this explanation because, in both cases, the category was presented twice at prime and once at probe, as in the ignored repetition condition of Experiment 1, and yet the interference effect at probe occurs only when the distracters were high output-dominant (Figure 3, lower panel) contrary to what might be anticipated on the basis of a build-up of PI, at category level, from prime to probe. Instead of being a simple function of the repetition of the category across trials, it appears that the relationship between the auditory distracter and to-be-remembered lists at prime is also crucial for negative priming at probe. Without this high-dominance relationship, relative to a no-repetition condition, facilitation at probe is observed.

Although not predicted, positive priming by repetition of low output-dominant distracters can be accounted for on the presumption that they are not particularly competitive (if at all) during retrieval of the to-be-recalled items—again as independently indicated by their failure to produce a between-sequence semantic auditory distraction effect. Ignoring these stimuli might not require inhibition, as their potency level is never sufficiently high to make them competitive at retrieval. Their presentation, in consequence, results in the kind of positive priming normally found from the repetition of an attended stimulus. This explanation leads to the prediction that positive priming should also be found for repetitions of distracter lists that are semantically-unrelated to to-be-remembered lists at prime, as these should also not compete for recall. We test this prediction in Experiment 3.

Experiment 3

The ignored repetition probe trials in Experiments 1 and 2 involved presenting to-be-remembered lists that were previously distracter lists and those distracters were semantically-related to the to-be-remembered items on the prime trial. This series has not yet examined conditions in which distracters that were semantically unrelated to to-be-remembered items at prime were repeated at probe. Indeed, semantic relatedness between target and distracter is not a typical feature of, and certainly not a prerequisite for observing, NP in perceptual selection tasks (e.g., Tipper, 1985). However, if, as the competitor inhibition account supposes, inhibition is only applied when there is competition between to-be-remembered items and distracters, NP should not be found for to-be-remembered items that were previously semantically-unrelated distracters. Indeed, Experiment 2 showed that to-be-remembered items that were previously low output-dominant distracters (semantically related to to-be-remembered items at prime) were positively primed relative to a no-repetition condition. We therefore predicted the same outcome here for previously presented but semantically-unrelated distracters. Once again, this outcome would be contrary to the predictions of episodic retrieval-based accounts that assume simply that NP is caused by the simultaneous retrieval of memory tokens and “ignore” or “do not respond” action tags, rather than reflecting the consequences of inhibitory processing.

Method

Participants

Thirty-six students at Cardiff University took part in the study in exchange for course credit. All reported normal or corrected-to-normal vision and normal hearing and were native English speakers.

Materials, Design, & Procedure.

These aspects of the method were the same as Experiment 1 with the following exceptions: to-be-remembered items and distracter items were both always taken from even positions in the category-norm lists. Categories were never repeated across pairs of trials, a different category was presented for recall on each of the 24 trials. There were 12 prime trials and 12 probe trials. For all 12 prime trials distracters were semantically-unrelated to the to-be-remembered lists. On 6 of the probe trials the to-be-remembered lists were identical to the distracter list on the preceding prime trial (ignored repetition condition). On the remaining 6 trials there was no repetition of distracters on the prime as to-be-remembered items on the probe (no-repetition control condition).

The categories used were those employed in Experiment 2. The condition to which the categories were assigned was counterbalanced across participants, such that any given category appeared equally often in all conditions. “Ignored-identity-repetition” and “no repetition” probe trials were presented alternately, as happened for the prime trials in Experiment 2.

Results

Figure 4 shows a basic auditory distraction effect whereby the presence of auditory distracters in the prime trials disrupts recall relative to recall of items in the absence of speech on probe trials (Beaman, 2004; Marsh et al., 2008). We checked whether this effect was statistically significant by comparing performance on the prime (unrelated speech) trials with performance in the no-repetition probe trials where no speech was played. No-repetition probe trials were chosen for this comparison because they yield a measure of auditory distraction uncontaminated by any effect of repeating distracters as to-be-remembered items in quiet. The comparison between the prime trials and the no-repetition probes was significant, $t(35) = -3.192$; $CI_{.95} =$ -.06, -.01, $p = .003$, thus confirming the expected effect of auditory distraction by any lexical items on category-exemplar free recall (Marsh et al., 2008). A meaningful comparison could not be carried out for Experiments 1 and 2 because the necessary contrast is between prime trials where unrelated distracters are presented and no-repetition probe trials (in quiet). In these experiments, the to-be-remembered items at probe are drawn from the same category, albeit different items, as the unrelated distracters at prime. Thus, any contrast confounds the well-established lexical distraction effects of unrelated speech (Beaman, 2004; Marsh et al., 2008; Neely & LeCompte, 1999) with the effects of repeating categories—but not items—from prime to probe, which is likely to cause proactive interference (Experiments 1 and 2) and also introduces a further confound of the output dominance of the items in question (Experiment 2).

Figure 4 here please

More importantly, Figure 4 also shows that, on probe trials, the recall of to-be-remembered items that were previously semantically unrelated distracters (those in the ignored-identity-repetition condition) is facilitated relative to a no-repetition control (i.e., positive priming). The comparison between the no-repetition and ignored repetition trials was significant, $t(35) = -2.86$; $CI_{.95} =$ -.04, -.01, $p = .007$, thus confirming a significant positive priming effect.

These data confirm the results of Experiment 2 in that they support the idea that ignored auditory distracters are, ordinarily, activated sufficiently to facilitate their later recall: a positive priming effect. Only when auditory distracters are sufficiently output dominant with respect to the to-be-remembered item category is their subsequent recall impeded, arguably because they attract inhibition on the prime trial with ongoing consequences for the probe trial.

General Discussion

The results of the current series of experiments can be summarized as follows: Experiments 1 and 2 demonstrated that performance on a free recall task is impaired when auditory distracters that are semantically related to, and therefore in competition with, to-be-recalled items at prime have subsequently to be recalled at probe. We have interpreted this as a form of negative priming (although the NP label itself carries no necessary implications that the mechanism underlying the effect is inhibitory). Experiment 2 revealed that high output-dominant distracters (strong competitors of to-be-remembered items) produced an auditory semantic distraction effect and gave rise to NP, but low output-dominant items (weak competitors of to-be-remembered items) produced neither an auditory semantic distraction effect nor NP. Indeed, low output-dominant distracters at prime resulted in positive priming when presented as to-be-remembered items at probe. Experiment 3 showed that positive priming rather than NP occurs at probe for distracters that are semantically unrelated to to-be-remembered items at prime thus demonstrating that semantic similarity-based competition at prime was a pre-requisite for NP.

The results of the series are consistent with the competitor inhibition account. The finding that distracters which were semantically related to to-be-remembered items at prime only gave rise to NP at probe when they were also high output-dominant (e.g., Experiment 2) is consistent with the competitor inhibition view that high output-dominant items are strong competitors of to-be-remembered items for retrieval. This retrieval competition is countered by actively inhibiting the distracting items. Although suppression of distracters aids retrieval of the contextually-appropriate or desired response (to-be-remembered items) whilst preventing retrieval of the distracting items, this inhibition process impairs the later recall of those distracters when they become relevant (Anderson et al., 1994; Anderson, 2003).

The failure to find NP from low output-dominant distracters semantically related to to-be-remembered items at prime (Experiment 2) and distracters semantically unrelated to to-be-remembered items at prime (Experiment 3) is also consistent with the competitor inhibition account. These distracters are either weak competitors of to-be-remembered items (Experiment 2) or non-competitors (Experiment 3) and should therefore not require inhibition. The results are inconsistent with episodic retrieval accounts of NP (e.g., Neill, 2007; Rothermund, Wentura & De Houwer, 2005; Treisman & DeSchepper, 1996) all of which assume that the requirement to ignore the distracter at prime, not the relationship between to-be-ignored and to-be-recalled items at prime, dictates the subsequent fate of the distracter items when they are repeated as to-be-recalled items at probe (cf. Tipper, 2001). On these accounts, equivalent NP effects should have been observed across all three experiments.

There are, however, a number of differences between “standard” NP and the finding here of negative priming at recall due to previous competitor inhibition. For example, as noted earlier, in typical perceptual selection tasks, NP does not depend on a semantic relationship between the relevant stimulus and distracter. Ignoring a green line-drawn picture of a trumpet whilst naming a semantically-unrelated picture (e.g., a red line-drawn picture of a dog), impairs later responding to trumpet despite the semantic dissimilarity between trumpet and dog. However, ignoring a picture of a dog can produce a slowed reaction when subsequently responding to a picture of a cat, an outcome that suggests that while a semantic relationship is not necessary for NP in this setting, inhibition can operate at a semantic level (Tipper & Cranston, 1985; see also Dalrymple-Alford and Budayr, 1966; Neill, 1977).

Within the current context, the requirement for a semantic relationship between to-be-remembered items and distracters at prime for inducing NP in free recall may be explained by the assumption that only the features of an internal representation of an object that could interfere with the coherent performance of a task need to be inhibited (Tipper, Weaver, & Houghton, 1994). Accordingly, since the goal of the category-exemplar recall task used in the present study is to encode and retrieve semantic representations, the inhibitory mechanism will be directed to the semantic features of the related distracters, as shown in Experiments 1 and 2. By the same token, semantic features of unrelated distracters will not interfere much (if at all) with the task-goal. It follows that any activation that those distracters accrue can remain within a semantic network and may serve to facilitate performance if those distracters subsequently become to-be-remembered items, as shown in Experiments 2 and 3. This is consistent with a competitor-inhibition view which supposes that only highly activated distracters are likely to interfere with responding and hence need to be inhibited (Malley & Strayer, 1995; Strayer & Grison, 1999).

A further difference between the current study and studies of NP in perceptual selection tasks is that, typically, NP is found only with conflict probes where there is a distracter to ignore during the selection of the repeated stimulus. When there is no distracter to ignore during selection of the repeated stimulus—nonconflict probes—either no NP or positive priming is found (e.g., Moore, 1994; Tipper & Cranston, 1985). Unlike the standard NP effect, NP was found in Experiments 1 and 2 in the absence of conflict probes (that is, there were no distracters on the probe trials). Historically, the finding that NP only appears on conflict probe trials has been problematic for any distracter-inhibition account of NP because there is no obvious reason why the spillover of inhibition (and hence NP) should be contingent on the presence of further distracters at probe (e.g., Milliken, Joordens, Merikle, & Seiffert 1998). However, a possible reason for why NP was observed in the present setting even with non-conflict probe relates to differences in processing demand imposed by perceptual selection as compared with free recall: Frings and Spence (2011) recently showed that NP is indeed produced in the absence of probe distracters in a standard perceptual selection-based NP task providing that perceptual or conceptual processing is sufficiently difficult at probe. The argument here is that responses to probe trials without distracters are sufficiently undemanding, thus rendering the NP manipulation irrelevant. From this standpoint, NP may have been observed in the present Experiments 1 and 2 in the absence of probe distracters because the free recall task is inherently more cognitively demanding than merely naming a single perceptual stimulus at probe (as in the more typical NP procedure).

One further difference worth noting between the NP effect observed here and standard NP is that since the prime and probe trials each consisted of the presentation of multiple items—with a gap between prime and probe of 30s to allow time for recall—the time from presentation of any given distractor item at prime to its re-presentation as a to-be-remembered item at probe was unusually long for a priming study. However, Cock, Berry, and Buchner (2002) previously reported a negative priming effect in sequence learning and, as Treisman and DeSchepper (1996; see also Grison, Tipper & Hewitt, 2005) have shown, NP can also be observed over much longer periods than one would might expect inhibition to last. This has been taken as evidence against an inhibitory account of NP but, as Grison et al. (2005) have pointed out, Houghton and Tipper's (1994) neural network model of inhibition can be expanded to account for these findings on the assumption that, as the model suggests, the expression of inhibition is co-determined by the application of inhibition to the distractor at prime and the reinstatement of that inhibitory state when the same representation is activated at probe: "the network may be reinstated into a transient inhibitory state just as it was on the prime display" (Grison et al., 1995, p. 1219; see also Tipper, 2001).

This suggestion is particularly relevant when the dependent variable is not speed to respond (which measures the speed to overcome either initial inhibition or a "do not respond" tag) but item recall. A problematic feature of applying the episodic retrieval accounts of NP to the current situation that has not yet been addressed is that such accounts assume retrieval of the "ignore" or "do not respond" tag alongside retrieval of the item itself slows responding and yet, in the current study, the accuracy of memory retrieval—not the speed of responding—is the variable of interest. An outline account which fits the current data and attempts to marry the two styles of theorizing can be drawn, however, based upon the suggestions of Grison et al. (2005).

We presume that retrieval of the to-be-remembered items of the prime trial requires inhibition of semantically-related auditory distracters. Despite the requirement to ignore semantically unrelated (Experiments 1-3) or low-output dominant distracters (Experiment 2), which might attract an "ignore" or "do not respond" tag when they are encoded alongside the to-be-remembered material, there is no requirement to actively inhibit them when retrieval on the prime trial is attempted. At probe, a context is established that matches not only the trial just experienced (the probe trial) but also at least one trial back (the prime trial). Reestablishment of the contextual state as it was immediately prior to the prime necessarily reinstates the transient state of the system at that time, as suggested by Grison et al. (2005). Hence items that were active at that time—including to-be-ignored auditory distractors—are then more available than would otherwise be the case. Items that were actively being inhibited or resisted during this period, however, are by the same token less available than they would be otherwise. Thus, the interference effect on memory which we have here labeled “negative priming” occurs at the point at which retrieval is attempted because of a backward-acting reinstatement of past context, as assumed by episodic retrieval theories of NP. However, the NP itself is only apparent if inhibition was actively applied during the earlier episode, as assumed by inhibitory theories of NP and RIF (for an extensive discussion of the reciprocal relationship between inhibition at prime and episodic retrieval at probe, see Tipper, 2001).

The circumstances in which NP was and was not produced in the present experiments may also shed light on the mechanism underpinning semantic auditory distraction and, more specifically, whether such distraction is not a unitary phenomenon but instead determined by more than one mechanism. We have conjectured previously (Marsh et al., 2008) that semantic auditory distraction may, at least in part, reflect an overhead of deploying inhibition so as to prevent a catastrophic failure to select the correct sequence of stimuli when the irrelevant stimuli are plausible candidates for retrieval. For example, it seems reasonable to suppose that having to inhibit the irrelevant word ‘apple’ could incur a cost to the correct retrieval of, e.g., ‘tomato’, due to inhibition spreading from the distracter through a semantic network that traverses the vegetable-fruit distinction (cf. Neumann & DeSchepper, 1992; note that ‘tomato’ in this example is categorized as a vegetable according to its everyday use in cooking, not according to its scientific classification). That both the semantic distraction effect and the NP effect were greater/only produced with highly competitive distracters is clearly in line with this view: the more competitive the distracters, the more they would need inhibiting. This would in turn cause a greater overhead for concurrent processing (semantic distraction) and the legacy of such inhibition (negative priming) is also more likely to be evident.

However, a more fine-grained analysis suggests that the overhead-of-inhibition account of semantic auditory distraction may not provide a comprehensive explanation. For example, the account seems to predict that, within any given condition, a positive correlation should be found between the degree to which a sequence of distracters impaired performance on trial N and the degree to which the repetition of those distracters produces NP on trial N+1. A check on this possibility in our data revealed no correlation. However, this is far from unusual: Most NP studies have found no relationship between the magnitude of concurrent distraction and the magnitude of NP (e.g., Beech, Baylis, Smithson, & Claridge, 1989; Beech & Claridge, 1987; Driver & Tipper, 1989; Stolzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993; although see Tipper, 1991; Tipper, Bourke, Anderson, & Brehaut, 1989).

One possibility, therefore, is that concurrent distraction is a composite of at least two mechanisms: the competition itself (and failure to inhibit it) and an overhead of successful inhibition of the competition. For some participants—or for some participants some of the time—one mechanism might dominate over the other in terms of its contribution to the concurrent distraction effect. Indeed, the notion that failure-to-inhibit contributes to the concurrent distraction effect seems to be required to explain the finding that distraction was found from unrelated speech together with a positive priming effect (Experiment 3). In other words, distraction was found in the absence of any evidence of inhibition in this case. To the extent that failure-to-inhibit and overhead-of-inhibiting both contribute to the overall measure of concurrent distraction, a straightforward relationship between this effect and NP would not be expected. Thus, a key direction for future study will be to unpack the semantic auditory distraction effect into these two putative components, if possible, one of which should correlate positively with NP (overhead-of-inhibition) and one of which should correlate negatively with NP (failure-to-inhibit).

In sum, although there are differences between a "standard" perceptual selection task giving rise to NP, and the free recall situation explored here, the results reported here fit quite comfortably within an approach that assumes that distraction during memory retrieval—e.g., from strongly competitive distracters—is countered through inhibiting the internal representations of those competing items. As such, the results suggest that the mechanisms of perceptual selection and selective attention in retrieval from long-term memory are both sub-served by inhibitory processes.

References

Anderson, M. C. (2003). Rethinking interference theory: Executive control and the mechanisms of forgetting. *Journal of Memory & Language, 49,* 415-445.

Anderson, M. C., Bjork, R. A., & Bjork, E. L. (1994). Remembering can cause forgetting: Retrieval dynamics in long-term memory. *Journal of Experimental Psychology: Learning, Memory & Cognition, 20,* 1063-1087.

Basden, B. H., Basden, D. R., & Gragano, G. J. (1993). Directed forgetting in implicit and explicit memory tests: A comparison of methods. *Journal of Experimental Psychology: Learning, Memory & Cognition, 19*, 603-616.

Bäuml, K. -H. (1998). Strong items get suppressed, weak items do not: The role of item strength in output interference. *Psychonomic Bulletin & Review, 5*, 459-463.

Beaman, C. P. (2004). The irrelevant sound effect revisited: What role for working memory capacity? *Journal of Experimental Psychology*: *Learning, Memory, & Cognition*, *30*, 1106-1118.

Beaman, C. P. (2005). Auditory distraction from low-intensity noise: A review of the consequences for learning and workplace environments. *Applied Cognitive Psychology*, *19*, 1041-1064.

Beaman, C. P., & Jones, D. M. (1998). Irrelevant sound disrupts order information in free as in serial recall. *Quarterly Journal of Experimental Psychology*, *51A*, 615-636.

Beaman, C. P., Marsh, J. E., & Jones, D. M. (2011). *Source monitoring under distraction: The disruptive role of response monitoring.* Manuscript submitted for publication.

Beech, A., Baylis, G. C., Smithson, P., & Claridge, G. (1989). Individual differences in schizotypy as reflected in measures of cognitive inhibition. *British Journal of Clinical Psychology, 28,* 117–129.

Beech, A., & Claridge, G. (1987). Individual differences in negative priming: Relations with schizotypal personality traits. *British Journal of Psychology, 78*, 349–356.

Bhatarah, P., Ward, G., & Tan, L. (2008). Examining the relationship between free recall and immediate serial recall: The serial nature of recall and the effect of test expectancy. *Memory & Cognition, 36*, 20-34.

Bjork, R. A. (1989). Retrieval inhibition as an adaptive mechanism in human memory. In: H. L. Roediger III & F. I. M. Craik (Ed.s). *Varieties of memory and consciousness: Essays in honour of Endel Tulving*. Hillsdale, N.J.: Erlbaum.

Bjork, E. L., & Bjork, R. A. (1996). Continuing influences of to-be-forgotten information. *Consciousness & Cognition, 5,* 176-196.

Buchner, A., Zabal, A., & Mayr, S. (2003). Auditory, visual and cross-modal negative priming, *Psychonomic Bulletin & Review*, *10*, 917-923.

Cock, J. J., Berry, D. C., & Buchner, A. (2002). Negative priming and sequence learning. *European Journal of Cognitive Psychology, 14*, 24-48.

Craik, F. I. M., & Birtwistle, J. (1971). Proactive inhibition in free recall. *Journal of Experimental Psychology, 91*, 120-123.

Dalrymple-Alford, E. C., & Budayr, B. (1966). Examination of some aspects of the Stroop colour-word test. *Perceptual and Motor Skill, 23,* 1211-1214,

Dempster, F. N. (1991). Inhibitory processes: A neglected dimension of intelligence. *Intelligence, 15*, 157-173.

Driver, J., & Tipper, S. (1989). On the nonselectivity of "selective" seeing: Contrasts between interference and priming in selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 15,* 304-314.

Faust, M. E., & Gernsbacher, M. A. (1996). Cerebral mechanisms for suppression of inappropriate information during sentence comprehension. *Brain & Language*, *53,* 234-259.

Frings, C., & Spence, C. (2011). Increased perceptual and conceptual processing difficulty makes the immeasurable measurable: Negative priming in the absence of probe distracters. *Journal of Experimental Psychology: Human Perception & Performance, 37,* 72-84.

Gorfein, D. S. & MacLeod C. M. (2007). *Inhibition in cognition*. Washington, DC: American Psychological Association.

Grison, S., Tipper, S. P., & Hewitt, O. (2005). Long-term negative priming: Support for retrieval of prior attentional processes. *Quarterly Journal of Experimental Psychology, 58A,* 1199-1224.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation* (pp. 193-225). New York: Academic Press.

Healey, M. K., Campbell, K. L., Hasher, L., & Ossher, L. (2010). Direct evidence for the role of inhibition in resolving interference in memory. *Psychological Science, 21,* 1464-1470.

Houghton, G. & Tipper, S. P. (1994). A model of inhibitory mechanisms in selective attention. In D. Dagenbach and T. Carr (Eds), *Inhibitory processes of attention, memory and language*, pp 53-112. Florida: Academic Press.

Hughes, R. W., & Jones, D. M. (2003). A negative order-repetition priming effect: Inhibition of order in unattended auditory sequences? *Journal of Experimental*

Psychology: Human Perception & Performance, 29, 199-218.

Johnson, S. K., & Anderson, M. C. (2004). The role of inhibitory control in forgetting semantic knowledge. *Psychological Science, 15,* 448-453.

Klein, R. M., & Taylor, T. L. (1994). Categories of cognitive inhibition with reference to attention. In: D. Dagenbach & T. H. Carr (Ed.s) *Inhibitory processes in attention, memory and language.* (pp. 113-150). San Diego, Ca.: Academic Press.

MacLeod, C. M. (2007). The concept of inhibition in cognition. In: D. S. Gorfein, & C. M. MacLeod (Eds.), *Inhibition in cognition* (pp. 3-23). Washington, DC: American Psychological Association.

Malley, G. B., & Strayer, D. L. (1995). Effect of stimulus repetition on positive and negative identity priming. *Perception & Psychophysics, 57,* 657–667.

Marsh, J. E., Hughes, R. W., & Jones, D. M. (2008). Auditory distraction in semantic memory: A process-based approach. *Journal of Memory & Language, 58,* 682-700.

Milliken, B., Joordens, S., Merikle, P. M., & Seiffert, A. E. (1998). Selective attention: A reevaluation of the implications of negative priming. *Psychological Review, 105,* 203-209.

Moore, C. M. (1994). Negative priming depends on probe-trial conflict: Where has all the inhibition gone? *Perception & Psychophysics, 56*, 133-147.

Neely, C. B., & LeCompte, D. C. (1999). The importance of semantic similarity to the irrelevant speech effect. *Memory & Cognition, 27*, 37-44.

Neill, W. T. (2007). Mechanisms of transfer-inappropriate processing. In: In D. S. Gorfein, & C. M. MacLeod (Eds.), *Inhibition in cognition* (pp. 63-78). Washington, DC: American Psychological Association.

Neill, W. T. (1977). Inhibition and facilitation processes in selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 3,* 444-450.

Neill, W. T., & Valdes, L. A. (1992). The persistence of negative priming: Steady state or decay? *Journal of Experimental Psychology: Learning, Memory & Cognition, 18*, 565-576.

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

Perfect, T. J., Moulin, C. J. A., Conway, M. A., & Perry, E/ (2002). Assessing the inhibitory account of retrieval-induced forgetting with implicit memory tests. *Journal of Experimental Psychology: Learning, Memory & Cognition, 28,* 1111-1119.

Perfect, T. J., Stark, L. J., Tree, J. J., Moulin, C. J. A., Ahmed, L. & Hutter, R. (2004). Transfer appropriate forgetting: The cue-dependent nature of retrieval-induced forgetting. *Journal of Memory & Language, 51*, 399-417.

Rothermund, K., Wentura, D., & De Houwer, J. (2005). Retrieval of incidental stimulus-response associations as a source of negative priming. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 31,* 482–495.

Shiu, L.-P., & Kornblum, S. (1996). Negative priming and stimulus-response compatibility. *Psychonomic Bulletin & Review, 3*, 510-514.

Stoltzfus, E. R., Hasher, L., Zacks, R. T., Ulivi, M. S. & Goldstein, D. (1993). Investigations of inhibition and interference in younger and older adults. *Journal of Gerontology: Psychological Sciences, 48,* 179-188.

Strayer, D. L., & Grison, S. (1999). Negative identity priming is contingent on stimulus repetition. *Journal of Experimental Psychology: Human Perception & Performance, 25,* 24–38.

Tipper, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *Quarterly Journal of Experimental Psychology, 37A,* 571–590.

Tipper, S. P (1991). Less attentional selectivity as a result of declining inhibition in older adults. *Bulletin of the Psychonomic Society, 29,* 45-47.

Tipper, S. P. (2001). Does negative priming reflect inhibitory mechanisms? A review and integration of conflicting views. *Quarterly Journal of Experimental Psychology, 54A,* 321-343.

Tipper, S., & Baylis, G. (1987). Individual differences in selective attention: The relation of priming and interference to cognitive failure. *Personality and Individual Differences, 8,* 667-675.

Tipper, S., Bourque, T, Anderson, S., & Brehaut, J. (1989). Mechanisms of attention: A developmental study. *Journal of Experimental Child Psychology, 48,* 353-378.

Tipper, S. P., & Cranston, M. (1985). Selective attention and priming: Inhibitory and facilitatory effects of ignored primes. *Quarterly Journal of Experimental Psychology, 37A*, 591–611.

Tipper, S. P., Weaver, B., & Houghton, G. (1994). Behavioural goals determine inhibitory mechanisms of selective attention. *Quarterly Journal of Experimental Psychology, 47A,* 809-840.

Tipper, S. P., Weaver, B., Kirkpatrick, J. & Lewis, S. (1991). Inhibitory mechanisms of attention: Locus, stability, and relationship with distractor interference effects. *British Journal of Psychology, 8,* 507-520.

Tresiman, A., & DeSchepper, B. (1996). Object tokens, attention and visual memory. In: T. Inui & J. L. McClelland (Eds). *Attention & performance XVI: Information integration in perception and communication*, Cambridge, Ma: MIT Press. pp. 14-46.

Van Overshelde, J. P., Rawson, K. A., & Dunlosky, J. (2004). Category norms: An updated and expanded version of the Battig and Montague (1969) norms. *Journal of Memory & Language, 50*, 289-335.

Verde, M. F., & Perfect, T. (2004). Retrieval-induced forgetting in recognition is absent under time pressure. *Psychonomic Bulletin & Review, 18*, 1166-1171.

Ward, G., Tan, L., & Grenfell-Essam, R. (2010). Examining the relationship between free recall and immediate serial recall: the effects of list length and output order. *Journal of Experimental Psychology: Learning, Memory & Cognition, 36*, 1207-1241.

Wentura, D., & Frings, C. (2005). Repeated masked category primes interfere with related exemplars: New evidence for negative semantic priming. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 31*, 108-120.

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Figure Captions

Figure 1. Schematic of the basic experimental design. At trial N+1, no auditory items were presented. Visual items at trial N+1 were either identical to auditory items from trial N (ignored repetition condition) or from the same semantic category as auditory items from trial N (control condition). In Experiment 1, visual items at trial N+1 were from the same semantic category as visual items at trial N in the ignored repetition condition but, for the control condition, were from a different semantic category. This confound is addressed in Experiment 2. The dependent variable in all experiments was the number of visually-presented items correctly recalled as a function of trial type and condition (for prime trials, distracters that were semantically related vs semantically unrelated to the visual list; for probe trials, visual lists that were identical to previous auditory distracters vs previously unheard but from the same semantic category as the previous auditory distracters).

Figure 2. Proportion of correct recall in category-exemplar recall as a function of experimental condition in Experiment 1. Error bars represent the standard error of the mean.

Figure 3. Proportion of correct recall in category-exemplar recall as a function of experimental condition in Experiment 2. Upper panel shows performance on Prime trials and lower panel shows performance on Probe trials. Error bars represent the standard error of the means.

Figure 4. Proportion of correct recall in category-exemplar recall as a function of experimental condition in Experiment 3. Error bars represent the standard error of the means.

Figure 1

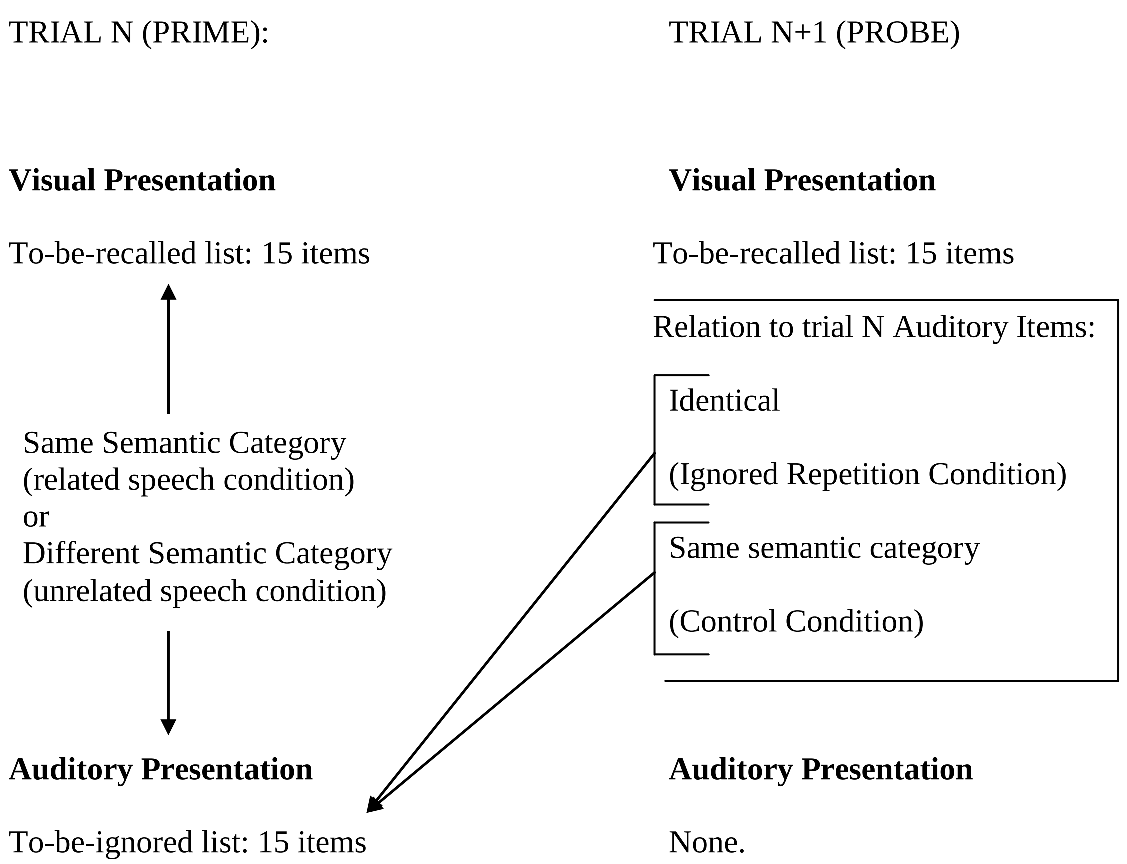

TRIAL N (PRIME):
TRIAL N+1 (PROBE)
Visual Presentation
To-be-recalled list: 15 items
Same Semantic Category
(related speech condition)
or
Different Semantic Category
(unrelated speech condition)
Auditory Presentation
To-be-ignored list: 15 items
Visual Presentation
To-be-recalled list: 15 items
Relation to trial N Auditory Items:
Identical
(Ignored Repetition Condition)
Same semantic category
(Control Condition)
Auditory Presentation
None.

Figure 2

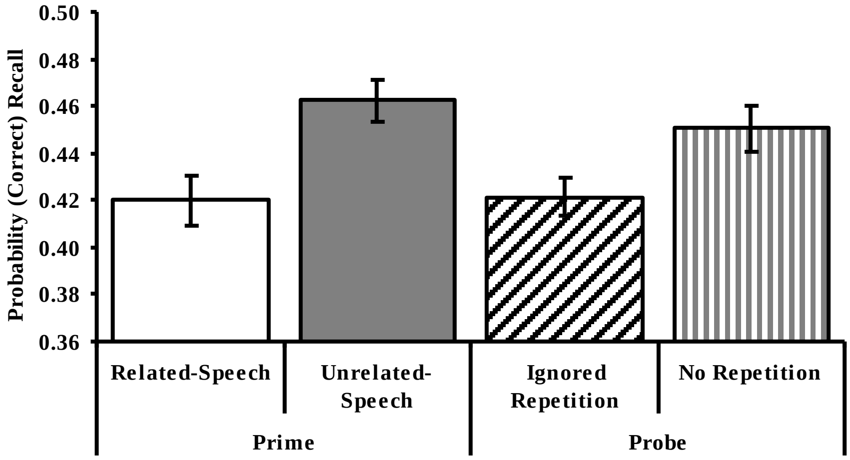

0.50
0.48
0.46
0.44
0.42
0.40
0.38
0.36
Probability (Correct) Recall
Related-Speech
Unrelated-Speech
Ignored Repetition
No Repetition
Prime
Probe

Figure 3.

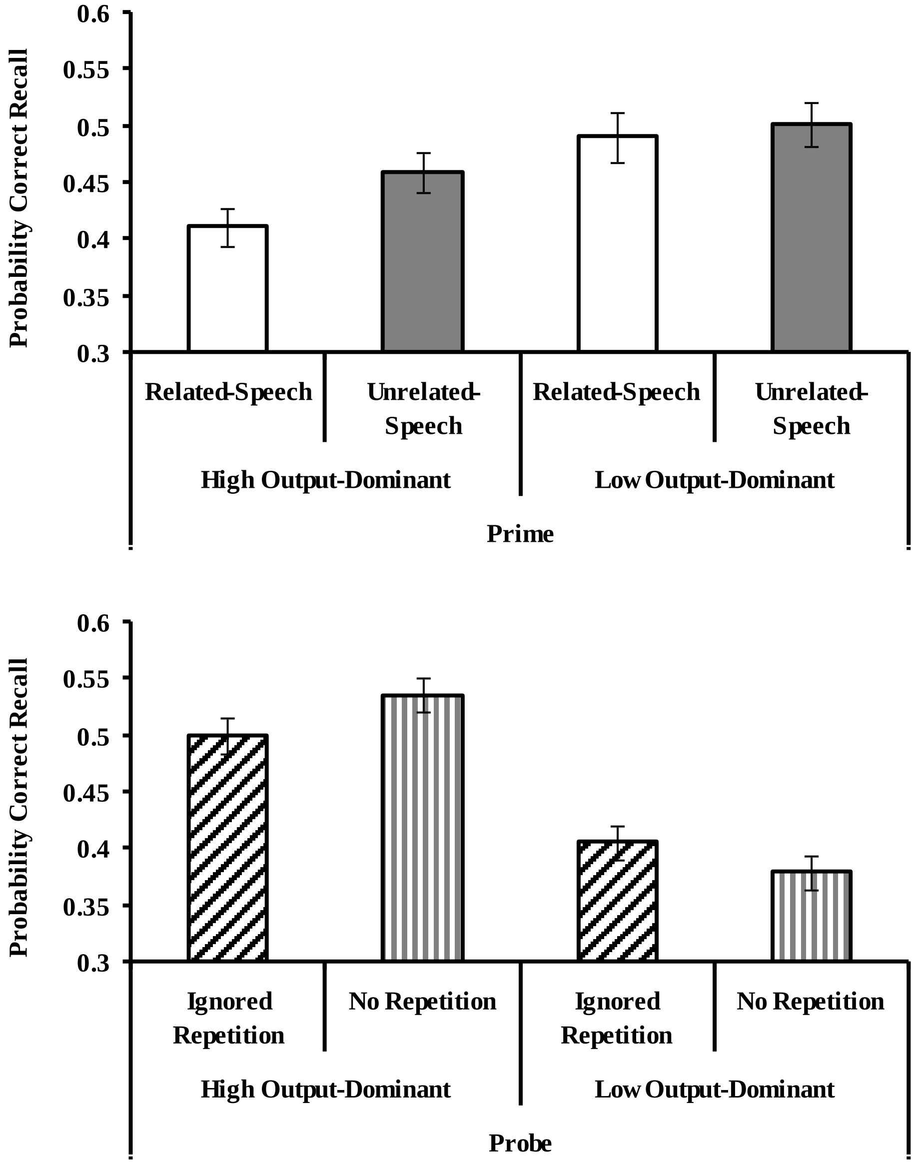
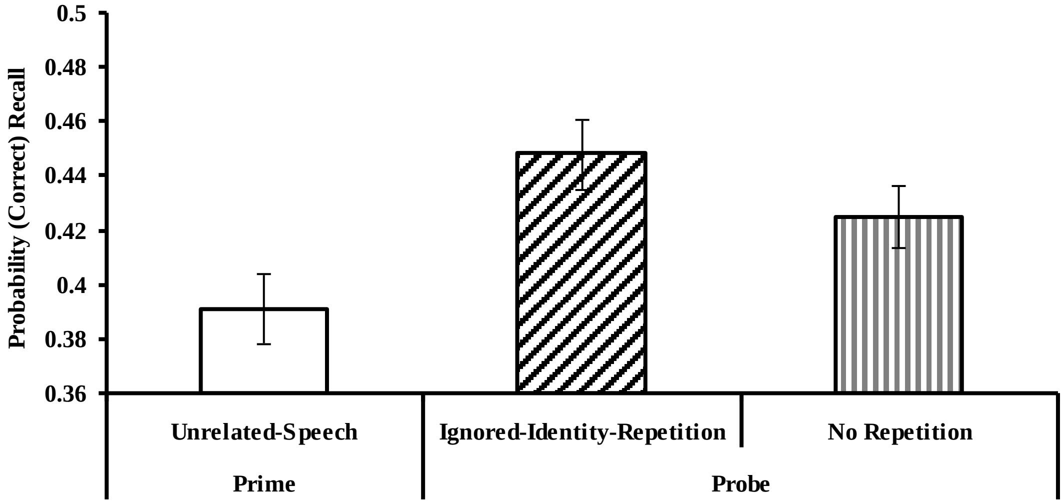

Probability Correct Recall
0.6
0.55
0.5
0.45
0.4
0.35
0.3
Related-Speech
Unrelated-Speech
Related-Speech
Unrelated-Speech
High Output-Dominant
Low Output-Dominant
Prime
Probability Correct Recall
0.6
0.55
0.5
0.45
0.4
0.35
0.3
Ignored Repetition
No Repetition
Ignored Repetition
No Repetition
High Output-Dominant
Low Output-Dominant
Probe

Figure 4.


Probability (Correct) Recall
0.5
0.48
0.46
0.44
0.42
0.4
0.38
0.36
Unrelated-Speech
Ignored-Identity-Repetition
No Repetition
Prime
Probe