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Thinking about meaning: level-of-processing modulates semantic auditory distraction

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ABSTRACT

An effect is reported of a level-of-processing manipulation on the between-sequence semantic similarity effect, the finding that the correct recall of visually-presented target items is disrupted more by the presence of to-be-ignored auditory items (distracters) drawn from the same as compared to a different semantic category. Participants engaged in either a vowel-counting task (shallow-processing) or a pleasantness-rating task (deep-processing) on lists during study. The between-sequence semantic similarity effect was observed in the deep-processing but not shallow-processing condition. Thinking about meaning therefore yielded susceptibility to disruption via the semantic properties of the irrelevant material. Intrusions of related distracters were found with both deep and shallow-processing, but shallow-processing resulted in more intrusions. We propose a two-process account of these findings wherein distracters have independent effects on response-generation and source-monitoring.

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Levels-of-processing; auditory distraction; free recall

It is well established that background noise can have a detrimental effect on cognitive performance (Banbury et al., 2001; Beaman, 2005; Hughes & Jones, 2001). Not all noise, however, is created equal. There are types of noise that are particularly disruptive (Hughes et al., 2005; Jones et al., 1992; MacDermid et al., 2023; Martin et al., 1988; Neely & LeCompte, 1999; Röer et al., 2017), and a common intuition is that natural human speech is the most pernicious type of noise (Tremblay et al., 2000). One reason this may be is that human speech is particularly complex—not only does it constitute a particularly complex set of auditory stimuli, but it also conveys information in other forms arguably unique to spoken language: the syntax, meanings, and pragmatics of the spoken language for a native or fluent listener. This inevitably means that human speech will be processed in a manner that is different than for other, meaningless forms of background sounds and is thus potentially endowed with greater disruptive power.

Another reason to expect meaningful auditory stimuli to influence patterns of distraction is that the focal tasks people are engaged in when background speech is present also commonly involve processing of meanings. Much of what people do in the presence of auditory distraction involves deriving meaning from visually presented materials, for example, any task that requires reading and understanding the content of a text. One hypothesis is thus that the patterns of distraction are not solely dependent on the type of noise, or the type of cognitive activity performed under noisy conditions, but rather they arise at the confluence of activity and noise—with distraction exacerbated, for example, when the focal activity requires processing of meanings while the accompanying noise is also rich in relevant meaning (e.g. Medina et al., 2021). In the present study, we present a test of this hypothesis using the paradigm of semantic auditory distraction (Beaman, 2004; Hanczakowski et al., 2017; Marsh et al., 2008; Neely & LeCompte, 1999), varying the relatedness of information conveyed by auditory stimuli to information processed in the focal memory task and directly manipulating the processing requirements of this memory task via a level-of-processing manipulation. We examine the effects of those two manipulations on two facets of the impairment distraction is known to cause—impaired memory for materials studied under distraction and increased preponderance of intrusions coming from meaningful distraction.

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The effects of semantic auditory distraction have typically been investigated using a category-exemplar free recall task wherein 10–16 nouns taken from a single semantic category are presented for study, followed by a free recall test. The concurrent, or subsequent, presentation of to-be-ignored auditory distracters (e.g. "apple", "banana") drawn from the same category as to-be-recalled visual targets (e.g. "mango", "lime") produces more disruption than the presentation of categorically-unrelated distracters (e.g. "hammer", "drill"; Beaman, 2004; Beaman et al., 2013; Bell et al., 2008; Hanczakowski et al., 2016; Marsh et al., 2008, 2009, 2012; Marsh, Hughes, Sörqvist, et al., 2015; Marsh, Sörqvist, Hodgetts, et al., 2015; Marsh, Sörqvist, and Hughes, 2015; Neely & LeCompte, 1999; Sörqvist et al., 2010). This disruption takes two forms: reduced recall of to-be-remembered words and an increased rate of intrusions from to-be-ignored words (Beaman, 2004; Bell et al., 2008; Marsh et al., 2008; Marsh, Hughes, Sörqvist, et al., 2015; Marsh, Sörqvist, Hodgetts, et al., 2015; Marsh, Sörqvist, & Hughes, 2015; Neely & LeCompte, 1999). Here we start our analysis with the correct recall patterns, only later discussing intrusions.

The finding of reduced correct recall under conditions of semantically related rather than unrelated distraction, referred to as the *between-sequence semantic similarity effect*, is apparent when a distracter is present either at encoding or during a retention interval, but only emerges if the memory task requires free recall (Marsh et al., 2008, 2009). In these studies, the need to freely recall a series of words from a single category, as opposed to a serial recall test, requires participants to focus on the meanings of to-be-remembered words. This type of processing, while supporting free recall performance, also means that the aspect of to-be-remembered words processed during study—their category membership—is shared with to-be-ignored words presented in the auditory channel. This overlap between semantic features present in distracters and processed within the focal memory task is a pre-condition for observing the between-sequence semantic similarity effect. In contrast, under serial recall instructions no similarity effect is observed, presumably because expectations of such a test encourage phonological and positional rather than semantic encoding (Jones et al., 2004). These findings led to the development of an *interference-by-process* view of auditory distraction effects (e.g. Jones & Tremblay, 2000; Linklater et al., 2024; Marsh et al., 2009; Meng et al., 2020), according to which disruption from to-be-ignored sound is jointly dependent on the nature of the sound and the processes deployed in the focal task governed by specific encoding strategies.

Several studies have yielded support for the interference-by-process account of semantic auditory distraction. For example, Meng et al. (2024a, see also Meng et al., 2024b) presented Chinese character pairs under conditions of auditory distraction to two different groups of participants who were instructed either to determine whether characters shared the same meaning (a semantic judgement task) or the same onset (a phonological judgement task). When meaningful speech was compared against phonotactically-legal but meaningless speech (for which phonemes are still identifiable), reaction times within the semantic judgement task were longer, but this effect was absent from the phonological judgement task. At the same time, for the phonological judgement task, both meaningful and phonotactically-legal meaningless speech equally prolonged reaction times as compared with spectrally-rotated speech (for which phonemes are no longer identifiable). Thus, consistent with the interference-by-process account, susceptibility to disruption via either the semantic or phonological properties of the to-be-ignored speech was driven by the extent to which the focal task drew upon either lexical-semantic or phonological processing, respectively.

On the interference-by-process view (Jones & Tremblay, 2000; Linklater et al., 2024; Marsh et al., 2009; Meng et al., 2020) the between-sequence semantic similarity effect should emerge if participants selectively attend to semantic features. Conversely, if participants are encouraged to selectively attend to the non-semantic features of the same stimuli, the between-sequence semantic similarity effect on correct recall should be attenuated or eliminated entirely. In earlier studies (Marsh et al., 2008, 2009) this attention was guided by expectations of a particular type of a memory test, but a more direct way for assessing the role of a junction between encoding processes and features of auditory distraction would be to control participants' strategies by the use of specific orienting tasks that require processing of either semantic or non-semantic features of studied items—in essence, the manipulation of levels of processing (Craik & Lockhart, 1972; Craik & Tulving, 1975; Lockhart et al., 1976). According to the interference-by-process account, the between-sequence semantic similarity effect should emerge under encoding conditions requiring deep, semantic processing of studied items but should be absent under conditions requiring shallow, phonological processing, a hypothesis assessed in the present experiment.[1]

[1]Here we are interested in the impact of semantic features of auditory distraction, usually present in human speech and giving rise to the between-sequences semantic similarity effect of auditory distraction. But our focus on semantic features should not be taken to mean that distraction cannot arise by interference caused by non-semantic features such as phonology. One could speculate that a shallow orienting task, requiring the processing of phonological features of studied items, would open the gates to distraction based on similarity between memoranda and distraction in terms of phonological rather than semantic

So far, we have discussed the effect semantic auditory distraction has on correct recall of studied items. However, another aspect of such distraction that leads to impaired memory performance, evident only with a different scoring system, is the number of items mistakenly recalled. Previous research has demonstrated that not only does semantic distraction reduce the number of correctly recalled items, but it also increases the number of incorrectly recalled items that were not presented visually (Beaman, 2004; Beaman et al., 2013; Bell et al., 2008; Hanczakowski et al., 2016; Marsh et al., 2008; Marsh, Hughes, Sörqvist, et al., 2015; Marsh, Sörqvist, Hodgetts, et al., 2015; Marsh, Sörqvist, & Hughes, 2015; Neely & LeCompte, 1999; Sörqvist et al., 2010). In other words, when semantically related auditory distraction accompanies encoding, the rate of intrusions by items which are experienced as auditory distracters is higher than the rate of intrusions of the same items when study is accompanied by semantically unrelated auditory distraction. For example, if the participant is attempting to recall a series of words which are all types of furniture, they are more likely to mistakenly recall "table" if that was presented as an auditory distracter (and not part of the to-be-recalled list) than if another, entirely unrelated, auditory distracter was used (e.g. "apple").

The increase in the rate of intrusions in semantically related auditory distraction appears to be underpinned by a mechanism distinct from their effect on correct recall, suggesting that recall of intrusions does not merely "block" correct recalls (Marsh, Hughes, Sörqvist, et al., 2015a). However, the exact source of these intrusions is unclear as there are at least two distinct possibilities for why semantic distraction could cause an increase in intrusion errors. On the one hand, these intrusions could reflect impaired internal monitoring, by which items used as distracters come spontaneously to mind more often when semantically related distraction augments activation of all items from a particular category and these spontaneously generated items are later offered as responses in a recall test, in much the same way as associative false memories are thought to arise (e.g. Robinson & Roediger, 1997). On this *activation account,* the likelihood of spontaneously generating an item is monotonically related to its activation level and activation in the related distraction condition spreads from the source of activation—a parent semantic category—to all instances of this category, including to-be-remembered items, but also—crucially for producing intrusions—to-be-ignored items. This activation is stronger in the related distraction condition, where both to-be-remembered and to-be-ignored items activate a shared semantic category, than in the unrelated distraction condition, wherein categories activated by to-be-remembered and to-be-ignored items are different. Here the fact that intrusions come from items used as distracters is incidental and is simply a by-product of using items activated by processing the same semantic category as to-be-ignored items in the related distraction condition.

Alternatively, intrusions under semantic auditory distraction could reflect impaired monitoring of an external source, by which increased similarity of to-be-remembered and to-be-ignored items in the related distraction condition is responsible for to-be-ignored items being falsely classified as to-be-remembered items, resulting in erroneous recall (Marsh et al., 2008). By this *source confusion account*, it is precisely the fact that related items serve as distracters that results in their greater likelihood of intruding in a memory report. This account would predict that unrelated distracters should also result in increased rates of intrusions in the unrelated distraction condition, but these items can be very easily excluded from report due to the mismatch with a semantic category that guides recall in this paradigm and which obviously serves as an ultimate criterion for belonging to the set of study items.

In the semantic auditory distraction paradigm, the levels-of-processing manipulation may serve to disentangle the activation and source confusion accounts of intrusions resulting from semantically related auditory distraction. The activation account postulates that intrusions under semantically related auditory distraction are a simple function of activation spreading through a network of category exemplars, which is particularly pronounced when common semantic aspects are highlighted by to-be-remembered and to-be-ignored items. The levels-of-processing manipulation should have a straightforward effect on such semantic activation, by which activation should be limited in a condition that does not require focus on the semantics during study—that is, under the shallow orienting-task condition. In comparison, in a deep orienting-task condition, where processing semantics is crucial, a pronounced effect of the meaning of the auditory distracter should be observed. The activation account thus predicts lower rates of intrusions in the shallow than in the deep encoding condition.

To formulate the predictions for the source confusion account, the patterns of intrusions in tasks other than

features. This potential interplay of the interference-by-process framework with the level-of-processing manipulation could be an avenue for subsequent research, as suggested by one of the anonymous reviewers of the present work.

the semantic auditory distraction paradigm need to be considered in relation to the levels-of-processing manipulation. Gallo et al. (2008) showed that deep processing at a semantic level results in distinctive memory representations that subsequently support monitoring of intrusions via a so-called distinctiveness heuristic (Gallo, 2004, 2010; Schacter et al., 1999; Schacter & Wiseman, 2006)—a strategy of rejecting potential candidates for a memory report based on these candidate responses lacking recollections one can reasonably expect of them due to their distinctive encoding. This was demonstrated with a criterial recollection task in which participants were specifically asked to endorse items from one of two external sources and intrusions from the to-be-excluded source were taken as a measure of the effectiveness of monitoring processes. The observation that those intrusions were less common when a memory test required endorsements of deeply encoded items, as compared to a test requiring endorsements of shallowly encoded items, indicated that deep encoding allowed for the use of the distinctiveness heuristic to reject potential intrusions. The results obtained by Gallo et al. thus speak directly to the role of the levels-of-processing manipulation for distinguishing across two external sources, indicating that deep as opposed to shallow processing supports monitoring of intrusions from the to-be-excluded source. This in turn leads straightforwardly to a prediction that if intrusions in this paradigm result from confusion across to-be-remembered and to-be-ignored sources, then such intrusions should be minimised when a deep orienting task, supporting monitoring of sources via the distinctiveness heuristic, is employed at encoding, as compared to a shallow orienting task.

Here we present an experiment assessing the impact of the levels-of-processing manipulation on the memory patterns driven by semantic auditory distraction. Participants were presented at study with lists of words coming from single categories. Encoding of those words was accompanied either by related auditory distraction (i.e. spoken words taken from the same category) or unrelated auditory distraction (i.e. spoken words taken from a different category). Participants were required to rate study words for pleasantness or count the number of vowels in each word. Memory performance was assessed via free recall after each study list.

The impact of related auditory distraction on correct recall has been attributed to an immediate competition between the distracters and list items at the point of their presentation. That is, semantically-related distracters interfere with semantic-based encoding (and organisation) processes that are brought to bear to guide later retrieval of the target-items (Marsh et al., 2008, 2009). For the correct recall of studied words, it was thus predicted that related distraction would reduce correct recall as compared to unrelated distraction, but only when studied words are processed for meaning in the deep encoding condition. For intrusions, diverging predictions were formulated based on the activation and source confusion accounts. According to the activation account, intrusions from related distraction should be maximised when studied words are processed for meaning in the deep encoding condition, which supports spreading activation to to-be-ignored words. According to the source confusion account, intrusions from related distraction should be minimised when studied words are processed for meaning in the deep encoding condition, which supports monitoring of to-be-ignored words via the distinctiveness heuristic (see Table 1 for an overview of the hypotheses relating to the study).

Method

Participants

We first established a target sample size based on accuracy data for the between-sequence semantic similarity effect size reported by Hanczakowski et al. (2016, Experiment 1). A power analysis was undertaken using G*Power (Faul et al., 2009): Given $\alpha = .05$, and the assumption that the average population correlation between the two levels of the repeated measures

Table 1. Summary of the hypotheses explored in the study, their prediction for correct/intrusion recall and the proposed mechanism.

Hypothesis	Account	Mechanism
Correct recall will be reduced in the presence of related distracters for deep, but not shallow, encoding of studied words.	Interference-by-Process/Competition-for-Action (e.g. Marsh et al., 2008, 2009; Marsh, Hughes, Sörqvist, et al., 2015).	Immediate competition for semantic-based and organisation processes between the distracters and list items during presentation.
Intrusions of related distracter words should be more prominent following deep, as compared with shallow, encoding of studied words.	Activation Account (e.g. Robinson & Roediger, 1997)	Deep processing of studied words supports spreading activation to related distracter words.
Intrusions of related distracters should be diminished following deep, as compared with shallow, encoding of studied words.	Source Confusion Account (e.g. Gallo, 2004, 2010)	Deep processing of studied words supports monitoring of distracter words via the distinctiveness heuristic.

factor is $\rho = .5$, and a between-sequence semantic similarity effect size of $dz = .56$, it was determined that a sample size of 36 participants would be adequate to detect the effect with a power of .90. Therefore, thirty-six undergraduate psychology students (20 from Cardiff University and 16 from the University of Central Lancashire), participated for course credit. All were native English speakers and reported normal or corrected-to-normal vision and normal hearing. Datasets for five participants were incomplete due to power failure (3) and the occurrence of a fire drill (2) and these were excluded from the analysis. Data for a further two participants were excluded because those participants provided the same response to every attended word (0) in the vowel-counting (shallow) condition. We replaced three of the excluded participants to counterbalance the study. Thus, the final sample comprised 32 participants. A sensitivity analysis showed that with $N = 32$, $\alpha = .05$, and a correlation of $\rho = .5$, between the two levels of the repeated measures factor, it is possible to detect an effect of size $dz = .59$ with a power of .90, or an effect size of $dz = .56$ (as reported by Hanczakowski et al. [2016, Experiment 1]) with a power of .87.

Apparatus/materials

The experiment was run using *Superlab Pro* software. Each participant received 36 trials in which they were visually-presented with 15 to-be-remembered words (targets) all drawn from one semantic category. On all trials, 15 auditory to-be-ignored words (distracters) were interleaved with the targets. Distracters were either all drawn from the same category as the targets or 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 2.75s (2000 ms on, 750 ms inter-stimulus interval; ISI). Distracters were presented over stereo headphones at 65 dB(A) and at a rate of one every 2.75s (750 ms on, 2000 ms ISI). The distracters were presented in the ISI between the targets when a blank screen was presented. 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 et al. (2004) category norms. Items from odd-ranked positions in the category-norm lists were assigned to the target lists and items from even positions 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. In both the first and second block there were 18 trials: 9 related and 9 unrelated. On the related trials of the first block, the auditory distracters were taken from the same category as the targets, thus only one of the pairs of categories was presented. On unrelated trials, the distracter items were taken from the semantically-unrelated category (e.g. "Fruit") that was paired with the target category ("Carpenter's Tools"). For the second block of 18 trials, the related trials incorporated the unused categories from Block 1 and the unrelated trials comprised the non-presented halves of categories from unrelated trials in Block 1. In the latter case, categories that were distracters in Block 1 served as targets in Block 2 (and vice versa). Finally, the to-be-remembered/to-be-ignored categories forming each unrelated trial in Block 2 were used in different combinations from their Block 1 pairings.

The presentation order of exemplars within each to-be-remembered and to-be-ignored sequence was random but the same 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 even across blocks). This order was reversed for the other half of the participants. Moreover, half the participants started with the shallow-processing block and half started with deep-processing. Categories were assigned such that, across participants, there was an equal likelihood of each category being an unrelated or related category, presented in the deep- or shallow-processing condition, and experienced in Block 1 or Block 2 of the experiment (see Table 2).

Design & procedure

Participants were tested individually in soundproof booths, seated approximately 60 cm from the PC

Table 2. Illustration of the block- and trial-ordering of conditions.

	Block 1		Block 2	
Number of Participants		Order of Trials		Order of Trials
$N = 8$	Deep Processing	Related-Unrelated	Shallow Processing	Related-Unrelated
$N = 8$	Deep Processing	Unrelated-Related	Shallow Processing	Unrelated-Related
$N = 8$	Shallow Processing	Related-Unrelated	Deep Processing	Related-Unrelated
$N = 8$	Shallow Processing	Unrelated-Related	Deep Processing	Unrelated-Related

monitor. Participants wore headphones throughout. They were told to ignore any words they heard over the headphones and that they would not be asked about them at any point during the experiment. Instead, participants were instructed to focus on the visually presented items and to rate the pleasantness of each item on a 1–3 scale (deep-processing) or to count the number of vowels in the word (shallow-processing) depending on which block they received first. Participants were required to speak judgments aloud into a microphone in front of them (recordings were made to ensure that a check could be made that all participants completed the orienting task as required). The target words were presented one at a time on the computer screen. After all 15 targets were presented, the prompt "recall" appeared on the screen. Participants then had 30s to write down on the response sheets provided, in any order, as many target items as they could but guessing was explicitly discouraged. After the 30s recall period a tone in the headphones signalled 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 each block.

Results

For all pairwise comparisons within the results section, we report Cohen's *dz* (for within-participant) or *d* (for between-participant) as a measure of effect size. Bayes factors were also computed using the default, standard *Cauchy* prior width of 0.707 within JASP (version 0.17.3; jasp-stats.org).

Proportion of correct responses

Responses were scored according to a free recall criterion; an item was scored as correct regardless of its position. Results are given in Figure 1. A 2 (Level-Of-Processing) × 2 (Type-Of-Distracter) × 15 (Serial Position) ANOVA was conducted on the overall probability of correct recall. Serial position was included because it sometimes interacts with auditory distraction effects. There was a main effect of Level-Of-Processing, $F(1, 31) = 159.324$, $MSE = 0.063$, $\eta_p^2 = .837$, $p < .001$, with more targets recalled in the deep- than shallow-processing condition. There was also a main effect of Type-Of-Distracter, $F(1, 31) = 16.999$, $MSE = 0.016$, $\eta_p^2 = .354$, $p < .001$, with more targets recalled in the unrelated condition than in the related condition. There was also a main effect of Serial Position, $F(14, 434) = 79.221$, $MSE = 0.040$, $\eta_p^2 = .719$, $p < .001$. Critically, there was also a Level-Of-Processing × Type-Of-Distracter interaction, $F(1, 31) = 16.059$, $MSE = 0.011$, $\eta_p^2 = .341$, $p < .001$. A simple effect analysis (LSD) revealed a between-sequence semantic similarity effect for the deep-processing condition ($CI_{.95} = .028, .057$, $p < .001$, $dz = 1.059$, $BF_{10} = 14189.812$) but not for the shallow-processing condition ($CI_{.95} = -.011, .021$, $p = .518$, $dz = 0.115$, $BF_{01} = 4.347$).

Level-Of-Processing interacted with Serial Position, $F(14, 434) = 4.254$, $MSE = 0.026$, $\eta_p^2 = .121$, $p < .001$. A simple effect analysis demonstrated that deep processing led to superior performance on all serial positions apart from positions 1 ($CI_{.95} = -.001, .133$, $p = .052$) and 15 ($CI_{.95} = -.050, .068$, $p = .766$). There was no interaction between Type-Of-Distracter and Serial Position ($F(4, 434) = 0.715$, $MSE = 0.024$, $\eta_p^2 = .023$, $p = .759$) nor was there a three-way interaction between Level-Of-Processing, Type-Of-Distracter and Serial Position ($F(4, 434) = 1.490$, $MSE = 0.024$, $\eta_p^2 = .046$, $p = .111$). Thus, the effect of between-sequence semantic similarity in deep processing was not confined to any part of the serial position curve and suggests that long-term encoding mechanisms play a role in the disruption it produces.

When Block-Order (deep vs. shallow first) was considered as a factor in the ANOVA, there was no main effect of Block-Order ($F(1, 30) = 0.006$, $MSE = 0.132$, $\eta_p^2 = .000$, $p = .939$), no interaction with Level-Of-Processing ($F(1, 30) = 0.421$, $MSE = 0.065$, $\eta_p^2 = .014$, $p = .522$) or Type-Of-Distracter ($F(1, 30) = 2.463$, $MSE = 0.015$, $\eta_p^2 = .076$, $p = .127$), nor was there any three-way interaction with these factors ($F(1, 30) = 1.122$, $MSE = 0.011$, $\eta_p^2 = .036$, $p = .298$).

To further ensure that the primary effects are not being driven by the repetition of the same items/categories across blocks, an analysis of Block 1 only was also conducted. For this block in isolation probability correct recall in shallow processing was .295 for the unrelated condition and .304 for the related condition, .469 for the unrelated deep processing condition and .421 for the related deep processing, showing the same overall pattern as the two blocks combined. This compares to values of .306, .301, .470 and .427 respectively, for the two blocks in combination. There was a main effect of Level-Of-Processing, $F(1, 30) = 45.284$, $MSE = 0.007$, $\eta_p^2 = .602$, $p < .001$, and of Type-of-Distracter, $F(1, 30) = 6.536$, $MSE = 0.001$, $\eta_p^2 = .179$, $p = .016$. There was also an interaction between these factors, $F(1, 30) = 13.506$, $MSE = 0.001$, $\eta_p^2 = .310$, $p < .001$. A simple effect analysis (LSD) revealed a between-sequence semantic similarity effect for the deep-processing condition ($CI_{.95} = .026, .071$, $p < .001$, $dz = .985$, $BF_{10} = 30.244$) but not for the shallow-processing condition ($CI_{.95} = -.031, .014$, $p = .435$, $dz = 0.229$, $BF_{01} = 2.723$).

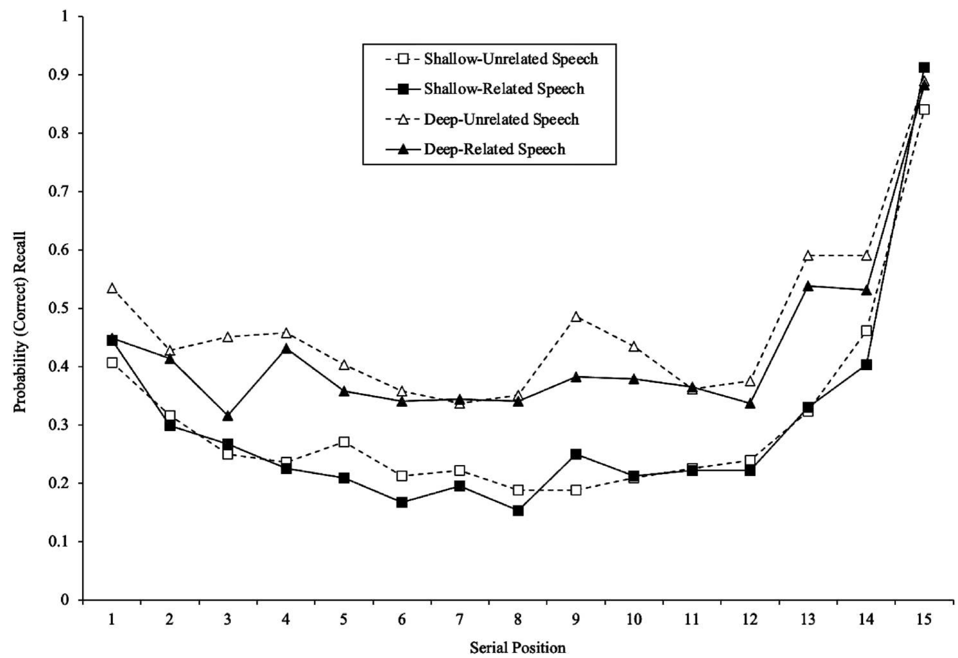

Figure 1. Proportion of targets correctly recalled as a function of serial position and experimental condition.

Seriation analysis

To gain additional insight into the nature of participants' encoding strategies we computed the pair-ordering measure (Beaman & Jones, 1998; Nairne et al., 1991). In this analysis items appearing adjacently in the participants' recall protocol are treated as pairs. The number of pairs comprising adjacent items in correct serial order relative to one another is summed and divided by the total number of pairs recall. This analysis results in a score between 0 and 1 whereby .5 indicates an absence of serial order retention (for further discussion, see Beaman & Jones, 1998). The seriation analysis was computed by ignoring any intrusion errors or response repetitions. A 2 (Level-Of-Processing) × 2 (Type-Of-Distracter) ANOVA was conducted on the seriation scores. There was a main effect of Level-Of-Processing, $F(1, 31) = 159.324$, $MSE = 0.013$, $\eta_p^2 = .160$, $p = .021$, with seriation scores being higher in the deep- ($M = .423$, $SE = .009$) as compared with shallow- ($M = .375$, $SE = .016$) processing condition ($BF_{10} = 2.342$). It is worth noting, however, that in both conditions these means pointed to a below-chance level of seriation, suggesting no role for serial ordering of recall. There was no main effect of Type-Of-Distracter, $F(1, 31) = 0.342$, $MSE = 0.005$, $\eta_p^2 = .001$, $p = .563$, and no Level-Of-Processing × Type-Of-Distracter interaction, $F(1, 31) = 2.100$, $MSE = 0.008$, $\eta_p^2 = .063$, $p = .157$. When Block-Order (deep vs. shallow first) was considered as a factor in the ANOVA, there was no main effect of Block-Order ($F(1, 30) = 1.030$, $MSE = 0.007$, $\eta_p^2 = .033$, $p = .318$), no interaction with Level-Of-Processing ($F(1, 30) = 0.070$, $MSE = 0.013$, $\eta_p^2 = .002$, $p = .793$), or Type-Of-Distracter ($F(1, 30) = 0.220$, $MSE = 0.005$, $\eta_p^2 = .007$, $p = .642$), nor was there any three-way interaction with these factors ($F(1, 30) = 0.084$, $MSE = 0.008$, $\eta_p^2 = .003$, $p = .774$).

Intrusions

A related-item intrusion was 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 irrelevant items on related trials. Such responses were scored as related-item intrusions even for unrelated trials (in which those exemplars had not been presented) thus providing an estimate of false recall probability. Figure 2 shows the mean number of related-item intrusions (across all trials) for each condition. Participants never recalled a distracter that was categorically-unrelated to the target-list.

A 2 (Level-Of-Processing) × 2 (Type-Of-Distracter) ANOVA on the number of related-item intrusions found a significant main effect of Level-Of-Processing, $F(1, 31) = 43.898$, $MSE = 8.074$, $\eta_p^2 = .586$, $p < .001$, with more related-item intrusions in the shallow compared to deep condition. There was also a significant main effect of Type-Of-Distracter, $F(1, 31) = 14.610$, $MSE = 5.673$, $\eta_p^2 = .320$, $p < .001$, with more related-item intrusions in the related compared to unrelated condition. Critically, there was once again a significant interaction between Level-Of-Processing and Type-Of-Distracter, $F(1, 31) =$

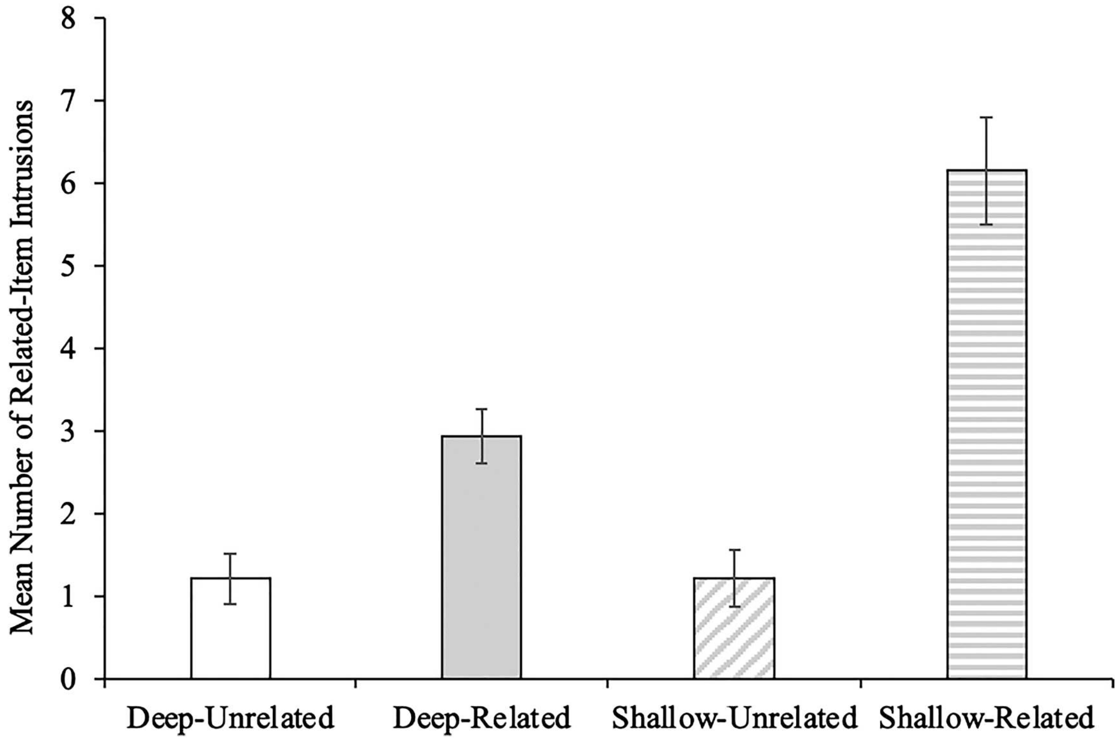

Figure 2. Mean total number of related-item intrusions in category-exemplar recall as a function of experimental condition. The error bars represent 95% confidence intervals computed with the method of Cousineau (2005) and Morey (2008).

19.485, $MSE = 4.254$, $\eta_p^2 = .386$, $p < .001$. A simple effects analysis (LSD) revealed that related-item intrusions were more common in the shallow-level-of-processing condition than in the deep-level-of-processing condition in the related condition ($CI_{.95} = 1.701, 4.737$, $p < .001$, $dz = .765$, $BF_{10} = 180.775$) but not in the unrelated condition ($CI_{.95} = -.526, .526$, $p = 1$, $dz = .000$, $BF_{01} = 5.295$). When Block-Order was considered as a factor in the ANOVA, there was no main effect of Block-Order ($F(1, 30) = 0.243$, $MSE = 23.443$, $\eta_p^2 = .008$, $p = .626$), no interaction with Level-Of-Processing ($F(1, 30) = 0.159$, $MSE = 8.299$, $\eta_p^2 = .005$, $p = .693$), or Type-of-Distracter ($F(1, 30) = 0.303$, $MSE = 5.804$, $\eta_p^2 = .010$, $p = .586$), nor was there any three-way interaction with these factors ($F(1, 30) = 0.656$, $MSE = 4.302$, $\eta_p^2 = .021$, $p = .424$).

Again, when the analysis is limited to Block 1 the overall pattern seen for both blocks is already evident, mean intrusions for the shallow condition are 0.875 with unrelated distracters and 6.313 with related distracters whereas for the deep condition they are 1.5 and 3.313, respectively, approximately comparable to the values shown on Figure 2. The main effect of Type-of-Distracter was significant, $F(1, 30) = 29.132$, $MSE = 7.173$, $\eta_p^2 = .494$, $p < .001$, the effect of Level-of-Processing was not, $F(1, 30) = 1.236$, $MSE = 18.248$, $\eta_p^2 = .040$, $p = .275$. The interaction between the two factors was significant, $F(1, 30) = 7.328$, $MSE = 7.173$, $\eta_p^2 = .196$, $p = .011$. A simple effects analysis (LSD) revealed that related-item intrusions showed a tendency to be more common in the shallow-level-of-processing condition than in the deep-level-of-processing condition in the related condition ($CI_{.95} = -0.389, 6.389$, $p = .081$, $d = .639$, $BF_{01} = 0.877$) but not in the unrelated condition ($CI_{.95} = -1.955, .705$, $p = .345$, $d = .339$, $BF_{01} = 2.091$). The mere tendency instead of a significant effect observed for intrusions in the related condition in the main analysis is not surprising however since, as Table 2 shows, analysing Block 1 in isolation halves the number of observations available and shifts the analysis from wholly within-subjects to a mixed ANOVA.

Discussion

Changing the level of processing, from shallow processing of phonological aspects of the study material to deep processing of its meaning, is one of the most investigated ways of manipulating memory performance. Just as numerous previous studies (e.g. Craik & Tulving, 1975), here we have clearly observed that under standard memory testing conditions—that is, using a free recall test—deeply processed items are remembered better than shallowly processed items. However, the role of level-of-processing for patterns of memory does not end with such direct effects. Here we focused on how changes in levels of processing moderate the patterns of semantic auditory distraction—a host of effects that emerge when learning proceeds under conditions of auditory distraction that remains semantically related to materials one tries to memorise. While the overall beneficial effects of deep processing on memory tested via free recall remained clear, we showed these benefits do not come without a cost. Specifically, concerning correct recall of study items, our study revealed that deep semantic processing of study items opens the gates for the negative effect of related auditory distraction. The between-sequence semantic similarity effect—a hallmark of memory impairment under conditions of semantic distraction—was observed in our study but only when study items were processed at a deep semantic level. At the same time, deep processing also had an indirect beneficial effect for memory performance. Related auditory distraction not only results in reduced correct performance but also in an increase in intrusions from items used as distracters and in the present experiment this increase in intrusions was mitigated by deep semantic processing of study items. We now discuss these two facets of semantic distraction in turn.

The between-sequence semantic similarity effect on correct recall has been observed under a number of conditions, with single-category lists (Hanczakowski et al., 2016; Marsh et al., 2008) and multiple-category lists (Marsh et al., 2009, 2014), and under conditions of externalised free recall, when participants are asked to report all items that come to their mind at retrieval (Marsh, Hughes, Sörqvist, et al., 2015). At the same time, important boundary conditions for this effect have been observed. Some of these conditions relate to processing of distraction, such as a situation in which to-be-remembered items are particularly difficult to process perceptually, fostering greater task engagement and limiting attention devoted to processing of to-be-ignored items (Marsh, Sörqvist, Hodgetts, et al., 2015). However, other conditions under which the between-sequence semantic similarity effect fails to emerge are more concerned with the type of processing that study items undergo than with the engagement of attention. Specifically, semantic distraction fails to affect correct recall when participants study in preparation for a serial recall test (Marsh et al., 2008, 2009). This observation stands behind the interference-by-process framework of semantic auditory distraction (Marsh et al., 2008, 2009), which assumes that in expectation of a free recall test participants focus on processing meaning of to-be-remembered words, in which case the related meaning of to-be-ignored words interferes with memory for to-be-remembered words. This interference does not occur when serial recall is expected because then non-semantic modes of study processing are engaged, rendering the meaning of distracters non-relevant. Indirect evidence that participants were not adopting a non-semantic mode of study in the current investigation was obtained from the seriation analysis (cf. Beaman & Jones, 1998; Nairne et al., 1991). This analysis strongly suggests that mnemonic strategies other than seriation are deployed when remembering categorised, as compared with, semantically unrelated lists of words (Nairne et al., 1991) and is consistent with recent suggestion that a strong semantic structure can attenuate or even eliminate the influence of temporal organisation on recall (Hong et al., 2024).

The results observed for correct recall in the present study remain consistent with the interference-by-process framework. While a deep orienting task condition, fostering semantic processing of to-be-remembered words, opened the gates to interference caused by the meaning of auditory distracters, a shallow orienting task eliminated such interference completely. One possible concern relating to correct recall is whether floor effects in the shallow-processing condition were masking a between-sequence similarity effect. However, between-sequence similarity effects were readily observed previously in studies with comparable levels of recall (e.g. Marsh et al., 2008; Neely & LeCompte, 1999), and in the current study there was no interaction with serial position as might be expected where performance improves in the recency portion of the curve, so on both these grounds this interpretation seems unlikely. Thus, the current results extend support for the interference-by-process framework to a situation in which the type of processing within the memory task is controlled directly by an experimenter via specific encoding strategies, rather than inferred from the expectations participants may have as to the nature of a memory test.

Turning now to the effects of the level-of-processing manipulation on the pattern of intrusions caused by semantic auditory distraction, the crucial finding of the present experiment was that shallow processing of to-be-remembered items produced greater false recall of related distracters than deep processing. This result remains consistent with the source confusion account of intrusions in the semantic distraction paradigm, by which these intrusions under standard encoding conditions result from to-be-ignored items not being completely ignored and instead being encoded to a sufficient extent as to be confused with to-be-remembered items on a later memory test (Marsh et al., 2008; see also Bell et al., 2008). Deep processing of study items imbues memory representations of to-be-remembered items with distinctive details, which later support monitoring of intrusions via the distinctiveness heuristic—to-be-ignored items can be edited out as potential responses because they lack such distinctive details (see Gallo, 2004, 2010; Gallo et al., 2008). Shallow encoding does not result in distinctive memory representations for to-be-remembered items, which undermines subsequent monitoring efforts, resulting in relatively high levels of intrusions from items participants were told to ignore.

The finding that the deep-orienting task reduced rather than increased the rate of false recall contradicts the activation account of intrusions, by which such false recalls are a direct function of activation accruing from semantic processing of categorised words. Such activation should be increased in the deep-processing condition, leading to an increase in intrusions that was not observed. This is not to say, however, that activation spreading to related words, some of them serving as to-be-ignored words, has no role in the semantic distraction paradigm. It seems likely that activation and source monitoring based on the distinctiveness heuristic are both important, as it has been argued in relation to results observed in the DRM paradigm (Gallo, 2010; Hunt & Smith, 1996; Israel & Schacter, 1997; Schacter et al., 1999). Here deep-level processing has been repeatedly found to increase the rate of false recall (Chan et al., 2005; Rhodes & Anastasi, 2000; Thapar & McDermott, 2001; Toglia, 1999; Wootan & Leding, 2015), even though the role of monitoring processes has also been amply documented (Dodhia & Metcalfe, 1999; Gallo, 2010; Gallo et al., 2001; Hanczakowski & Mazzoni, 2012; McDermott & Roediger, 1998; Roediger et al., 2001). The argument is that deep processing serves both to increase associative processing that gives rise to false recall and to support monitoring that reduces false recall, with the ultimate balance depending on the details of a particular paradigm.

Why then should deep-processing be more effective in supporting monitoring in the case of the semantic distraction paradigm, while being more effective in producing false recall in the DRM paradigm? The difference may come down to the transparency of semantic relationships across the materials used in these paradigms. The DRM paradigm (Deese, 1959; Roediger & McDermott, 1995) uses as materials associative lists for which semantic relationships may not always be easy to grasp (Coane et al., 2016), in which case deep-level processing is likely to result in additional activation, overriding any benefits from more efficient monitoring processes. By contrast, categorised lists used in the semantic distraction paradigm, particularly when presented in single-category lists, provide a very transparent case of semantic relationships. In this scenario, activation produced by single-category lists might reveal the role of enhanced monitoring via deep-level processing. While speculative, this approach allows for testable predictions. For example, the level-of-processing manipulation could lead to patterns of intrusion errors more like those observed in DRM procedures under conditions of less transparent semantic relationships, for example in a version of the paradigm with multiple-category lists used previously by Marsh et al. (2009). These tests of the role of activation in the semantic distraction paradigm awaits future research.

The effect of between-sequence semantic similarity on the proportion of correct responses produced was much larger in the pleasantness condition of the current study ($dz = 1.059$) than in previously reported studies wherein free recall was required in the absence of an orienting task (e.g. $dz = 0.56$, Hanczakowski et al., 2016). This could be the result of between-study differences in presentation times (targets were presented at a rate of one every 2.75 s in the current study compared to one every 1.5 s in previous studies [Hanczakowski et al., 2016; Marsh et al., 2012] to enable orienting task responses). If, however, this methodological explanation can be ruled out, the remaining possibility is that the vulnerability of focal target processing to disruption via semantically-similar distracters is increased due to the semantic processing underpinning pleasantness ratings (deep processing) relative to no orienting task. In the latter case free recall may be underpinned by numerous encoding and retrieval strategies some of which may be independent of the processing of meaning of memoranda (Beaman & Jones, 1998). Future work should examine the impact of between-sequence semantic similarity on correct recall and intrusions by comparing three encoding conditions—standard free recall deep orienting task (pleasantness rating), and a shallow orienting task (vowel counting). If the magnitude of the between-sequence semantic similarity effect is associated with greater demands on semantic focal task processing then its impact on correct recalls will be greater following a deep orienting task compared to standard free recall and shallow orienting, and greater for standard free recall than shallow orienting. In relation to intrusion of critical lures from DRM lists, previous research has shown a reduction in false recall following deep orienting relative to standard free recall (Hunt et al., 2011; Smith & Hunt, 1998). If deep processing supports monitoring, then one would expect false recall of related distracters to be lower following a deep orienting task than no orienting (i.e. standard free recall) and a shallow orienting task. Further, false recalls of related distracters should be greater following a shallow orienting task than no orienting (i.e. standard free recall) because monitoring processes are, to some degree, expected to operate with standard free recall.

To conclude, the results cohere with the interference-by-process approach (Jones & Tremblay, 2000; Marsh et al., 2009; Meng et al., 2020, 2024a, 2024b). This account assumes that the disruptive impact of the background auditory environment on the performance of a prevailing focal task jointly depends on the nature of the cognitive processes deliberately brought to bear on the task and the nature of processing preattentively applied to the to-be-ignored sound. Although the framework may benefit from some refinement (Hanczakowski et al., 2017), the interference-by-process account correctly predicts that tasks requiring order processing exhibit more susceptibility to disruption via acoustic-based order processing of the irrelevant sound (e.g. Beaman & Jones, 1997) and that tasks that require serial order memory are unimpaired by the semantic properties of irrelevant sound (Marsh et al., 2008, 2009). Moreover, it correctly predicts that tasks that require memory for semantic-category information, independent of its order of presentation are disrupted by similar semantic information conveyed by irrelevant sound (Marsh et al., 2008, 2009; current study) but not its acoustic attributes (Marsh et al., 2008, 2009). The growing empirical body of research demonstrating the importance of the relationship between the focal task and irrelevant sound processing (Beaman & Jones, 1997; Linklater et al., 2024; Marsh et al., 2008, 2009; current study; Hanczakowski et al., 2017; Meng et al., 2020, 2024a, 2024b) is compelling and should be accounted for by any complete theoretical or computational account of auditory distraction.

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Data availability statement

The data that support the findings of this study are available from https://uclandata.uclan.ac.uk/id/eprint/456.

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