Retrieval from Memory: Vulnerable or Inviolable?

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RUNNING HEAD: Retrieval and Distraction

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Abstract

We show that retrieval from semantic memory is vulnerable even to the mere presence of speech. Irrelevant speech impairs semantic fluency—namely lexical retrieval cued by a semantic category name—more than meaningless speech (reversed speech or nonwords). Moreover, speech related semantically to the retrieval category is more disruptive than unrelated speech. That phonemic fluency—in which participants are cued with the first letter of words they are to report—was not disrupted by the mere presence of speech, only by speech in a related phonemic category, suggests that distraction is not mediated by executive processing load. The pattern of sensitivity to different properties of sound as a function of the type of retrieval cue is in line with an interference-by-process approach to auditory distraction.

Keywords: Auditory Distraction, Lexical Retrieval, Semantic Fluency, Phonemic Fluency

Lexical retrieval is a fundamental capacity of language that underpins oral and written language production, involving the access and selection of context-appropriate lexical items to express an intended meaning. One of the most frequently-used tests of lexical retrieval is *semantic fluency,* in which a semantic category cue is given (e.g., ‘Animals’) and the task is to retrieve from long-term semantic memory as many examples as possible from that category (Bousfield & Sedgewick, 1944; Newcombe, 1969). We ask whether this process of search by semantic criterion is vulnerable to the presence of concurrent to-be-ignored sound, given that there is a body of work suggesting that retrieval processes generally are largely inviolable to all but the most attentionally-demanding concurrent tasks (Craik, Govoni, Naveh-Benjamin, & N. D. Anderson, 1996). We also attempt to discover how the lexical and semantic status of the sound’s contents determine the degree to which semantic fluency is impaired, with a view to revealing the level of abstraction at which distraction occurs. Phonemic fluency (e.g., Benton, 1968), in which the criterion for production is phonemic, not semantic, is also studied in order to provide baseline conditions that share some processes—including key executive processes—with semantic fluency, but not those related to semantic retrieval. This allows examination of whether semantic auditory distraction has a process-specific effect on semantic retrieval, namely whether it only occurs when the focal task also requires semantic (but not phonemic) retrieval, or whether common (executive) processes are vulnerable.

Fluency tasks have not been used to study auditory distraction and the work reported here is the first of its kind. Their attraction as a research tool for students of distraction is that they are relatively process-pure in terms of retrieval. Evidence collected so far relating to disruption by sound of lexical-semantic processing has used, almost exclusively, list-based tasks, ones that are not to the same degree process-pure as the fluency task. Because they are list-based, performance measured in those studies will reflect elements of encoding and will variously embody several forms of episodic processing (including residues of serial processing, even when recall is nominally 'free' that is undertaken in any order; cf. Beaman & Jones, 1998), as well as elements of source monitoring and so forth (Marsh, Hughes, & Jones, 2008). The absence of serial order processing in fluency tasks is of particular analytic significance. A good deal is already known about auditory distraction and serial recall: typically, disruption in serial recall is related to the physical properties of the sound, particularly those properties that encode the order information in the sound (see Jones, Hughes, & Macken, 2010). Interest in this paper centers on those properties of distraction peculiar to retrieval, which theory suggests should be qualitatively different from those of serial recall. Additionally, verbal fluency affords an opportunity to examine the impact of irrelevant sound on lexical retrieval in a setting in which the episodic component is low (but not absent entirely; see Graesser & Mandler, 1978) and because there is no list to encode, the source-monitoring element is minimal.

The study reported here is part of a series whose goal is to describe a generic mechanism of distraction at a level of description that transcends a diverse range of focal cognitive activities. Thus far, results from this work suggest an *interference-by-process* account of auditory distraction. On this account, disruption of cognitive performance by irrelevant sound is the product of the extent to which the obligatory (passive) processing of the sound and the active processing of the focal task (e.g., Jones & Tremblay, 2000) call on similar processes. So, the serial processing that dominates serial recall is disrupted by the degree to which the sound embodies cues to order in the form of physical (acoustic) change. Essentially, these cues compete for action: maintaining the order of the to-be-remembered competes for hegemony over the preattentive processing of auditory order cues (Hughes & Jones, 2003a, b, 2005;

Jones & Macken 1993; Jones & Tremblay, 2000). In semantic free recall, this process of competition is countered by inhibition of the irrelevant events (Marsh, Beaman, Hughes & Jones, 2011). Different focal tasks will result in different patterns of disruption such that where semantic processing dominates, those semantic (not acoustic) features of the sound will now play a dominant role in disruption. Nevertheless, the pattern of disruption follows from the same general principle, namely disruption by similarity of process. Tasks measuring list memory in which semantic-based processing predominates are susceptible specifically to semantic properties of sound (Marsh et al., 2008, 2009).

Although semantic memory tasks are susceptible to distraction by semantically-rich sound, a specific effect on semantic retrieval processes has yet to be established. The interference-by-process framework suggests that there should be one, but other work suggests the contrary. One body of research suggests that lexical retrieval, far from being vulnerable to the mere presence of sound, may be inviolable, and only show disruption when the concurrent task presents a particularly burdensome processing load. A number of studies have noted the inviolability of retrieval in general to disruption by concurrent processing. For instance, in their review, Craik et al. (1996) noted that '[divided attention] at retrieval has little or no effect on memory performance' (p. 159, see also Naveh-Benjamin, Craik, Guez, & Dori, 1998; Naveh-Benjamin & Guez, 2000). Specifically in relation to verbal fluency, the available evidence suggests that the secondary activity needs to be particularly attention demanding—involving high executive load—before it disrupts retrieval. For instance, concurrent suppression (vocalization of a digit sequence) and concurrent memory load (serial retention of a digit sequence), significantly impair fluency, the effects of the latter task being particularly marked (Baddeley, Lewis, Eldridge, & Thomson, 1984; but see also Azuma, 2004; Rosen & Engle, 1997;

Troyer, Moscovitch & Winocur, 1997; Moscovitch, 1994). However, to date no study has shown fluency to be vulnerable to passively-processed concurrent material such as to-be-ignored sound.

The inviolability of retrieval is further suggested by work on auditory distraction, albeit in settings different from semantic fluency. The typically strong effects of irrelevant sound on serial recall do not apply to the retrieval stage of the task. It is possible to break down a typical serial recall task involving, say, the recall of seven consonants, into three stages; the irrelevant speech can be confined to each: the encoding stage (during which stimuli are presented), the rehearsal stage (during which items are held by sub-vocal rote rehearsal, pending a retrieval cue) and the retrieval stage (following the retrieval cue during which the list is reproduced). Only the encoding and rehearsal stage are susceptible to the effects of irrelevant sound (Miles, Jones, & Madden, 1991; Macken, Mosdell, & Jones, 1999). This is consistent with the inviolability of retrieval to passive concurrent processing. As we mentioned before, serial recall is vulnerable to auditory distraction through the impairment of rehearsal, not retrieval. However, it is logically possible that retrieval from semantic memory is vulnerable to auditory distraction particularly through the action of semantic similarity.

The particular vulnerability of fluency to executive-based secondary activities is explained usually by appealing to the fact that fluency itself also involves numerous executive processes: self-monitoring to prevent repetition, suppression of responses previously retrieved and the generation of cues to access new names (Baldo, Schwartz, Wilkins, & Dronkers, 2006; Rosen & Engle, 1997; Troyer, Moscovitch, Winocur, Alexander, & Stuss, 1998). For example, reduced working memory capacity (for ‘controlled attentional’ processes) due to a demanding dual task has been implicated in the impairment of fluency (Rosen & Engle, 1997). Moreover, the pattern of impairment of fluency due to divided attention has been likened to frontal lobe dysfunction which is associated with deficits in executive control (Troyer et al., 1997).

However, fluency also involves a passive, automatic, process of activation spreading from the cued category name (and generated responses; Rosen & Engle, 1997). So, from the standpoint of the ‘interference-by-process’ framework it is also not unreasonable to expect the concurrent passive processing of irrelevant sound to have a marked effect on this automatic aspect of retrieval. Given the lack of precedent of the effects of concurrent auditory stimuli, we begin the exploration of this issue by asking whether lexical retrieval within semantic fluency is vulnerable to the passive processing of the lexical-semantic properties of irrelevant sound, but not its acoustic properties, as our ‘interference-by-process’ framework suggests: Given the minimal involvement of an episodic/ordering component in fluency tasks, the acoustic properties of sound—operationalized by the mere presence of meaningless sound—should, unlike in serial recall, be ineffectual in this setting. Our framework suggests that semantic properties of speech, however, seem likely to have the capacity to disrupt fluency: In the context of semantic fluency, the spreading activation that supports lexical retrieval (e.g., Collins & Loftus, 1975) may be disrupted appreciably by activation of task-irrelevant nodes that then contaminate retrieval. We will return, at length, to the notion of automatic activation of semantic networks by speech in passive listening, as a mechanism for disrupting semantic fluency.

Alternative views of the mechanism of auditory distraction invoke quite different sets of constructs. The interference-by-process perspective contrasts sharply with a view of distraction that invokes generalized attentional capacity as a construct, specifically the idea that passive processing of irrelevant sound can reduce the level of resource available for any attentionally-demanding focal task, and in particular for any controlled, executive, process which as a class are very attention-demanding (e.g., Buchner, Rothermund, Wentura, & Mehl, 2004; Cowan, 1995; Elliott, 2002; see also Neath, 2000). This suggests that it is the executive component of retrieval that is the most vulnerable, simply because it is the most attention demanding: Any additional consumption of capacity from concurrent activity may exceed readily the total available capacity. From this standpoint, the particular type of processing—either of the sound or the focal task—is immaterial. Accordingly, in this alternative view, it should be possible to observe distraction effects on non-semantic retrieval tasks, and non-semantic to-be-ignored stimuli could have distracting effects in semantic focal tasks (Buchner et al., 2004; Buchner & Erdfelder, 2005; Cowan, 1995).

Later in the series we will be addressing this issue of the specificity of distraction effects on semantic processing—and in turn whether more general features of retrieval, such as the size of the processing load it presents, or the degree to which it engages executive processes—by contrasting semantic retrieval with phonemic retrieval. In phonemic retrieval tasks, the retrieval cue is based on phonemic features—requiring the participant to recall all words beginning with, say, ‘f’—so that the set produced is lexically similar but semantically diverse. This will prove to be a critical contrast that helps us refine our characterization of semantic auditory distraction.

Experiment 1

We begin our exploration of the impact of passive processing of sound on retrieval by examining whether semantic fluency is impaired by semantic but not non-semantic sound. From the interference-by-process standpoint (Marsh et al., 2008, 2009), the obligatory passive processing of to-be-ignored meaningful speech (forward speech), but not meaningless speech (reversed speech), should impair the semantic processing underlying the fluency task. Alternatively, according to the executive-load view (Buchner et al., 2004; Buchner & Erdfelder, 2005; Cowan, 1995), both meaningful and meaningless speech should impair fluency because any concurrent sound processing should reduce executive resources needed for the focal task. Based on the idea that only other executive processes (such as those involved in the performance of a demanding secondary task) disrupt the executive component of semantic retrieval, there should be no disruption at all, on the reasonable assumption that speech is passively processed and does not entail an executive component.

Method

Participants

Thirty-six undergraduate students at Cardiff University, all reporting normal or corrected-to-normal vision and normal hearing, participated in the experiment in return for course credit. All were native English speakers.

Apparatus and Materials

To-be-generated material. Eighteen category names (e.g., “Four-legged Animals”) were selected from the Van Overschelde, Rawson, and Dunlosky (2004) norms.

Irrelevant Sound. Irrelevant sounds comprised the 10 most dominant responses to the “Vegetables” category-name taken from the Van Overschelde et al. (2004) norms (see Appendix 1). Exemplars were recorded in a male voice sampled with a 16-bit resolution at a rate of 44.1kHz using *SoundForge 5* software (Sonic Inc., Madison, WI, 2000). Each exemplar was digitally edited to 500 ms using the sound compression function of *SoundForge 5* (Sonic Inc., Madison, WI, 2000). Irrelevant sequences were created using 12 random orders of the 10 exemplars and selecting these in pseudo-random fashion ensuring that there were no adjacent repeats of a given irrelevant exemplar. This meaningful irrelevant sequence was reversed using the ‘reverse’ function in *SoundForge 5* (Sonic Inc., Madison, WI, 2000) to create meaningless speech (reversing speech tokens reorganizes phonetic properties that usually enable lexical access and therefore semantic processing; Sheffert, Pisoni, Fellowes, & Remez, 2002).

Design

A within-participant design was used with one factor, ‘Sound Condition’, incorporating three levels: meaningful sound, meaningless sound, and quiet. The category-names and irrelevant sounds were counterbalanced between participants such that each category name and sound appeared equally often together as they did apart. There were three trials, one for each sound condition.

Procedure

Each participant was seated in an individual cubicle, seated at a viewing distance of approximately 60 cm from a PC monitor on which category-names were displayed in a central position. Category-names appeared in lower-case black 72-point *Times New Roman* font against a white background. Each category-name appeared for 2 min. Generation was immediate following the onset of the category-name.

Participants were informed that three category names would be presented one at a time on the computer monitor and that they were to generate as many words as possible, writing them down on the response sheets provided. One practice trial was presented before the experimental trials (in quiet); participants were told that they would have 2 min to generate as many words as they could and that after this time a tone would sound to signal the onset of the next list (some 5 s following the tone). Participants were asked to ignore any sound heard through the headphones and that they would not be tested on its content at any point in the experiment.

Results and Discussion

Summary results for each experiment are given in Table 1. Fluency performance was assessed in terms of the total number of exemplars generated (discounting inappropriate responses and repeats). Least Significant Difference (LSD) test was used to determine pairwise differences significant at the $p < .05$ level. Fluency diminished more in the meaningful speech condition ($M = 12.19$, $SE = .78$) than in the meaningless speech condition ($M = 14.81$, $SE = 1.09$) or the quiet condition ($M = 14.92$, $SE = .98$). An ANOVA confirmed a main effect of Sound Condition, $F(2, 70) = 4.01$, $MSE = 21.29$, $p < .05$, $r = .23$, with post hoc testing revealing a significant difference between quiet and meaningful speech ($p < .05$, $CI_{.95} = -.43, 5.01$), and between meaningless and meaningful speech ($p < .05$, $CI_{.95} = .16, 5.06$), but not between quiet and meaningless speech ($p > .05$, $CI_{.95} = -1.73, 1.95$). Thus, reversed speech failed to produce disruption relative to quiet indicating that, unlike in serial recall where reversed speech does produce appreciable disruption (e.g., Jones et al., 1990), irrelevant sound produces on effect on semantic fluency. Disruption to semantic retrieval results from the presence of meaning in the sound.

The outcome of Experiment 1 can be explained by supposing that the obligatory processing of meaning within task-irrelevant sound impairs semantic fluency: Meaningful speech had a significant disruptive impact on the total number of exemplars generated even though the speech was to be ignored. Thus, in sharp contrast to previous work, retrieval is vulnerable to concurrent stimuli that do not require deliberate processing and active manipulation.

It might be argued that the use of reversed speech as a comparison with normal speech is, at some levels, questionable. In the particular case of reversed speech, we can only regard this condition as providing a control for an effect of variable auditory input and strictly speaking it is only an approximate control for spectro-temporal characteristics of speech, lacking as it does legitimate phonetic and syllabic structure. In Experiment 2, therefore, we used non-words as a comparison to meaningful speech and quiet. Certainly, the use of non-words can also prove problematic inasmuch as sub-lexical segments could potentially prime semantic representations, thus diminishing the strength of the contrast. Nevertheless, it seems important to address the shortcomings of reversed speech so that the effects of meaning can be established unequivocally.

Experiment 2

Experiment 2 addressed the possibility that the reversed speech condition in Experiment 1 failed to produce disruption because it differed from the forward speech condition on levels other than just meaning. In Experiment 2 nonwords were constructed using words as a basis (Wallace, Shaffer, Amberg, & Silvers, 2001) in order to more closely match the meaningful (word) and meaningless (nonword) speech conditions on phonetic and syllabic dimensions. Consonant with the predictions of Experiment 1, on the interference-by-process account (Marsh et al., 2008, 2009), meaningful, but not meaningless, speech should impair semantic fluency. In contrast, the executive-load view (Buchner et al., 2004; Buchner & Erdfelder, 2005; Cowan, 1995) predicts that both words and nonwords will be disruptive whilst the general view that retrieval is inviolable to passive concurrent processing (Craik et al., 1996) again predicts no disruptive effects.

Method

Participants

Seventy-two undergraduates from Cardiff University participated for course credit. Each reported normal hearing and normal or corrected-to-normal vision and was a native English speaker. The participants were randomly divided into two 36-participant groups.

Apparatus and Materials

To-be-generated material. Thirty-six category-names were selected from the Van Overschelde et al. (2004) norms. Categories chosen had minimal category-exemplar overlap. The presentation of the category-names was determined pseudo-randomly with the constraint that obviously associated categories did not appear consecutively.

Irrelevant Sound. Irrelevant sounds comprised four words chosen from the 1st to the 8th most dominant responses to the thirty-six category-names that served as the basis for item generation. Items were recorded in a male voice sampled with a 16-bit resolution at a rate of 44.1kHz using *SoundForge 5* software (Sonic Inc., Madison, WI, 2000). Each was edited in duration to 500 ms. Irrelevant non-word items were generated by modifying the word items: For any monosyllabic word, one vowel was changed (e.g., “gun” became “gan”) and for di- and poly-syllabic words, two and three vowels were changed, respectively (e.g., “pistol” becomes “pustal”, and “catapult” becomes “cutopalt”; cf. Calvo & Castillo, 1995). When it was not possible to change a vowel, a consonant was altered instead (cf. Martin, Wogalter, & Forlano, 1988, Experiment 5). Nonwords were recorded in the same fashion as word stimuli.

Sequences of exemplars were generated by creating all 24 permutations of 4 exemplars and selecting them in a random fashion until the desired sample duration of 60 s was obtained. This ensured that the number of times each exemplar was presented was evenly distributed throughout the 60 s sample duration. The irrelevant sounds were presented at a rate of 2 words per second and played at 65-70dB(A) via stereo headphones that were worn throughout the experiment.

Design

A mixed design was used with one within-participant factor with two levels: Sound Condition (quiet and sound unrelated to the to-be-generated category) and one between-participants factor: Lexicality (word vs. nonword).

The category-names and irrelevant sounds were each divided into 2 groups of 18. Half the participants from each group received one set of 18 category-names whilst the other half from each group received the remaining set. The 18 category-names were randomly assigned to one of the two irrelevant sound conditions (ensuring that obviously associated categories were not presented adjacently or as to-be-generated and irrelevant sounds in the same trial). To control for order effects, the order of irrelevant sounds within each block was counterbalanced across participants.

When a category-name was coupled to an unrelated sound condition, the sound-sequence was randomly selected from one of the 18 categorically-unrelated sound-sequences that were not represented by any of the 18 category-names for that group.

Results

Summary outcomes for each of the experiments are given in Table 1. In Experiment 2, semantic fluency was diminished in the meaningful speech condition (M = 9.29, SE = .32) more than in the meaningless speech condition (M = 10.36, SE = .35) or the quiet condition (M = 10.58, SE = .30, word group, M = 10.58, SE = .29, nonword group). An ANOVA confirmed a main effect of Sound Condition, $F(1, 70) = 9.29$, MSE = 20.51, $\eta_p^2 = .12$, $p < .05$, r = .34, and a significant interaction between Sound Condition and Lexicality, $F(1, 70) = 4.70$, MSE = 2.21, p = .034, r = .25. Within-group post hoc testing revealed a significant difference between speech and quiet for the word group ($p < .05$, $CI_{.95}$ = .59, 1.99) but not the nonword group (p = .54). Post hoc tests for the between-groups comparison revealed a significant difference between the word and nonword conditions ($p < .05$, $CI_{.95}$ = .10, 2.04) but not between the two and the quiet condition (p = .99).

Discussion

Words but not nonwords reduced the total number of exemplars retrieved. These results also suggest that the impairment produced by sound is not mediated by the processing of irrelevant phonological representations that may, in theory, affect the retrieval of lexical-phonological (lexeme) representations in word production (e.g., Levelt, Roelofs, & Meyer, 1999).

One way to account for the vulnerability of semantic processing within the semantic fluency task to the meaningfulness of irrelevant sound may be found in the competitor inhibition approach (e.g., M. C. Anderson, 2003). Processing a word activates a concept node corresponding to its meaning that in turn leads to spreading activation—through learned associations—to concept nodes representing other semantically-related words that join to form localized networks of semantic associates (J. R. Anderson, 1983; Collins & Loftus, 1975). The presentation or generation of a cue thus activates several items that may compete for retrieval. Just how the process of competition works is a matter of some debate (see below for a more extensive discussion) but for the moment we adopt the idea of selection-through-inhibition as a working hypothesis. Set within this framework, semantic auditory distraction may reflect a side-effect of inhibiting information that broadly fits—and hence is a candidate for retrieval—in the semantic-based processes supporting recall of the task-relevant material (see Marsh et al., 2008, 2009): Inhibition-of-the-irrelevant could impair fluency performance by disturbing the flow of activation of linkages between related items/concepts that is typically thought to underpin such performance (Mayr, 2002). One prediction that flows from this account tested in Experiment 3 is that semantic fluency should show a graded sensitivity to disruption: As the semantic similarity between the distractors and the cued retrieval set increases so should the degree of disruption.

The adoption of inhibition as an attentional control mechanism at retrieval is suggested by studies of auditory distraction using a negative priming paradigm. Procedurally, this involves presenting the stimulus sequence that was ignored on one trial as to-be-remembered material on the immediately following trial. Typically, the re-presented material is less well recalled than control sequences. That this has now been demonstrated in both serial recall (Hughes & Jones, 2003b) and semantic free recall (Marsh et al., 2011) suggests a common mechanism for relatively disparate settings. However, the volume of evidence in favor of inhibition is not yet great enough to rule out other mechanisms of control in semantic retrieval.

Experiment 3

Having established an effect attributable to the meaningfulness of irrelevant sound in Experiments 1 and 2, in Experiment 3 we examine whether the impairment varies as a function of the degree of semantic similarity between the retrieved (or to-be-retrieved) items and the irrelevant sound. In studies using list memory, between-sequence semantic similarity[1] is manipulated most straightforwardly by comparing same versus different semantic category sounds (e.g., Marsh et al., 2008). However, using this method is problematic with semantic fluency. For example, presenting items drawn from the *same* category as to-be-generated items potentially poses a focal-task-engagement problem: Does the participant attend to the speech and withhold recall of those items, listen to the speech and recall its contents, or attempt to ignore it altogether? Instead, therefore, in the semantically-similar condition in the present experiment, the to-be-generated category of items (“Fruit”) and the to-be-ignored category of items (“Vegetables”) belonged to an associated, rather than the same, semantic category. According to the semantic activation view, associated categories such as “Fruit” and “Vegetables” share semantic features and properties (e.g., they can both be round or long; can be cooked, and so on) thus, cross-categorically, “apple” can activate/prime “potato” (cf. McRae & Boisvert, 1998). On the basis of the competitor-inhibition view (M. C. Anderson, 2003), disruption should therefore be particularly great when having to ignore irrelevant items drawn from a category associated to the to-be-generated category-exemplars.

We also examined a more detailed prediction that flows from the competitor-inhibition view: Based on the concept of spreading inhibition within a semantic memory network (e.g., Neumann, Cherau, Hood, & Steinnagel, 1993), the inhibition of dominant exemplars from an associated, but irrelevant, category (e.g., “carrot”) may lead to greater inhibition of the dominant exemplars of the to-be-generated category (e.g., “apple”) because inhibition will spread more readily from “carrot” → “Vegetable” → “Fruit” → “apple” than it will from “carrot” → “Vegetable” → “Fruit” → “raspberry”. This is because the associative link between “Fruit” and “apple” is stronger than that between “Fruit” and the less-dominant exemplar “raspberry” (e.g., McCloskey & Glucksberg, 1978). Thus, in this experiment, as well as examining the total number of exemplars retrieved, we scrutinized the typicality of the responses to examine whether the retrieval of dominant exemplars is particularly affected by exposure to associated speech.

A subsidiary goal of Experiment 3 was to again examine the alternative view that semantic distraction effects in semantic fluency are due to a disturbance of domain-general (i.e., not specifically semantic-based) executive processes rather than semantic activation processes. One such executive process is response-monitoring in order to avoid repetitions (Rosen & Engle, 1997). Thus, an executive account might predict that semantic distraction effects would take the form of an increase in the frequency of repetition. This could not be examined in the context of Experiments 1 and 2 because in each case the number of repetitions was so low as to defy statistical analysis. One possible reason for this was the written output procedure in which participants were able to see their output (and hence able to check easily for repetition). In Experiment 3, therefore, we required vocal output in an attempt to increase the overall likelihood of repetitions.

Method

Participants

Thirty-six undergraduate students at Cardiff University, all reporting normal or corrected-to-normal vision and normal hearing, participated in the experiment in return for course credit. All were native English speakers. None had taken part in Experiments 1 and 2.

Apparatus and Materials

These aspects of the method were the same as Experiment 1 apart from the following: Nine pairs of associated categories (e.g., “Fruits” – “Vegetables”, “Flowers” – “Trees”), and hence category-names were selected from the Van Overschelde et al. (2004) norms (see Appendix 1). Irrelevant sounds comprised the 10 most dominant responses to the 18 category-names taken from the Van Overschelde et al. (2004) norms (see Appendix 1). To verify our choice of ‘associated’ categories we used Latent Semantic Analysis (LSA; Landauer & Dumais, 1997; available: http://lsa.colorado.edu/). LSA was used to compute the similarity in meaning between words within and between categories in order to demonstrate that associated categories comprise items more similar in meaning than non-associated categories. LSA yields a similarity value based on the assumption that words that have similar meaning occur close together in similar contexts in large corpora of text. Similarity in meaning between given words is based upon how far apart words are within semantic space: the closer together they are, the more similar they are in meaning. Similarity scores yielded by LSA are between -1 and +1 and are based on the cosine of the relationship between the two words on 300 dimensions. Using the words chosen as distractors (see Appendix 1), we computed the similarity between all combinations of words both within and between the categories. Appendix 2 shows examples of these comparisons. As shown, the mean pairwise similarity within a category (e.g., Four-Legged Animals; M = .23) is greater than between two associated categories (e.g., Four-Legged Animals *vs*. Birds; M = .14) that is in turn greater than between two non-associated categories (e.g., Four-Legged Animals *vs*. Clothing; *M* = .06). Appendix 3 shows the semantic similarity between all categories used in Experiment 3. On the basis of the mean similarity values obtained from all within and between category comparisons, the mean similarity score for words within the same category was .30 (*SE* = .04), between associated categories it was .16 (*SE* = .02), and between non-associated categories (based on the average similarity between all sixteen 'non-associated' categories for each given category) it was .08 (*SE* = .005). An ANOVA revealed a main effect of Category Comparison (same *vs*. associated *vs*. non-associated), $F(2, 34) = 32.45$, $MSE = .007$, $p < .001$, $r = .70$, and post hoc analyses demonstrated significant differences between all three conditions (same and associated, $CI_{.95}$ = .07, .20; same and non-associated, $CI_{.95}$ = .15, .30; non-associated and associated, $CI_{.95}$ = .06, .12).

Design and Procedure

The procedure was the same as Experiment 1 except that the three levels of the Sound Condition factor were associated-category sound, non-associated-category sound, and quiet. The category-names and irrelevant sounds were counterbalanced between-participants such that each category name and sound appeared equally often as to-be-generated and to-be-ignored and as an associated and non-associated category. Instead of writing responses, participants were informed that they were to generate as many words as possible and speak them aloud. Responses were recorded at a sampling rate of 44.1 kHz using *SoundForge 5* (Sonic Inc., Madison, WI, 2000) software.

Results

Summary outcomes for each of the experiments are given in Table 1.

Exemplars generated

Figure 1 shows that the total number of category-exemplars generated was lower in the associated speech condition (*M* = 12.28, *SE* = 0.64) than in the non-associated speech condition (*M* = 14.25, *SE* =1.06) and lower in both irrelevant sound conditions compared to quiet (*M* = 17.06, *SE* = 1.17). An ANOVA confirmed a main effect of Sound Condition on the total number of exemplars generated, $F(2, 70) = 9.65$, $MSE = 21.51$, $p < .01$, $r = .35$, and post hoc analyses demonstrated significant differences between all three conditions (quiet and non-associated speech, $CI_{.95}$ = 366, 5.25; quiet and associated speech, $CI_{.95}$ = 2.52, 7.04; non-associated speech and associated speech, $CI_{.95}$ = .044, 3.90). Despite the requirement for oral output in this experiment, the number of repeats was still too low for statistical analysis (under 3% of responses) but was numerically comparable between conditions (*M* = .36, *SE* = .12 for Quiet; *M* = .36, *SE* = .11 for non-associated speech and *M* = .33, *SE* = .08 for associated speech). Participants did not produce any of the irrelevant items even in the condition in which they were associated to the to-be-generated category.

Response Dominance/Typicality of Sequences

The typicality of each response was calculated based upon the response frequency/dominance of items within the Van Overschelde et al. (2004) norms. Response frequency/dominance was based on the ‘Total’ measure in the Van Overschelde et al. (2004) norms which is computed by dividing the number of participants giving a particular response by the number of participants who generated any response. Each response was given a rank based on its response frequency within the set of responses for its category. Thus the response ”dog” which was produced by 98% of the participants to the “Four-footed Animals” was given the rank of 1, “cat” which was produced by 97% of participants was given the rank of 2, “horse”, produced by 52% of participants, was given 3 and so on. When two or more items had the same response-frequency (e.g., 23% of participants recalled “deer” and “mouse”) the same rank was given to both items. If a response did not appear in the category-norms it was given a value one greater than the lowest rank.

A typicality index for the entire set of responses given for each participant in each irrelevant sound condition was calculated, first, by taking the ordinal position of each response in the participant's output protocol, dividing it by the response probability ranking of that response from the Van Overschelde et al. (2004) category-norms, and then averaging across all of these values (see Kiang & Kutas, 2006). A low value on this index indicates a response sequence comprising highly typically items whereas higher values indicate the output of responses that are less typical. Thus, the output sequence: "dog, cat, horse, lion, bear, tiger" which, in this order, are the six most popular responses to the "Four-Footed Animals" category-name (and thus ranked by response-probability) will receive the minimum possible value of 1. However, the same sequence recalled in reverse order: "tiger, bear, lion, horse, cat, dog" will achieve the higher value of 1.86 reflecting the fact that the sequence of responses is less typical. Moreover, a sequence: "mouse, pig, rat, giraffe, squirrel, rabbit"—the 10^{th}-15^{th} most frequently produced items—will receive the much higher (i.e., less typical) value of 4.68.

The mean typicality index value for the overall sequence indicated that response sequences were more typical in the quiet condition (M = 1.81, SE = .094) and the non-associated speech condition (M = 1.92, SE = .096) than they were in the associated speech condition (M = 2.34, SE = .127), $F(2, 70) = 9.38$, MSE = .37, $p <$ .001, r = .34, and the subsequent post hoc tests revealed no significant difference between the quiet and non-associated speech condition but did reveal a significant difference between these conditions and the associated speech condition (quiet and non-associated speech, $CI_{.95}$ = -.39, .16; quiet and associated speech, $CI_{.95}$ = -.82, -.23; non-associated speech and associated speech, $CI_{.95}$ = -.72, -.11).

The same pattern of results was also evident for the *first* response produced, with an ANOVA demonstrating a main effect of Sound Condition, $F(2, 70) = 4.62$, $MSE = 16.26$, $p < .05$ $r = .25$. Post hoc tests showed that the first response was more atypical in the associated-speech condition ($M = 5.33$, $SE = .99$) than in either the quiet ($M = 2.89$, $SE = .51$) or the non-associated speech condition ($M = 2.78$, $SE = .48$), which were not different from each other (quiet and non-associated speech, $CI._{95} = -1.41, 1.64$; quiet and associated speech, $CI._{95} = -4.61, -.28$; non-associated speech and associated speech, $CI._{95} = -4.59, -.52$).

Discussion

The results of Experiment 3 demonstrate a between-sequence semantic similarity effect in the context of semantic fluency: Passive exposure to irrelevant items semantically-associated with the retrieval category impaired semantic fluency more than non-associated irrelevant items. Nevertheless, a non-associated irrelevant sequence still impaired semantic fluency significantly compared to quiet as would be expected on the basis of the effects of mere meaningfulness obtained in Experiments 1 and 2.

Between-sequence similarity had a significant disruptive impact on the total number of exemplars generated. The results are consistent with the notion that semantic activation of one concept within a semantic network can render other concepts less accessible and that automatic activation of an irrelevant—but related—concept can prevent the usually automatic retrieval of words once a concept has been discovered (e.g., Gruenewald & Lockhead, 1980; Rosen & Engle, 1997).

Between-sequence semantic similarity also reduced the typicality of the first response as well as the typicality of the response sequence: Semantic similarity impaired retrieval of dominant responses but had little effect on non-dominant responses. This finding is consistent with the view that the semantic distraction effects reflect inhibition applied to prevent the intrusion of irrelevant items. Impairment of the retrieval of dominant responses may reduce semantic fluency in several ways. For example, dominant items tend to be prototypical exemplars of a category and are more strongly connected to their conceptual category than more atypical category-exemplars (Schmidt, 1996). Thus, dominant items tend to be cues for more than one subcategory (e.g., “dog” can cue “Pets” and “Canines”) and may also be capable of bridging subcategories thus facilitating fluent retrieval. Inhibiting the retrieval of dominant category-exemplars makes subcategories containing those items more difficult to sample. This could also produce disruption by impairing the execution of an effective retrieval strategy (Basden & Basden, 1995; Marsh et al., 2009).

We have argued thus far that irrelevant semantic material derives its disruptive power in semantic fluency in Experiments 1-3 through its effect on specifically semantic processing and not on general executive processes. That the sound must have semantic content to disrupt semantic fluency already poses a difficulty for the executive-load account: any concurrent processing, not just processing involving meaningful material, might be expected to usurp executive resources on this account. However, we turn now to test another prediction of the executive-load view, namely, that the sound conditions that disrupted semantic fluency in Experiments 1-3 should retain their disruptive potency even in a non-semantic fluency task, so long as that focal task imposes a high executive load. In contrast, according to the interference-by-process account, the semantic properties of sound should be impotent in the context of a non-semantic focal task (cf. Jones et al., 1990).

Experiment 4

For the remaining experiments we use a phonemic fluency task, that is, one in which words are generated from long-term memory from a letter cue (but not necessarily a phoneme because although “farm” is correct for the letter-cue “f”, “pharmacy” is incorrect; Benton, 1968; Troyer et al., 1997). There is consensus that phonemic fluency is as heavily-weighted on executive processes as the semantic fluency task (if not more so) but is relatively free of semantic processing (Henry, Crawford, & Phillips, 2004). Phonemic fluency shares with semantic fluency many of the executive elements, but one component—the automatic process of activation spreading from the cued category name (Rosen and Engle, 1997, p. 224)—is qualitatively different: The task involves a more algorithmic, instance-based, search process based on abstract or novel rules and is thus not entirely semantic (Azuma, 2004; cf. Schwartz, Baldo, Graves, & Brugger, 2003). Indeed, according to some, phonemic fluency involves the ability to suppress the habit of using words according to their meaning (Perret, 1974). However, both tasks seem to have common executive components: both tasks require “effortful” (self-initiated) retrieval processes, response initiation, shifting mental set (switching between sub-categories; cf. Mayr, 2002), self-monitoring and inhibition of previously made responses, inhibition of irrelevant responses (such as phonemic parallels: responding with “phone” when the cue letter is “f” in phonemic fluency tasks), and organization of verbal retrieval (Glosser & Goodglass, 1990; Grafman, Holyoak, & Boller, 1995; Crawford & Henry, 2005; Milner, 1995).

We capitalize here on the fact that semantic fluency is impaired by the meaningfulness of irrelevant sound (and not just by semantic similarity) to more fully tease apart the semantic interference-by-process and executive load views of the distraction effects found in semantic fluency. On the executive load view, the mere meaningfulness of irrelevant sound should reduce the level of resource available for any controlled executive process regardless of the particular (e.g., semantic-based) processes involved. Thus, if the executive load view is correct, phonemic, like semantic, fluency should be disrupted by meaningful irrelevant stimuli.

At the same time, Experiment 4 provides a test of a third class of explanation for the results of Experiments 1-3, namely compound cue theory (McKoon & Ratcliff, 1992; Ratcliff & McKoon, 1988). This theory supposes that multiple cues are combined to form a compound cue in short-term memory; this then acts as a retrieval cue that is compared against all items in long-term memory via a matching process. The match between a compound cue is faster if it is associated with items in long-term memory: this facilitates retrieval and gives rise to semantic priming (Ratcliff & McKoon, 1994). Assuming that compound cues can act as cue items in long-term memory for verbal fluency, compound cue theory can account for the pattern of the data observed in Experiment 1-3 by assuming that irrelevant items form a compound cue which disrupts the passive search of long-term memory.

Because there exist connections between all (lexical) compound-cues and all items in long-term memory regardless of their semantic association, compound cue theory predicts an effect of mere meaningfulness (cf. Experiments 1 and 2). Moreover, it predicts a larger effect of semantic relatedness (cf. Experiment 3) because there are stronger links between the compound cue and associated items in long-term memory and therefore a greater likelihood of cuing items from a related but wrong category. In other words, when there is semantic association between potential targets and distractors this increases the likelihood that distractors—and items associated to the distractors—will be erroneously cued. However, unlike the semantic interference-by-process view, the compound cue theory also predicts an effect of meaningfulness on phonemic fluency. That is, if irrelevant items form compound cues and these cues are linked via connections with all lexical items in long-term memory, then the theory predicts an effect of mere meaningfulness even in the context of phonemic fluency.

Method

Participants

Thirty-six undergraduate students at Cardiff University, all reporting normal or corrected-to-normal vision and normal hearing, participated in the experiment in return for a small honorarium. All were native English speakers. None had taken part in Experiments 1-3.

Apparatus and Materials

To-be-generated material. The letters “f”, “a”, and “s” were used as letter cues for the phonemic fluency task.

Irrelevant sound. Irrelevant sounds comprised the ten most dominant responses to the “Vegetable” semantic category (see Appendix 1). These were chosen because we have already established that these sounds produce disruption of the semantic fluency task even when presented as non-associated sounds (see Experiment 1), and none of the exemplars began with the same initial letter as any of the letter cues. The irrelevant sound items were reversed to make meaningless irrelevant sound. Again, we have already established in Experiment 1 that reversed (meaningless) speech fails to disrupt semantic fluency compared to quiet. Experiment 2 showed that a similar pattern of findings emerges if non-words are used instead of reversed speech as a control condition.

Design

A within-participant design was used with one factor, ‘Sound Condition’, with three levels: forward speech, reversed speech, and quiet. The order of presentation of letter cues was fixed, with the presentation of irrelevant sound randomized across participants. An equal number of participants (six) were presented with each of the six random orders of the irrelevant sound conditions.

Procedure

The procedure was similar to that of Experiments 1-3 with the exception that participants were required to vocally-generate words in response to the initial letter cues “f”, “a”, and “s”. Participants were informed that three letters would be presented one at a time on the computer monitor and that they were to generate as many words as possible that began with that letter and speak them aloud. They were informed that they could not produce proper names (e.g., “France” or “Fred” for “f”) or variants of the same word (e.g., “ant” and also “ants” for “a”).

Results and Discussion

Summary outcomes for each of the experiments are given in Table 1. The fluency measure was again the total number of exemplars generated. A repeat of a word was only scored if it was made clear by the participant during retrieval that s/he was producing a homonym (e.g., “*sail* as in boat and *sale* as in buying”; see Troyer et al., 1997). The mean number of words generated was 21.47 (*SE* = 0.89) for quiet, 19.22 (*SE* = 0.87) for reversed speech, and 20.08 (*SE* = 1.06) for forward speech. An ANOVA showed that there was no significant effect of Sound Condition on the number of words generated, $F(2, 70) = 1.58$, $MSE = 29.36$, $p = .22$, $r = .15$.

Unlike Experiments 1 and 2, the mere presence of speech, even when meaningful, had no effect on phonemic fluency. This suggests that semantic distraction effects in semantic fluency are unlikely to be due to depletion of a general-purpose executive resource (cf. Buchner & Erdfelder, 2005; Cowan, 1995; Elliott, 2002; see also Neath, 2000). Rather, the effects seem to arise because of the disruption of processes related to the semantic activation of candidate items. Phonemic fluency may be inviolable to semantic distraction despite incidental semantic activation of words (Howard et al., 1992) because the search for subcategories and exemplars in this task is based more on phonological information such as initial letter sounds and spelling rather than on semantic activation (Rohrer, Salmon, Wixted, & Paulsen, 1999; cf. Schwartz et al., 2003).

The fact that phonemic fluency was not susceptible to disruption by meaningful irrelevant sound is also at odds with compound cue theory (Ratcliff & McKoon, 1988): On this approach, the meaningfulness of speech should impair phonemic fluency because compound cues formed by the irrelevant items should link to, and promote, erroneous retrieval of inappropriate responses from long-term memory.

Experiment 5

We have argued that semantic distraction in semantic fluency is the result of the concurrency of two similar (semantic) processes in line with the interference-by-process account of semantic auditory distraction (Marsh et al., 2008). Within this framework, it follows that phonemic fluency may indeed be impaired by irrelevant sound if its processing conflicts with the particular (phonemic) processing involved in that task. In Experiment 5, therefore, we examined whether hearing irrelevant spoken words that have the same initial phoneme as the to-be-generated responses (but which begin with a different letter)—e.g., hearing the phonemic parallels “phone” or “pharmacy” when trying to retrieve words beginning with the letter “f”—does indeed, unlike sound-meaningfulness, impair phonemic fluency. This would follow on the basis that such irrelevant processing would lead to a competition for retrieval given its contextual relevance but response inappropriateness.

This experiment also embodies a test for whether any disruption caused by phonemic parallels arises from their phonemic, rather than lexical, properties, by including a non-word condition. Items presented in the non-word condition shared onset phonemes but not lexical status with to-be-generated words. Any difference between the word and non-word conditions would most likely be attributable to a combination of the phonemic and lexical status of the irrelevant items.

Method

Participants

Ninety-six undergraduate students at Cardiff University, all reporting normal or corrected-to-normal vision and normal hearing, participated in the experiment in return for a small honorarium. All were native English speakers. None had taken part in Experiments 1-4.

Apparatus and Materials

To-be-generated material. The letters “f”, “n”, “r”, and “s” were used as the letter cues.

Irrelevant sound. For the word group, irrelevant sounds comprised 4 sets of 10 words that began with the letters “p”, “k”, “w” and “c”. The words chosen shared the same onset phoneme, but not first letter, with target words (including, for example, “phone” for “f”, “knitting” for “n”, “wrestle” for “r” and “cinema” for “s”). For the non-word group, irrelevant sounds comprised 4 sets of 10 non-words—selected from the Rastle, Harrington, and Coltheart (1992) non-word database—that began with the letters “f”, “n”, “r” and “s” (e.g., “frooped”, “nempt”, “rhergs”). Within each group, the irrelevant sequence was always the same, with the manipulation of relatedness being implemented by changing the target letter cue.

Design

A mixed design was used with one within-participant factor and one between-participants factor. The within-participant factor was ‘Sound Condition’ with two levels: Related and unrelated speech. The between-participants factor was ‘Lexicality’ incorporating two levels: Word or non-word speech. The order of presentation of letter cues and irrelevant items was randomized such that all 48 possible order-combinations were created for both the word and non-word groups.

Procedure

The procedure was similar to Experiment 4 except that one quiet trial—which required the generation of words beginning with the letter “a”—preceded the experimental trials. In contrast to Experiment 4, output was written. There is no principled reason to suppose that this should make a difference to the outcomes.

Results and Discussion

Summary outcomes for each of the experiments are given in Table 1. In Experiment 5, for the word condition, the mean number of words generated was 11.9 (SE = .44) for the unrelated speech condition and 9.6 (SE = .41) for the related speech condition. For the non-word condition, the mean number of words generated was 11.63 (SE = .49) for the unrelated speech condition and 11.75 (SE = .54) for the related speech condition. A 2 (Similarity: similar or dissimilar) × 2 (Lexicality: word or non-word) ANOVA showed a main effect of Similarity, $F(1, 94) = 9.41$, MSE = 5.99, $p < .005$, $r = .3$. There was no between-participants main effect of Lexicality ($p > .05$). However, there was an interaction between Similarity and Lexicality, $F(1, 94) = 11.71$, MSE = 5.99, $p < .005$, $r = .38$. A simple effects analysis (LSD) revealed that there were significant differences between the phonemically similar and dissimilar conditions for the word group ($CI._{95}$ = 1.30, 3.28, $p < .001$), but not for the non-word group ($CI._{95}$ = -1.12, .87, $p > .05$). These results indicate that the phonemic properties of irrelevant items impair phonemic fluency only when they posses lexical status. Irrelevant words that share the same onset phoneme as potential focal task responses are contextually-relevant (to producing words with a given onset phoneme) but, unlike irrelevant nonwords, have an accepted spelling that renders them response-inappropriate.

Experiment 5 demonstrates that phonemic fluency is vulnerable to disruption via a combination of the lexical and phonemic properties of irrelevant sound. Phonemic fluency was impaired if irrelevant items shared onset phonemes with to-be-generated items but only if those irrelevant items had a lexical status: Non-words that shared onset phonemes with to-be-generated items produced no disruption.

In the case of phonemic fluency it seems plausible that the activation of irrelevant items may produce competition for retrieval within a network (or neighborhood) of phonological associates (Luce & Pisoni, 1998). Because these irrelevant items—although beginning with onset phonemes that are appropriate for a response and thus contextually-relevant—are inappropriate responses (due to their incompatible spelling with regard to the retrieval cue), they must be inhibited or edited from the output. The requirement for inhibition in this setting could, just as with semantic fluency, incur a residual cost for the retrieval of response-appropriate information perhaps through spreading inhibition. The associative frequency of particular words to a phonemic or letter category, unlike semantic categories, is unlikely to be as stable across participants (particularly since the fluency task itself requires more of an algorithmic based search process). Moreover, in the absence of any published norms for phonemically-related words and thus their individual dominance given a letter cue we are unable to investigate whether the more dominant responses to a phonemic category or letter cue are more impaired than the less dominant ones as found with semantic fluency in Experiment 3.

To ensure that the null effect of the meaningfulness of irrelevant sound obtained in Experiment 4 and the significant effect of phonemic relatedness in Experiment 5 was not simply a consequence of using different letter sets (“f”, “n” “s” and “f”, “n”, “r” respectively), in a supplementary experiment we replicated Experiment 4 but with the letters “f”, “n”, and “r”. Eighteen participants were tested and vocal responses were required. Again, we found that forward-played (meaningful) speech that comprised dominant category-items (Vegetables) produced no more disruption than the same items reversed and a quiet condition: quiet, $M = 11.72$ ($SE = .80$), reversed speech, $M = 11.78$ ($SE = .67$), forward speech, $M = 11.94$, $SE = .56$). By replicating the stimuli used in Experiment 4, we found no effect of Sound Condition and thus no effect of irrelevant sound meaningfulness, $F(2, 34) = .033$, $MSE = 7.26$, $p > .05$, $r = .03$.

General Discussion

The results of the series suggest that retrieval from memory is impaired by the mere presence of to-be-ignored auditory stimuli that bear an associative relation to to-be-retrieved items. The logic and outcomes of the experiments were as follows. Experiments 1 and 2 established an effect of meaningfulness on semantic fluency, using, respectively, reversed speech and non-words as control conditions. Experiment 3 demonstrated a between-sequence semantic similarity effect. Moreover, based on the typicality of responses, Experiment 3 showed that associated speech induces a deviation from the usual retrieval pattern in semantic fluency whereby the retrieval of high dominance items is impaired. Experiment 4 revealed that for phonemic fluency, the semantic properties of irrelevant sound have no effect. Finally, Experiment 5 showed that phonemic fluency is instead impaired by the phonemic similarity between to-be-ignored and to-be-generated items, although this was true only for lexical items.

Together, these findings lend weight to an idea that has been applied in quite distinctly different contexts—such as verbal serial recall—namely that distraction depends on the joint action of the particular demands of the focal-task and irrelevant stimulus processing (see Jones & Tremblay, 2000; Marsh et al., 2008, 2009). Broadly, they support the ‘similarity of process’ view of auditory distraction (Jones &

Tremblay, 2000): that it is the degree to which obligatory processing of the sound produces outcomes compatible to the output of the focal task. The results do not harmonize well with the idea that concurrent to-be-ignored sound results in an increase in some domain-independent processing load.

The results shed some light on factors that determine the susceptibility of retrieval to disruption from concurrent events. Up to now, memory retrieval generally has been shown to be largely inviolable and only disrupted by other deliberate controlled processing. In contrast, the current experiments show through the study of fluency that retrieval is in fact vulnerable to concurrent passive processing. It is clear that, just as with serial recall, speech undergoes obligatory processing and those features of it that are relevant to the processing of the focal task disrupt the selection of responses: in serial recall this is seriation derived from organizational cues embedded in the sound, in semantic memory it is the semantic content of the sound, while in phonemic fluency, it is the sound's phonological-lexical content.

The present study offers little support for the idea that the action of irrelevant speech on fluency is the result of an increase in executive processing load. Proponents of executive load models of distraction (Buchner et al., 2004; Buchner & Erdfelder, 2005; Cowan, 1995; Elliott, 2002) argue that the semantic properties of the irrelevant sound disrupt through their depletion of a limited executive (or 'attentional') resource that is necessary for the successful completion of the focal task. The key findings of the current series that go against this general executive load account are that: a) the typicality of responses is reduced by semantic similarity; given that retrieval of atypical (or low dominance) items is associated with greater executive control (e.g., Schmidt, 1996), the putative impairment of executive control by semantic distraction may be expected to affect particularly low-dominance exemplar retrieval and not, as was found in Experiment 3, high-dominance exemplar retrieval; and b), more critically, the meaningfulness of irrelevant sound does not impair phonemic fluency. Given the common assumption that fluency involves executive processing, the executive load view suggests that it should be disrupted regardless of whether it involves semantic processing. Accounts based on executive load thus fail to explain why it is that the effects of auditory distraction are so acutely sensitive to the character—not just the degree of difficulty—of the dominant prevailing mental activity (present experiments; Hughes, Vachon, & Jones, 2007; Jones & Macken, 1993; Marsh et al., 2008 a,b).

Retrieval from Semantic Memory

By showing that semantic distraction is related to the lexical status of the content of the sound as well as its associative links with the material to be retrieved, it is also possible to question accounts of distraction that are based on the corruption of representations of to-be-generated items arising from their structural similarity to irrelevant items (e.g., Oberauer & Lange, 2008). A class of explanations involving structured semantic networks seems more appropriate to the results, in which activation from the obligatory processing of irrelevant items spreads within the network to the same part of the semantic space as that occupied by context appropriate responses, leading to competition for retrieval (M. C. Anderson & Bjork, 1994). However, data relating to the typicality of responses (Experiment 3) suggest that this may be an overly simplistic account. Instead, what these results suggests is that the impairment may reflect the cost of inhibiting irrelevant material whose character is broadly compatible with the context-appropriate response, coming close to—but falling short of being—a perfect match for the criteria for production (e.g., M. C. Anderson, 2003; Neumann et al., 1993). In such settings, inhibition of the events that 'nearly fit the bill' spreads more generally, to include legitimate candidates for retrieval as well as those not appropriate. This would explain the interaction of the effect with dominance: nodes relating to to-be-generated exemplars (particularly high-dominance items) could be suppressed as a consequence of inhibiting representations of irrelevant exemplars from the same or similar semantic category thereby impairing their accessibility (M. C. Anderson & Spellman, 1995; Johnson & M. C. Anderson, 2004; Neumann et al., 1993). This idea is an appealing one inasmuch as it chimes nicely with similar mechanisms for distraction in quite dissimilar circumstances, such as serial recall (see Hughes & Jones, 2003b, 2005), list-based retrieval from semantic memory (Marsh et al., 2011) and random number generation (Marsh & Jones, 2011) suggesting a generic mechanism for auditory distraction.

While identifying spreading activation and inhibitory control as a possible generic mechanism, it is important to acknowledge that the interplay of activation and inhibition is not the only way to construe the findings of the current series. For example, compound cue theory (e.g., McKoon & Ratcliff, 1992; Ratcliff & McKoon, 1988) does not allow any role for inhibition. On this account, irrelevant items form a compound cue in short-term memory that can disrupt retrieval because they can cue non-target representations in long-term memory and produce greater interference to the extent that they are related to the target representations and share similar links to representations in long-term memory. Compound cue theory, however, fails to account for the finding that meaningful speech did not impair phonemic fluency when meaningful irrelevant items did not share the same first letter (Experiment 4, replicated in the supplementary experiment). On compound cue theory, meaningful irrelevant speech should give rise to a compound cue that can trigger the retrieval of non-target representations in long-term memory regardless of the type of fluency required. Further, semantic network accounts (e.g., J. R. Anderson, 1983) in which retrieval difficulty is a passive side effect of changing patterns of resource-limited activation also often eschew inhibitory processes. One way of accounting for the current results without invoking the construct of inhibition is to use a mechanism that relies on relative activation. That dominant exemplars are less accessible in the associated speech conditions of Experiment 3 may arise from the fact that related irrelevant sounds produce an abnormally broad spread of activation within a subfield of semantic memory (e.g., that representing both "Fruit and Vegetables"; e.g., Crutch & Warrington, 2003). It follows that exemplars that are more weakly associated with the semantic fluency category cue (e.g., "gooseberry" for the category "Fruit") will receive more activation than they would in the absence of distracting sound. In turn, the difference in activation between dominant and non-dominant exemplars is less than in silence, resulting in an increased likelihood that non-dominant exemplars will be produced in the task (cf. Kiang & Kutas, 2006).

Another alternative explanation invokes the notion of feature overlap. This suggests that the more typical the category exemplar, the fewer features it shares with members of an associatively-related category. By the same token, the more atypical a category exemplar, the fewer features it shares with members of an associated category (Cutting & Schatz, 1976). Sorting time for exemplars of semantically similar categories ("Fruit" *vs.* "Vegetables") takes longer than sorting times for members of semantically dissimilar categories ("Fruit" *vs.* "Clothing"). Moreover, sorting time is a function of the typicality of associated categories members. For example, the time taken to sort atypical members of a category ("Vegetables": olive, parsley; "Fruit": date, prune) is longer than for medium-level typicality ("Vegetables": bean, peppers; "Fruit": fig, raspberry) which in turn takes longer than for prototypical exemplars ("Vegetables": pea, spinach; "Fruit": apricot, melon) but only when the to-be-sorted categories are associatively related ("Fruit" *vs.* "Vegetables"). These results are consistent with the idea that the less typical exemplars of a category (e.g., "Fruit") share more features with the more typical exemplars of an associated category (e.g., "Vegetables") which makes less typical responses more difficult to sort but easier to recall.

Implications for Lexical Selection in Language Production

More generally, the results reported here may be construed in terms of their implications for language production. Viewed from this standpoint, the current work suggests that language production in everyday life would be vulnerable to the effects of noisy environments in which speech is a major component. Whether this would encompass both the development of language skills, from the acoustic environment of the home, school, or elsewhere, has yet to be established by field work. It would be fair to say that research on the effects of noise in the community and at work has been pre-occupied with the effects of sound defined primarily in terms of its intensity and the effect that has on the individual's expression of annoyance at the sound. Indeed, it is the case that noise annoyance (the subjective irritation and dismay caused by noise, not its effect on cognitive performance) is related to noise level, with up to 45% of the variance associated with annoyance being accounted for by noise intensity (cf. Shield & Dockrell, 2008). However, it is known from extensive laboratory work that distraction measured by cognitive tasks is not related to intensity (at least in the range of intensities that encompasses everyday sounds); rather, it is related to the acoustic variability of the sound (Hughes & Jones, 2001; Jones et al., 2010). Moreover, susceptibility to performance impairment does not necessarily correlate with annoyance (see Zimmer, Ghani, & Ellermeier, 2008). So language performance and possibly language development may be vulnerable in a range of settings outside the laboratory, with those on language development possibility having long term effects on language competence.

Viewing the effects of distraction on fluency in terms of an effect on language production brings convergence with other paradigms, such as picture-word interference. Such tests require overt naming of line drawings of familiar objects (e.g., of a cat) whilst at the same time ignoring visual or auditory distractor words (e.g., DOG or HOUSE). Here again we witness lexical retrieval to a conceptual cue: a category name in the context of semantic fluency and a picture in the context of picture-word interference coupled with the presence of concurrent to-be-ignored stimuli.

Picture-naming responses (e.g., of a cat) are slowed when the distractor word is semantically related to the picture (e.g., DOG) as compared to when it is semantically unrelated (e.g., HOUSE) and semantically unrelated words impair naming more than nonwords (Glaser & Düngelhoff, 1984) much like the pattern of results observed in Experiments 1-3 with semantic fluency. The semantic interference effect (slower responding in the presence of related as compared to unrelated distractors) is taken as strong evidence that lexical selection is a competitive process: the semantic relatedness between the distractor word and the picture increases the competition at a pre-production stage. However, some researchers have taken results from this task to support not the lexical competition account but the response exclusion hypothesis (Finkbeiner & Caramazza, 2006). This supposes that distractors block an articulatory output buffer at a post-lexical stage thereby impeding picture-naming. Perhaps the strongest evidence for this approach is the effect of distractor-frequency: Low frequency distractors impede picture-naming more than high-frequency distractors (Miozzo & Caramazza, 2003). Because frequency is often thought of as reflecting resting levels of activation (McClelland & Rumelhart, 1981) this is the opposite pattern to what the lexical competition account predicts (but see Roelofs, Piai, & Schriefers, 2011; see also findings related to semantic distance, Mahon et al., 2007).

Although the parallels of auditory distraction and fluency with picture-word naming are attractive, its relevance to the current experimental setting should not go unqualified. The settings are far from identical in terms of processing requirements; the fact that picture-word naming typically has the constraint that two stimuli, both visual, are concurrent, represents an encoding difficulty. For distraction during fluency-based tasks, the process of retrieval is more predominant, and less contaminated with the effects of encoding (for an example of how distractor modality affects picture-word interference, see Hantsch, Jescheniak, & Schriefers, 2009). Arguably, distraction measured through fluency is a more pure measure of the influence of distraction on retrieval. Moreover, fluency tests are ones of sequence production, not single stimulus and response selection as is the case in settings such as picture-word naming. This at the same time makes it more similar to everyday language production in shifting the burden onto output more akin to sentence production while also calling upon processes that are largely absent from single response production, like the episodic memory for recent output and so forth.

On the face of it, our findings with fluency appear compatible with the lexical selection-by-competition accounts. Mere meaningfulness (as presented by unrelated words in comparison to non-words) should activate nodes that are distal to target nodes in the lexicon but still reduce the activation level of (and spread of activation to) target nodes. Moreover, the lexical nodes for closely-related distractors ("Vegetables" when the target category is "Fruit") should be more active and pose more competition due to the task-relevant and task-irrelevant lexical entries. Additionally, the absence of any effect of meaningful speech on phonemic fluency suggests that the effect on semantic fluency is a semantic competition effect. That phonemic parallels (cinema, circle) of target (e.g., "s") words produce disruption but nonwords do not (Experiment 5) is consistent with the notion of interference-by-process. In this case, the competition effects are not semantic but are lexical-phonemic and determined by category membership to the phonemic category. Here, nodes representing the phonemic parallels receive activation via spreading activation through a network representing acoustic-phonetic patterns of lexical items within long-term memory. The nodes of task-irrelevant words (e.g., cinema, circle) that have similar acoustic-phonetic patterns to the target words (e.g., sea, supper) receive higher levels of activation and confer strong competition for the retrieval of targets but nonwords—even if similar in sound to targets—will not produce competition because they do not have associated lexical nodes.

Whilst the pattern of findings in relation to Experiments 1-5 appear broadly consistent with the lexical competition approach it is also possible to make a case for a response-exclusion account (e.g., Mahon et al., 2007). By this account, irrelevant items/distractors gain access to an articulatory output buffer. This could prevent retrieval of other responses in the fluency task. Moreover, the process of removing the distractor from the output buffer uses semantic criteria: Words semantically related to the targets take longer to remove than semantically unrelated distractors (Mahon et al., 2007). In principle, this could explain the greater impact of semantically-associated speech on the fluency task (Experiment 3). Therefore, it does not seem possible to differentiate the lexical-selection-by-competition account from the response exclusion account on the basis of the evidence of our experiments here; however, as we noted before, evidence of negative priming from auditory distraction in a variety of tasks suggests at least some role for inhibition (Hughes & Jones, 2003; Marsh et al., 2011).

The interference-by-process account of the present findings, based upon the notion that distraction reflects lexical competition as a function of task demand, suggests a number of novel predictions. One is that the phonemic fluency task would reveal a process-based semantic auditory distraction effect if participants spontaneously adopted (Schwartz et al., 2003), or were encouraged to adopt, a semantic-based strategy (“sand”, “sea”, “sun”). Likewise, it would also be predicted that the between-sequence phonemic similarity effect would be attenuated if participants were, instead, instructed to use a visual orthographic strategy (whereby the visual representations of words are used to search an orthographic lexicon) and, conversely, accentuated when an auditory phonemic strategy is used to search the phonemic lexicon (Fu et al., 2006).

The present findings may also have implications for the very long-standing inclusion of verbal fluency in psychometric batteries (e.g., Thurstone’s Primary Mental Abilities test, 1938). Its importance—or at least popularity—as a test is evident from the several hundred clinical studies in psychopathology, neurology, and neuropsychology using it to measure executive processing. The current study illustrates that tests of fluency also have a potential to reflect domain-specific retrieval processes. Some have included differentially-characterized retrieval processes in their neuropsychological descriptions of the fluency task. Among them, Moscovitch (1992, 1994) suggests an array of modules from which fluency performance may draw, some dedicated to input and one, the temporal lobe-hippocampal module (MTL-H module), that mediates encoding and retrieval, retrieval being cue-dependent and episodic in character, operating largely automatically. Another module, located in the frontal lobes and strategic, purposeful and goal-directed in character, has received most attention in clinical studies. This may be remiss; the present results suggest that our understanding of a range of potential clinical cases may yield to a more inclusive functional description of fluency that embodies disorders of retrieval.

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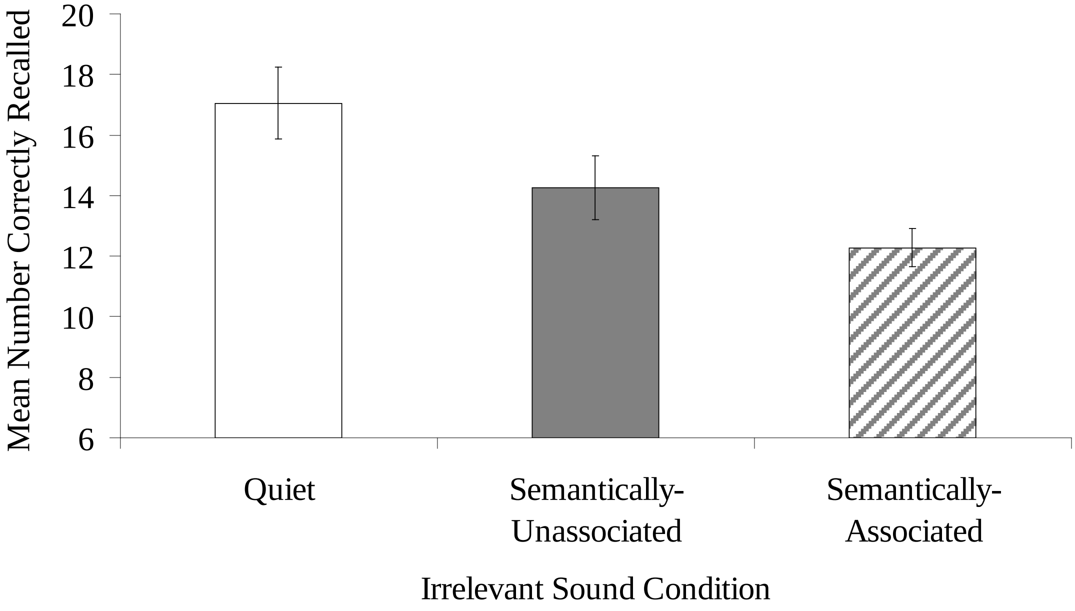
Footnotes

1. Although we will use the term ‘between-sequence’ as a convenient descriptor, there is of course no actual external sequence of relevant stimuli in this task, only a potential sequence of responses.

Figure Caption

Figure 1. Mean number of exemplars generated over a 2 min retrieval period for the 3 conditions in Experiment 2.

Figure 1.


Mean Number Correctly Recalled
20
18
16
14
12
10
8
6
Quiet
Semantically-Unassociated
Semantically-Associated
Irrelevant Sound Condition

EXPERIMENT	FLUENCY TASK	DISTRACTION CONDITIONS	EFFECTS (FLUENCY)
Experiment 1	Written semantic	Auditory distraction with unrelated distractors e.g., “Animal” fluency with “Vegetable” distractors (meaningful speech) vs. reversed speech vs. quiet.	Quiet = Reversed Speech > Meaningful Speech
Experiment 2	Written semantic	Auditory distraction with unrelated distractors (e.g., “Animal” fluency with “Vegetable” distractors (meaningful speech) vs. nonword speech vs. quiet.	Quiet = Nonwords > Meaningful Speech
Experiment 3	Spoken semantic	Auditory distraction with unrelated vs. related distractors (e.g., “Animal” fluency with “Bird” distractors vs. “Vegetable” fluency and “Tool” distractors) vs. quiet.	Quiet < Unrelated speech < Related speech
Experiment 4	Written letter	Auditory distraction with unrelated distractors (e.g., F letter fluency with “Vegetable” distractors) vs. reversed speech vs. quiet.	Quiet = Reversed speech = Meaningful speech
Experiment 5	Written letter	Auditory distraction with word vs. nonwords related or unrelated (e.g., F letter fluency with PH distractors vs. F letter fluency with C distractors vs. F letter fluency with F nonwords vs. F Letter fluency with C nonwords)	Unrelated nonword = Unrelated word = Related nonword < Related word

Appendix 1: Categories Used in Experiment 3

Words in italics refer to category names. Non-italicized words refer to irrelevant exemplars drawn from the corresponding category. Associated categories are paired together.

Fabric: cotton, denim, leather, nylon, polyester, rayon, satin, silk, spandex, wool.

Clothing: hat, jacket, shirt, shoes, shorts, skirt, socks, sweater, trousers, underwear.

Flowers: carnation, daffodil, daisy, dandelion, lily, orchid, pansy, rose, sunflower, tulip.

Trees: aspen, birch, dogwood, elm, evergreen, maple, oak, pine, redwood, spruce.

Four-Legged Animals: bear, cat, cow, deer, dog, elephant, horse, lion, mouse, tiger.

Birds: blackbird, crow, duck, eagle, hawk, parrot, pigeon, robin, seagull, sparrow.

Fruit: apple, banana, grape, kiwi, orange, peach, pear, pineapple, strawberry, watermelon.

Vegetables: beans, broccoli, carrot, celery, corn, cucumber, lettuce, onion, peas, potato.

Genre/Type of Music: alternative, blues, classical, country, jazz, pop, punk, rap, reggae, rock.

Musical Instrument: clarinet, drum, flute, guitar, piano, saxophone, trombone, trumpet, tuba, violin.

Land Vehicle: car, bike, bus, lorry, motorcycle, scooter, taxi, train, underground, van.

Non-land Vehicle: aeroplane, battleship, canoe, helicopter, kayak, raft, sailboat, speedboat, submarine, yacht.

Weapons: bat, bomb, club, fists, grenade, gun, missile, pistol, rifle, sword

Carpenter's Tools: drill, hammer, level, nail, ruler, saw, sander, screw, screwdriver, wrench.

Human Dwelling: apartment, cave, dormitory, house, hut, mansion, shack, tent, trailer, tepee.

House part: basement, bathroom, ceiling, door, floor, roof, room, stairs, wall, window.

Kitchen Utensil: blender, bowl, fork, knife, ladle, pan, pot, spatula, spoon, whisk.

***Gardener's Tools*:** gloves, hoe, hose, lawnmower, pick, plough, rake, shovel, spade, trowel.

Appendix 2: Examples of item similarity within and between categories used in Experiment 3 as computed with Latent Semantic Analysis (LSA)

Four-Legged Animals	bear	cat	cow	deer	dog	elephant	horse	lion	mouse	tiger	
bear		-0.02	0.03	0.38	0.04	0.08	0.06	0.24	0.11	0.08	
cat	-0.02		0.24	0.07	0.36	0.22	0.06	0.53	0.72	0.45	
cow	0.03	0.24		0.16	0.12	0.16	0.18	0.25	0.3	0.3	
deer	0.38	0.07	0.16		0.07	0.36	0.08	0.43	0.19	0.31	
dog	0.04	0.36	0.12	0.07		0.05	0.07	0.01	0.07	0.07	
elephant	0.08	0.22	0.16	0.36	0.05		0.09	0.56	0.3	0.5	
horse	0.06	0.06	0.18	0.08	0.07	0.09		0.02	-0.03	0.05	
lion	0.24	0.53	0.25	0.43	0.01	0.56	0.02		0.64	0.68	
mouse	0.11	0.72	0.3	0.19	0.07	0.3	-0.03	0.64		0.59	Mean Similarity
tiger	0.08	0.45	0.3	0.31	0.07	0.5	0.05	0.68	0.59		0.23

Four-Legged Animals vs. Birds	blackbird	crow	duck	eagle	hawk	parrot	pigeon	robin	seagull	sparrow	
bear	-0.04	0.15	0.54	0.11	0.09	-0.09	0.08	0.26	-0.03	0.01	
cat	0.11	0.3	0.35	0.14	0.2	0.48	0.07	0.09	0	0.13	
cow	0.09	0.19	0.15	0.12	0.12	0.06	0.05	0.09	-0.07	0.05	
deer	0.15	0.35	0.26	0.39	0.24	0.07	0.32	0.2	0.03	0.11	
dog	0.11	0.08	0.23	0.07	0.08	0.28	0.02	0.1	-0.02	0.05	
elephant	0.08	0.21	0.2	0.19	0.12	0.17	0.2	0.05	-0.05	0.06	
horse	0.03	0.27	0.09	0.07	0.29	0.03	0.08	0.03	0.02	0.03	
lion	0.09	0.31	0.3	0.24	0.18	0.23	0.12	0.11	-0.06	0.05	
mouse	0.21	0.31	0.4	0.19	0.22	0.21	0.09	0.16	0.02	0.18	Mean Similarity
tiger	0.18	0.28	0.29	0.28	0.2	0.23	0.09	0.16	0.04	0.07	0.14

Four-Legged Animals vs. Clothing	hat	jacket	shirt	shoes	shorts	skirt	Socks	sweater	trousers	underwear	
bear	0.16	0.03	-0.02	-0.01	-0.05	-0.01	0.08	0.03	0.01	0.01	
cat	0.14	0.07	0.09	0.12	0.06	0.06	0.25	0.06	0.02	0.02	
cow	0.11	0.05	0.05	0.07	0.01	0.07	0.08	0.06	0.01	0.01	
deer	0.08	0.1	0.11	0.05	0.02	0.08	0.05	0.02	0.1	0.02	
dog	0.04	0.06	0.05	0.06	0.08	0.04	0.17	0.05	0	0.02	
elephant	0.22	0.15	0.15	0.12	0.09	0.16	0.12	0.05	0.1	0.01	
horse	0.14	0.04	0.1	0.04	0.07	0.05	0.11	0.05	0.04	0.16	
lion	0.14	0.05	0.01	0.02	0.02	0.02	0.07	-0.02	-0.01	-0.03	
mouse	0.18	0.07	0.04	0.12	0.04	0.1	0.22	0.04	0.02	-0.02	Mean Similarity
tiger	0.14	0.11	0.02	0.05	0.02	0.03	0.07	-0.07	0.03	-0.03	0.06

Appendix 3: Similarity between categories used in Experiment 3 as computed with Latent Semantic Analysis (LSA)

	Fabric	**Clothing**	**Flowers**	**Trees**	**Four-Legged Animals**	**Birds**	**Fruit**	**Vegetables**	**Genre/ Type of Music**	**Musical Instrument**	**Land Vehicle**	**Non-land Vehicle**	**Weapons**	**Carpenter's Tools**	**Human Dwelling**	**House Part**	**Kitchen Utensil**	**Gardener's Tools**
Fabric	0.37	0.27	0.05	0.09	0.02	0.06	0.06	0.08	0.03	0.06	0.05	0.04	0.05	0.04	0.07	0.08	0.08	0.09
Clothing	0.27	0.56	0.11	0.10	0.06	0.12	0.12	0.08	0.08	0.07	0.13	0.08	0.14	0.09	0.14	0.22	0.14	0.19
Flowers	0.05	0.11	0.18	0.16	0.06	0.10	0.12	0.16	0.04	0.02	0.05	0.04	0.06	0.05	0.05	0.08	0.06	0.09
Trees	0.09	0.10	0.16	0.51	0.10	0.10	0.17	0.11	0.04	0.03	0.05	0.07	0.07	0.05	0.09	0.09	0.06	0.11
Four-Legged Animals	0.02	0.06	0.06	0.10	0.23	0.14	0.09	0.05	0.05	0.02	0.06	0.03	0.07	0.04	0.10	0.07	0.06	0.07
Birds	0.06	0.12	0.10	0.10	0.14	0.30	0.10	0.05	0.04	0.04	0.05	0.09	0.10	0.06	0.08	0.09	0.07	0.09
Fruit	0.06	0.12	0.12	0.17	0.09	0.10	0.19	0.23	0.05	0.03	0.08	0.04	0.06	0.04	0.07	0.10	0.18	0.10
Vegetables	0.08	0.08	0.16	0.11	0.05	0.05	0.23	0.41	0.05	0.02	0.05	0.02	0.04	0.03	0.05	0.08	0.23	0.09
Genre/Type of Music	0.03	0.08	0.04	0.04	0.05	0.04	0.05	0.05	0.14	0.16	0.06	0.03	0.06	0.06	0.06	0.07	0.06	0.05
Musical Instrument	0.06	0.07	0.02	0.03	0.02	0.04	0.03	0.02	0.16	0.55	0.03	0.03	0.05	0.07	0.05	0.05	0.07	0.04
Land Vehicle	0.05	0.13	0.05	0.05	0.06	0.05	0.08	0.05	0.06	0.03	0.16	0.05	0.09	0.06	0.10	0.12	0.06	0.09
Non-land Vehicle	0.04	0.08	0.04	0.07	0.03	0.09	0.04	0.02	0.03	0.03	0.05	0.17	0.11	0.05	0.07	0.05	0.03	0.04
Weapons	0.05	0.14	0.06	0.07	0.07	0.10	0.06	0.04	0.06	0.05	0.09	0.11	0.21	0.08	0.10	0.10	0.08	0.08
Carpenter's Tools	0.04	0.09	0.05	0.05	0.04	0.06	0.04	0.03	0.06	0.07	0.06	0.05	0.08	0.25	0.06	0.09	0.11	0.14
Human Dwelling	0.07	0.14	0.05	0.09	0.10	0.08	0.07	0.05	0.06	0.05	0.10	0.07	0.10	0.06	0.17	0.21	0.08	0.12
House Part	0.08	0.22	0.08	0.09	0.07	0.09	0.10	0.08	0.07	0.05	0.12	0.05	0.10	0.09	0.21	0.52	0.12	0.14
Kitchen Utensil	0.08	0.14	0.06	0.06	0.06	0.07	0.18	0.23	0.06	0.07	0.06	0.03	0.08	0.11	0.08	0.12	0.31	0.13
Gardener's Tool	0.09	0.19	0.09	0.11	0.07	0.09	0.10	0.09	0.05	0.04	0.09	0.04	0.08	0.14	0.12	0.14	0.13	0.15