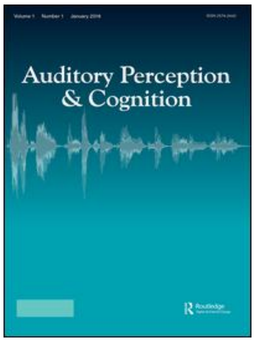

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The Categorical Deviation Effect May Be Underpinned by Attentional Capture: Preliminary Evidence from the Incidental Recognition of Distracters

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ABSTRACT

The performance of a visual focal task is appreciably disrupted by an unexpected change (or deviation) in the properties of a task irrelevant auditory background. A vast amount of evidence suggests that a change in the acoustic properties of sound disrupts performance via attentional capture. However, an emerging body of evidence suggests that the disruption of task performance by a change in semantic category within a stream of sounds does not behave the same and is therefore not produced by attentional capture. This preliminary study aimed to further investigate whether the disruption produced by a categorical deviant was underpinned by attentional capture. In a single experiment, participants were presented with an irrelevant sound stream while they memorized a categorized list for free recall. We examined whether free recall performance was disrupted by an unexpected change in category within the sound and later investigated, via a surprise recognition test, whether participants had superior memory for deviant items as compared to items from the same positions in control sequences. Results revealed that the categorical deviation effect manifested in poorer free recall performance. Additionally, post-study, participants demonstrated better recognition memory for deviant items compared to control items. On the assumption that explicit recognition requires attentional encoding of deviant items, our results yield evidence that the categorical deviation effect may indeed be produced via attentional capture.

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The influence of previously unattended information on our thoughts and behaviors has often been the goal of political powers (e.g., Bu et al., 2019), advertising companies (see Elci & Sert, 2015), and language-learners (e.g., Schmidt, 2010), to name just a few. In the laboratory, the fate of unattended information has been explored in classic studies of dichotic listening (Broadbent, 1958; Cherry, 1953) whereby the extent of processing of the unattended auditory input is often gauged by questioning participants about the characteristics of that information. Despite explicit instruction to ignore the unattended auditory input, participants typically report its pre-categorical physical properties such as

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pitch or timbre but not its post-categorical semantic content (Broadbent, 1958; Cherry, 1953). This has been taken to suggest an early filtering of semantic content, rendering it unavailable for further processing and incapable of affecting response (e.g., Broadbent, 1958). However, more recent research suggests that unattended semantic information is in fact processed (Röer et al., 2017; Vachon et al., 2020) as, for example, indexed by priming subsequent performance on an incidental task (Richardson et al., 2022; Röer et al., 2017). That these effects reflect unattended semantic processing implies that they occur in the absence of attentional shifts to the semantic material and recent evidence suggests this may be the case (Labonté et al., 2022; Richardson et al., 2022; Vachon et al., 2020). However, whether unattended semantic information can be identified in the absence of attention remains controversial (Lachter et al., 2004). The current study is a preliminary investigation that critically reappraises the view of unattended semantic processing through investigating whether participants demonstrate explicit recognition of previously unattended semantic content that disrupted ongoing focal task performance. If explicit recognition of the content of to-be-ignored speech is taken to reflect earlier attentional shifts toward the material during a focal task (e.g., Eich, 1984; Lachter et al., 2004), then finding such recognition would undermine the notion of *unattended* semantic processing.

The extent to which background sound is processed has been a perennial topic of investigation. In dichotic listening tasks participants are required to attend to auditory information, typically speech, presented to one ear (usually accompanied by repeating the words aloud, called shadowing) and ignoring information presented to the other ear. Later, participants are asked about the content of material in the attended and/or unattended auditory channel (Broadbent, 1958; Cherry, 1953; Treisman, 1964; Treisman & Geffen, 1968) and this is used to gauge the extent to which an unattended message is processed. Evidence from these studies reveals that despite being told to ignore auditory information presented to one ear (e.g., to selectively process the attended ear), participants are often able to notice changes (e.g., a change of pitch reflected by a switch between male and female speakers; Cherry, 1953) or specific content (e.g., one's own name or sexual words; Moray, 1959; Nielsen & Sarason, 1981) in the auditory stream presented to the rejected ear. However, if the content is not salient (e.g., non-valent words) then participants fail to identify the material even if it is presented many times (Cherry, 1953). However, the interpretation of evidence for or against semantic unattended processing using the dichotic listening paradigm may be problematic since both sources of information are presented in the same modality – both verbally and aurally. Therefore, any preattentive semantic processing may be overestimated due to a difficulty in perceptually separating the two auditory sources. One way around this potential confound is to use a visual-verbal paradigm in which the attended information is presented in one modality (e.g., visual) and the unattended information is presented in another modality (e.g., auditory). Furthermore, within the latter paradigm participants can be instructed to completely ignore auditory information and are usually reassured (cf., Röer et al., 2017) that they will not be tested on it later.

The disruptive impact of background sound on concurrent performance has commonly been observed using a visual-verbal task within the irrelevant sound paradigm. Like the dichotic listening task, this paradigm involves verbatim repetition of to-be-remembered information while ignoring auditory input. Specifically, participants engage in the visual-verbal focal task of serial recall that requires the recall, in presentation order, of a to-be-recalled (TBR) series of around 7–9 items (usually digits, letters, or words) whilst ignoring background sound that may also contain digits, letters, words, or even nonspeech sounds (Colle & Welsh, 1976; D.M. Jones et al., 1992; Salamé & Baddeley, 1982). In the context of the irrelevant sound paradigm, the extent of processing of to-be-ignored sound is often linked to the potency of sound characteristics in producing disruption of visual-verbal serial recall. While pre-categorical factors, such as acoustic changes, appear important in determining disruption, post-categorical factors play very little role. For example, to-be-ignored speech comprising narrative prose in a language understood by the participant, produces no more disruption than a translation of that narrative into a language foreign to the participant, or the same narrative played backwards (e.g., D. M. Jones et al., 1990). At first glance, this would appear consistent with the notion that the post-categorical attributes of to-be-ignored sound are filtered out early (and therefore cannot impact on, or influence performance). However, an alternative view is that the post-categorical processing of sound still takes place but does not influence the focal task because it does not clash with the processing necessary for efficient primary task performance (Richardson et al., 2022; Röer et al., 2017).

In the context of this irrelevant sound paradigm, two auditory distraction effects have been observed: the changing-state effect (D.M. Jones et al., 1992) and the deviation effect (Hughes et al., 2005, 2007). The classic changing-state effect alludes to the poorer serial recall performance in the presence of a changing-state (acoustically-varying) series of sounds (e.g., "n, r, p ... ") compared to a steady-state sequence (e.g., "c, c, c ... "). According to the duplex account (an overarching account of auditory distraction; Hughes, 2014) the changing-state effect derives from unwanted sound interfering with the specific processes in the focal task (commonly termed interference-by-process). What is essential for the manifestation of the changing-state effect is participant's reliance on serial rehearsal to aid their recall (Beaman & Jones, 1997; Perham et al., 2007) and for the sound to demonstrate acoustic variation. According to the duplex account, the changing-state effect represents a conflict between the processing of order information inherent in the focal task and the automatic processing of order information in the changing-state sounds. During this conflict of processing order information, the post-categorical properties are not endowed with disruptive power because they do not clash with the processes necessitating efficient task performance that are subvocal motoric processes that are independent of semantic content (Marsh et al., 2009; note that when semantic processing is an important feature of focal task processing, then the semantic properties of sound interfere, consistent with a semantic-inference-by-process; e.g., 2009; Meng et al., 2020).

Of more relevance to the current investigation is the deviation effect. This refers to disruption of focal task performance that is produced by an unexpected or irregular event that differs from a preceding sequence of items (Hughes et al., 2013, 2005, 2007; Vachon et al., 2012). Examples include a single item differing from the rest in terms of its pitch (e.g., a spoken item produced by a male in a sequence of items otherwise spoken by a female) or timing (e.g., one sound item being presented for longer duration than others within the same sequence; Hughes et al., 2005, 2007). Unlike the changing-state effect, the deviation effect can manifest in tasks that do not require visual-verbal serial recall (Hughes et al., 2007).

It is widely regarded that a deviant item captures attention and diverts attentional resources away from the focal task (attentional capture; Hughes, 2014; Hughes et al., 2005, 2007). The mechanism underpinning attentional capture stems from Sokolov's (1963) work on the orienting response: the reaction of an organism when it is presented with a novel stimulus. Researchers have found several immediate changes that occur during this process such as skin conductance response (SCR; Tuvblad et al., 2012; Williams et al., 2000), electroencephalogram (EEG; Näätänen et al., 2001), and heart rate (Graham & Clifton, 1966), as well as eye movements (Pavlov, 1927; Sokolov, 1963) and head movements (Brimijoin et al., 2010; Pavlov, 1927; Sokolov, 1963). This new stimulus contradicts the representation that the organism has created when processing their, in our case, auditory environment and consequently causes the organism to disengage with their primary task and divert their attention toward the source of this deviation. Deviant sound items automatically capture attention due to the physical (e.g., acoustical) mismatches in the auditory stream. An alternative to this novelty account of the deviation effect is the expectancy violation account (see, e.g., Bendixen et al., 2007; Hughes et al., 2007; Marois et al., 2020; Vachon et al., 2012). On this account, violations of expectations of the auditory stream that emerge from the invariability of the auditory context, gift a sound its attention-grabbing power. Thus, a sound does not have to be novel, nor comprise an acoustic change from the context, in order to produce a deviation effect.

The expectancy violation account of auditory deviation in the context of visual-verbal serial recall is particularly relevant to the recent discovery that the task is also disrupted by a single post-categorical change within an otherwise post-categorically predictable stream (Labonté et al., 2022; Littlefair et al., 2022; Vachon et al., 2020). This effect occurs within a sequence characterized by constant acoustic changes that are thought not to capture attention (e.g., Marois et al., 2019; but see Bell et al., 2019). Vachon et al. (2020) found that the categorical deviation effect was not dependent on the relevance and importance of the deviant to the participant because non-significant deviants (i.e., deviants that were not relevant or important to participants) produced the effect. For example, the categorical deviant effect occurred when the deviant was a single letter within a sequence of digits (or vice versa) or a semantically rich category-exemplar drawn from a category different to that representing all others within a sequence. Vachon et al. (2020) concluded that the disruptive impact of a categorical deviation may reflect preattentive extraction rather than attentional capture. However, it should be mentioned that the semantic content of irrelevant sound has the power to capture attention in settings within which irrelevant stimuli are motivationally significant. For example, task-irrelevant emotionally arousing words produce attentional capture (e.g., Keil et al., 2007; Marsh, Yang et al., 2018; Sokka et al., 2014; Thierry & Roberts, 2007) and impair focal task processing (e.g., Buchner et al., 2004, 2006; Keil et al., 2007; Marsh, Yang et al., 2018). However, as in the case for one's own name (Röer et al., 2013), the motivational salience of the stimuli may bias the contents of awareness (e.g., Holeckova et al., 2006; Roye et al., 2007; West et al., 2009) and increase the priority of a stimulus for attentional selection. Such automatic biases toward motivationally significant stimuli likely increase their power to trigger attentional capture.

Concerning the categorical deviation effect, there are two key issues of interest. The first pertains to the post-categorical, semantic processing of the unattended material. For a categorical deviation to be detected, some lexical-semantic processing of the preceding items must occur (Vachon et al., 2020). This is consistent with the notion that the post-categorical properties of to-be-ignored speech are ordinarily processed but simply have little or no effect on visual-verbal serial recall because they do not interfere with the nature of the focal task processing (Marsh et al., 2009; Richardson et al., 2022; Röer et al., 2017). The second issue pertains to the nature of the mechanism underpinning the disruption produced by the categorical deviation. For the interest of parsimony, it would seem appropriate to characterize the categorical deviation effect as one that, like acoustic deviation effects, is attributable to attentional capture. On this view, it is possible that a representation of the unfolding sound sequence is fashioned to include post-categorical features and thus a violation of forward predictions based on this information could trigger attentional capture (e.g., Marsh et al., 2014). However, recent studies suggest that the categorical deviation effect differs from the acoustic deviation effect in systematic ways that appear to undermine the notion that both are explicable in terms of an attentional capture mechanism (Labonté et al., 2022; Littlefair et al., 2022; Vachon et al., 2020).

A key feature of the acoustic deviation effect is that it can be brought under control by factors relating to top-down cognitive control. For example, increasing task-engagement via increasing encoding load (Hughes et al., 2013; but see Kattner & Bryce, 2022) or perceptual load (Marsh et al., 2020) reduces or eliminates the disruption produced by an acoustic deviation (see also, Hughes & Marsh, 2019). Moreover, giving participants the opportunity to predict the content of the upcoming sequence in a top-down manner by presenting them with foreknowledge, tempers the acoustic deviation effect (Hughes et al., 2013). However, neither encoding load, nor foreknowledge, materially affects the magnitude of the categorical deviation effect (Vachon et al., 2020). Further, trait capacity for cognitive control as reflected by individual differences in working memory capacity has been related to the magnitude of the acoustic deviation effect, with higher working memory capacity individuals being less susceptible to deviation effects than their lower working memory capacity counterparts (Hughes et al., 2013; Marsh et al., 2017; Sörqvist, 2010; but see, Körner et al., 2017). In contrast, working memory capacity is unrelated to the magnitude of the categorical deviation effect (Labonté et al., 2022). Finally, it is typically the case that an acoustic deviant loses its disruptive potency following repetitions. The orienting response to the deviant event is said to habituate as it becomes easier to represent the change within a predictive model (Röer et al., 2013). In contrast, however, no such habituation has been observed in relation to the impact produced by a categorical deviation (Littlefair et al., 2022). Considering the body of evidence accruing, there is speculation that the categorical deviation effect is the manifestation of a fully automatic semantic processing mechanism that evades amelioration via top-down cognitive control and is thus attributable to a mechanism other than attentional capture. In other words, the categorical deviation effect does not produce disruption because the irregularity results in shifts of attention to the to-be-ignored sound as a result of processing the categorical deviant.

Whether attentional shifts explain the influence of the post-categorical properties of to-be-ignored speech on concurrent task performance or the performance of a later task is of both historic (e.g., Eich, 1984) and more contemporary (Richardson et al., 2022) interest. For example, in the unattended channel of a dichotic listening study, Eich (1984) presented participants with pairs of words comprising a word and a homophone (e.g., ink-dye) that referred to the less common meaning of the two potential meanings (e.g., dye versus die). They were asked to shadow words presented to one ear and ignore the homophones presented to the other ear. After completing the shadowing task, participants were auditorily presented with some of the homophones presented to the unattended channel earlier and some new homophones and asked to spell them. They spelt the words consistent with the non-dominant spelling more frequently if they had previously been exposed to them in the to-be-ignored channel. Further, in a surprise recognition test, participants failed to recognize the earlier encountered homophones. Eich (1984) concluded that evidence of unattended semantic processing can be observed through implicit memory tests (e.g., spelling) but not explicit (e.g., recognition) memory tests that arguably requires some attentional processing of the to-be-ignored auditory words that could only take place via attentional shifts to that material. However, Eich's conclusion concerning homophone priming has been undermined by Wood et al. (1997) who compared the original presentation rate in Eich (1984, p. 85 words per minute) with a condition wherein they were presented twice as fast (170 words per minute) which, they argued, reduced opportunity for attentional switches to the to-be-ignored channel. Consistent with their argument, Wood et al. (1997) reported implicit priming for to-be-ignored words at the slower presentation rate, but no evidence of any priming at the faster presentation rate. This suggests that the so-called implicit (priming) effect observed by Eich (1984) was also the consequence of attentional shifts to the to-be-ignored stream. However, in an analogous experiment using the irrelevant sound paradigm, Richardson et al. (2022), like Eich (1984) demonstrate semantic priming of non-dominant homophones even in cases where only close associates of the non-dominant homophones are presented as to-be-ignored speech. Further, as there was no relationship between the amount of priming and serial recall performance, the authors concluded that there was no evidence for any attentional shifts to the unattended sound thereby supporting the argument of semantic processing of unattended sound in the absence of attentional shifts (Vachon et al., 2020).

The notion that explicit recognition or identification requires attention is a central claim of proponents of early filtering accounts (e.g., Broadbent, 1958) and chronologically later selective filter theories (e.g., Lachter et al., 2004). According to Lachter et al. (2004) lexical-semantic processing without attention is referred to as *leakage* through an attentional filter, whereas *slippage* refers to an attentional allocation to to-be-ignored items even if unintentional. According to Lachter et al. (2004) all evidence for lexical-semantic processing without attention that could lead to recognition (e.g., identification) of to-be-ignored material can be attributed to *slippage* whereby attention is allocated to irrelevant items thereby resulting in their attentional encoding and thereafter identification. Lachter et al.'s (2004) notion of slippage parallels what we mean by attentional switches. Crucially, on early filter accounts, recognition of to-be-ignored material, via its lexical-semantic processing, is not possible while attention is focused elsewhere, and all evidence for such apparent *leakage* suffers from a lack of experimental control over the occurrence of slippage (for a review, see, Lachter et al., 2004).

If one assumes, as the early filter views (Broadbent, 1958; Lachter et al., 2004) propose, that later explicit recognition of previously to-be-ignored speech items can *only* occur following shifts of attention to those items (see, e.g., Eich, 1984), then deploying such a test could help adjudicate whether the categorical deviation effect, like the acoustic deviation effect, is underpinned by an attentional capture mechanism or is instead subtended by a functionally distinct mechanism (Labonté et al., 2022; Littlefair et al., 2022; Vachon et al., 2020). Richardson et al. (2022) did not compare an explicit incidental memory test (recognition) with their implicit memory test (spelling) and so from this standpoint a part of the puzzle is missing: it is difficult to rule out whether the priming effects they observed were attributable to attentional shifts. Further, in the context of the categorical deviation effect (Labonté et al., 2022; Littlefair et al., 2022; Vachon et al., 2020) no previous study has used an incidental explicit recognition test to provide insight into the possible attentional encoding of the categorical deviant itself – which would arguably follow if the categorical deviant produced attention capture.

The current study, then, addressed this shortfall by requiring participants to free recall to-be-remembered visual words that were presented whilst participants ignored auditory sequences that comprised a single categorical deviant among otherwise categorically homogenous exemplars (termed the deviant sound condition) compared with auditory sequences that comprised completely categorically homogenous exemplars (termed the nondeviant condition). Specifically, the deviant belonged to a different category to the others within the auditory sequence. The rationale for the use of the free recall task was underpinned in part by the call for researchers to investigate the impact of background sound on tasks other than the typically used serial recall task (see, Schmidt, 2010). Serial recall is a task sensitive to disruption from task-irrelevant sound which measures the short-term retainment of sequences of (usually) visual items. The processes tapped by the serial recall task likely support complex cognitive activities such as understanding read or heard text. However, free recall tasks may tap other cognitive processes such as semantic processing that also subserve performance on complex cognitive tasks. Thus, using free recall allows one to investigate the impact of distraction on a task that likely involves both serial and non-serial (e.g., semantic) processes. Since the categorical deviant effect is manifest on both serial and non-serial short-term memory tasks (Vachon et al., 2020) it was expected to manifest on the free recall task.

Following completion of the free recall task, participants completed a "surprise" recognition test which included words from the to-be-ignored speech as well as words that were related and unrelated to the deviant words. It was predicted that recall performance would be significantly worse in the deviant condition compared to a nondeviant condition and a quiet control condition (cf., Labonté et al., 2022; Littlefair et al., 2022; Vachon et al., 2020). Further, if the categorical deviation effect is underpinned by attentional capture and thus attentional shifts occur to the unattended information, then participants should demonstrate superior recognition for the "deviant" item compared to a matched control item (e.g., in the nondeviant condition). On the other hand, if the categorical deviation effect is not underpinned by attentional capture, then one might expect no difference in recognition rates between deviant and control items. A further exploration of processing of the deviant words was predicted to come from recognition rates of words that were never presented as to-be-ignored (TBI) sounds. In these cases, they were either related or unrelated to the deviant. If attention was captured by the deviant, thus its meaning was consequently processed, then we predicted that this would result in greater false recognition for words that were related to the deviant words compared to words that were unrelated to them.

Method

Participants

A convenience sample of 30 native English-speaking participants from a university in south Wales took part for course credit. Eight of the participants were female and twenty-two participants were male. All were aged between 18 and 30 years.

Materials

Category Recall Lists

Two hundred and seventy English language category exemplars were used to create the 30 to-be-remembered (TBR) 9-item lists (10 lists per sound condition). To ensure a large enough number of words for each list, each list comprised exemplars from both the high and medium output-dominance scores from Van Overschelde et al. (2004). This was an updated and expanded version of Battig and Montague's (1969) category norms in which participants were presented with a list of categories and asked to generate all the exemplars that they could for each category. Thus, output-dominance is the frequency with which a word is produced as an exemplar for a particular category. The top ten highest category-normed words were classed as high output-dominance, the second set of ten classed as medium output-dominance, and the third set of ten classed as low output-dominance. Output-dominance scores were calculated by dividing the number of participants who gave that particular response (e.g., generating dog as an exemplar of the category four-legged animals) by the number of participants who gave any response to that category. Given that the number of participants who completed the task ranged from 633 to 710 participants (mean = 672), the output-dominance scores ranged from low double-digit figures for medium category norms to figures in the 600s for high category norms. See, Table 1 for means of category norms and Appendix for word lists.

A *Powerpoint* presentation was used to present all the word lists. Each list comprises three words from three categories with words from each category grouped together. Each word was written in black, bold 72 font, Arial typeface, and presented for 1 second on an individual slide with no interstimulus interval and after each of the 9 words from each trial was presented, participants were instructed that they had 20 seconds to write down all the words on a sheet of paper. This was indicated by the presentation of the word "Recall" written in red, bold, 72 font, Arial typeface. All participants received the same trials and synchronous, individual sounds in the same order.

To ensure that there were minimal differences between the TBR lists, one-way between ANOVAs were conducted on the category output-dominance ratings and number of syllables for each sound condition (see, Table 1 for means and standard

Table 1. Mean and standard deviation of the output-dominance and syllables of the to-be recalled lists by sound condition.

Sound	Output-dominance	Syllables
Quiet	144.79 (22.99)	1.96 (0.83)
Nondeviant	159.46 (22.99)	1.90 (0.75)
Deviant	159.13 (22.99)	1.91 (0.82)

deviations). Output-dominance ratings (high and medium) and syllables were mean averaged across lists and analyzed between sound conditions.

No significant difference was found between the sound conditions for the output-dominance category-exemplars (F (2, 27) = 0.13, MSE = 5283.5, p = .88, η_p^2 = .01) and the syllables of the TBR words (F (2, 27) = 0.17, MSE = .1, p = .85, η_p^2 = .01).

Irrelevant Sound

TBI sequences of English language category exemplars taken from Van Overschelde et al.'s (2004) category norms list were used to create the irrelevant sound. Each TBI sequence comprised 9 words from a single category (apart from those associated with the deviance sound condition which comprised 8 words from a single category and the remaining word was from a category previously unused in the study). Similar to the composition of the TBR items, six of the ten deviant words had a high output-dominance and the rest had a medium output-dominance. In the deviant condition, the deviant word was always the 7th item, out of 9, in the sequence. This is consistent with previous work wherein the deviant item is typically placed toward the end of the auditory sequence (usually in the third or second to last position) and is shown to disrupt visual-verbal serial recall performance compared with a control (nondeviant) condition (Hughes et al., 2005, 2007). All sounds were recorded using KAYPentax Multi-speech software at a rate of one word per second to align with presentation of the TBR items and embedded to the individual Powerpoint slides that they were synchronous to. They were recorded in the same female voice in an even pitch. The sound was played through the headphones between 65 and 75 dB(A). See Appendix for words in the background sound. Finally, as the sound conditions were blocked, sound was counterbalanced such that five participants each received the sound conditions in a different order.

Although no word was repeated throughout the trial (word list or sound), to ensure that we had a sufficiently large number of words and lists, some categories were presented more than once – see Appendix.

Where repetition of categories did happen, there were at least four trials between the repetition of categories (7, 6, 8, 4, 5, and 8 trials, respectively, see below). This happened on one occasion for the nondeviant trials for the category of metals – it was the third of the TBR categories on the third trial and the background sound of the ninth trial. More repetition of categories occurred in the deviant condition due to the additional categories required for the deviant items. Car manufacturers appeared as the background sound for the second trial and the first category of the TBR items on the ninth trial. Mythical creatures appeared as the third category of the TBR items in the second trial and the deviant item in the eighth trial. Reading material appeared as the first category of the TBR items in the second trial and the third category of the TBR items in the tenth trial. Boats appeared in as the deviant item in the first trial and the second category of the TBR items in the fifth trial. Ship parts appeared as the deviant item in the third trial and as the first category of the TBR items in the eighth trial. Finally, weapons appeared as the second category of the TBR items in the second trial and the background sound in the tenth trial.

Recognition Test

A recognition test was also conducted using *Excel* comprising 120 category exemplars where participants had to answer "yes (Y)" or "no (N)" if they recognized the words from those presented as background sound in the study. All words from the irrelevant sound in the first, sixth, seventh, eighth, and ninth positions were included as well as 10 words that were related to, and 10 words that were categorically unrelated to, the deviant items. These words were of high and medium output-dominance but had not been used as background sound in the study (Van Overschelde et al., 2004).

We wished to explore how well the deviant item was recognized compared to the nondeviant in the equivalent (7th) position in the irrelevant sequence and the words presented on either side of the deviant/nondeviant (sixth and eighth positions in the sequence). We also explored recognition for the first and last (ninth) irrelevant items so that we could compare recognition of the deviant item with items that are likely to be recognized most – first and last items produce primacy and recency effects, respectively, in serial recall and we expected, although speculatively, that this would also occur for irrelevant items. We considered this to be the case due to temporal distinctiveness – irrelevant items occupying the first and last positions do not have preceding and succeeding auditory items, respectively, thus their unintentional encodings may benefit from this saliency much like the last item in an auditory sequence demonstrates a recall benefit from being at an object boundary (see, Macken et al., 2016). Therefore, the two independent variables were word list (deviant and nondeviant) and the position of the item (1st, 6th, 7th, 8th, and 9th).

To further explore the potential of attention shifting to the deviant item via unpresented words, we included 20 words in the recognition test that were not presented in the experiment at all – see above for details. Categorical relatedness, related or unrelated, was the independent variable.

Design

A within participants design was adopted for the recall task with the independent variables of sound condition (deviant, nondeviant, and quiet) and item position (1 to 9). All trials within each sound condition were presented together and sound condition presentation was fully counterbalanced with each participant receiving one, out of six, possible counterbalancing orders. Although it is more typical to present deviant trials interspersed with nondeviant trials throughout a block of trials, presenting trials containing deviants in a blocked fashion still means that there are standards within each trial that occur before the presentation of the category change. Furthermore, blocking the deviant *vs*. nondeviant trials is a purer way of manipulating deviance. When using randomized conditions within a block, there is a potential confound of across- against within-trial deviation effects. Previous work demonstrates across-trial deviation effects, at least when the across-trial pattern is obvious (e.g., Vachon et al., 2012). Thus, we expected to find a categorical deviation effect. The dependent variable was free recall score which ranged from 0 to 9.

For the recognition component of the study, two designs were required for two separate analyses. A within design, with the independent variables of position (1st, 6th, 7th, 8th, and 9th) and sound (deviant and nondeviant) and the dependent variable of recognition, explored whether the deviant item was recognized more than its equivalently positioned counterpart. Finally, a within design, with the independent variable of categorical relatedness (related or unrelated to the deviant item) and the dependent variable of recognition, explored whether words that had not been presented were recognized and whether this was influenced by their categorical relationship with the deviant item.

Procedure

Participants were tested in groups of up to 6, with each participant in a separate cubicle and given an instruction sheet which gave a brief account of the experiment. They were then verbally instructed that they would be presented with a succession of individual words on the monitor which they had to observe and when the prompt "Recall" appeared they had 20 seconds to write down as many of the words, in any order, they could remember on sheets provided. They were also told to ignore any sounds they heard and to focus on what is displayed on the monitor rather than what they heard through the headsets. After completing all the recall trials, participants were then told to complete the recognition task. The experiment lasted approximately 45 minutes.

Results

Five sets of analyses were conducted and reported below. The first focused on the proportion of correct free recall and how the sound and position of the TBR impacted upon it. The second set explored the extent to which participants employed strategies of seriation and categorization to aid their recall performance. The third set examined whether participants habituated to the deviant across trials. The fourth set explored recognition rates of irrelevant items. Finally, we investigated whether participants recognized the deviant items more than the nondeviant items and whether this was associated with the recall of the TBR items.

Free Recall Task

Responses were scored as correct if they were identical to the items presented in the list or if they were an incorrect spelling of said items e.g., "brocolli" instead of "broccoli." Figure 1 reveals that performance did not follow the typical serial recall pattern as observed in serial recall which is not surprising as there were differences between the current task and serial recall, most notably the instructions to recall the TBR items in any order. Performance is around 50% in the quiet condition with it generally being lower in the deviant and nondeviant conditions from positions 1 to 6. Recall of the final three items seemed to produce a recency effect with recall increasing from 50% up to 70%. More importantly for the purposes of the current paper are the differences between the sound conditions on position 7, where the deviant item occurred, and position 8, the position following the deviant. Recall of item 7 is lower in the deviant compared to the nondeviant and quiet conditions respectively. This pattern is similar at position 8 except that recall in the nondeviant and quiet conditions are almost identical. Finally, recall of the final item, at position 9, is the highest across the sequence and almost the same for all three sound conditions.

A two-way within ANOVA was conducted on the recall data. Mauchly's test revealed that the assumption of sphericity was violated for sound, $\chi^2(2) = 6.2$, $p = .05$, position, χ^2

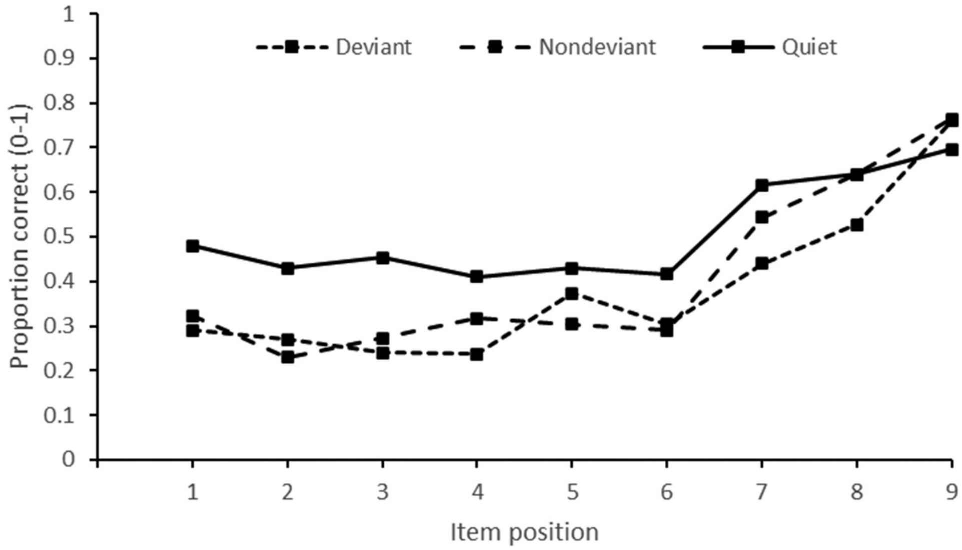

Figure 1. Mean of free recall across sound condition and position.

(35) = 109.59, $p < .001$, and sound by position interaction, $\chi^2(135) = 201.69$, $p < .001$, therefore Greenhouse-Geisser corrected tests are reported ($\varepsilon = .8$). The results revealed a significant main effect of sound on free recall, $F(1.67, 48.39) = 30.67$, $MSE = .05$, $p < .001$, $\eta_p^2 = .51$, and a significant main effect of position on free recall, $F(3.01, 87.23) = 55.08$, $MSE = .01$, $p < .001$, $\eta_p^2 = .66$. However, this was superseded by a significant interaction of sound and position on free recall, $F(8.2, 237.7) = 4.02$, $MSE = .05$, $p < .001$, $\eta_p^2 = .12$. Significant pairwise comparisons, with a Bonferroni adjustment, were observed between positions for each individual sound condition.

For the deviant condition, free recall performance in the 9th position was significantly better than in all other positions (all $p < .001$) and free recall performance in the 8th position was significantly better than in positions 1 to 7 (position 1, $p = .03$; positions 2 to 6, $p < .001$). Further, free recall performance in the 7th position was significantly better than in the 4th position ($p < .001$) and, in the 5th position, significantly better than in the 2nd ($p = .04$), 3rd ($p = .05$), and 4th positions ($p < .001$).

For the nondeviant condition, free recall performance in the 9th position was significantly better than in positions 1 to 7 (all $p < .001$), free recall performance in the 8th positions was significantly better than in positions 1 to 6 ($p < .001$), and free recall performance in the 7th position was significantly better than in positions 1 to 6 (position 1, $p = .009$; positions 2 to 6, $p < .001$).

Finally, in the quiet condition, free recall performance in the 9th position was significantly better than in positions 1 to 6 (position 1, $p = .002$; position 2, $p = .003$; position 3, $p = .005$; positions 4 to 6, $p < .001$), free recall performance in the 8th position was significantly better than in positions 2 to 6 (position 2, $p = .05$; position 4, $p = .01$; positions 5 and 6, $p < .001$), and free recall performance in the 7th position was significantly than in positions 4 to 6 (position 4, $p = .02$; position 5, $p = .004$; position 6, $p = .002$).

More importantly for the purposes of the research, significant pairwise comparisons were observed between sounds at certain positions. At positions 1 and 3, free recall performance in quiet was better than that in the deviant and nondeviant conditions, respectively (position 1: $p < .001$ and $p = .003$; position 3: both $p < .001$). For positions 2 and 6, free recall performance was better than that in the nondeviant and deviant conditions respectively (position 2: $p < .001$ and $p = .007$; position 6: $p = .005$ and $p = .01$), respectively. In positions 1, 2, 3, and 6, no significant difference was observed in free recall performance between the deviant and nondeviant conditions (all $p > .05$). At position 4, free recall performance was significantly better in the quiet than in the deviant condition ($p = .004$), and at position 5, free recall performance was significantly better in the quiet than in the nondeviant condition ($p = .01$). No other significant differences were observed in these two positions.

Finally, we reported the comparisons between sound conditions on positions where the deviant was likely to have had most impact and reported their effect sizes and Bayes' factors. At positions 7 and 8 (where the deviant occurred and the item following the deviant), free recall performance was significantly poorer in the deviant condition than in the quiet and nondeviant conditions respectively (position 7: $p = .008$, Cohen's $d = 0.6$, $BF_{01} = .08$ (indicating strong evidence for H_1) and $p = .03$, Cohen's $d = 0.49$, $BF_{01} = .3$ (indicating moderate evidence for H_1); position 8: $p = .02$, Cohen's $d = 0.55$, $BF_{01} = .16$ (indicating moderate evidence for H_1) and $p = .03$, Cohen's $d = 0.51$, $BF_{01} = .24$ (indicating moderate evidence for H_1)) but no significant difference was observed between the quiet and nondeviant conditions (position 7: $p = .28$; position 8: $p = 1$). To conclude reporting of the pairwise comparisons, we found that there was no significant difference in free recall performance between any of the sound conditions at position 9 (deviant-quiet, $p = .38$, Cohen's $d = 0.29$, $BF_{01} = 2.26$ (indicating anecdotal evidence for H_0), nondeviant-quiet, $p = .39$, Cohen's $d = 0.29$, $BF_{01} = 2.26$ (indicating anecdotal evidence for H_0), and deviant-nondeviant, $p = .99$, Cohen's $d = 0.01$, $BF_{01} = 7.06$ (indicating moderate evidence for H_0)).

Seriation and Categorization

For all participants, we calculated both seriation and categorization indices to explore the strategies that participants employed when recalling the word lists. We followed Perham et al.'s (2007) calculations which allowed a more sensitive measure of seriation, compared to the strict serial recall criteria of only counting an item as being correct if both identity and position were correct. Both our indices were calculated from successive pairs of items. For seriation, a point was awarded whenever any pair of items were in the correct presentation order. So, for example, if the TBR list contained "stone, cold, crazy" and the participant recalled "stone, cold, crazy" then they would receive two points as each successive pair, "stone, cold" and "cold, crazy," were in presentation order. The total seriation score was divided by the maximum number of points possible for the total number of words recalled obtaining a percentage of seriation adopted which could be compared to the percentage of categorization adopted – one point for two words, two points for three words, three points for four words, up to eight points for nine words recalled.

For categorization, a point was only awarded for each pair of correctly recalled words that belonged to that same category, words belonging to the same category separated by a word from a different category did not receive a point. As this list comprised three words from three categories, if one word was recalled then zero points were awarded, if two words were recalled then one point could (if both belonged to the same category) be awarded, for three or four words recalled two points could be awarded (e.g., "red, green, blue" would still produce the same score as "red, blue, green, table" as the fourth word does not form part of a pair of words – "red, blue" or "blue, green" – from the same category), for five words recalled three points could be awarded, for six or seven words four points could be awarded, for eight words recalled five points could be awarded, and for nine words recalled six points could be awarded. Again, as with the seriation index, a proportion of categorization was calculated by dividing the score by the maximum number of points possible for the total number of words recalled – from one to a maximum of six points.

Figure 2 shows that categorization, as a recall strategy, tended to be adopted more than seriation for all three sound conditions. Further, for both indices, the meaning of the TBI items affected categorization, hence categorization was more pronounced in the quiet condition compared to the other two sound conditions, which were about equal. Overall, correct recall in the deviant and nondeviant sound conditions was lower compared to quiet for the seriation than for the categorization index.

A two-way within ANOVA was conducted with sound and index as the within variables which revealed both significant main effects of index, $F(1, 29) = 94.57$, $MSE = 219.67$, $p < .001$, $\eta_p^2 = .77$, and sound, $F(2, 58) = 15.23$, $MSE = 188.5$, $p < .001$, $\eta_p^2 = .34$, as well as a significant interaction between index and sound, $F(2, 58) = 3.16$,

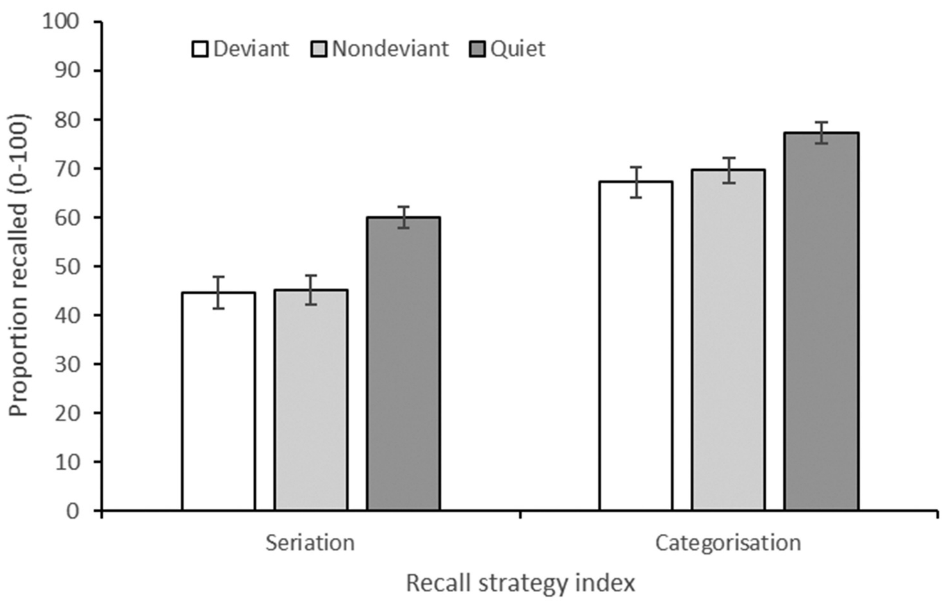

Figure 2. Mean and standard error of seriation and categorization recall strategy across sound condition.

MSE = 64.92, p = .05, η_p^2 = .1. Pairwise comparisons showed that for each sound condition, categorization was observed significantly more than seriation, (all p < .001; deviant, Cohen's d = 1.42, BF_{01} = 0 (indicating extreme evidence for H_1), nondeviant, Cohen's d = 1.63, BF_{01} = 0 (indicating extreme evidence for H_1), and quiet, Cohen's d = 1.18, BF_{01} = 0 (indicating extreme evidence for H_1).

For the seriation index, seriation was observed significantly more in the quiet compared to the two the deviant and nondeviant conditions, respectively (both p < .001; Cohen's d = 0.84, BF_{01} = 0 (indicating extreme evidence for H_1) and Cohen's d = 0.88, BF_{01} = 0 (indicating extreme evidence for H_1)) with no significant difference between the latter two (p = .99, Cohen's d = 0.03, BF_{01} = 6.99 (indicating moderate evidence for H_0)) which is consistent with previous findings demonstrating that irrelevant sound impairs seriation in free recall (Beaman & Jones, 1997). For the categorization index, categorization was observed significantly more in the quiet condition compared to the other two conditions – quiet-deviant, (p < .01, Cohen's d = 0.61, BF_{01} = .08 (indicating strong evidence for H_1)) and quiet-nondeviant (p = .01, Cohen's d = 0.56, BF_{01} = .13 (indicating moderate evidence for H_1)) – with no significant difference between the deviant and nondeviant conditions (p = .94, Cohen's d = 0.19, BF_{01} = 4.27 (indicating moderate evidence for H_0)). This pattern is consistent with several studies demonstrating that to-be -ignored semantic information impairs the categorization process due to a semantic interference-by-process (e.g., Marsh et al., 2009, 2014).

Habituation

We explored whether participants were able to habituate to the deviant sounds across trials via two analyses. The first, simple regression, was conducted with trial number (1 to 10) as the predictor variable and free recall performance as the criterion variable. It revealed that trial did not significantly predict free recall performance, $F(1, 8)$ = 0.95, *MSE* = .06, p = .95. Further, R^2 showed that only 11% of the variance within the data was explained by the data. Using the slope (−.026), standard error of the slope (.027), degrees of freedom (8), and a p-value of .05, suggested that the slope of the regression line was equal to zero. However, the small number of data points (10 trials) meant that this analysis was statistically underpowered.

A second analysis explored mean recall performance across the list via one-way within ANOVAs with trials grouped into three groups of trials – 1^{st} to 3^{rd}, 4^{th} to 7^{th}, 8^{th} to 10^{th}. Free recall performance was around 40% across all three groups of trials (trials 1–3: M = 3.98, SD = .68; trials 4–7: M = 3.93, SD = .78; trials 8–10: M = 3.93, SD = .7). The ANOVA revealed a non-significant effect of trial on recall performance, $F(2, 58)$ = 0.18, *MSE* = .14, p = .84, η_p^2 = .01.

Recognition Task

To undercover how well participants recognized items in the background sound and how this was related to their recall performance, a recognition test was given after the study. This included all items presented in the background sound (10 per position) as well previously unpresented words that were either related (N = 10) or unrelated (N = 10) to the deviant items. Figure 3 shows that recognition of irrelevant items was generally better

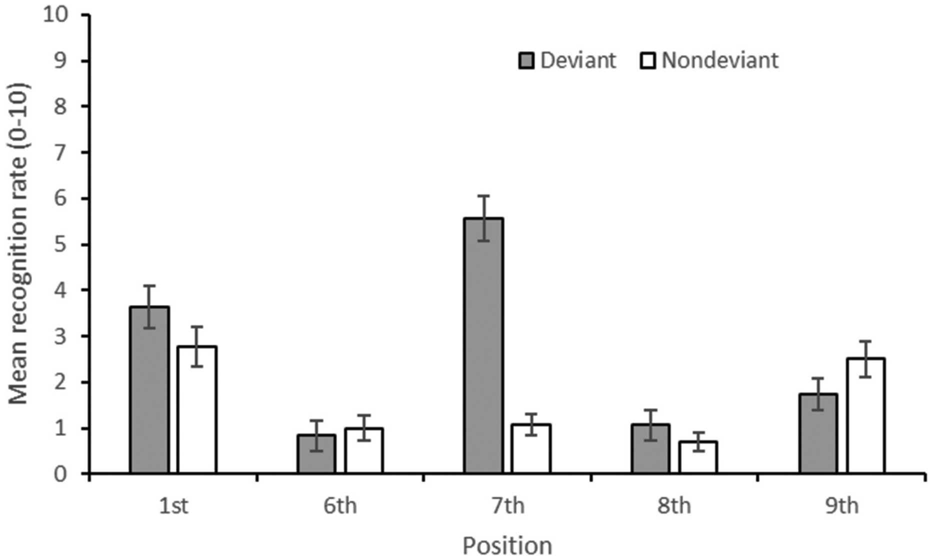

Figure 3. Mean and standard error of recognition of irrelevant sound items by position.

at the start and end of the series. However, the one exception to this was recognition of the 7th item (where the deviant occurred) which was almost double the value of the nearest recognition rate on position 1 in the deviant condition. More specifically, recognition for the first, seventh, and eighth position items was greater for words in the deviant, compared to the nondeviant, condition. Conversely, recognition for the sixth and ninth position items was greater for the nondeviant, compared to the deviant, condition. Importantly, the biggest difference between the deviant and nondeviant sound conditions occurred at position seven with recognition of this word being over five times greater in the deviant, compared to the nondeviant, condition. Regarding recognition of unpresented words (see means in analysis below), this was greater for related than unrelated words with a recognition rate in the related condition similar to that observed with words in the sixth and ninth positions – around 1.

A two-way within ANOVA was conducted on recognition rates with position and sound as the within variables. Mauchly's test revealed that the assumption of sphericity was violated for position, $\chi^2(9) = 17.98$, $p = .04$ and sound by position interaction, $\chi^2(9) = 29.12$, $p < .001$; therefore, Greenhouse-Geisser corrected tests are reported ($\varepsilon = .8$). The ANOVA showed significant main effects of both sound, $F(1, 29) = 26.21$, $MSE = 2.64$, $p < .001$, $\eta_p^2 = .48$, and position on recognition, $F(3.106, 90.087) = 34.06$, $MSE = 3.16$, $p < .001$, $\eta_p^2 = .54$, as well as a significant interaction between sound and position on recognition, $F(2.62, 76.06) = 37.81$, $MSE = 2.6$, $p < .001$, $\eta_p^2 = .57$. Pairwise comparisons (effect sizes and Bayes' factors reported for comparisons exploring recognition of words before, during, and after presentation of the deviant word – positions 6, 7, and 8) showed that recognition was significantly better in the deviant, compared to the nondeviant, condition on positions 1 and 7 (position 1, $p = .04$; position 7, $p < .001$, Cohen's $d = 1.63$, $BF_{01} = 0$ (indicating extreme evidence for H_1)). This significant pattern was reversed for position 9 ($p = .006$). Within the deviant condition, recognition was significantly greater at position 7 than all other positions ($p < .001$ – position 6, Cohen's $d = 1.67$, $BF_{01} = 0$ (indicating extreme evidence for H_1), and position 8, Cohen's $d = 1.57$, $BF_{01} = 0$ (indicating extreme evidence for H_1)) and recognition was significantly greater at position 1 than positions 8 and 9 ($p < .001$). In the nondeviant condition, recognition for items in position 1 was significantly greater than those at positions 6, 7, and 8 (position 6, $p = .001$; position 7, $p = .002$; position 8, $p < .001$) and recognition at position 9 was significantly greater than at positions 6 and 8 (position 6, $p < .001$; position 7, $p = .003$; position 8, $p < .001$). No other significant differences were observed.

Recognition of the two sets of unpresented words – words that were either related or unrelated to the deviant words – were analyzed by way of a paired t-test. It revealed that (false) recognition of the related words ($M = .9$, $SD = 1.1$) was significantly greater than recognition of the unrelated words ($M = .2$, $SD = .9$), $t(29) = 3.55$, $p < .001$, Cohen's $d = 0.65$, $BF_{01} = .04$ (indicating strong evidence for H_1).

Correlations

If participants' attention had been captured by the deviant items, thus producing greater recognition for those items, then one might expect those participants who showed this greater recognition to have poorer free recall for the TBR words presented at that time. Presented below are the scatterplots depicting the relationship between recall of list items at positions 7 and 8 with recognition of irrelevant items at positions 7 and 8 across both deviant and nondeviant sound conditions. Figures 4 and 5 showed this relationship for positions 7 and 8, respectively, in the deviant condition and suggest non-significant but slight negative associations, $r = -.19$, $p = .32$ (Cohen's $d = 1.9$, $BF_{01} = 0$, indicating extreme evidence for H_1) and $r = -.13$, $p = .49$ (Cohen's $d = 0.29$, $BF_{01} = 2.17$ (indicating anecdotal evidence for H_0). Figures 6 and 7 showed that there is a non-significant

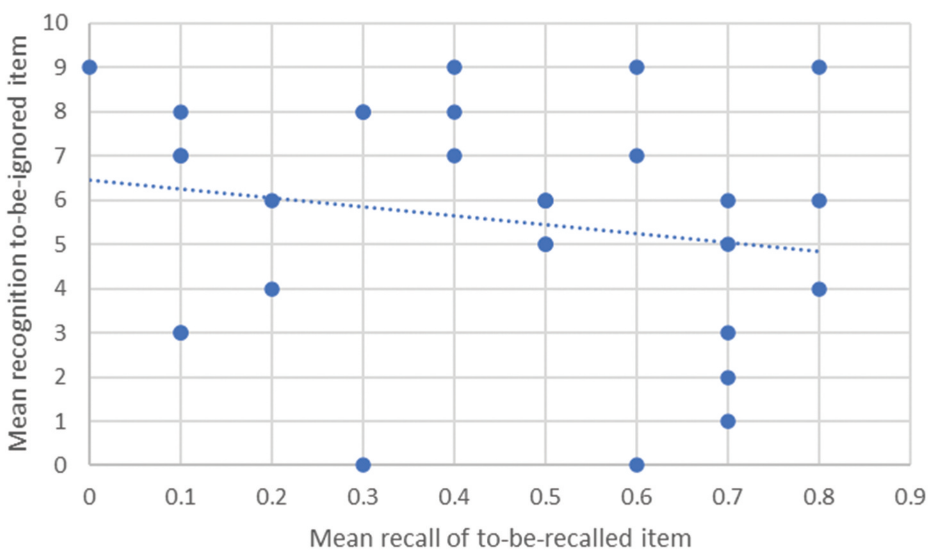

Figure 4. Relationship between recall and recognition of 7th to-be-recalled item in the deviant sound condition.

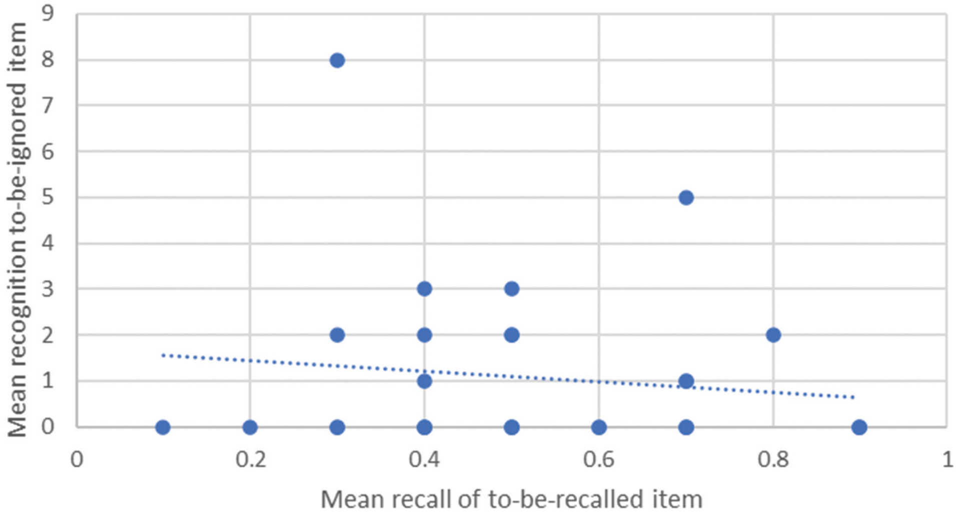

Figure 5. Relationship between recall and recognition of 8th to-be-recalled item in the deviant sound condition.

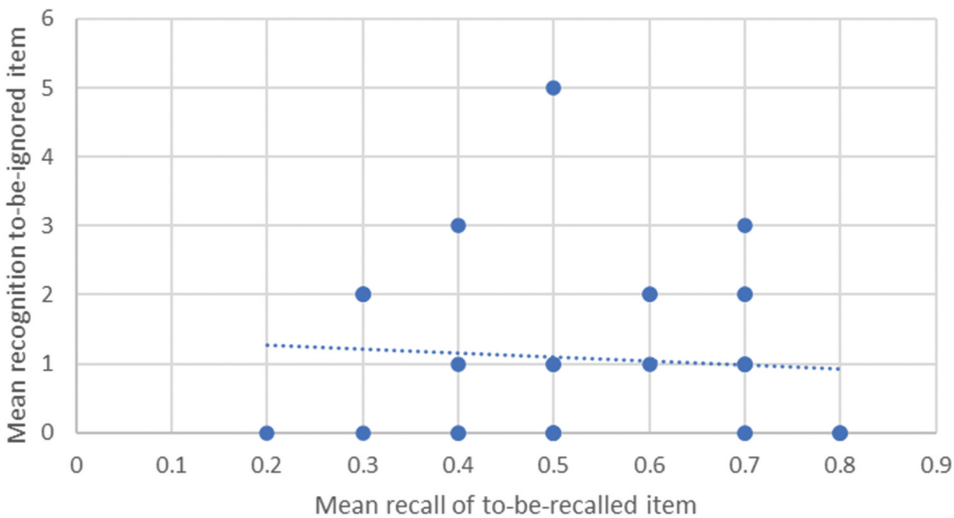

Figure 6. Relationship between recall and recognition of 7th to-be-recalled item in the nondeviant sound condition.

relationship between recall and recognition for the nondeviant condition at positions 7 and 8, $r = -.08$, $p = .68$ (Cohen's $d = 0.42$, $BF_{01} = 0.69$, indicating anecdotal evidence for H_1) and $r = -.02$, $p = .92$ (Cohen's $d = 0.05$, $BF_{01} = 6.82$, indicating moderate evidence for H_0). In conducting correlation analyses between the recall and recognition scores, it should be noted that for position 7 in the deviant condition there were 28 participants who recognized at least one irrelevant sound. For the other conditions, this was a lot less – in position 8 in the deviant condition there were 12 participants, in position 7 of the nondeviant condition there were 17 participants, and in position 8 of the nondeviant

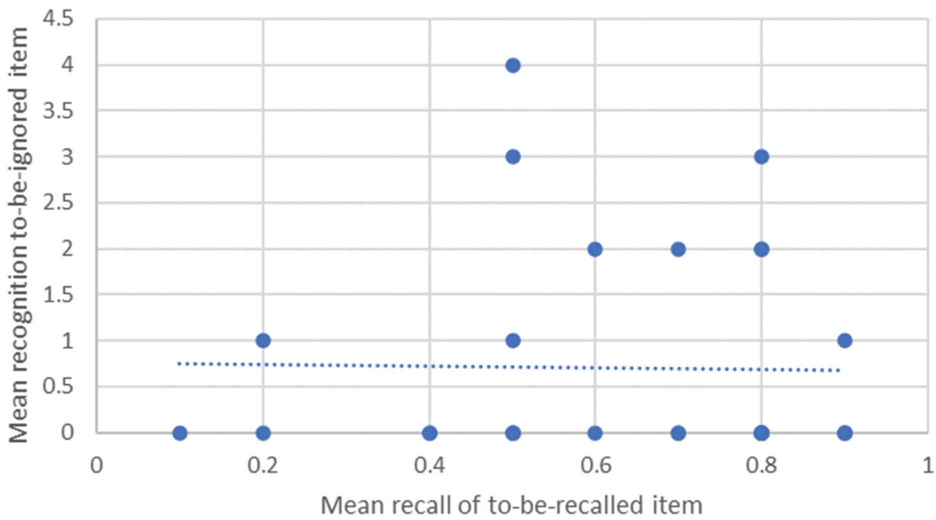

Figure 7. Relationship between recall and recognition of 8th to-be-recalled item in the nondeviant sound condition.

condition, there were 10 participants. Therefore, we might place less confidence in the latter three correlations.

To summarize the above analyses, first, free recall of the 7th TBR item (where the deviant occurred) was significantly poorer than in the nondeviant and quiet conditions respectively. Further, this pattern was almost identical for 8th TBR item (where there was no deviant) except that performance was not significantly different between nondeviant and quiet conditions. This suggests that participants' attention was captured specifically by the 7th TBI item and that its negative impact was observed on the recall of the subsequent TBR item. Second, participants used categorization more than seriation recall strategies which is unsurprising given the categorizable nature of the TBR items. Further, both strategies were significantly reduced by the deviant and nondeviant sounds. Third, regression and ANOVA suggested that participants were unable to habituate to the deviant sound across the time course of these trials. Fourth, recognition of the deviant item was significantly greater than that of its counterpart in the nondeviant sound whereas recognition of items either side of it (where they were all nondeviant with respect to the words in their sound) showed no difference. Further, false recognition of items semantically-related to the deviants was significantly higher than for items not semantically-related to the deviants. Finally, exploration of the relationship between recall of 7th and 8th TBR item and recognition of the 7th and 8th TBI items respectively in both the deviant and nondeviant sounds, showed a tendency for a negative relationship in the deviant sound, with items being recalled less if they had been ignored, but no such relationship in the nondeviant sound.

Discussion

The current study was a preliminary investigation exploring whether 1) "unattended" categorical auditory deviants impair free recall performance and 2) whether the categorical auditory deviants are better recognized than their nondeviant counterparts in a follow up surprise recognition task. In terms of performance impact, the results replicated recent findings (Labonté et al., 2022; Littlefair et al., 2022; Vachon et al., 2020) demonstrating that the presence of a categorical deviant impairs visual-verbal recall performance. The results also demonstrate that participants had superior recognition memory for categorical deviants as compared to equivalently-positioned nondeviant items. And further, that they had inferior free recall for visual items occurring contemporaneously with the deviant item compared to visual items occurring at the same serial position on nondeviant trials. Assuming explicit recognition of a to-be-ignored auditory stimulus requires attention to be directed to it, this observed superior recognition for categorical-deviant as compared with categorical nondeviant items suggests that the occurrence of the deviant caused participants to shift their attention to the TBI sound. Support for this claim that attention is withdrawn from the focal task and directed to the sound at deviant onset is buttressed by the finding of a reduction in the report of the visual item accompanying the deviant in online free recall. These findings appear to contradict recent findings that suggest the categorical deviation effect is produced via a mechanism other than attentional capture (Labonté et al., 2022; Littlefair et al., 2022; Vachon et al., 2020).

Previous work (Labonté et al., 2022; Littlefair et al., 2022; Vachon et al., 2020) shows that the categorical deviant effect does not behave similarly to the impact of an auditory deviant. For example, Littlefair et al. (2022) demonstrated that the disruption produced by an acoustic deviant diminished during the course of an experimental session, but that produced by a categorical deviant did not. The former finding is consistent with habituation of the orienting response following repeated repetition (Röer et al., 2013) while the lack of habituation in the context of categorical deviants hinted that the effect might not be underpinned by attentional capture. Similarly, Labonté et al. (2022) showed that individual differences in working memory capacity, taken to reflect inter-individual differences in attentional control according to the executive attention view of working memory capacity (Engle, 2002; Kane et al., 2004), showed no relationship with the categorical deviation effect. In contrast, a positive relationship was found between the acoustic deviation effect and individual differences in working memory capacity replicating previous work (Hughes et al., 2013; Marsh et al., 2017; Sörqvist, 2010; but see, Körner et al., 2017). If working memory capacity is involved in suppressing the orienting response (or attentional capture; Sörqvist et al., 2012) and the categorical deviation effect, like the acoustic deviation effect, was underpinned by attentional capture, then it would be expected that both effects would be amenable to top-down cognitive control via working memory capacity. The resistance of the categorical deviation effect to top-down cognitive control suggests that the acoustic and categorical deviation effect rely on different mechanisms for their expression (Labonté et al., 2022; Vachon et al., 2020).

The current study replicates the categorical deviation effect to the extent that it also disrupted behavioral performance on a visual-verbal based cognitive task. However, it also demonstrated explicit recognition of the identity of the deviant. Assuming identification of to-be-ignored material requires attention (Broadbent, 1958; Lachter et al., 2004), this finding suggests that the categorical deviant did produce attentional capture and the increased failure to report the visual item presented at the same time as the deviant suggests a withdrawal of attention from the focal free recall task. Although there was no correlation between the online measure of disruption of free recall performance by categorical deviation, and the subsequent recognition of deviant items these data are likely noisy with the recognition task occurring sometime after the behavioral task. Yet, the failure to observe any reduction of the behavioral disruption to free recall produced by the categorical deviation over the course of the study (i.e., absence of habituation) on the face of it, would appear to favor the notion that, unlike the acoustic deviation effect, it is not underpinned by attentional capture.

How then, can the results of the current study be reconciled with those of foregoing studies (e.g., Labonté et al., 2022; Littlefair et al., 2022; Vachon et al., 2020)? One possibility is that the categorical deviation effect, like the acoustic deviation effect, is indeed attributable to attentional capture and simply evades cognitive control. Such an explanation would naturally account for the absence of habituation (Littlefair et al., 2022; current study) and the failure of variables associated with cognitive control to temper the categorical deviation effect (Labonté et al., 2022; Vachon et al., 2020). The finding that participants had superior recognition of items that had previously been deviants (as compared to position-matched nondeviants) in the current study also seems to gel with intrusion data reported by Vachon et al. (2020). They found that participants frequently introduced the categorical deviant (e.g., the 5 in the sequence f, q, t, l, 5, r, n, h) into their sequence recall when it was taken from the same set as the to-be-remembered sequence (e.g., 2, 6, 3, 9, 4, 7, 1, 8). The explanation for this pattern of intrusion errors, could be the same as that for the superior recognition of deviant items in the current study. In the case of intrusions, it could be that attentional capture by the categorical deviant led to the attentional encoding of that item and its later availability for production, possibly due to source-monitoring error (see, also Marsh et al., 2008, 2015). Further analysis of the data of Vachon et al. (2020), not reported in the published paper, demonstrates that the intrusions of to-be-ignored category deviants are not associated with a reduced likelihood of correct recall of the visual item that occurs at the same time as the deviant, or reduced recall of the list more generally. This appears at odds with the current study whereby recall of the visual item accompanying the deviant was impaired.

It is important to note, however, that early filter views (e.g., Lachter et al., 2004) are based on reviews of empirical evidence which suggest that all studies reporting identification without attention do not adequately control for attentional slippage (either voluntary or involuntarily toward the to-be-ignored items). It therefore remains possible that the explicit recognition of deviants in the current study could be attributable to leakage whereby semantic processing of irrelevant items could take place while attention is focused elsewhere. Vachon et al. (2020) proposed that detection of the categorical deviation may arise from the preattentive extraction of semantic characteristics. In this way, it is possible that some semantic extraction via leakage, rather than attentional capture via slippage, could explain superior recognition of the categorical deviant words. However, the fact that participants did not demonstrate good recognition of nondeviant words that require semantic processing for categorical deviance detection to occur, appears difficult to consolidate within such a view.

Why the categorical deviation effect is resistant to the influence of top-down cognitive control, while the acoustic deviation effect is modulated by such control, remains a key issue. We can only speculate as to why this might be the case. One possibility is that the strength of the internal representations against which incoming representations are compared is different for acoustic against categorical deviations. For the case of acoustic deviations, a neural model based upon the preceding patterns of sounds may be weaker and ephemeral, compared to the semantic representations of incoming sounds that could be supported by long-term memory representations in the form of activation in a relatively long-lasting semantic network. It is possible that the strength or longevity of such internal representations renders the categorical deviation effect invulnerable to the influence of top-down cognitive control relative to the acoustic deviation effect. Further work manipulating the level of activation within streams of words that are weakly- or strongly- semantically related to one another may shed light on this tentative account. Here, a weaker categorical deviant effect more amenable to the influence of top-down cognitive control would be expected for a categorical deviant in the context of a sequence of words that are weakly against strongly related to one another.

Limitations and Further Directions

The current study was a preliminary, single study deploying a modest sample size. As such it generates a plethora of questions about the underpinnings of the categorical deviation effect. Overall, the results of the current study indicate that a categorical deviation produces attentional capture. However, it would be prudent to replicate this finding with a smaller material set to reduce potential associations and priming between to-be-recalled and to-be-ignored words. We recognize that although it is very difficult to remove associations between words and categories, especially when some categories are repeated, a future study should attempt to minimize these associations and repetitions. This could be achieved by reducing the number of trials to avoid such repetition.

If the categorical deviation effect is underpinned by attentional capture (and one that is resistant to cognitive control) then it is possible that the (electro)psychophysiological correlates can be uncovered. For example, an acoustic deviation gives rise to a triumvirate of event-related potentials – the P3a, mismatch negativity (MNN) and re-orienting negativity (RON; Horváth et al., 2008) and psychophysiological responses such as the pupil dilation response (Marois et al., 2018). A task using convergent methodological techniques with a particular attention to the latency of components (e.g., the RON) might help establish whether the categorical deviation produces attentional capture but perhaps with a different temporal course to acoustic deviation.

It is possible that features of the design of the current study generated an empirical setting that increased the likelihood of occurrence of attentional capture that might not ordinarily occur within other paradigms. For example, in the current study semantically rich to-be-remembered material was presented to participants for free recall. It is possible that this activated a task set that exerted some influence on, or sensitized, the processing of the task-irrelevant material that was also semantically rich. If attentional capture is contingent on the congruency (e.g., in terms of semantic properties) between the task set and the distractors (cf. Meade & Fernandes, 2016), then the experimental conditions within the current study contrive a situation in which attentional capture (and thereafter explicit recognition of the deviant event) will arise. Evidence consistent with this suggestion arose from the seriation and categorization indices whereby it was shown that participants tended to adopt a semantic categorization strategy for free recall. Adopting a semantic strategy could lead to the formulation of a task-set that engenders a congruency between the task set and distractors thereby triggering an attention-capture mechanism in a task-contingent fashion (cf. Meade & Fernandes, 2016). Furthermore, the to-be-remembered material, consisting of three items from three different semantic categories blocked by category, may ready the system to detect the categorical switches. The relevance of categorical switches in the to-be-remembered material could therefore, also increase the sensitivity of the cognitive system to detect categorical switches regardless of modality. One way in which the role of category switches in determining the potential role of task-contingent attentional capture in producing disruption could be examined would be to vary list structure. For example, via comparing lists wherein all items are drawn from one semantic category against a categorized list in which three items each from three different categories are blocked in presentation against other lists in which three items from three different categories are presented without no same-category repetitions. If task-contingent attentional capture occurs, then one would predict a greater categorical deviation effect for list types wherein three items from three different categories are organized according to semantic category.

Previous studies of the categorical deviation effect (e.g., Vachon et al., 2020) were designed to guard against task-contingent capture and it would perhaps be apposite to go a step further and replicate the current study by minimizing the relationship between the goal-related and irrelevant materials. If, for example, superior explicit recognition arose for the categorically-deviant item in the context of a visual-verbal serial recall, or visuo-spatial serial recall (c.f. Vachon et al., 2020), then the argument that the categorical deviant effect is underpinned by a task non-contingent attentional capture mechanism would be more persuasive. A further observation worth mentioning here is that the impact of an acoustic deviant in the context of visual-verbal serial recall is not localized to the to-be-recalled items that are temporally proximal to the deviation. In fact, there is propagation and back propagation of errors throughout the list (Hughes et al., 2005). Although not reported by the authors, this pattern was also observed for the impact of categorical deviations (Labonté et al., 2022; Littlefair et al., 2022; Vachon et al., 2020). In contrast, the impact of the categorical deviant in the current study is marked on the correct free recall of the visual item that it is closest in time to (e.g., co-occurring with) the categorical deviation and the visual item that immediately following visual item. In contrast, recall of the visual item that occurred immediately before the categorical deviant was unaffected. Such a result further underscores the need to investigate whether the cognitive underpinnings of the categorical deviation effect reported here, and elsewhere (Labonté et al., 2022; Littlefair et al., 2022; Vachon et al., 2020) are the same, or different.

Previous work compares implicit tasks (e.g., spelling of homophones) with explicit tasks (e.g., recognition of previously irrelevant items). Eich (1984) found priming of non-dominant spellings when word pairs comprising a homophone and an associate of its non-dominant meaning was presented in an unattended channel (see, also Richardson et al., 2022), but no recognition of the homophones. Eich (1984) proposed that explicit recognition requires attentional shifts (attentional encoding) while homophone priming during spelling can occur in the absence of previous awareness of words in the unattended channel (but see, Wood et al., 1997). Future work should compare implicit with explicit mnemonic measures using different focal task paradigms (e.g., controlling for task-contingent processing; Meade & Fernandes, 2016) and categorical deviants to gain further insights into the mechanism(s) underpinning the categorical deviation effect. Further behavioral work could also focus on how the processing of the categorical deviant impacts upon later processing. Richardson et al. (2022) found that these deviants affected performance in a subsequent spelling test, but could they also affect reasoning or decision-making? One possibility would be to include the deviant words in abstract or deontic versions of Wason's selection task to explore whether they were differentially processed and consequently influenced reasoning (Perham & Oaksford, 2005).

It is worth pointing out that some other methodological differences exist between the current study and those in the attentional capture literature, that could also have some impact on our results. To ensure that the deviant trial exerts its maximum impact, some studies ensure that deviant trials are as unexpected as possible in two ways. The first is that they comprise a minority of trials – 13.33% (Hughes et al., 2007; Vachon et al., 2017), 16.67% (Marois et al., 2019), 20% (Li et al., 2013; Parmentier & Hebrero, 2013; Vachon et al., 2020). However, in the current study the deviant trials occurred the same number of times as trials from the other conditions, similar to studies by Hughes et al. (2005), Körner et al. (2017, 2019), Röer et al. (2015), Vachon et al. (2012). Given that all these studies demonstrated deviant effects this casts doubt on the necessity of the deviant trials to occur with such rarity. The second way to promote the unexpectedness of the deviant trials was to present them interspersed with trials from the other conditions so that participants could not predict when they would occur – Hughes et al. (2005, 2007), Körner et al. (2017, 2019), Li et al. (2013), Parmentier and Hebrero (2013), and Vachon et al. (2020). However, in the current study we grouped our trials into blocks such as that all the deviant trials were presented together, as were all the nondeviant trials and quiet trials. Using this method of presentation, participants might often anticipate which type of trial they would be experiencing based on the one that preceded it. Yet the deviant effect was still observed suggesting that even if expectations were created, they did not prevent the disruption due to the deviant. This observation casts doubt on the necessity of the interspersed presentation to obtain a categorical deviant effect. Furthermore, one might consider the finding of a pure within-trial deviation effect in the current paper to be impressive since there are no across-trial deviation effects (e.g., Vachon et al., 2012) that would inflate the size of the effect. The observation of the categorical deviation effect and the absence of any evidence of habituation (cf., Littlefair et al., 2022; current study) may also speak to the notion, entertained here, that categorical deviation effects reflect a mechanism of attentional capture that evades cognitive control. However, it should be noted here that our assumption that blocking trials within which sequences comprise a deviant could affect unexpectedness and scarcity is predicated on the view that the categorical deviation effect is underpinned by attentional capture. The alternative viewpoint is the categorical deviation effect arises from preattentive extraction of semantic information which, arguably, should be uninfluenced by both unexpectedness and scarcity. On this line of reasoning the materialization of performance disruption despite the absence of unexpectedness or scarcity could alternatively be viewed as evidence that the categorical deviation effect is not underpinned by attentional capture. Follow-up empirical work comparing blocked vs. intermixed deviant trials wherein the deviants are acoustic or categorical might be undertaken to further examine whether the theoretical mechanisms underpinning acoustic and categorical deviation effects are different, or the same.

Conclusion

This preliminary study adds to the novel literature on the categorical deviance effect by suggesting the mechanism underpinning the effect is one of attentional capture that may by-pass cognitive control. However, the current study possesses numerous design features that may have increased the tendency for attentional capture to occur. Extending the current design features to arguably more typical paradigms, we suggest future avenues of research that can help adjudicate between attentional capture and non-capture accounts of the categorical deviation effect.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

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Appendix

Categories for to-be-remembered and to-be-ignored trials across all three sound conditions
Quiet condition

Trial number/Category position	First category	Second category	Third category
1 to-be-recalled	Four-legged animal	Clothing	Ship part
2 to-be-recalled	Musical instrument	Occupation	Vegetable
3 to-be-recalled	Insect	Color	Living place
4 to-be-recalled	Car part	Kitchen utensil	Rodent
5 to-be-recalled	Furniture	Building	Flower
6 to-be-recalled	Weapon	Shape	Can manufacturer
7 to-be-recalled	Natural formation	Alcoholic beverage	Fish
8 to-be-recalled	Subject	Transport	Country
9 to-be-recalled	Food flavoring	Precious stone	Mythical creature
10 to-be-recalled	Reading material	Tree	Music genre

Nondeviant sound condition

Trial number/Category position	First category	Second category	Third category
1 to-be-recalled	Carpenter's tool	Fruit	Sport
1 to-be-ignored		Music genre	
2 to-be-recalled	Boat	Bird	Metal
2 to-be-ignored		Body part	
3 to-be-recalled	Shape	Waterway	Clothing
3 to-be-ignored		Natural formation	
4 to-be-recalled	House part	Garden tool	Dance
4 to-be-ignored		Subject	
5 to-be-recalled	Fish	Four-legged animal	Occupation
5 to-be-ignored		Country	
6 to-be-recalled	Insect	Flower	Kitchen utensil
6 to-be-ignored		Transport	
7 to-be-recalled	Living place	Furniture	Military title
7 to-be-ignored		Weather	
8 to-be-recalled	Musical instrument	Vegetable	Color
8 to-be-ignored		Food flavoring	
9 to-be-recalled	Precious stone	Rodent	Car part
9 to-be-ignored		Metal	
10 to-be-recalled	Building	Alcoholic beverage	Tree
10 to-be-ignored		Fabric	

Deviant sound condition

Trial number/Category position	First category	Second category	Third category
1 to-be-recalled	Flower	Metal	Dance
1 to-be-ignored (deviant)		Car manufacturer (Boat)	
2 to-be-recalled	Reading material	Weapon	Mythical creature
2 to-be-ignored (deviant)		Fish (Furniture)	
3 to-be-recalled	Body part	Weather	Transport
3 to-be-ignored (deviant)		Military title (Ship part)	
4 to-be-recalled	Bird	Country	Alcoholic beverage
4 to-be-ignored (deviant)		Vegetable (Clothing)	
5 to-be-recalled	Carpenter's tool	Boat	Waterway
5 to-be-ignored (deviant)		Musical instrument (Car part)	
6 to-be-recalled	Rodent	Living place	Precious stone
6 to-be-ignored (deviant)		Four-legged animal (Kitchen utensil)	
7 to-be-recalled	Garden tool	Music genre	House part
7 to-be-ignored (deviant)		Fruit (Occupation)	
8 to-be-recalled	Ship part	Tree	Fabric
8 to-be-ignored (deviant)		Building (Mythical creature)	

(*Continued*)

Trial number/Category position	First category	Second category	Third category
9 to-be-recalled	Car manufacturer	Food flavoring	Natural formation
9 to-be-ignored (deviant)		Color (Shape)	
10 to-be-recalled	Insect	Sport	Reading material
10 to-be-ignored (deviant)		Weapon (Subject)	

To-be remembered Quiet condition

Trial/ Item	1	2	3	4	5	6	7	8	9
1	Sheep	Dog	Elephant	Socks	Dress	Trousers	Sail	Deck	Starboard
2	Trumpet	Piano	Tambourine	Teacher	Nurse	Policeman	Broccoli	Cabbage	Cucumber
3	Bug	Spider	Worm	White	Yellow	Aqua	Castle	Hotel	Flat
4	Engine	Clutch	Motor	Bowl	Knife	Grater	Rat	Hamster	Raccoon
5	Cabinet	Pillow	Bed	Garage	Factory	Barn	Poppy	Daffodil	Rose
6	Dagger	Cannon	Missile	Rhombus	Polygon	Rectangle	Honda	Subaru	Mazda
7	Cave	Continent	Hill	Champagne	Margarita	Martini	Goldfish	Salmon	Trout
8	Anatomy	Genetics	Astrology	Jet	Subway	Wagon	Japan	India	Australia
9	Sugar	Butter	Mustard	Crystal	Pearl	Gem	Fairy	Dragon	Witch
10	Journal	Article	Newspaper	Oak	Pine	Birch	Metal	Classical	Punk

To-be remembered Nondeviant condition

Trial/ Item	1	2	3	4	5	6	7	8	9
1	Drill	Bolts	Hammer	Mango	Watermelon	Raspberry	Swimming	Polo	Basketball
2	Yacht	Cargo	Rowboat	Eagle	Owl	Robin	Gold	Brass	Copper
3	Cone	Pyramid	Circle	River	Waterfall	Canal	Hat	Jacket	Tie
4	Window	Bathroom	Kitchen	Spade	Bucket	Shovel	Swing	Cha-cha	Rumba
5	Swordfish	Pike	Catfish	Leopard	Fox	Donkey	Doctor	Judge	Dentist
6	Butterfly	Cockroach	Dragonfly	Carnation	Tulip	Marigold	Cup	Oven	Spatula
7	Palace	Tent	Igloo	Rug	Television	Couch	Pilot	Major	Colonel
8	Guitar	Violin	Harp	Tomato	Peppers	Celery	Blue	Green	Red
9	Emerald	Marble	Sapphire	Squirrel	Beaver	Skunk	Wheel	Brakes	Bumper
10	Office	Bank	Warehouse	Beer	Scotch	Whiskey	Magnolia	Maple	Walnut

To- be remembered Deviant condition

Trial/ Item	1	2	3	4	5	6	7	8	9
1	Sunflower	Lily	Daisy	Cobalt	Chrome	Iron	Ballet	Samba	Ballroom
2	Book	Dictionary	Magazine	Gun	Pistol	Grenade	Unicorn	Elf	Mermaid
3	Foot	Stomach	Finger	Flood	Thunder	Sunshine	Helicopter	Train	Bus
4	Hawk	Bluebird	Sparrow	Portugal	Iraq	Spain	Vodka	Brandy	Tequila
5	Screws	Ladder	Tape	Canoe	Dinghy	Tugboat	Pond	Stream	Ocean
6	Chipmunk	Gerbil	Mouse	Bungalow	Cottage	House	Diamond	Topaz	Ruby
7	Fertilizer	Wheelbarrow	Hose	Blues	Hip-hop	Soul	Hallway	Stairs	Basement
8	Mast	Hull	Flag	Evergreen	Willow	Aspen	Polyester	Lace	Wool
9	Toyota	Nissan	Ford	Oregano	Thyme	Vinegar	Volcano	Glacier	Desert
10	Ladybird	Wasp	Fly	Baseball	Running	Hockey	Textbook	Notes	Poem

To-be ignored Nondeviant condition

Trial/ Item	1	2	3	4	5	6	7	8	9
1	Rap	Funk	Gospel	Opera	Dance	Folk	Jazz	Pop	Reggae
2	Leg	Elbow	Brain	Hair	Eye	Ear	Hand	Neck	Mouth
3	Mountain	Island	Crater	Rock	Cliff	Valley	Land	Canyon	Beach
4	Mathematics	Chemistry	Philosophy	Biology	Sociology	Physiology	Zoology	Ecology	Neuros cience
5	America	Sweden	Switzerland	Argentina	Italy	Russia	China	Mexico	Brazil
6	Tractor	Scooter	Plane	Bike	Moped	Van	Jeep	Convertible	Shuttle
7	Clouds	Rain	Cyclone	Tsunami	Snow	Earthquake	Sleet	Blizzard	Typhoon
8	Cinnamon	Paprika	Herbs	Basil	Garlic	Pepper	Curry	Salt	Ginger
9	Aluminum	Sodium	Bronze	Platinum	Lead	Silver	Nickel	Magnesium	Tin
10	Leather	Denim	Suede	Cotton	Silk	Cashmere	Velvet	Satin	Nylon

To-be ignored Deviant condition

Trial/ Item	1	2	3	4	5	6	7	8	9
1	Volkswagen	Audi	Ferrari	Saab	Volvo	Lexus	Sailboat	Porsche	Jaguar
2	Shark	Tuna	Whale	Cod	Dolphin	Halibut	Bed	Piranha	Hearing
3	Sergeant	Chief	Soldier	Airman	Captain	Marshall	Paddle	Officer	Commander
4	Cauliflower	Radish	Potato	Onion	Spinach	Turnip	Underwear	Corn	Carrot
5	Harmonica	Clarinet	Saxophone	Organ	Banjo	Tuba	Radiator	Flute	Drum
6	Tiger	Wolf	Deer	Bear	Lion	Giraffe	Tongs	Zebra	Cheetah
7	Tangerine	Lime	Pear	Kiwi	Plum	Apricot	Scientist	Grape	Cherry
8	Skyscraper	Mall	Restaurant	Museum	Library	Prison	Cyclops	School	Hospital
9	Magenta	Brown	Black	Orange	Grey	Violet	Square	Pink	Indigo
10	Blade	Bomb	Sword	Ax	Rope	Spear	Geography	Bazooka	Tank