Dynamic Cognitive Control of Irrelevant Sound:

Increased Task-Engagement Attenuates Semantic Auditory Distraction

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Abstract

Two experiments investigated reactive top-down cognitive control of the detrimental influence of spoken distractors semantically related to visually-presented words presented for free recall. Experiment 1 demonstrated that an increase in focal task-engagement—promoted experimentally by reducing the perceptual discriminability of the visual target-words—eliminated the disruption by such distracters of veridical recall and also attenuated the erroneous recall of the distracters. A recall instruction that eliminates the requirement for output-monitoring was used in Experiment 2 to investigate whether increased task-engagement shields against distraction through a change in output-monitoring processes (back-end control) or by affecting the processing of the distracters during their presentation (front-end control). Rates of erroneous distracter-recall were much greater than in Experiment 1 but both erroneous distracter-recall and the disruptive effect of distracters on veridical recall were still attenuated under reduced target-word discriminability. Taken together, the results show that task-engagement is under dynamic strategic control and can be modulated to shield against auditory distraction by attenuating distracter-processing at encoding thereby preventing distracters from coming to mind at test.

Keywords: Cognitive Control; Distraction; Semantic Processing; Veridical Recall; Erroneous Recall.

Attentional selectivity ensures that only a fraction of the mélange of inputs constantly bombarding our various senses reaches perceptual awareness in support of efficient goal-directed behavior. This selection process, however, has to satisfy two opposing requirements: engagement with the task-relevant material (focusability) must be balanced against the requirement for continuous evaluation of currently irrelevant information such that it can compete for, and if necessary win, the control of action, in case that information signals potential danger or opportunity (distractibility; e.g., Allport, 1989; Johnston & Strayer, 2001). But despite the adaptive advantage of distractibility, the processing of task-irrelevant information can disrupt cognitive activity. In these situations, the cognitive system must find a way to reduce the impact of the undesired processing of the irrelevant material. Thus, selective attention is thought to be a highly dynamic and reactive system that can boost the processing of task-relevant stimuli or/and dampen the processing of potentially distracting material depending on the particular task-demands and task-goals (Anderson, 2003; Houghton & Tipper, 1996; Hughes & Jones, 2003b; Monsell & Driver, 2000; Sörqvist, Stenfelt, & Rönnberg, 2012).

There is a burgeoning body of work, particularly on auditory distraction, indicating that top-down factors such as increased task-engagement in response to high task-difficulty (Halin, Marsh, Haga, Holmgren, & Sörqvist, 2014b; Halin, Marsh, Hellman, Hellström, & Sörqvist, 2014a; Hughes, Hurlstone, Marsh, Vachon, & Jones, 2013; SanMiguel, Corral, & Escera, 2008; Sörqvist et al., 2012), increased motivation (e.g., via monetary incentive; Small et al., 2005), high trait-capacity for focal task-engagement (Hughes et al., 2013; Sörqvist et al., 2012), and foreknowledge about potential distraction (Hughes et al., 2013; Röer, Bell, & Buchner, 2015; Sussman, Winkler, & Schröger, 2003; Vachon, Hughes, & Jones, 2012), modulate the balance between focusability and distractibility (Duncan, 1993; Monsell & Driver, 2000). In particular, such factors have been found to attenuate distraction by task-irrelevant sound (Halin et al., 2014a, 2014b; Hughes et al., 2013; Sörqvist, 2010; Sörqvist et al., 2012) either by preventing a shift of attention to the sound (Hughes et al., 2013) or/and by weakening background sound processing (Sörqvist et al., 2012). Here, we examine the role of top-down cognitive control in the modulation of the focusability-distractibility balance in the context of the disruption of free recall by irrelevant sound that is semantically related to the memoranda (Beaman, 2004; Bell, Buchner, & Mund, 1998; Marsh, Hughes, & Jones, 2008, 2009; Neely & LeCompte, 1999). The semantic distraction setting affords a unique opportunity to expand the understanding of the precise mechanisms of top-down control of distraction because it exhibits two distinct empirical manifestations of distraction: the disruption of veridical recall and the erroneous recall of the distracters. In particular, we examine the impact of increased focal task-engagement on these two separable components of distraction as a means of determining whether cognitive control is realised by constraining the access of irrelevant material at the time it is presented (*front-end cognitive control*) or by modulating processes that monitor response-candidates after they are sampled but before they are output (*back-end cognitive control*).

In the experiments reported here we employ a version of the standard semantic auditory distraction paradigm (e.g., Marsh, Hughes et al., 2015; Marsh, Sörqvist, Hodgetts, Beaman, & Jones, 2015) wherein participants view visually-presented lists of items (targets; e.g., “chair, desk, wardrobe…”) that are members of the same category (e.g., Furniture) and are asked to recall them in any order when presented with a “recall” cue. During some trials, to-be-ignored spoken words (distracters) are presented—usually concurrently with the targets—that are either taken from the same semantic category as the targets (e.g., other Furniture; e.g., “table, sofa, bookshelf…”) or from a different semantic category (e.g., Professions; “nurse, secretary, carpenter...”). Despite explicit instruction to ignore the distracters, and to avoid guessing at recall, the proportion of targets recalled (veridical recall) is lower when the targets and distracters are semantically related compared to when they are semantically unrelated (Marsh et al., 2008). Another often-replicated finding within this setting is the presence of extra-list intrusions: Distracters that are categorically related to targets are erroneously recalled at a rate greater than if those items had not been presented (e.g., when targets and distracters are unrelated; Beaman, 2004; Bell et al., 2008; Marsh et al., 2008; for analogous effects with categories defined phonologically, see Marsh, Vachon, & Jones, 2008). This is an example of an intrusion error of a kind frequently observed in episodic free recall (e.g., Zaromb, Howard, Dolan, Sirotin, Tully, & Kahana, 2006) but not often the direct subject of inquiry.

Thus, semantic similarity between targets and distracters impairs episodic memory for semantically-rich information as manifest in both reduced veridical recall and increased erroneous recall. That free recall of words shows this *between-sequence semantic similarity effect* (B-SSSE) differentiates the setting empirically from other irrelevant sound effects (such as that found in serial recall wherein items have to be recalled in the order of presentation) that are largely insensitive to semantic similarity between target and distracter material (e.g., Buchner, Irmen, & Erdfelder, 1996). According to the interference-by-process account (Marsh et al., 2008, 2009), the involuntary semantic processing of the sound interferes with the semantic-based processes used to perform the recall task. More specifically, semantic distracters spread activation in a semantic network and this activation must be inhibited to aid the accurate retrieval of the target items and avoid erroneous recall of distracters. In this view, the B-SSSE on veridical recall will occur to the extent that the semantic distracters have not been successfully inhibited (Marsh, Beaman, Hughes, & Jones, 2012) and may be due in part also to a spillover of any successful distracter-inhibition to target items (Marsh, Sörqvist, et al., 2015). Evidence for distracter-inhibition in this setting comes from the finding that when semantically-related distracters on trial *n* are repeated as visually-presented targets on trial *n* + 1 fewer of those targets are recalled compared to when there is no such cross-trial repetition. This reduction of recall is presumed to reflect the legacy of the inhibition applied to the items on trial *n* (Marsh et al., 2012; Marsh, Sörqvist et al., 2015; see also Hughes & Jones, 2003a). In contrast, the B-SSSE on erroneous recall is thought to be due to semantic interference at encoding coupled with a breakdown of source monitoring (i.e., the ability to monitor whether a particular item originated from a visual or an auditory source).

Further evidence suggesting that auditory distraction more broadly is amenable to top-down cognitive control comes from studies of individual differences (Hughes et al., 2013; Marsh, Sörqvist, et al., 2015; Sörqvist, 2010; Sörqvist et al., 2012). For example, the detection of an auditory stimulus in an unattended channel that is personally significant (such as one's own name; e.g., Moray, 1959) is less likely in those with a high capacity for inhibition and/or task-goal maintenance (Conway, Cowan, & Bunting, 2001). Likewise, high capacity individuals are less susceptible to attentional capture from sound events that deviate from the expected pattern of sound stimulation (i.e., the deviation effect; Hughes et al., 2013; Sörqvist, 2010) and less susceptible to the B-SSSE, in terms of both disrupted veridical recall (Marsh, Sörqvist et al., 2015) and erroneous distracter-recall (Beaman, 2004).

In the present experiments, we study the extent to which cognitive control of distraction is dynamic and reactive to particular focal task-demands. We also capitalize on the distinction between the effects of B-SSS on the disruption of veridical recall and on the erroneous recall of non-targets as a means of examining in more detail how such dynamic cognitive control might be implemented.

Experiment 1

In the present experiments, we examine whether focal-task engagement can be increased reactively as a means of shielding against semantic auditory distraction by B-SSS during free recall of visually-presented lists. We sought to influence the level of task-engagement by increasing task-difficulty, specifically, by making it more difficult to perceptually identify the target items. In the high task-difficulty condition, each word in the to-be-remembered list was made transparent and embedded in static visual noise (for an example, see right panel of Figure 1; cf. Hughes et al., 2013; Parmentier, Elford, Escera, Andrés, & San Miguel, 2008; Yi, Woodman, Widders, Marois, & Chun, 2004). In the low task-difficulty condition each of the words in the to-be-remembered list was presented in the usual fashion: clearly in black against a white background (cf. left panel of Figure 1). We reasoned that the greater task-difficulty in the degraded condition would promote active focal task-engagement as a means of compensating for that increase in difficulty. We predicted that such increased engagement will, in turn, attenuate the B-SSSE on veridical and erroneous recall, just as the same increase in task-difficulty shields serial recall performance from attentional capture by an irrelevant auditory deviant (Hughes et al., 2013) and office-related tasks from distraction by irrelevant meaningful speech (compared to quiet; Halin et al., 2014a, 2014b). The backdrop for this expectation is that increased focal-task difficulty has been shown to limit the extent to which background sound is processed, as indexed by event-related potentials (Sörqvist et al., 2012) and behavioral auditory attentional capture effects (Hughes et al., 2013). Given that sound-processing is reduced under increased task-difficulty there should, in the present setting, be less (undesired) spread-of-activation in the semantic network from which the target-words are retrieved at recall. As a result, it would be expected that veridical recall would be less disrupted by the distracters and fewer distracters would be erroneously recalled due to their not reaching the threshold for production (see also Muller-

Gass, Stelmack, & Campbell, 2006; Zhang, Chen, Yuan, Zhang, & He, 2006; Yi et al., 2004). However, another possibility—that we go on to address in Experiment 2—is that increased task-engagement, rather than constraining the distracters' access to processing during their encoding, exerts its effect through *back-end* monitoring processes during retrieval.

Method

Participants. Thirty-two students at the University of Central Lancashire participated for an honorarium of £6 each. All were native English speakers and reported normal or corrected-to-normal vision and normal hearing.

Materials and Design. The experiment was run using E-Prime software. Each participant received 36 trials in which they were visually-presented with 15 target words all drawn from one semantic category and 15 auditory distracters that were also taken from a single semantic category. Auditory distracters were presented synchronously with the targets. Therefore, one auditory distracter was presented for each visual target word. Distracters were either all drawn from the same category as the targets, or they were all drawn from a different category. Targets appeared centrally on the computer screen in black 72-point Times font on a white background at a rate of one every 1.5 s (750ms on, 750ms inter-stimulus interval; ISI). Distracters were presented over stereo headphones (Sennheiser HD 202) at 65dB(A) and at a rate of one every 1.5 s (750ms on, 750ms ISI). The distracters were digitally recorded in a male voice at an even-pitch and sampled with a 16-bit resolution at a sampling rate of 44.1 kHz using Sound Forge 5.

Thirty words were chosen from each of 36 semantic categories taken from the Van Overschelde, Rawson, and Dunlosky (2004) category norms. Fifteen items from odd-ranked positions in the category-norm lists (e.g., 1, 3, 5…29) were assigned to the target lists and fifteen items from even positions (e.g., 2, 4, 6…30) were distracters. The 36 selected categories were first arranged into pairs of unrelated categories (e.g., "Fruit-Carpenter's

Tools”). There were two experimental blocks of 18 trials: 9 related and 9 unrelated. On the related trials, the auditory distracters were taken from the same category as the targets. On unrelated trials, the distracters were taken from the semantically-unrelated category (e.g., “Fruit”) that was paired with the target category (“Carpenter’s Tools”).

Two versions of the target words were created and saved as bitmap files on the computer controlling the presentation of the stimuli. In one set, the words were clearly visible, whereas in the second set the words were degraded by adding a visual mask comprising static Gaussian visual noise (400%) over the item, and by setting the transparency of the noise to 27% using Powerpoint software. For both sets, the word sustained an angle of about 2.6^{o} (participants sat at approximately 50 cm from the screen). Figure 1 provides an illustration of one of the words from the non-degraded (left panel) and the degraded (right panel) sets.

The presentation order of exemplars within each target and distracter sequence was random but identical for each participant. Half the participants received a semantically-related trial first followed by a semantically-unrelated trial (with trials alternating thereafter between related and unrelated). This order was reversed for the other half of participants. Categories were assigned such that, across participants, there was an equal likelihood of each category being encountered in the unrelated or related condition.

A manipulation check was first conducted to determine whether degrading the items did indeed make stimulus identification more difficult, and it is reported here briefly. Eight participants (staff members and students at the University of Gävle) were presented with eighteen lists of fifteen category-exemplars in Swedish: 9 lists with non-degraded and 9 lists with degraded items (created in exactly the same way as the English items used for the experiments proper [reported below]). Presentation of the lists was blocked by perceptual discriminability. Each word was presented for 750 ms followed by a blank screen whereby participants were required to write down the item. Pressing the spacebar initiated the presentation of each item. The start of a new list was cued after all fifteen category-exemplars had been presented. Participants were told to work as fast and as accurately as possible to transcribe the words. Each list appeared equally as often at each level of perceptual discriminability and whether the perceptual discriminability block came first or second was counterbalanced across participants. Participants were given 5 min to transcribe as many words as possible. After each block, participants were asked to rate on a 7 point likert scale how demanding they found the task (1 not demanding at all...7 extremely demanding). The results substantiated the effectiveness of the degradation manipulation. Participants transcribed more words in the non-degraded condition (*M* = 87.88, *SE* = 5.42) than in the degraded condition (*M* = 73.88, *SE* = 6.25; $t(7) = 8.5$, $p < .001$; $CI_{.95}$ = 10.1, 17.9). Participants' transcription accuracy was high and the number of errors did not differ between the two conditions (*M* = .25, *SE* = .31, non-degraded; *M* = .75, *SE* = .16, degraded; $t(7) = 1.53$, $p = .17$; $CI_{.95}$ = 1.27, -.27). Moreover, the participants reported that the task was more demanding in the degraded condition (*M* = 3.63, *SE* = .38) than in the non-degraded condition (*M* = 1.63, *SE* = .38; $t(7) = 6.11$, $p < .001$; $CI_{.95}$ = 2.77, 1.23).

Procedure. Participants were tested individually in a quiet room. Participants wore headphones throughout the experiment. Participants began by reading standardized instructions and they were told specifically that they should ignore the distracter words and that they would not be asked anything about them during the experiment. Participants were instructed to focus on memorizing the visually presented items. The target words were presented one at a time on the computer screen. After all 15 targets had been presented the prompt “recall” appeared on the screen. Participants then had to type, in any order, as many items as they could remember. Pressing the space-bar initiated presentation of the next list. One practice trial (in quiet) was given at the start of the experiment.

Results

Veridical Recall. Responses were scored according to a free recall criterion; an item was scored as correct regardless of its position. As can be seen in Figure 2, participants produced fewer correct responses in the related condition as compared with the unrelated condition in the low task-difficulty condition but this effect was eliminated under high task-difficulty.

A 2 (Task Difficulty: High Difficulty *vs*. Low Difficulty) × 2 (Target-Distracter Relation: Related *vs*. Unrelated) analysis of variance (ANOVA) revealed a main effect of Target-Distracter Relation, $F(1, 31) = 21.36$, $MSE = .001$, $p < .005$, $\eta_p^2 = .41$, but no main effect of Task Difficulty, $F(1, 31) = 2.36$, $MSE = .003$, $p = .14$, $\eta_p^2 = .07$. However, critically, there was a significant interaction between these two factors, $F(1, 31) = 12.12$, $MSE = .001$, $p = .002$, $\eta_p^2 = .28$. A simple effects analysis (LSD) revealed a significant difference between unrelated and related speech under low task-difficulty ($p < .001$; $CI_{.95} = .036, .061$), but not under high task-difficulty ($p = .55$, $CI_{.95} = -.015, .027$, observed power = .09). It is worth highlighting the fact that task-difficulty did not, in and of itself, influence recall accuracy. This is of particular value analytically, as it avoids the difficulty that can arise with interpreting an interaction when there are differences in baseline performance.

Erroneous Recall. A response that matched one of the fifteen items from the even positions in the Van Overschelde et al. (2004) norms (that were presented as distracters on related trials) was scored as an intrusion, even for the unrelated condition in which those items had not been presented, which provides an estimate of baseline erroneous recall probability (see Beaman, 2004; Marsh et al., 2008). Figure 3 shows the mean number of related-item intrusions for each condition. The number of intrusions was greater in the related condition compared to the unrelated condition, but the difference was attenuated under high task-difficulty.

A 2 (Target-Distracter Relation) × 2 (Task Difficulty) ANOVA revealed a main effect of Target-Distracter Relation, $F(1, 32) = 33.17$, $MSE = 8.06$, $p < .001$, $\eta_p^2 = .52$, a main effect of Task Difficulty, $F(1, 32) = 10.72$, $MSE = 3.67$, $p = .003$, $\eta_p^2 = .26$, and a significant interaction between these two variables, $F(1, 32) = 8.02$, $MSE = 1.80$, $p = .008$, $\eta_p^2 = .21$, reflecting the fact that the relatedness effect on intrusions was appreciably smaller under high task-difficulty. A simple effects analysis (LSD) showed that the relatedness effect nevertheless reached significance regardless of task-difficulty (under low task-difficulty: $p < .001$; $CI_{.95} = 2.19, 4.94$; under high task-difficulty: $p < .001$; $CI_{.95} = 1.396, 3.04$). It is important to note also that the main effect of task-difficulty was driven for the most part by the reduction in the disruptive effect of related speech under high task-difficulty; indeed, there was no significant effect of task-difficulty within the unrelated (i.e., effectively baseline) condition ($p = .18$, $CI_{.95} = -.22, 1.09$) indicating again that task-difficulty in and of itself did not affect the intrusion rate.

Discussion

Experiment 1 demonstrated that task-difficulty attenuates—indeed eliminates—the B-SSSE on veridical recall and also attenuates the effect on erroneous recall. This finding is clearly in accordance with the assumption that background sound is processed to a lesser extent when task-engagement is boosted to compensate for increased task-difficulty. Indeed, the fact that task-difficulty did not itself affect recall performance—just as it did not affect accuracy (only time-taken) in the manipulation-check experiment—but rather only modulated the effects on that performance of irrelevant sound, supports the idea of a compensatory shift in task-engagement. If task-engagement were not boosted, the level of recall performance would be expected to be reduced directly by increased task-difficulty (see, e.g., Eggemeier & O'Donnell, 1983). Increased task-engagement, in turn, may result in the suppression of activity in the cortical (and subcortical) areas responsible for sound/speech processing

(Regenbogen et al., 2012; Sörqvist et al., 2012; see also Halin et al., 2014a, 2014b; Hughes et al., 2013).

Such suppression of irrelevant material at the time it is presented would be an example of *front-end* cognitive control (Halamish, Goldsmith, & Jacoby, 2012; Jacoby, Kelley, & McElree, 1999; Jacoby, Shimizu, Daniels, & Rhodes, 2005; Jacoby, Shimizu, Velanova, & Rhodes, 2005; Thomas & McDaniel, 2013). Another possibility, however, is that increased task-engagement exerts its effect through *back-end* monitoring processes responsible for ensuring, at retrieval, veridical recall of target items and the rejection of non-target, distracter, items (i.e., monitoring what enters the recall protocol; Beaman, Hanczakowksi, Hodgetts, Marsh, & Jones, 2013; Koriat & Goldsmith, 1996). In Experiment 2, therefore, we seek evidence that should help determine which of these two possible mechanisms underpins the impact of increased task-engagement on distraction.

Experiment 2

In Experiment 2, we adopt the so-called inclusion test for free recall (e.g., Brainerd & Reyna, 1998; Hege & Dodson, 2004) as a way of identifying the locus of the effect of increased task-engagement on semantic distraction. The inclusion test requires that participants output not only the target items but also any other related items that come to mind during test. It is widely assumed that post-access monitoring is a key part of retrieval and that semantically-associated, non-presented, items, often come to mind at test but are edited prior to retrieval as part of a post-access monitoring process (e.g., Hunt, Smith, & Dunlap, 2011). Inclusion tests require that participants disengage the post-access monitoring process operating during standard free recall, thereby allowing non-target items—that are usually edited in standard free recall—to be output as part of the recall protocol (cf. Hunt et al., 2011).

The rationale for introducing the inclusion test into the present setting was as follows. If the reduction in erroneous recall of related distracters under high task-difficulty is still found, and to a roughly equivalent degree, under inclusion free recall instructions, as it was under standard free recall instructions (as used in Experiment 1), then the effect of task-difficulty most likely operates on encoding processes during study (front-end control). For example, the distracters may not gain access to semantic analysis under high task-difficulty and hence do not come to mind during the semantically-based retrieval processes operating at test. Alternatively, to find that high task-difficulty does not reduce erroneous recall under inclusion free recall instructions would favor the view that increased task-engagement has its effect via back-end control processes operating at test. For example, the increased level of engagement required to encode each to-be-remembered word under degraded visual conditions may enrich each visual-item encoding episode such that the source of each item that comes to mind at test (visual vs. auditory) is more clearly distinguishable and non-target items can, as a result, be edited out more readily.

The use of an inclusion criterion also enables us to address whether the impairment of veridical recall by B-SSS is attributable to the erroneous recall of distracters. Blocking accounts assume that erroneous recall is a determinant of the probability of veridical recall. Specifically, in this view, the perseverative erroneous recall of the distracters—which match the semantic category, and hence retrieval cue, of to-be-remembered items—directly impairs access to the targets (Beaman et al., 2013; cf. Raaijmakers & Jakab, 2012). Under standard free recall instructions, the relationship between erroneous and veridical recall is obscured because erroneous recalls may be edited out prior to overt output. That is, erroneous recall could indeed impair veridical recall but such a relationship may go undetected because the rate of would-be but edited-out erroneous recalls is not observable. Inclusion recall instructions allow a means of observing otherwise covert instances of erroneous recall and their negative effect, if any, on veridical recall.

An alternative to the blocking account—the two-mechanism account of the impact of B-SSS (Marsh et al., 2008; Marsh, Hughes et al., 2015)—holds that the increase in erroneous recall is attributable to the use of a semantic-category cue at retrieval coupled with poor source-discrimination (see also Bell et al., 2008). On this account, the impairment of veridical recall is therefore unrelated to the effect of B-SSS on erroneous recall. Moreover, this account supposes that at least some of the impairment of veridical recall may reflect competition from the distracters at the point of presentation, rather than the retrieval of those distracters as potential output candidates at test (Marsh, Hughes et al., 2015).

Thus, in sum, we apply the inclusion criterion (Hege & Dodson, 2004) to free recall to investigate, for the first time, whether increased task-engagement reduces semantic auditory distraction at a relatively early stage (e.g., the suppression of sound processing at presentation) or at a relatively late stage (an editing process at retrieval) or some combination of the two.

Method

Participants. Thirty-two students at the University of Central Lancashire participated for an honorarium of £6 each. All were native English speakers and reported normal or corrected-to-normal vision and normal hearing. None had taken part in Experiment 1.

Materials, Design, and Procedure. All other aspects of the method were identical to Experiment 1 with the exception that participants were instructed to output any related words that came to mind when trying to remember the visually-presented target items.

Results and Discussion

Veridical Recall. As can be seen in Figure 4, the ease with which the visually-presented target items could be perceived again modulated the effect of background speech on veridical recall. Related speech was more distracting than unrelated speech when the target-words were easy to perceive, but there was no difference between related and unrelated speech when the target-words were difficult to perceive.

A 2 (Task Difficulty: High Difficulty *vs*. Low Difficulty) × 2 (Target-Distracter Relation: Related *vs*. Unrelated) ANOVA revealed a main effect of Target-Distracter Relation, $F(1, 31) = 35.86$, $MSE = .001$, $p < .001$, $\eta_p^2 = .54$, and Task Difficulty, $F(1, 31) = 14.34$, $MSE = .001$, $p = .001$, $\eta_p^2 = .32$. There was also a significant interaction between these two factors, $F(1, 31) = 42.54$, $MSE = .001$, $p < .001$, $\eta_p^2 = .58$. A simple effects analysis (LSD) revealed a significant difference between unrelated and related speech in the low task difficulty condition ($p < .001$; $CI_{.95} = .047, .077$), but not in the high task difficulty condition ($p = .27$, $CI_{.95} = -.022, .006$, observed power = .19). As in Experiment 1, task difficulty did not directly affect recall as evident from the fact that there was no effect of task-difficulty within the unrelated speech condition ($p = .8$, $CI_{.95} = -.013, .016$).

Erroneous Recall. Figure 5 shows that the attenuating effect of high task-difficulty on the B-SSSE on intrusion rate found in Experiment 1 was replicated here under inclusion-instructions. There was a main effect of Target-Distracter Relation, $F(1, 31) = 37.72$, $MSE = 76.06$, $p < .001$, $\eta_p^2 = .55$, and Task Difficulty, $F(1, 31) = 32.45$, $MSE = 7.63$, $p < .001$, $\eta_p^2 = .51$, as well as a significant interaction between these two factors, $F(1, 31) = 47.98$, $MSE = 7.32$, $p < .001$, $\eta_p^2 = .61$. A simple effects analysis (LSD) showed that the B-SSSE was nevertheless significant regardless of task-difficulty (low task-difficulty: $p < .001$; $CI_{.95} = 9.24, 16.32$; high task-difficulty: $p < .001$, $CI_{.95} = 3.13, 9.18$). Again, the main effect of task-difficulty was driven by the impact of this factor on the relatedness effect, as there was no effect of task-difficulty within the unrelated condition ($p = .32$, $CI_{.95} = -.537, 1.599$).

The key finding of Experiment 2 is that the B-SSSE on veridical recall and erroneous recall persists even with inclusion recall instructions. Although the magnitude of erroneous recall was much greater in Experiment 2 overall, in comparison with Experiment 1, high task-difficulty still reduced erroneous recall. One interpretation of this finding is that the effect of task-difficulty on erroneous recall acts on encoding processes (front-end control) rather than via output monitoring processes (back-end control). If the task-difficulty manipulation had its effect via output monitoring processes, the effect should disappear when participants are instructed to avoid output monitoring (i.e., instructed to output all words that come to mind at test). This is not to say that output monitoring does not contribute at all to the recall pattern seen here, only that it seems unable to explain why increased task-difficulty shields against distraction. Although speculative, one possibility is that task-difficulty eliminates the direct competition from the distracters during study, but still allows a few to appear within the consideration-set of possibilities during test, thereby reducing, but not eliminating, erroneous recall. To corroborate this speculation, we conducted a cross-experiment analysis.

Cross-Experiment Analysis.

Veridical recall. For veridical recall, a 2 (Target-Distracter Relatedness) × 2 (Task-Difficulty) × 2 (Recall Instruction [or ‘Experiment’]: Standard Free Recall *vs*. Inclusion Free Recall) ANOVA revealed a main effect of Task Difficulty, $F(1, 62) = 12.53$, $MSE = .002$, $\eta_p^2 = .17$, and Target-Distracter Relatedness, $F(1, 62) = 56.16$, $MSE = .001$, $p < .001$, $\eta_p^2 = .48$, but no main effect of Recall Instruction, $F(1, 62) = 1.81$, $MSE = .037$, $p = .18$, $\eta_p^2 = .03$. There was no interaction between Task difficulty and Recall Instruction, $F(1, 62) = 1.09$, $MSE = .002$, $p = .301$, $\eta_p^2 = .02$, or between Target-Distracter Relatedness and Recall Instruction, $F(1, 62) = .82$, $MSE = .001$, $p = .37$, $\eta_p^2 = .013$. There was an interaction between Task Difficulty and Target-Distracter Relatedness, $F(1, 62) = 42.94$, $MSE = .001$, $p < .001$, $\eta_p^2 = .41$. A simple effects analysis (LSD) showed that the B-SSSE was significant for low task-difficulty ($p < .001$; $CI_{.95} = .046, .065$) but not for high task-difficulty ($p = .26$, $CI_{.95} = -.005, .020$, observed power = .201). However, most critically for present purposes, there was no three-way interaction between Task Difficulty, Target-Distracter Relatedness and Recall Instruction, $F(1, 62) = .64$, $MSE = .001$, $p = .43$, $\eta_p^2 = .01$.

Erroneous recall. In terms of erroneous recall, a 2 (Target-Distracter Relatedness) × 2 (Task-Difficulty) × 2 (Recall Instruction: Standard Free Recall *vs*. Inclusion Free Recall) ANOVA revealed a main effect of Target-Distracter Relation, $F(1, 62) = 58.11$, $MSE = 42.06$, $p < .001$, $\eta_p^2 = .48$, and Task Difficulty, $F(1, 62) = 42.86$, $MSE = 5.65$, $p < .001$, $\eta_p^2 = .41$. There was also, as would be expected in relation to intrusion rate, a main effect of Recall Instruction, $F(1, 62) = 40.49$, $MSE = 80.77$, $p < .001$, $\eta_p^2 = .40$. There was an interaction between Task Difficulty and Recall Instruction, $F(1, 62) = 7.92$, $MSE = 5.65$, $p = .007$, $\eta_p^2 = .11$, Target-Distracter Relation and Recall Instruction, $F(1, 62) = 16.46$, $MSE = 42.06$, $p < .001$, $\eta_p^2 = .21$, and Task Difficulty and Target-Distracter Relation, $F(1, 62) = 55.71$, $MSE = 4.56$, $p < .001$, $\eta_p^2 = .47$. Moreover, these two-way interactions were subsumed under a significant three-way interaction between Task Difficulty, Target-Distracter Relation and Recall Instruction, $F(1, 62) = 24.47$, $MSE = 4.56$, $p < .001$, $\eta_p^2 = .28$.

As can be seen when comparing Figures 3 and 5, the three-way interaction emerged because, with inclusion free recall, the difference between unrelated and related speech in the non-degraded condition was significantly larger than the difference between unrelated and related speech in the degraded condition, in comparison to this difference with standard free recall instructions. Most importantly, there was a comparable reduction in erroneous recall under both standard recall and inclusion recall instructions when task-difficulty was increased through stimulus degradation. Erroneous recalls were more frequent under inclusion instructions than under standard instructions—thereby corroborating the effectiveness of the instruction manipulation—but this was the case in both the unrelated and related speech conditions. This is consistent with the idea that post-access monitoring is *generally* part of retrieval (Brainerd & Reyna, 1998) and that inclusion instructions disengage post-access monitoring, allowing more related intrusions to arise regardless of whether they were presented as distracters. If post-access monitoring was responsible for the reduction in the recall of distracters under high task-engagement, however, then the effect should disappear under inclusion instructions when the post-access monitoring is disengaged. This was not the case. Therefore, the shielding effect of increased task-engagement cannot be attributed to back-end control.

The results of Experiment 2 also have implications for understanding the B-SSSE on veridical recall. The results are at odds with the blocking approach (Hanczakowski, Beaman, & Jones, 2012; Raaijmakers & Jakab, 2012) in which reduced veridical recall is caused by erroneous recall of distracter-items that block the retrieval of target items. The finding that inclusion recall—that permits erroneous recall—failed to dramatically increase the B-SSSE on veridical recall suggests that the B-SSSE on veridical and erroneous recall is not attributable to a single, blocking, mechanism (cf. Hanczakowski et al., 2012). However, this dissociation between erroneous and veridical recall is consistent with a two-mechanism account of the impact of B-SSS (Marsh et al., 2008; Marsh, Hughes et al., 2015) wherein erroneous recall is attributed to poor source-discrimination due to the use of the semantic-category cue that is shared by targets and distracters at retrieval (see also Bell et al., 2008). On this account, the impairment of veridical recall is unrelated to the effect of B-SSS on erroneous recall, and the impairment may reflect competition from the distracters at the time they are presented, rather than the retrieval of those distracters as output candidates at test (Marsh, Hughes et al., 2015; Marsh, Sörqvist et al., 2015).

General Discussion

One means by which the cognitive system overcomes unwanted distraction flowing from auditory analysis of task-irrelevant stimuli is to increase focal-task engagement. We have shown here that this is not restricted to distraction due to attentional capture by unexpected sounds (Hughes et al., 2013) but generalizes to higher-order cognitive processes: Greater focal-task engagement (as manipulated through differences in visual-task difficulty in this case) decreases semantic distraction. Furthermore, extending considerably beyond other recent work on auditory distraction (Halin et al., 2014a, 2014b; Hughes et al., 2013), we have been able to show that increased task-engagement exerts its impact via a selection process taking place at the point of presentation of distracters rather than later during retrieval processes.[1]

The Relation Between Veridical and Erroneous Recall

The results reported here are consistent with the interference-by-process view of semantic auditory distraction (Marsh et al., 2008, 2009) in which the B-SSSE on veridical recall is a result of a conflict between semantic processes, and the B-SSSE on erroneous recall is a result of such conflict and a breakdown of source monitoring (Marsh, Sörqvist et al., 2015). Evidence for the independence of the two mechanisms comes, for example, from studies showing that the B-SSSE on erroneous recall is attenuated substantially if the distracters are presented during a retention interval instead of synchronously with target presentation, whereas the B-SSSE on veridical recall is largely unaffected by this (e.g., Marsh et al., 2008; Marsh, Sörqvist et al., 2015; Sörqvist, Marsh, & Jahncke, 2010). The experiments reported here provide further support for this two-mechanism account as the task-difficulty manipulation seems to have different effects on veridical recall and erroneous recall: The B-SSSE on veridical recall disappears under high task difficulty whereas the B-SSSE on erroneous recall is only attenuated. Furthermore, the inclusion recall instructions did not eliminate the B-SSSE on veridical recall, even though the instruction drastically increased recall of non-target items.

The independence of erroneous and veridical recall (Beaman, 2004; Marsh et al., 2008; Marsh, Hughes et al., 2015) further undermines the idea that blocking (Rundus, 1973) is the mechanism that produces the B-SSSE on veridical recall (cf. Hanczakowski et al., 2012). The blocking account assumes that the erroneous recall of automatically encoded distracters prevents the retrieval/production of other items (e.g., targets) typically by seizing control of a limited-capacity output buffer (Kimball & Bjork, 2002; Raaijmakers & Shiffrin, 1980; Raaijmakers & Jakab, 2012; Rundus, 1973). One prediction from a blocking account (Hanczakowski et al., 2012; Rundus, 1973) is that there should be a relation (significant negative correlation) between the number of veridical items recalled and the number of intrusions of spoken distracters, particularly under inclusion instructions. As recall of spoken distracters increases, the recall of targets should decrease, but this is not borne out by the data (present study; Beaman, 2004; Marsh et al., 2008; Marsh, Hughes et al., 2015).

Front-End Control

An increase in task-difficulty attenuates the effect of background speech on veridical recall and—to a lesser degree—on erroneous recall. Our interpretation of this finding is that the task-difficulty manipulation reduces processing of the irrelevant material via a front-end mechanism such that the B-SSSE on veridical recall is eliminated. However, despite the reduction in processing of the irrelevant sound, some distracters are inevitably processed, thereby bringing source monitoring ability into play. As a consequence, the effect of B-SSS on erroneous recall is attenuated but not eliminated entirely.

The nature of the front-end mechanism operating to protect against distraction remains open for debate. On the interference-by-process account of the B-SSSE, the involuntary semantic processing of irrelevant material while attention remains focused on a task dominated by semantic-based processes results in a conflict of two concurrent semantic processes, thereby impairing free recall (Jones et al., 2012; Marsh et al., 2008). In broad terms, the B-SSSE can be seen as an example of distraction due to *attentional leakage:* semantic processing of irrelevant material whilst attention is focused elsewhere (Lachter, Forster, & Ruthruff, 2004). From this standpoint, increased task-engagement in the face of high task-difficulty attenuates that involuntary semantic processing during presentation (front-end control); thus, the degree of attentional leakage is not fixed but is to some extent under dynamic cognitive control. This leads to preserved veridical recall and a partial reduction of the B-SSSE on erroneous recall. However, the question remains as to what exactly increased task-engagement entails. One possibility is that it involves a boosting of that aspect of the focal task-set involved in the timely perceptual identification of each word such that the perceptual features that differentiate target from distracter material (e.g., that the targets are visual and the irrelevant stimuli are auditory) are rendered more salient (e.g., Van der Heijden, 1981). This boosted task-set may, as a passive side-effect, attenuate the early sensory processing of the sound (thereby limiting its semantic analysis; Sörqvist et al., 2012). Another possibility is that increased task-engagement does not involve (or only involve) the boosting of the focal task-set but (also) involves greater inhibition of the irrelevant material (e.g., Tipper, 1985). As noted in the Introduction, we have shown previously that distracters are indeed subject to inhibition at presentation: recall is particularly difficult if the items were recently presented as distracters (Marsh et al., 2012; Marsh, Sörqvist, et al., 2015). However, evidence that inhibition occurs does not necessarily show that increased task-engagement entails increased distracter-inhibition. Thus, at present, the data available seem equally consistent with a task-set boosting account and an increased-distracter inhibition account of how the front-end control of the B-SSSE is implemented. Future studies in which an index of inhibition (e.g., negative priming; Marsh et al., 2012) is combined with a manipulation of task-difficulty as used here may allow for the determination of whether increased task-engagement is indeed associated with increased distracter-inhibition; if not, the alternative, task-set boosting, account would be favored.

A further candidate mechanism for how front-end control might be implemented in the present setting is, we believe, more readily discounted. It is possible that some of the disruptive effect of semantically-related speech on free recall is due to attentional diversion or *attentional slippage* (Lachter et al., 2004) whereby the distracters draw the focus of attention away from the encoding of the target items (e.g., Cowan, 1995). Previous research has demonstrated that salient semantic information can indeed capture attention. For example, in a shadowing task in which participants continuously repeat aloud a message presented to one ear while ignoring another message presented to the other ear, about a third of participants hear their own name when it is spoken in the to-be-ignored channel (Conway et al., 2001; Moray, 1959; Wood & Cowan, 1995; see also Röer, Bell, & Buchner, 2013). Perhaps it is no coincidence, therefore, that participants who score highly on a working memory capacity task make fewer intrusions of related spoken distracters in the semantic distraction task (Beaman, 2004; Marsh, Sörqvist et al., 2015) and are less likely to make shadowing mistakes, or hear their name at the time it is presented in the to-be-ignored channel, in the context of dichotic listening (Conway et al., 2001). Therefore, one possibility is that the B-SSSE may be due (in part) to both attentional leakage (producing interference-by-process; Marsh et al., 2008, 2009) and attentional slippage: the allocation of attention, perhaps without intention, to the irrelevant items. Attentional slippage in the semantic auditory distraction setting may involve the involuntary redirection of attention towards a spoken item and then back to the visual targets. Increased task-engagement might serve to prevent such slippages of attention to the semantic distracters just as it prevents attentional capture by acoustically deviant sounds (Hughes et al., 2013; SanMiguel et al., 2008). However, a likely consequence of attentional slippage in the present context is a greater analysis of the spoken distracter from which modality information could be encoded and thereafter used—if instructed to do so (e.g., via forewarning)—to edit the item post-retrieval.

Therefore, intrusions of spoken distracters would be expected to be reduced if attention regularly switched from targets to distracters. Given that B-SSS in fact increases erroneous recall, the pattern of results is difficult to reconcile with an attentional slippage account.

This disaffection with the attentional slippage view is compounded by further findings within the semantic distraction literature that the attentional slippage account fails to explain. For example, an account based purely on attentional slippage would seem to suggest that a B-SSSE should arise for a broad array of tasks. However, this is not the case: If participants are required to recall a list in serial order, the B-SSSE disappears (Marsh et al., 2008, Experiment 3; Marsh et al., 2009; Experiment 3). Moreover, on the attentional slippage account, one would also expect recognition to demonstrate a B-SSSE. However, while related distracters attract more false alarms within tests of recognition, they do not affect hit rate (Hanczakowski et al., 2012). Finally, it would appear that the attentional slippage account predicts greater disruption when distracters are presented during the encoding of targets, as compared with their retention, and greater disruption when presented during their retention as compared with retrieval. Although the incidence of erroneous recalls fits this pattern—intrusion of distracters decreases as a function of the temporal proximity to the targets—the disruption that B-SSS produces to veridical recall does not. Disruption of veridical recall is of the same magnitude regardless of whether the distracters are presented during encoding, retention, or retrieval phases of the task (Marsh et al., 2008; Marsh, Perham, Sörqvist, & Jones, 2014). Therefore, the attentional slippage account is at best an incomplete account of the B-SSSE on veridical and erroneous recall.

The Role of Back-End Control

In general, the present results suggest that one effect of increased task-engagement is to attenuate the encoding of distracters which in turn makes them less likely to come-to-mind at test. However, to some degree such front-end control is most likely supplemented by back-end control (e.g., Thomas & McDaniel, 2013). The fact that erroneous recall was higher under the lenient inclusion instructions than standard test instructions is consistent with the notion that a back-end monitoring process indeed exists to examine accessed memories for evidence of their presence in the cued event. One possibility is that in standard free recall the process of response-generation at test involves bringing-to-mind the encoding episode: The features associated with a covertly retrieved item, such as its modality information, is evaluated in terms of whether it can be differentiated as a target or distracter. The item is produced (if it matches relevant features of the encoding episode) or is withheld if no match occurs. Relaxing the requirement for accuracy, as with inclusion instructions, attenuates the monitoring strategy such that related items are accepted, resulting in more erroneous recall than under standard conditions. However, at odds with expectations from back-end control is that with inclusion instructions—which effectively remove the influence of back-end control—the apparent suppression of erroneous recall produced by high task-difficulty did not diminish. This suggests that the effect of task-difficulty on erroneous recall is via encoding processes (front-end control) rather than monitoring at test (back-end control): if the task-difficulty manipulation had its effect via output-monitoring processes, the effect should diminish or disappear when participants are instructed to avoid output monitoring.

Before we can disregard the back-end control explanation of the task-difficulty effect, however, it is worth considering the concepts of "relational processing" and "item-specific processing" (Arndt & Reder, 2003; Hege & Dodson, 2004). Relational processing refers to processing of information shared by all items within an event, such as the shared category-membership of a list. Item-specific processing involves the processing of information that is unique to an item within a list. Study manipulations that affect the balance of relational and item-specific processing could have consequences for the processing, and erroneous recall of, distracters. In this view, one possibility is that degrading visual stimuli reduces relational processing and enhances item-specific processing thereby reducing processing of the shared category-membership between list items. To the extent that category-membership is a key retrieval cue—subserving both veridical and erroneous recall—this diminution of the representation of category information would lead to less erroneous recall. Consistent with this notion, Mulligan (1999) demonstrated that degrading/masking visual stimuli that comprised several items taken from different semantic categories during study reduced the degree to which those items were recalled by category at test. Typically, this reduction in semantic clustering of list-items at test is taken as evidence of reduced relational processing during encoding. However, this relational processing-deficit view (Hege & Dodson, 2004) is difficult to reconcile with the current findings for a number of reasons. First, impoverished relational processing typically reduces veridical recall (Hunt & McDaniel, 1993) yet high task-difficulty did not reduce veridical recall in the present experiments. Second, one would expect the visual-perceptual manipulation to also reduce erroneous recall of items semantically related to the target-words in the unrelated speech condition (i.e., the baseline level of erroneous recall should drop) whereas in fact, regardless of task-instruction, this was not the case. Third, the finding that inclusion instructions under high, as well as low, task-difficulty gave rise to increased erroneous recall of distracters indicates that relational processing clearly took place under high-task difficulty. Fourth, if item-based distinctive processing (processing the differences between items within the global similarity of the list) was enhanced, one would expect better veridical recall under high task-difficulty even in the unrelated condition (similar to a deep-orienting manipulation; Hunt, 2003; Hunt et al., 2011). Again, this did not occur. Therefore, reduced relational processing appears unable to explain the failure to access distracters at retrieval (i.e., it is unable to explain why high task-difficulty reduced erroneous recall even with the inclusion recall criterion). We conclude that whereas back-end control is probably operating at recall, front-end control, not back-end control, best explains why the task-difficulty manipulation shields against distraction and erroneous recall.

Greater focal-task engagement, as induced by visual-task difficulty, has been shown to reduce the difference in performance between individuals with low and high working memory capacity (Halin et al., 2014a; Hughes et al., 2013). Therefore, it is quite informative to consider whether the greater focal-task engagement can affect the maintenance of information, as well as the processes involved in searching for target material within memory (a form of back-end control). If so, then greater focal-task engagement may modulate the maintenance and search processes of low-capacity individuals in such a way as to make them more comparable to that of high-capacity individuals. According to the model of Unsworth and Engle (2007a, 2007b), differences in the processes of maintenance within primary memory and controlled search within secondary memory explain the differences in performance between individuals with high and low working memory capacity. On their approach, primary memory serves to maintain activation of a small number of separate representations for ongoing processing. However, this maintenance process requires the continuous allocation of attention. The removal of attention results in the displacement from primary memory of the representations, leaving only a trace within secondary memory. During study, a hierarchy of context cues are encoded including global context cues (associated with relatively invariant features including the study environment), contextual elements that represent the list, and contextual elements that are associated with each item. The latter context changes more rapidly than the list context. According to the model, if there is some impedance to the maintenance of primary memory traces, then the task-relevant information must be retrieved from secondary memory. However, retrieval from secondary memory is cue-dependent, and requires controlled/strategic search to discriminate target from distracter information and to reduce competition at retrieval (cf. Capaldi & Neath, 1995).

Can Unsworth and Engle's (2007a) model explain the present results? One way in which the model could potentially do so is by assuming that greater task-difficulty enhances maintenance of items in primary memory by promoting more effective encoding of fine-grained contextual information concerning the targets, thereby reducing the B-SSSE on veridical recall. However, this would predict that high task-difficulty should improve veridical recall and reduce erroneous recalls in the unrelated condition, which did not happen. Moreover, the account predicts that minimizing the requirement for accessing contextual cues using inclusion instructions as in Experiment 2 should reduce or eliminate the beneficial effect of high task-difficulty, which it does not (when distracters are related). Another possible means for the model to explain the task-difficulty effect is by assuming that distracters no longer interfere because they are not represented within the search set delimited for targets. Therefore, increased task-engagement promotes a retrieval environment that mimics that of high working memory capacity individuals, whereby few irrelevant representations appear in the search sets during recall. This is a plausible account but one problem for it is that the dynamics of the model advocate blocking as a mechanism of retrieval interference. The model assumes that items are sampled one at a time (serial search) from the search set through random sampling with replacement. Therefore, once an item has been sampled and recalled it has an equal chance of being sampled again. The probability of finding new recoverable target representations is affected by the number of previously sampled representations regardless of whether they are target or distracter representations. Therefore, the model predicts a negative relationship between veridical and erroneous recall: sampling a distracter will have a suppressive effect on the capability of discovering yet-to-be recalled target representations. This relationship is not observed (Marsh et al., 2008; Marsh, Hughes et al., 2015; present study). It remains possible that independent effects of B-SSS could be due to the sampling process, since only after sampling does an item exceed some absolute threshold by which it can be recovered into consciousness (cf. Raaijmakers & Shiffrin, 1980). Therefore, a related distracter could have a suppressing effect on a target response within the search set *prior* to its recovery/retrieval. However, this is difficult to reconcile with the finding that increased task-engagement eliminated the B-SSSE on veridical recall but only reduced the effect on erroneous recall. If anything, the reverse would be expected since it would seem that the recovery of distracters should be related to their sampling prior to recall, and if sampled they should suppress target items.

A final back-end control mechanism we consider is response withholding. The response withholding interpretation assumes that the B-SSSE within the context of standard free recall, as in Experiment 1, is attributable to a conservative report criterion. Specifically, in contrast to the unrelated condition wherein distracters can be edited from output on the basis of their mismatch with the semantic category from which the targets were drawn, the semantic category information cannot be used as a basis for discriminating whether a covertly retrieved exemplar was a target or distracter in the related condition. Faced with this discrimination, or source confusion, problem, participants may withhold responses, altering their report criterion to avoid high intrusion rates (Koriat & Goldsmith, 1996). Therefore, in the related condition, a conservative shift in report criterion may result in the withholding of targets in addition to distracters. That the B-SSSE was not reduced with inclusion instructions rather undermines the view that it is produced by response withholding. Moreover, the extension of this view to explain why perceptual degradation of the targets eliminates (in the case of veridical recall) and reduces (in the case of erroneous recall) the B-SSSE seems to require too many additional gyrations: Perceptual degradation must lead to a more liberal shift in report criterion at test that only exerts its effect on targets, since perceptual degradation reduced rather than increased erroneous recall of distracters. Therefore, high task-difficulty does not appear to modulate the B-SSSE through differences in report strategies.

Conclusions

In sum, the results reported here suggest that increased task-engagement can shield against the disruptive effects of between-sequence semantic similarity on veridical and erroneous recall. Here, we have again shown that these two effects are dissociable: Top-down cognitive control modulates both the veridical and erroneous recall components but whereas the effect on the veridical recall component is eliminated entirely by increased task-engagement, the erroneous recall component is only reduced. This suggests that erroneous recall does not just depend on the level of irrelevant sound processing—which can be modulated by increased task-engagement—but also on some other process (e.g., source monitoring) that is not so modulated. We have also reviewed several possible candidate mechanisms by which veridical recall is impaired by B-SSS and how this impairment is eliminated by increased task-engagement. The available data from both the present study and previous work leads us to favor a front-end control account in which increased task-engagement may be understood either in terms of the boosting of the focal task-set, resulting in a passive attenuation of irrelevant sound processing, or the accentuation of an active distracter-inhibition process. Further research will be required to adjudicate between these two possibilities.

It is worth noting in closing that the shielding effect of increased task-engagement against distraction may have applied as well as the theoretical implications that we have emphasized here: We have now shown that it extends to a variety of applied tasks (proof-reading; Halin et al., 2014a; text memory; Halin et al., 2014b) and to a variety of sound-types including acoustically deviant sounds (Hughes et al., 2013) and meaningful speech (present study; Halin et al., 2014a; 2014b). Whilst no doubt counterintuitive, degrading visual stimuli may have value as a practical intervention for individuals with poor attentional control such as those with cognitive deficits characterising schizophrenia (Cellard, Tremblay, Lehoux, & Roy, 2007), normal ageing (e.g., Hasher & Zacks, 1988), dementia of the Azheimer's type (Levinoff, Li, Murtha, & Cherktow, 2004) and attentional deficit hyperactivity disorder (Pelletier, Hodgetts, Lafluer, Vincent, & Tremblay, 2013).

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Footnotes

1. It is worth noting that, at first glance, this front-end control account would seem to be in line with the *load theory* of attention in which high focal-task perceptual load usurps resources required for task-irrelevant processing and thereby reduces distraction (Lavie, 2005). However, according to load theory, the kind of manipulation used here—perceptual degradation—does not qualify as an increase in perceptual load but rather of sensory load which, according to the theory, should *accentuate* distraction (Lavie & DeFockert, 2003). Thus, load theory does not in fact appear to provide a useful framework for interpreting the present findings (see also Hughes, 2014).

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Figure Captions

Figure 1. Illustration of how one of the target words appeared in the low task-difficulty and high task-difficulty conditions. Note: All target stimuli in a given set were either all clearly visible (low task-difficulty condition) or visually degraded (high task-difficulty condition).

Figure 2. Mean veridical recall of visually-presented items that are either masked by visual noise (degraded condition) or not masked by visual noise (non-degraded condition) in Experiment 1. Background speech was either semantically related to the target items or unrelated to the target items. Standard free recall instructions where used. Error bars represent standard error of means.

Figure 3. Mean erroneous recall in Experiment 1. An item in the recall protocol was scored as an intrusion when it was not part of the target set. Standard free recall instructions where used. Error bars represent standard error of means.

Figure 4. Mean veridical recall of visually-presented items that are either masked by visual noise (degraded condition) or not masked by visual noise (non-degraded condition) in Experiment 2. Background speech was either semantically related to the to-be-recalled items or unrelated to the target items. Inclusion free recall instructions where used. Error bars represent standard error of means.

Figure 5. Mean erroneous recall in Experiment 2. An item in the recall protocol was scored as an intrusion when it was not part of the target set. Inclusion free recall instructions where used. Error bars represent standard error of means.

Figure 1.

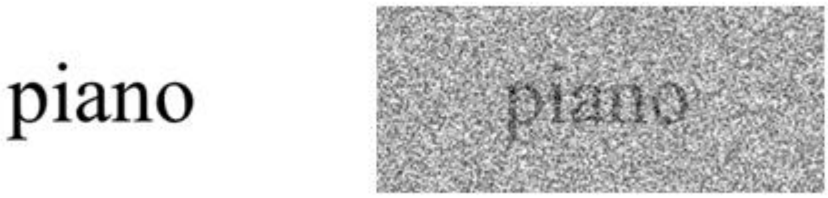


Figure 2.

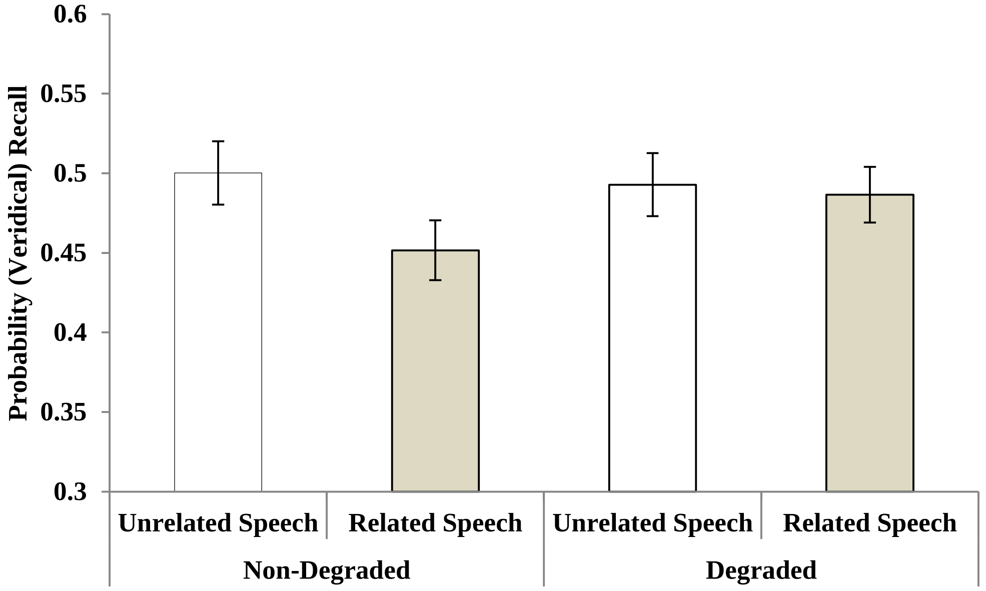

Probability (Veridical) Recall
0.6
0.55
0.5
0.45
0.4
0.35
0.3
Unrelated Speech
Related Speech
Unrelated Speech
Related Speech
Non-Degraded
Degraded

Figure 3.

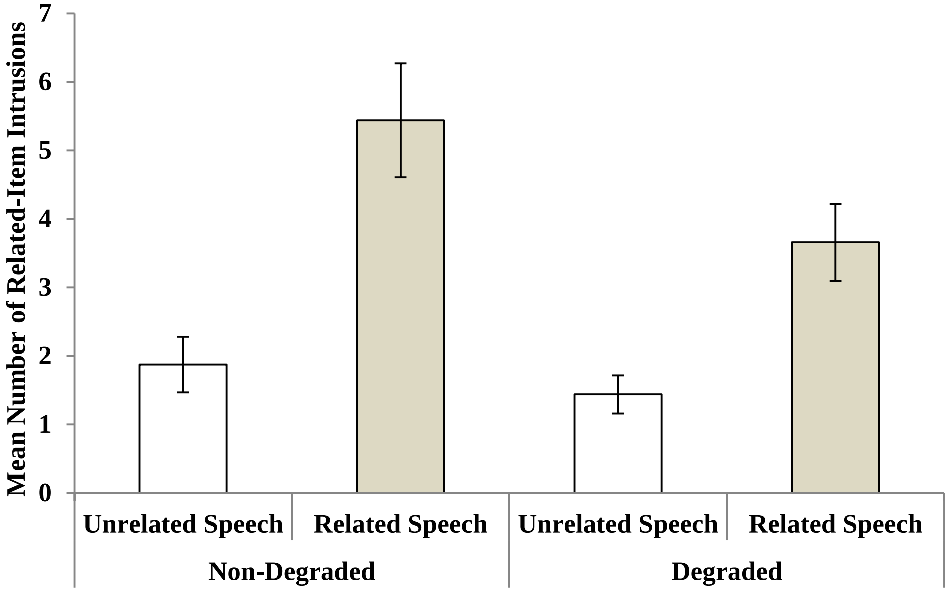

Mean Number of Related-Item Intrusions
7
6
5
4
3
2
1
0
Unrelated Speech
Related Speech
Unrelated Speech
Related Speech
Non-Degraded
Degraded

Figure 4.

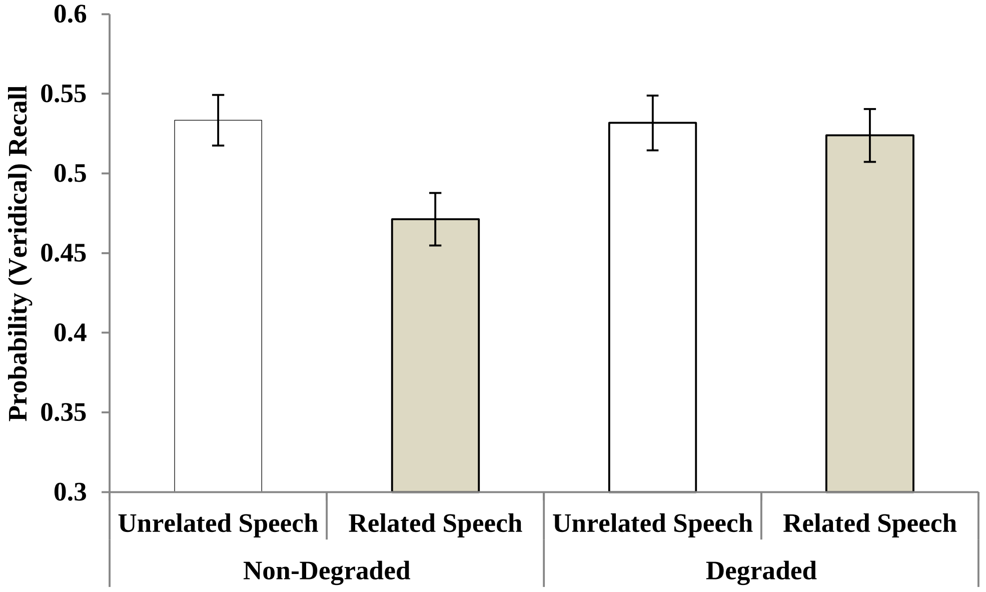
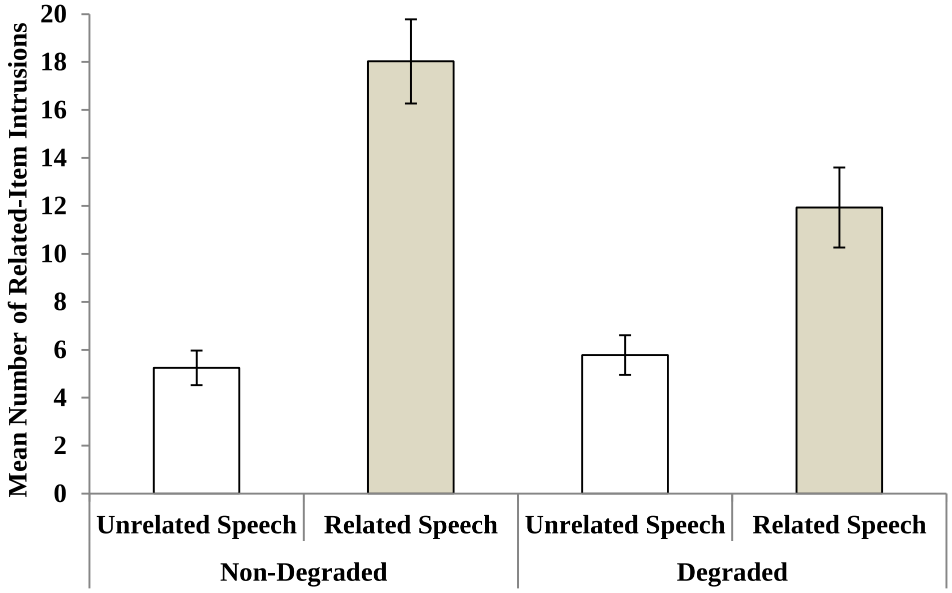

Probability (Veridical) Recall
0.6
0.55
0.5
0.45
0.4
0.35
0.3
Unrelated Speech
Related Speech
Unrelated Speech
Related Speech
Non-Degraded
Degraded

Figure 5.


Mean Number of Related-Item Intrusions
0
2
4
6
8
10
12
14
16
18
20
Unrelated Speech
Related Speech
Unrelated Speech
Related Speech
Non-Degraded
Degraded