Post-Categorical Auditory Distraction in Serial Short-Term Memory: Insights from Increased Task Load and Task Type

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RUNNING HEAD: Post-categorical auditory distraction

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Abstract

Task-irrelevant speech impairs short-term serial recall appreciably. On the *interference-by-process* account, the processing of physical (i.e., pre-categorical) changes in speech yields order cues that conflict with the serial-ordering process deployed to perform the serial recall task. In this view, the post-categorical properties (e.g., phonology, meaning) of speech play no role. The present study reassessed the implications of recent demonstrations of auditory post-categorical distraction in serial recall that have been taken as support for an alternative, attentional-diversion, account of the irrelevant speech effect. Focusing on the disruptive effect of emotionally valent compared to neutral words on serial recall, we show that the distracter-valence effect is eliminated under conditions—high task-encoding load—thought to shield against attentional diversion whereas the general effect of speech (neutral words compared to quiet) remains unaffected (Experiment 1). Furthermore, the distracter-valence effect generalizes to a task that does not require the processing of serial order—the missing-item task—while the effect of speech per se is attenuated in this task (Experiment 2). We conclude that post-categorical auditory distraction phenomena in serial short-term memory are incidental: they are observable in such a setting but, unlike the acoustically driven irrelevant speech effect, are not integral to it. As such, the findings support a duplex-mechanism account over a unitary view of auditory distraction.

Keywords: Irrelevant speech; Serial short-term memory; Serial recall; Auditory distraction; Attention; Emotional valence

The capacity to retain and reproduce the serial order of stimuli over a period of a few seconds—*serial short-term memory*—has long been regarded as fundamental to cognition, playing a central role in functions such as language processing and learning, problem-solving, and reasoning to name but a few (Baddeley, 2007; Lashley, 1951; Marshuetz, 2005). Over the past few decades, a good deal of theorizing about the mechanisms supporting serial short-term memory has capitalized on the peculiar vulnerability of serial recall—the quintessential test of serial short-term memory—to disruption by task-irrelevant speech (e.g., Beaman & Jones, 1997; Colle & Welsh, 1976; Ellermeier & Zimmer, 1997; Elliott, 2002; Hanley, 1997; Hughes & Marsh, 2017; Jones & Macken, 1993; Macken, 2014; Neath, 2000; Salamé & Baddeley, 1982; Tremblay & Jones, 1998). A prominent account of this *irrelevant speech effect* posits that the property of speech that is specifically disruptive of serial ordering is its acoustic variability over time, or its ‘changing-state’ quality. It is argued that acoustic changes in the speech yield order cues which conflict with vocal-motor sequence-planning within the focal task (the *interference-by-process* account; e.g., Hughes & Jones, 2001; Jones & Tremblay, 2000; Jones & Macken, 1993). In this view, the post-categorical properties of speech (e.g., semanticity, phonology) are argued to play no role in its disruption of serial short-term memory (Jones, 1999). The interference-by-process account of the irrelevant speech effect has played a pivotal role in the recent emergence of a more general account of serial short-term memory performance that emphasizes the action of ‘peripheral’ perceptual and motor processes (e.g., Hughes, Chamberland, Tremblay, & Jones, 2016; Hughes & Marsh, 2017; Hughes, Marsh, & Jones, 2009; Jones, Macken, & Nicholls, 2004; Jones, Hughes, & Macken, 2006).

Interest in the present article centres on a recent challenge to the interference-by-process account, namely, the demonstration of post-categorical auditory distraction effects in serial recall (Buchner, Mehl, Rothermund, & Wentura, 2006; Buchner, Rothermund, Wentura, & Mehl, 2004; Buchner & Erdfelder, 2005; Röer, Bell, & Buchner, 2013; Röer, Körner, Buchner, & Bell, 2017). Such effects have been taken as support for an alternative theory in which irrelevant speech disrupts serial recall by diverting attention away from the recall task (Buchner et al., 2006, 2004; Cowan, 1995; Elliott, 2002; Röer, Bell, Dentale, & Buchner, 2011; Röer et al., 2013, 2017; Röer, Bell, & Buchner, 2015). Using the disruptive effect of the emotional valence of speech distracters on serial recall (Buchner et al., 2006, 2004) as a test case, we show that post-categorical auditory distraction in serial recall is incidental; it is due to attentional diversion that can occur in serial recall but is not integral to it. As such, the results provide further evidence for a duplex-mechanism account of auditory distraction (Hughes, 2014; Hughes, Vachon, & Jones, 2005) and are problematic for a unitary, attentional-diversion based, account (e.g., Cowan, 1995; Elliott, 2002; Röer, Bell, & Buchner, 2014).

Interference-By-Process in Serial Short-Term Memory

The typical irrelevant speech experiment involves the sequential visual presentation of around 6-9 verbal items (e.g., digits, letters, words) in a random order at a rate of around one item per second, which then have to be recalled in serial order. The presence of task-irrelevant speech, either during item-presentation or/and any retention interval markedly disrupts serial recall (for reviews, see Beaman, 2005; Hughes & Jones, 2001, 2003; Jones, Hughes, & Macken, 2010). The necessary and sufficient condition for such disruption as far as the speech is concerned is the presence of perceptually segmentable elements that change acoustically from one to the next. Thus, the sequence “B, F, K, L…”, for instance, disrupts serial recall appreciably whereas a repeated speech-token (e.g., “B, B, B, B…”) produces typically little, if any, disruption compared to quiet: the *changing-state effect* (e.g., Jones, Madden, & Miles, 1992; Jones & Macken, 1993).

That it is the pre-categorical, acoustic, properties of speech that underpin its capacity to disrupt serial recall is supported by the fact that the auditory material need not be speech at all, so long as it is perceived as a succession of discrete acoustically-changing elements. Thus, a sequence of pure tones or noise bursts changing in frequency from one to the next disrupts serial recall appreciably (Divin, Coyle, & James, 2001; Elliott, 2002; Jones & Macken, 1993; Sörqvist, 2010; Tremblay, Macken, & Jones, 2001), as does a pitch-glide interrupted by silent gaps (Jones, Macken, & Murray, 1993; Klatte, Kilcher, & Hellbruck, 1995) or instrumental music (Klatte, Kilcher, & Hellbrück, 1995; Perham & Vizard, 2011; Schlittmeier, Hellbrück, & Klatte, 2008; Salamé & Baddeley, 1989). Indeed, it has long been argued that 'irrelevant *sound* effect' is a more apt term than 'irrelevant speech effect' (Beaman & Jones, 1997)[1].

Further support for the pre-categorical, acoustic, basis of the disruptive effect of irrelevant speech on serial recall comes from findings suggesting that post-categorical attributes of speech play no role. For example, reversed speech is as disruptive as forward speech (Jones, Miles, & Page, 1990; Röer, Körner, Bell, & Buchner, 2016) and speech in a language the participant does not understand is as disruptive as speech in his or her native tongue (Colle & Welsh, 1976; Jones et al., 1990; Salamé & Baddeley, 1982). And neither does the phonological (Jones & Macken, 1995; LeCompte & Shaibe, 1997) nor semantic overlap (Buchner, Irmen, & Erdfelder, 1996) between the irrelevant speech and the to-be-remembered material play a role in the disruption of serial recall (though see Bell, Mund, & Buchner, 2011; Hughes & Jones, 2005; Hughes & Marsh, 2017).

That the disruptive potency of irrelevant speech in the context of serial short-term memory derives from its pre-categorical, changing-state, properties is an important empirical

[1] Nonetheless, we will often use the term 'irrelevant speech effect' in the present article as interest centres on the possible role of the post-categorical features of speech per se in its disruptive effect.

pillar of the interference-by-process account of the irrelevant speech/sound effect. This account is part of a more general *perceptual-motor account* of serial short-term memory performance (e.g., Hughes et al., 2016; Hughes & Marsh, 2017; Jones et al., 2004) in which such performance is supported by general-purpose perceptual and motor processes rather than a dedicated short-term memory store or working memory space (Baddeley, 2007; Cowan, 1999, 2001). In this view, serial short-term memory is underpinned in large part by the opportunistic recruitment of the skill of vocal-motor sequence-planning: The planning process itself serves to bind to-be-remembered items that bear little or no pre-existing relation to one another (i.e., they exhibit low transitional probabilities). However, a skill in and of itself does not specify the full set of action-parameters required to execute an appropriate motoric response; the skill must be populated with specific content (Hommel, 2010; Neumann, 1996). Thus, the assimilation of the required content (the to-be-remembered items in the present context) and the cyclical (subvocal) execution of the plan embodying that content renders serial recall vulnerable to disruption by other extraneous sequential information. Critically, it is argued that the processing of changing-state sound generates such an extraneous sequence as a by-product of obligatory auditory perceptual organization of sound into streams (cf. Bregman, 1990): The perception of change between successive sounds yields order cues that interfere with the motor sequence-planning process. In contrast, the repetition of a single, steady-state, sound yields little if any sequential information and hence interferes little if at all (for further discussion, see Hughes & Marsh, 2017; Jones, Beaman, & Macken, 1996).

A second key empirical pillar of the interference-by-process account is the task-process specificity of the changing-state effect: The view that the effect is caused by a conflict of two similar ordering processes predicts that only tasks such as serial recall that rely on, or tend to invoke, a serial ordering process should be susceptible to the effect. The results of several studies support this prediction. For example, free recall—in which serial recall is, by definition, not an explicit requirement—is immune to the effect (Beaman & Jones, 1998; see also Salamé & Baddeley, 1990) unless a serial rehearsal strategy happens to be adopted (Beaman & Jones, 1998). Similarly, a task requiring the identification of which item is missing from a randomly ordered list drawn from a well-known set (e.g., that *6* is missing from the list *31784952* drawn from the set *1-9*)—a task that tends not to invoke a serial ordering strategy (cf. Morrison, Rosenbaum, Fair, & Chein, 2016)—also typically exhibits little or no changing-state effect (Elliott et al., 2016; Hughes et al., 2007; Jones & Macken, 1993; see also Beaman & Jones, 1997).

An Alternative, Attentional-Diversion, Account

An alternative account posits that rather than interfering specifically with the serial ordering process involved in serial recall, irrelevant speech/sound disrupts serial recall because it diverts attention away from the task (e.g., Buchner et al., 2004; Cowan, 1995; Elliott, 2002; Röer, Bell, & Buchner, 2013, 2015). This account is derived from a broader *embedded processes model* (Cowan, 1999, 2001) in which short-term remembering is constrained by a 'focus of attention' that is highly capacity-limited (to around 4 items) but whose contents are immediately accessible. If the focus of attention is diverted to task-extraneous events (such as changing sounds), task-relevant items that were in the focus may be lost and hence short-term memory performance is impaired. From this perspective, the changing-state effect is explained by supposing that acoustic changes exogenously capture attention (cf. the 'orienting response'; Sokolov, 1963) away from the focus whereas with a steady-state sound the capture response rapidly habituates, leaving serial recall relatively unscathed (Bell, Röer, Dentale, & Buchner, 2012; Cowan, 1995; Elliott, 2002; Röer, Bell, & Buchner, 2014, 2015).

Of particular interest in the present article, a further line of evidence cited in support of the attentional-diversion account of the irrelevant speech/sound are recent studies suggesting that post-categorical properties of speech that have been independently associated with attention-diverting power can indeed modulate its disruption of serial recall. For instance, low-frequency words have been found to produce more disruption of serial recall than high-frequency words (Buchner & Erdfelder, 2005; but for numerous failures to replicate this particular post-categorical distraction effect, see Elliott & Briganti, 2012). Moreover, distracter sentences containing the participant's name (cf. Moray, 1959; Wood & Cowan, 1995) disrupt serial recall more than sentences containing a yoked control-name (Röer et al., 2013), as do taboo compared to neutral words (Röer et al., 2017). Of most relevance to the current study, serial recall has also been found to be modulated by the valence of speech distracters. Thus, a sequence of negatively valenced distracter words (e.g., "desperate", "embittered") produce more disruption than a sequence of either positively valenced distracters (e.g., "loving", "amicable") or neutral distracters, while positively valenced distracters produce more disruption than neutral distracters (Buchner et al., 2004, 2006; but see Lapointe et al., 2013). In light of ample independent evidence of the attention-capturing power of taboo compared to neutral words (Dhooge & Hartsuiker, 2011; Siegrist, 1995), of one's own name compared to another's name (Moray, 1959), and of valent compared to neutral stimuli (e.g., Bonano, Davis, Singer, & Schwartz, 1991; Hodsoll, Viding, & Lavie, 2011; Keil et al., 2007; Pratto, 1994; Pratto & John, 1991; Sokka et al., 2014; Thierry & Roberts, 2007), it has been suggested that such post-categorical auditory distraction effects in serial recall support an attentional diversion account of the irrelevant speech effect (e.g., Buchner et al., 2006, 2004; Röer et al., 2013) and that they are problematic for the acoustic-based interference-by-process account.

Present Study

Our central argument in the present article is that the fact that serial recall can be disrupted by factors that divert attention does not mean that such disruption speaks to an understanding of serial short-term memory performance per se (other than showing that it is attentionally demanding). For example, it is well established that an unexpected task-irrelevant deviant sound diverts attention and disrupts serial recall performance (the deviation effect; e.g., Hughes et al., 2005, 2007; Marsh, Vachon, & Sörqvist, 2017; Röer, Bell, Marsh, & Buchner, 2015; Vachon, Labonté, & Marsh, 2017). Critically, though, it does so across a range of other task-settings too, including, unlike the changing-state effect, tasks that involve little if any order processing (e.g., Hughes et al., 2007; Schröger, 1996; Sussman, Winkler, & Schröger, 2003; Parmentier, 2008; Vachon et al., 2017). Thus, the fact that serial recall per se exhibits a deviation effect (Hughes et al., 2005, 2007) is of little consequence as far as the theoretical understanding of serial recall—or serial short-term memory more generally—is concerned. Importantly, however, it does suggest that attentional diversion effects are functionally dissociable from the changing-state driven irrelevant speech effect. Indeed, this empirical dissociation forms the basis of a duplex-mechanism account of auditory distraction in which attentional diversion is a general, task-process non-specific, form of distraction while interference-by-process, by definition, is a joint product of the processing of the sound and the particular processes deployed in the focal task (e.g., Hughes, 2014; Hughes et al., 2005; Hughes, Hurlstone, Marsh, Vachon, & Jones, 2013; Vachon et al., 2017).

We argue here that the foregoing logic applies also to the post-categorical auditory distraction effects found in serial recall such as the own-name effect (Röer et al., 2013), the taboo-word effect (Röer et al., 2017), word frequency effects (Buchner & Erdfelder, 2005; cf. Elliott & Briganti, 2012) and distracter-valence effects (Buchner et al., 2006, 2004). That is, we argue that these are, like the deviation effect (Hughes et al., 2007), attentional diversion effects that are incidental to the classical irrelevant speech effect and of serial short-term memory. In the present study, we use the distracter-valence effect (Buchner et al., 2006, 2004) to put our general argument to the test. Our approach was to capitalize on two empirical observations: First, the auditory deviation effect—a distraction effect universally attributed to attentional diversion—is attenuated by factors thought to boost focal task-engagement (e.g., high task-encoding load) whereas interference-by-process (as indexed, from our theoretical standpoint, by the changing-state effect) is not (Hughes et al., 2013). Second, there is ample evidence that distraction due to attentional diversion—again as indexed, for example, by the deviation effect—is found independently of the involvement of serial order processing in the focal task (e.g., Hughes et al., 2007; Parmentier, 2008; Vachon et al., 2017) whereas the changing-state driven irrelevant speech effect is not (e.g., Hughes et al., 2007; Jones & Macken, 1993). Thus, in the current experiments, we test whether the distracter-valence effect is due to an attentional diversion mechanism unrelated to the changing-state driven irrelevant speech effect by examining: i) whether the valence effect is attenuated under increased task-encoding load (Experiment 1), and ii) whether it is observed not only in a serial short-term memory task but also in a missing-item task in which serial order processing is assumed to play little role (Experiment 2). If so, the duplex-mechanism account (Hughes, 2014; Hughes et al., 2013) would clearly be favored over the unitary, attentional diversion-based, account of auditory distraction (e.g., Röer, Bell, & Buchner, 2015; Röer et al., 2017).

Experiment 1

A distraction effect found in serial recall and universally regarded as being due to attentional diversion—the auditory deviation effect (e.g., Hughes et al., 2005; Röer, Bell, Marsh, & Buchner, 2015)—is eliminated by high task-encoding load. Specifically, if the perceptual discriminability of visually-presented to-be-remembered items is reduced by adding static visual noise to each item (see Figure 1), the usual disruptive impact of an unexpected deviant sound on serial recall is abolished (Hughes et al., 2013). It was argued that the higher task-encoding load boosts focal task-engagement thereby countering the task-disengagement (or attentional diversion) caused by the deviant (Hughes et al., 2013). Importantly, the changing-state driven irrelevant speech effect, which we argue reflects interference-by-process, not attentional diversion, is immune to the same modulation of task-encoding load (Hughes et al., 2013). Thus, based on the duplex-mechanism account, our rationale is that if the disruptive effect of valent compared to neutral irrelevant speech tokens (Buchner et al., 2006, 2004) is an attentional diversion effect unrelated to the classical irrelevant speech effect, then it should, like the deviation effect, be reduced or eliminated under high task-encoding load. At the same time, the same increase in encoding load should have little influence on a relatively pure measure of the classical irrelevant speech effect, namely, the disruptive effect of neutral distracters compared to quiet. In contrast, the unitary, attentional-diversion, account predicts no such dissociation.

Method

Participants. One hundred and thirty-four psychology students at the University of Central Lancashire and Cardiff Metropolitan University took part in the experiment in return for course credits or a small honorarium. All reported normal hearing and normal or corrected-to-normal vision. Within each lab, participants were randomly assigned to either a low task-encoding load group or a high task-encoding load group. In the event, seventy participants were assigned to the low task-encoding load condition and sixty-four were assigned to the high task-encoding load condition. For the low task-encoding load group, 42 participants took part at the University of Central Lancashire and 28 took part at Cardiff Metropolitan University. For the high task-encoding load group, 24 participants took part at the University of Central Lancashire and 40 participants took part at Cardiff Metropolitan

University. Participants for the low task-encoding load group comprised 48 females and 22 males (*mean age* = 21.9, *SD* = 6.4; *age range* = 18-54) and participants for the high task-encoding load group comprised 38 females and 26 males (*mean age* = 24.4, *SD* = 7.2; *age range* = 18-46).

Apparatus and materials. *To-be-remembered items*. The visually-presented to-be-remembered lists comprised eight digits sampled without replacement from the set *1-8*. These were arranged in a pseudo-random order with the constraint that no ascending or descending runs of more than two digits occurred in a given list. The digits appeared one at a time in the central position of a computer display for 350 ms each with a 450 ms interstimulus interval. Digits sustained a visual angle of about 2.6^{o} (participants sat at approximately 50 cm distance from the screen). For the high task-encoding load group, the to-be-remembered digits were made more difficult to read. Specifically, following Parmentier, Elford, Escera, Andrés, and Miguel (2008; see also Hughes et al., 2013; Marsh, Sörqvist, & Hughes, 2015), the digits were degraded by adding a visual mask comprising static Gaussian visual noise (400% over the item, and by setting the transparency of the item to 50% using Adobe Photoshop software). Figure 1 provides an illustration of one of the digits as it appeared in the two load conditions.

Auditory distracter sequences. For the irrelevant auditory sequences, five categories of eight spoken words were recorded in a female voice: (1) neutral: *badger, deer, donkey, elephant, hamster, rabbit, sheep, turtle*; (2) negatively valent—physical: *assault, cancer, coffin, damage, hurt, mutilate pinch, robber*); (3) negatively valent—social: *coward, hate, inferior, insane, lonely, neglect, stupid, tease*; (4) positively valent—physical: *carefree, cuddle, dazzle, greet, protect, lively, safe, secure*); and (5) positively valent—social: *admire, engage, gentle, hope, intimate, loyal, passion, virtue* (see Appendix). The neutral words were categorically related to one another so as to partially control for the semantic associations within the positive and negative categories (Tipple, 2010). Across categories, the words were matched as closely as possible for psycholinguistic factors including word length, Kucera-Francis written frequencies, Thorndike-Lorge written frequencies, number of letters, number of syllables, and concreteness. Words were selected from a variety of published studies including Korfine and Hooley (2000), Helfinstein, White, Bar-Haim and Fox (2008), Beck et al. (2011), Taake, Jaspers-Fayer, and Loitti (2009), Maidenberg et al. (1996), Asmundson and Stein (1994), Hope et al. (1990), Mansell and Clark (1999), Mansell et al. (2002) and Mathews, Mogg, May, and Eysenck (1989). The online MRC Psycholinguistic Database, Version 2.0 (Informatics Division Science and Engineering Research Council Rutherford Appleton Laboratory Chilton, Wilson, 1987) was also used to search for, and compare, the psycholinguistic properties of the words. There were no statistical differences between the word-sets according to any of the variables. Social and physical sub-categories of the valent words were used in line with common practice in the emotional valence literature (Fox, 1993; Mathews et al., 1989).

Within and across sets, the words were recorded at an approximately even pitch and sampled with a 16-bit resolution at a sampling rate of 44.1 kHz using *Sound Forge 8*. They were normalized to 65 dB(A) and edited to last 750 ms using Audacity software (Audacity Development Team, 2015). The eight words were presented in a different random order for each trial. The onset of the each distracter word co-occurred with the onset of each to-be-remembered digit. There was a 50 ms interstimulus interval between each spoken word. Auditory sequences were presented via headphones at a sound level of approximately 65 dB(A). The experiment was executed on a PC running an E-Prime 2.0 program (Psychology Software Tools) that controlled stimulus presentation.

Design. A mixed-measures design was used with Sound (quiet, neutral, negatively valent—physical, negatively valent—social, positively valent—physical and positively valent—social) as the within-participant variable and Task-encoding load as the between–participants variable. Regardless of Task-encoding load group, each participant received 90 trials (15 trials per condition) divided into two blocks. Block 1 comprised 7 quiet trials, 8 neutral trials, 8 positively valent—social trials, 7 positively valent—physical trials, 7 negatively valent—social trials, and 8 negatively valent—physical trials. Block 2 comprised 8 quiet trials, 7 neutral trials, 7 positively valent—social trials, 8 positively valent—physical trials, 8 negatively valent—social trials, and 7 negatively valent—physical trials. Within each block, the distracter conditions were assigned to trials in a random order (fixed across all participants) with the constraint that no distracter condition was encountered twice in immediate succession.

Procedure. The participants were informed via standard written instructions that any sound that they heard through the headphones was irrelevant to the task and that it should be ignored. Two quiet trials were delivered to participants to familiarize them with the serial recall task. Following presentation of the last to-be-remembered item in a sequence, the digits were re-presented at random positions within a circular array. Beneath the array there were eight horizontally arranged response boxes corresponding to the each position in the to-be-remembered list. Participants were required to reproduce the to-be-remembered list in forward serial order by selecting the digits using the mouse-driven pointer. Once a digit was selected, it disappeared for 50 ms before reappearing and a copy of the digit appeared in the response window corresponding to the current recall position. Because items remained in the circular array once selected, repetitions of the same item were possible, as with written recall. If participants were unsure of the correct item at a given recall position, they could either guess or they could click on a "?" button in the center of the array in order to record a "don't know" response.

Results

Responses were scored according to the strict serial recall criterion: each outputted digit was only scored as correct if its position in the response-output corresponded to its absolute serial position in the presented list. The recall data were then averaged across serial positions for the purpose of analysis as the competing theories do not make predictions regarding any interaction between serial position and any of the other factors. Given that recall performance in this study was assessed using analyses of variance (ANOVAs), the Greenhouse-Geisser procedure was applied on every within-subject effect for which the sphericity assumption was violated.

An initial analysis showed that there were no significant differences according to sub-category of valence (i.e., physical *vs.* social) and thus we collapsed the data across these sub-types for the analysis proper; this now therefore comprised two valence conditions (positive, negative) alongside the neutral and quiet conditions. Preliminary analysis revealed no main effect of Lab, $F(1, 130) = 1.94$, $MSE = 0.087$, $p = .17$, $\eta_p^2 = .53$, nor any interaction between Lab and Sound, $F(3, 390) = 0.96$, $MSE = 0.005$, $p = .41$, $\eta_p^2 = .01$, nor between Lab, Sound and Task-encoding load, $F(3, 390) = 0.43$, $MSE = 0.005$, $p = .73$, $\eta_p^2 < .001$. Therefore Lab was not included in the analyses reported below.

Figure 2 shows serial recall performance in each of the 8 [2(Task-encoding load) × 4 (Sound)] conditions. The results are very clear-cut. In the low task-encoding load condition, there is evidence that positively valent distracters impaired serial recall performance more than neutral distracters and quiet. Moreover, negative distracters produced more disruption than positive distracters, neutral distracters, and quiet. In sharp contrast, in the high task-encoding load condition, all effects associated with valence were eliminated while the disruptive effect of irrelevant speech generally (i.e., regardless of its content), as compared to quiet, remained unchanged. A mixed ANOVA revealed a main effect of Sound, *F*(2.174, 286.694) = 148.81, *MSE* = 0.007, $p < .001$, $\eta_p^2 = .53$, and, while there was no main effect of Task-encoding load (cf. Hughes et al., 2013), $F(1, 132) = 1.25$, *MSE* = 0.093, $p = .27$, $\eta_p^2 = .01$, critically, the interaction between Task-encoding load and Sound condition was significant, $F(2.174, 286.694) = 3.40$, *MSE* = 0.007, $p = .031$, $\eta_p^2 = .03$. Decomposition of this interaction via a simple effects analysis showed that, under low task-encoding load, negative distracters were more disruptive than neutral distracters ($p < .001$, 95% CI [.025, .065], $\eta_p^2 = .27$) and positive distracters ($p = .009$, 95% CI [.005, .034], $\eta_p^2 = .10$), and positive distracters were more distracting than neutral distracters ($p = .014$, 95% CI [.005, .046], $\eta_p^2 = .08$). In contrast, under high task-encoding load, negative distracters were no more disruptive than neutral distracters ($p = .75$, 95% CI [-.024, .017], $\eta_p^2 = .001$) or positive distracters ($p = .94$, 95% CI [-.016, .015], $\eta_p^2 < .001$), and positive distracters were no more disruptive than neutral distracters ($p = .79$, 95% CI [-.024, .018], $\eta_p^2 = .001$). Finally, an additional ANOVA incorporating the Task-Encoding load factor and only the quiet and neutral conditions from the Sound factor confirmed that the effect of irrelevant speech per se was not modulated by high encoding load: While there was a main effect of Sound, $F(1, 132) = 178.51$, *MSE* = 0.007, $p < .001$, $\eta_p^2 = .56$, there was no main effect of Task-encoding load, $F(1, 132) = 0.176$, *MSE* = 0.046, $p = .68$, $\eta_p^2 = .001$, and no interaction between Sound and Task-encoding load, $F(1, 132) = 0.016$, *MSE* = 0.007, $p = .90$, $\eta_p^2 < .001$.

Discussion

Experiment 1 showed that the disruptive effect of post-categorical properties of irrelevant spoken distracters on serial recall performance—specifically their emotional valence (cf. Buchner et al., 2006, 2004)—is abolished under high task-encoding load. At the same time, the disruptive effect of irrelevant speech per se (operationalized here in terms of the contrast between neutral words compared to quiet)—which would have been driven, we argue, by the acoustically-driven changing-state effect (Jones & Macken, 1993)—was unaffected by the same increase in load. This pattern of findings provides compelling evidence that the distracter-valence effect in serial recall is due to attentional diversion (or task-disengagement) such that a manipulation that plausibly serves to boost focal task-engagement (increased encoding load; cf. Hughes et al., 2013; Marsh et al., 2015) prevents such diversion. While the attentional-diversion account of the irrelevant speech effect (Buchner et al., 2006, 2004; Röer et al., 2013, 2017) can accommodate this aspect of the data, problematic for this account is that high encoding load selectively eliminated the valence effects while leaving the effect of irrelevant speech per se untouched. In contrast, this dissociation is entirely consistent with the duplex-mechanism account in which the classical irrelevant speech effect is not due to attentional diversion but due instead to interference-by-process based on the acoustically changing-state property of the speech (Hughes, 2014; Hughes et al., 2013).

The finding that negatively-valent distracters were more disruptive than positively-valent distracters replicates that of Buchner et al. (2006, 2004) and hence provides useful corroboration for the view that the distracter-valence effects observed here were qualitatively equivalent to their effects despite the use of not only different word-sets but a different language (English as opposed to German). Indeed, that negatively- and positively-valent distracter conditions differ from one another in this setting reinforces the view that these are attentional-diversion effects (Buchner et al., 2004): There is independent evidence from other classic attention research paradigms (e.g., visual search, the Stroop task) that negatively-valent stimuli are more attention-diverting than positively-valent ones (Horstmann, Scharlau, & Ansorge, 2006; Kahan & Hely, 2008).

The effect of increased task-encoding load mimics closely that previously shown in the context of the disruptive effect of an unexpected deviant sound (e.g., a male-spoken item in amongst otherwise female-spoken items): Hughes et al. (2013) established that the same increase in task-encoding load abolishes this deviation effect. It was argued in that case that the high encoding load triggered a top-down cognitive shift in the degree of focal-task engagement such that the deviant's 'call for attention' (cf. Näätänen, 1990), while still heard, is more readily denied (Hughes et al., 2013; see also Halin, Marsh, Haga, Holmgren, & Sörqvist, 2014; Halin, Marsh, Hellman, Hellström, & Sörqvist, 2014; Halin, 2016; Marsh et al., 2015; Marsh, Ljung, Jahncke, MacCutcheon, Pausch, & Vachon, 2017). The present results suggest that the particular power of valent distracters to draw attention is also diminished when focal-task engagement is increased. We return in the General Discussion to consider this issue in more detail and to consider alternative mechanisms (e.g., perceptual filtering; Lavie, 2005) by which high encoding load may have exerted its effect. For now, the load manipulation has served its purpose, that is, to reveal that the valence effect behaves in the same way in response to increased encoding load as an attentional-diversion based effect (the deviation effect) and differently from the classical irrelevant speech effect (Hughes et al., 2013).

Adopting a converging operations approach, we now seek further evidence for the incidental status of post-categorical auditory distraction in serial recall—again capitalizing on the distracter-valence effect—using a quite distinct empirical tactic from that used in Experiment 1. By definition, our argument that post-categorical distraction effects are incidental to *serial* short-term memory predicts that they should be found regardless of whether the task requires serial order processing. In Experiment 2, therefore, we move away from serial recall and examine whether the distracter-valence effect is produced in a missing-item task, in which the adoption of a serial ordering strategy has been shown to be relatively infrequent (Morrison, Rosenbaum, Fair, & Chein, 2016).

Experiment 2

In the missing-item task, participants are required to report which item is missing from a list composed of all but one of a well-known set (e.g., *1-9*). For example, *6* is missing from the list *31784952* (e.g., Buschke, 1963; Klapp, Marshburn, & Lester, 1983). Note that in this task the order of the items in the list is irrelevant to identifying the missing item. Furthermore, several independent lines of evidence suggest that the majority of participants do not adopt a serial ordering strategy to support performance of the task: Unlike serial recall (and other order-recall tasks), the task is immune to the effects of articulatory suppression (Klapp et al., 1983) which is often assumed to impair serial rehearsal processes (e.g., Baddeley, 2007; Jones et al., 2006; Murray, 1968) and also immune to the effect of talker variability (when presented in spoken form), an effect also argued to be located in the serial rehearsal process (Hughes, Marsh, & Jones, 2011). Most recently, a study of self-reported strategy-use across a range of short-term/working memory tasks indicated that missing-item task performance exhibited a distinctly different profile from all other tasks studied (Morrison et al., 2016). In particular, relatively few participants (around 25%) reported using serial rehearsal to perform the task. The available evidence suggests that it tends to be performed instead using a "checking off" strategy, with each item being checked off a representation of the fixed ordinal sequence during list presentation; the missing-item is thereafter identified on the basis of recognition of which item in the ordinal sequence was not checked off (Beaman & Jones, 1997; Buschke & Hinrichs, 1968; Humphreys & Schwartz, 1971; Morrison et al., 2016). While the understanding of how the missing-item task is performed remains inchoate, it is sufficient for the logic of the present experiment that there is good evidence that the task is not strongly order-based. To elaborate, previous studies have found that changing-state irrelevant speech has little if any effect on the missing-item task (Beaman & Jones, 1997; Elliott et al., 2016; Hughes et al., 2007; Jones & Macken, 1993) while the deviation effect—

ascribed universally to attentional diversion—is clearly evident in this task (Hughes et al., 2007; Vachon et al., 2017). Thus, we predict based on the duplex-mechanism account that distracter-valence effects should also be produced in the missing-item task while the effect of speech per se (neutral words vs. quiet) should be attenuated. This would provide further strong evidence that the distracter-valence effect, like the deviation effect, is functionally distinct from the changing-state driven irrelevant speech effect. Whilst the unitary, attentional-diversion, account would also predict a valence effect in this task, there is no reason to expect the general effect of speech per se to be attenuated.

Method

Participants. Sixty-five psychology students (39 females, 26 males; *mean age* = 23.1, *SD* = 5.4; *age range* = 18-41) at the University of Central Lancashire took part in the experiment in return for course credits or a small honorarium. All reported normal hearing and normal or corrected-to-normal vision. None had taken part in Experiment 1.

Apparatus and materials. The materials were identical to those of Experiment 1 except for the fact that the set from which the eight items were taken was, necessarily, one item larger (*1-9*). The item missing from the list was determined randomly for each trial.

Design. The experiment had one repeated-measures factor (Sound) with four levels: Quiet, neutral words, negatively valent words, and positively valent words (the valent words could again be either physical or social in nature). The block structure was identical to that in Experiment 1.

Procedure. The procedure was also identical to that of Experiment 1 except for the response phase of each trial: After the offset of the last memory item, the digits *1–9* appeared in a horizontal array on the screen but this time the "?" in the middle of the array was replaced with a digit to make the set of 9. Participants were to click on the digit that they thought was missing from the just-presented list.

Results

Figure 3 shows missing-item performance—the proportion of correctly identified missing items—in the quiet, neutral, positively-valent, and negatively-valent conditions. The pattern across the latter three (with-distracter) conditions closely replicates that found in the low task-encoding load condition of Experiment 1: positive distracters impaired performance compared to neutral distracters (as well as quiet) and negative distracters impaired performance compared to positive distracters (as well as neutral distracters and quiet). A one-way repeated-measures ANOVA (quiet, neutral distracters, positive distracters, negative distracters) yielded a main effect of Sound, $F(3, 192) = 38.91$, $MSE = .008$, $p < .001$, $\eta_p^2 = .38$. Pairwise comparisons revealed significant differences between quiet and each of the other three sound conditions (quiet *vs.* neutral, $p < .001$, 95% CI [.046, .114], $\eta_p^2 = .26$; quiet *vs.* positive; $p < .001$, 95% CI [.084, .148], $\eta_p^2 = .45$; quiet *vs.* negative, $p < .001$, 95% CI [.130, .195], $\eta_p^2 = .61$). Furthermore, there was a significant difference between performance in the neutral and positive conditions ($p = .017$, 95% CI [.007, .065], $\eta_p^2 = .09$), between neutral and negative ($p < .001$, 95% CI [.053, .112], $\eta_p^2 = .33$), and between positive and negative ($p = .002$, 95% CI [.018, .075], $\eta_p^2 = .14$).

Further analysis confirmed that the magnitude of the distracter valence effects was comparable to those found in serial recall (Experiment 1). A cross-experiment analysis excluding the quiet condition from both experiments revealed a main effect of Sound, $F(2, 266) = 28.61$, $MSE = .005$, $p < .001$, $\eta_p^2 = .18$, but no main effect of Experiment (or Task), $F(1, 133) = .008$, $MSE = .076$, $p = .93$, $\eta_p^2 < .001$, nor an interaction between these factors, $F(2, 266) = 2.6$, $MSE = .005$, $p = .076$, $\eta_p^2 = .02$. Important also is that although there remained a significant disruptive effect of neutral words compared to quiet in the present experiment, this was attenuated compared to Experiment 1: A 2 (Experiment/Task: Serial Recall vs. Missing Item) × 2 (Quiet vs. Neutral Distracters) cross-experiment comparison using only the data from the low load condition of Experiment 1 revealed a main effect of Sound, $F(1, 133) = 103.56$, $MSE = .008$, $p < .001$, $\eta_p^2 = .44$, no main effect of Task, $F(1, 133) = .35$, MSE - .047, $p = .56$, $\eta_p^2 = .003$, but, critically, a significant interaction between Sound and Task, $F(1, 133] = 7.33$, $MSE = .008$, $p = .008$, $\eta_p^2 = .05$, in line with a larger effect of neutral words compared to quiet in the serial recall task ($\eta_p^2 = .61$) compared to that in the missing-item task ($\eta_p^2 = .26$).

Discussion

Experiment 2 established that the auditory distracter-valence effect—which, in the short-term memory literature, has previously only been tested in the context of serial recall (Buchner et al., 2006, 2004; present Experiment 1)—is also found in a short-term missing-item task in which serial-order processing is an infrequently adopted strategy (Morrison et al., 2016). At the same time, the effect of neutral words compared to quiet was attenuated as compared to Experiment 1. The findings therefore provide converging evidence for our argument that the distracter-valence effect found in serial recall (Buchner et al., 2006, 2004; present Experiment 1) is incidental: it is an attentional diversion effect unrelated to the classical, changing-state driven, irrelevant speech effect.

One aspect of the results of Experiment 2 appears at first glance not to cohere entirely with our account however. In Experiment 1, we interpreted the disruptive effect of neutral distracters compared to quiet—which survived high encoding-load—as indicative of the classical, changing-state driven, irrelevant speech effect. If this interpretation is correct, however, it is then not entirely clear why disruption from neutral distracters compared to quiet was evident at all in Experiment 2 in the context of the missing-item task: If this contrast reflects the changing-state effect, then it should have been eliminated, and not merely attenuated, in this task. However, tasks are rarely process- or strategy-pure and hence the significant effect of neutral words compared to quiet in Experiment 2 may have been driven by participants that adopt a serial rehearsal strategy even in the missing-item task (cf. Morrison et al., 2016). Whilst we cannot be certain of this in relation to the present experiment, the results of another recent study support our supposition: Using a similar self-report procedure to Morrison et al. (2016), we found that participants who reported using a serial rehearsal strategy in the missing-item task exhibited a changing-state effect while those that reported a non-serial-rehearsal strategy did not (Hughes & Marsh, 2017).

General Discussion

The current study examined the status of post-categorical auditory distraction in serial short-term memory, capitalizing in particular on the greater disruptive effect on serial recall of valent compared to neutral distracters (Buchner et al., 2004, 2006). The results of two experiments suggest that the fact that serial recall per se is vulnerable to post-categorical auditory distraction is incidental: The distracter-valence effect, at least, is due to a general attentional diversion mechanism that is, unlike the classical irrelevant speech effect, blocked when greater focal-task engagement is promoted via an increase in task-encoding load (Experiment 1). Moreover, in line with the inherent generality of attentional diversion, or its task-process non-specificity, it is found in a task—the missing-item task—for which serial-order processing is a relatively infrequently-adopted strategy (Experiment 2). The results thus provide further support for a duplex-mechanism account of auditory distraction (Hughes, 2014; Hughes et al., 2005, 2007, 2013) in which the classical irrelevant speech effect is driven by pre-categorical, acoustic, changes that generate order cues that conflict specifically with short-term serial-order processes such as those heavily tapped by tasks like serial recall (Morrison et al., 2016). Attentional diversion is a second, distinct, mechanism that is more open to top-down cognitive control (e.g., Hughes et al., 2013, present Experiment 1) and whose action is more general, operating potentially in any task-setting (cf. Vachon et al., 2017) so long as it has not been wholly automatized (cf. Neumann, 1996). At the same time, the results are problematic for a unitary account of auditory distraction based on the embedded-processes model of working memory (Cowan, 1995; Buchner et al., 2004; Elliott, 2002; Röer et al., 2013).

Whilst we used the distracter-valence effect in particular to test our general argument in the present study, this choice was largely arbitrary; we would argue that other post-categorical distraction effects in serial recall, such as the taboo-word effect (Röer et al., 2017) and the own-name effect (Röer et al., 2013) are also attentional-diversion effects unrelated to serial short-term memory processes per se. It may seem tempting to go on to conduct further studies to test whether our argument does indeed have such generality but this would, arguably, be redundant: It is already known that these effects are not specific to serial short-term memory: The own-name effect is better known as the 'cocktail party effect', long cited as a classic instance of attentional capture typically demonstrated in the context of the immediate repetition (or 'shadowing') of an unrelated speech-stream (Conway, Cowan, & Bunting, 2001; Moray, 1959; Wood & Cowan, 1995). While such a task clearly relies on an accurate perception of serial order, it is unlikely to impose much demand on serial-order retention given the relatively high transitional probabilities between the constituent elements of the to-be-shadowed speech (Treisman, 1964). Similarly, the taboo-word effect (Röer et al. 2017) could be described as an extreme instance of the distracter-valence effect and has also been found in tasks that are unlikely to place a great demand on serial order processing, including the Stroop task (Siegrist, 1995) and picture-naming (Dhooge & Hartsuiker, 2011). Thus, again, we would argue that the cocktail party and taboo-word effects in the context of serial recall (Röer et al., 2013) do not speak to serial short-term memory per se.

One means, however, by which an attentional diversion account might accommodate some of the present results is by appealing to a recent two-component variant of the account: Röer et al. (2015) suggest that any sound elicits a "basic call for attention process enabling the organism to detect an auditory stimulus and to compare it to an existing neural model" but some sounds will, in addition, cause a "full attention switch to the auditory modality" (p. 700). Thus, in relation to the present Experiment 1, it could be argued that the neutral words produced a basic call for attention that occurs regardless of task-encoding load whilst, as we also suppose, that same load blocked a full attention-switch to the sound by valent stimuli. However, we see several problems with the 'call-for-attention' component of this account: First, the notion that any sound elicits a resource-demanding (and hence disruptive) 'call for attention' because it needs to be compared with a neural model of preceding stimuli predicts that there should be a robust disruptive effect of steady-state sound compared to quiet. That is, the same resource-demanding judgment process that is required to determine that a sound differs from the previous one must presumably be needed to determine that it is the same as the previous one. And yet while a small 'steady-state effect' is sometimes found, it is far from robust (e.g., Jones, 1994; Jones & Macken, 1993; Jones et al., 1992). One potential counterargument might be that once two or three sounds in a steady-state condition have been presented, the system is already strongly predicting another steady-state sound and so the judgment process is circumvented. However, this then commits the account to the idea that the disruptive effect of irrelevant sound on serial recall is a function of its predictability, but this is not the case: Presenting a relatively unpredictable sequence such as "HJUCUCJHUCHJ…" is no more disruptive than a relatively predictable one such as "CHJUCHJUCHJU…" (Jones et al., 1992; see also Hughes & Jones, 2005, Marsh et al., 2014; Tremblay & Jones, 1998). Second, the account cannot explain the fact that there is a non-monotonic relationship between the degree of changing-state between successive sounds and the degree to which they disrupt serial recall. For instance, if the difference in pitch between two alternating tones is very great (10 semi-tone difference) the disruption is less than if the difference is more modest (5 semi-tone difference; Jones, Alford, Bridges, Tremblay, & Macken, 1999). This is readily explained within the interference-by-process account because the changing-state effect is intimately linked with auditory perceptual organization: When the pitch difference is great the tones will tend to split into two steady-state streams and hence produce less disruption than the 5 semi-tone difference sequence in which the difference is modest enough for the tones to be perceived as changing elements within a single stream. Third, the results of the present Experiment 2 remain problematic for the account: Given that the call-for-attention is presumably not task-sensitive, it cannot explain why the effect of neutral words compared to quiet was attenuated in the missing-item task compared to the serial recall task (see also Beaman & Jones, 1997; Elliott et al., 2016; Hughes et al., 2007; Jones & Macken, 1993).

Interference-by-Process: Implications for Inferring the Fate of the Unattended

The present results are consistent with the assumption of the interference-by-process account that it is the pre-categorical, acoustic, properties of speech—specifically, acoustic variation or changing-state—not its post-categorical, linguistic, attributes (e.g., phonology, syntax, meaning) that endows it with the power to disrupt serial recall per se (Jones, 1999). That this is the case says nothing, however, about whether or not irrelevant speech is *processed* beyond its acoustic properties. Indeed, the distracter-valence effect studied here, as well as other post-categorical distraction effects found in serial recall such as the taboo-word effect (Röer et al., 2017), demonstrates that post-categorical properties of irrelevant speech are indeed processed and can, through a functionally distinct attentional diversion mechanism, add to the overall disruption of serial recall by irrelevant speech. Indeed, other recent findings indicate that the post-categorical properties of irrelevant speech are processed during serial recall. For example, words presented as irrelevant speech in a serial recall task prime the responses generated in a subsequent semantic fluency task (Röer et al., 2016). Furthermore, an unexpected deviation on the post-categorical dimension of a sequence of speech distracters disrupts serial recall (Marsh, Röer, Bell, & Buchner, 2014) just as a deviation on the acoustic dimension does (Hughes et al., 2007). An important implication of such evidence is that it means that the classical question concerning the extent to which irrelevant stimuli are processed (cf. the 'fate of the unattended', e.g., Broadbent, 1958; Jones, 1995) must be separated conceptually from the question of which properties of irrelevant stimuli underpin their capacity to interfere with task performance (Cosman, Mordkoff, & Vecera, 2016; Driver & Tipper, 1989; Marsh et al., 2014; Röer et al., 2017). That is, it has often been assumed that the properties of irrelevant material that underpin its disruptive power in a given task-setting provides information about the level to which unattended stimuli are processed—or, more specifically, about which of their properties are *not* processed—and hence about the locus of attentional selection (e.g., Francolini & Egeth, 1980; Jones, 1995; Kahneman & Chajczyk, 1983; Lavie & Tsal, 1995). Research using irrelevant speech during serial recall, then, shows quite clearly that such logic is flawed. For example, the fact that forward speech is no more disruptive of serial recall than backward speech (Jones et al., 1990; Röer et al., 2016) cannot be taken to indicate that irrelevant speech is only processed to an acoustic level. Rather, in some task-settings, the processing involved in the focal task, while seemingly not a determinant of the level of distracter processing, determines which distracter properties will assume disruptive potency (Jones, 1999; see also Jones, Marsh, & Hughes, 2012; Marsh, Hughes, & Jones, 2008, 2009; Marsh, Vachon, & Jones, 2008). For example, whereas forward speech is no more disruptive of serial recall than reversed speech (Jones et al., 1990), when the focal task involves semantic processing (unlike the typical serial recall task) forward speech is indeed more disruptive than reversed speech (Marsh et al., 2009).

The Action of High Task-Encoding Load

The results of the present Experiment 1 add to an emerging body of evidence showing that high task-encoding load shields against some forms of auditory distraction (Halin, Marsh, Hellman et al., 2014; Halin, Marsh, Haga et al., 2014; Halin, 2016; Hughes et al., 2013; Marsh et al., 2015, 2017). It was argued in Hughes et al. (2013; see also Hughes, 2014) that the same increase in task-encoding load as implemented here abolished the disruptive effect of an unexpected deviant sound by promoting a top-down upward shift in focal-task engagement (for similar ideas, see, e.g., Buetti & Lleras, 2016; Matthews et al., 2002). Consistent with this, while it is well established that the perceptually degraded items used in the present Experiment 1 are indeed more difficult to encode (Hughes et al., 2013; Parmentier, 2008), serial recall performance itself was not affected by the degradation (as observed also in Hughes et al., 2013); only the effect of distracter-valence on serial recall was modulated. This is consistent with the idea that under the sub-optimal high load conditions, participants strategically shift their level of task-engagement in order to maintain task performance (cf. Eggemeier, Crabtree, & LaPointe, 1983). This increase in task-engagement may prevent attentional diversion by enhancing the capacity to resist the 'call for attention' by the otherwise attention-diverting material (what might be called the *late-blocking mechanism*; Hughes, 2014). Another, non-mutually exclusive, candidate mechanism is *sensory gating*: High task-engagement may shield against attentional diversion by attenuating the processing of the sensory input itself (see also Buetti & Lleras, 2016; Marsh & Campbell, 2016; Marsh et al., 2015; Sörqvist et al., 2012; Sörqvist & Marsh, 2015). In the latter case, the potentially attention-diverting event fails to divert attention because it is simply not detected (or not as readily).

In the context of the present distracter-valence effect, then, the late-blocking view would assume that the meaning and hence valence of the speech was processed under high task-encoding load but the boost in task-engagement in response to that increased load prevented the usual shift of attention to such material. An appeal instead to the sensory gating mechanism could also account for the elimination of the valence effect and the survival of the effect of speech per se (i.e., neutral speech *vs.* quiet) by supposing that the high load only attenuated perceptual processing to the extent that meaning was no longer registered while acoustic processing proceeded regardless. However, a consideration of previous findings using the same load manipulation suggests late blocking as the more likely mechanism. Hughes et al. (2013) found that the same increase in load dissociated two forms of distraction operating *within* the acoustic dimension: it eliminated the impact of a single acoustically deviant sound but left the impact of continuously changing sounds (i.e., the changing-state effect) unaltered. If increased task-engagement leads to a general gating of sensory processing, then one would expect the changing-state effect to have also been attenuated.

A third candidate mechanism for the action of high encoding-load in the present study is that embodied in Lavie's (1995, 2005) *Load Theory* of attention. This model posits a limited-capacity attentional resource dedicated to perceptual processing such that if that resource is exhausted by the perceptual load imposed by the focal task, this has the automatic effect of preventing the processing of any non-task stimuli and hence eliminates their distracting power. A potential strength of this account in the present context is that it is, arguably, more parsimonious as it eliminates the need to invoke the notion of dynamic changes in task-engagement; the abolition of distraction in this view is a passive, bottom-up, consequence of the increase in perceptual load. But again the dissociation between the effect of the present high task-encoding load on two forms of acoustically-driven distraction (Hughes et al., 2013) appear to rule out this account (Hughes, 2014). In addition, according to proponents of Load Theory, the load manipulation implemented here (and in Hughes et al., 2013) is not, in any case, one of perceptual load. Rather, stimulus degradation is classed in this theory as an increase in sensory, not perceptual, load (Lavie & de Fockert, 2003). Critically, the theory assumes that increased sensory load *increases* rather than reduces distraction. In addition, it has been shown that an increase in non-perceptual (cognitive) load—in the form of a secondary concurrent-articulation task—also eliminates attentional diversion by a deviant sound (Hughes, Hurlstone, & Jones, 2017). While this result can be explained by supposing that any increase in task-load (whether perceptual or cognitive) instigates a shift in levels of task-engagement, Load Theory predicts the opposite result: that high cognitive load, as with high sensory load, should increase distraction. Thus, regardless of whether, on this theory, the present manipulation would be conceptualized as one of perceptual or sensory load, it cannot readily account for the present findings nor more generally those from what is now a fairly substantial body of work on the interactions between task load and auditory distraction (e.g., Hughes et al., 2013; Marsh et al., 2015, 2017; Halin, Marsh, Hellman, et al., 2014; Halin, Marsh, Haga, et al., 2014; Halin, 2016; see also Murphy, Fraenkel, & Dalton, 2013).

It seems worthwhile to also consider briefly how the present effect of task load on distraction by emotional valence relates to the large literature on emotion regulation (e.g., Ochsner & Gross, 2005; Mitchell, 2011). It has been argued that the processing of emotional stimuli—particularly threat-related stimuli—is ‘special’ insofar as it is not subject to the same kind of attentional control as that of other stimuli. For example, it has been reported that the amygdala response to threat stimuli (e.g., fearful faces) is not influenced by attentional focus, leading to models in which the processing of such stimuli is ‘automatic’, unconstrained by the availability of attention (Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003; Dolan and Vuilleumier 2003; Vuilleumier, Armony, Driver, & Dolan, 2001). That increased task-engagement eliminates the effect of threat words in the current study is not easily reconcilable with such models. Our findings instead reinforce several other recent reports that demonstrate that, at odds with “automatic” models of threat detection, an attenuation of threat-driven distraction under high task load (Bishop, Jenkins, & Lawrence, 2007; Gupta, Hur, and Lavie, 2016; Tavares, Logie, & Mitchell, 2016). Our findings also cohere with the notion that emotion dysregulation may be linked to a reduction in the efficacy of attentional control networks that otherwise impose limits on the number and/or strength of spontaneous, unwanted, emotional intrusions on cognition (Tavares et al., 2016). Several recent studies have shown that high task load suppresses amygdala activity with the proposed effect of inhibiting emotional responses to ensure current behaviour remains goal-directed (e.g., Van Dillen, Heslenfeld, & Koole, 2009; Okon-Singer, Lichtenstein, & Cohen, 2013). Moreover, this suppression of amygdala activity may be a by-product of higher task load that occurs independently of the emotional valence of distracter stimuli (see Sörqvist, Dahlström, Karlsson, & Rönnberg, 2016).

Implications for the Phonological-Store Based Account of the Irrelevant Speech Effect

We have focused in the present article on adjudicating between the interference-by-process (e.g., Hughes & Jones, 2001) and the unitary, attentional-diversion, accounts of the irrelevant speech/sound effect (Buchner et al., 2004; Röer et al., 2013). However, a recent account of the irrelevant speech effect based on the *Working Memory* model (Baddeley, 1986, 2007) can be described as a hybrid of the interference-by-process and attentional diversion accounts: The processing of acoustic changes in the speech interfere with the serial ordering involved in the focal task. However, rather than disrupt motor-planning as in the interference-by-process account, it is argued that the encoding of the order of the sounds usurps attentional resources required to set up an initial representation of the order of the to-be-remembered items (specifically, through a primacy gradient; Page & Norris, 1998) in a dedicated phonological short-term store (Norris, Baddeley, & Page, 2004; Page & Norris, 2003). This phonological-store based account can explain the results of Experiment 2 in a similar way to the interference-by-process account: The effect of speech per se in the missing-item task is attenuated because the task does not specifically require the encoding of item-order while distracter-valence disrupts performance because it draws attentional resources required for any (non-automatic) task. However, the results of Experiment 1 are problematic for this account for the same reason as they are for the unitary, attentional diversion, account: It predicts, incorrectly, that the prevention of attentional diversion by high task-encoding load should attenuate not only the distracter-valence effect but also the effect of speech generally. One of the other key difficulties for any phonological-store based account of the irrelevant speech/sound effect is that it predicts that there should be an irrelevant speech effect even when motor-planning is blocked by articulatory suppression so long as the to-be-remembered items enjoy obligatory access to the phonological store by being presented auditorily (Hanley, 1997; Hanley & Broadbent, 1987). However, this is not the case: In line with the interference-by-process account, the effect is abolished when motor-planning is impeded regardless of the modality of list-presentation (Jones et al., 2004).

Conclusions

In conclusion, the present results support the view that post-categorical auditory distraction in serial short-term memory is functionally unrelated to the classical irrelevant speech effect (Jones, 1993) and hence to serial short-term memory more generally. We maintain that the irrelevant speech/sound effect is underpinned by the perception of pre-categorical, acoustic, changes within the auditory material and is best explained through interference-by-process and not attentional diversion. At the same time, the dissociations found here between the effect of speech per se and the valence of the speech provide further support for the duplex-mechanism account of auditory distraction in which both attentional diversion and interference-by-process mechanisms can determine distraction depending on the nature of the sound and the demands of the focal task (Hughes, 2014; Hughes et al., 2007, 2013).

The appeal within the interference-by-process account solely to perceptual organization and motor-planning processes has paved the way to an approach to serial short-term memory generally in which such general-purpose processes are invoked without the encumbrance of a specific structure or set of mechanisms dedicated to short-term remembering. This perceptual-motor account has by now enjoyed a good deal of success in providing what we would argue are more parsimonious explanations of an array of canonical serial short-term memory phenomena, including the phonological similarity effect (Jones et al., 2004) and its interaction with sensory modality and articulatory suppression (Jones et al., 2006, 2004; Maidment & Macken, 2012), perceptual variability effects (Hughes et al., 2009, 2011, 2016), modality effects (Macken, Taylor, Kozlov, Hughes, & Jones, 2016), and the reciprocal relation between short- and long-term learning processes (G. Jones & Macken, 2015; Macken, Taylor, & Jones, 2014; Sjöblom & Hughes, 2017; Woodward, Macken, & Jones, 2008).

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Figure and Table captions

Figure 1. In the low task-encoding load condition, all digits in a given list appeared as shown on the left; in the high task-encoding load condition, they appeared as shown on the right.

Figure 2. Mean proportion of correct responses for quiet, neutral, positive distracter and negative distracter conditions for the low and high task-encoding load conditions of Experiment 1. Error bars represent the standard errors of the mean.

Figure 3. Mean proportion of missing items correctly identified in quiet, neutral distracter, positive distracter and negative distracter conditions of Experiment 2. Error bars represent the standard errors of the mean.

Table 1. Psycholinguistic properties of the neutral, positive and negative distracters used in Experiments 1 and 2.

Figure 1.

Figure 2.

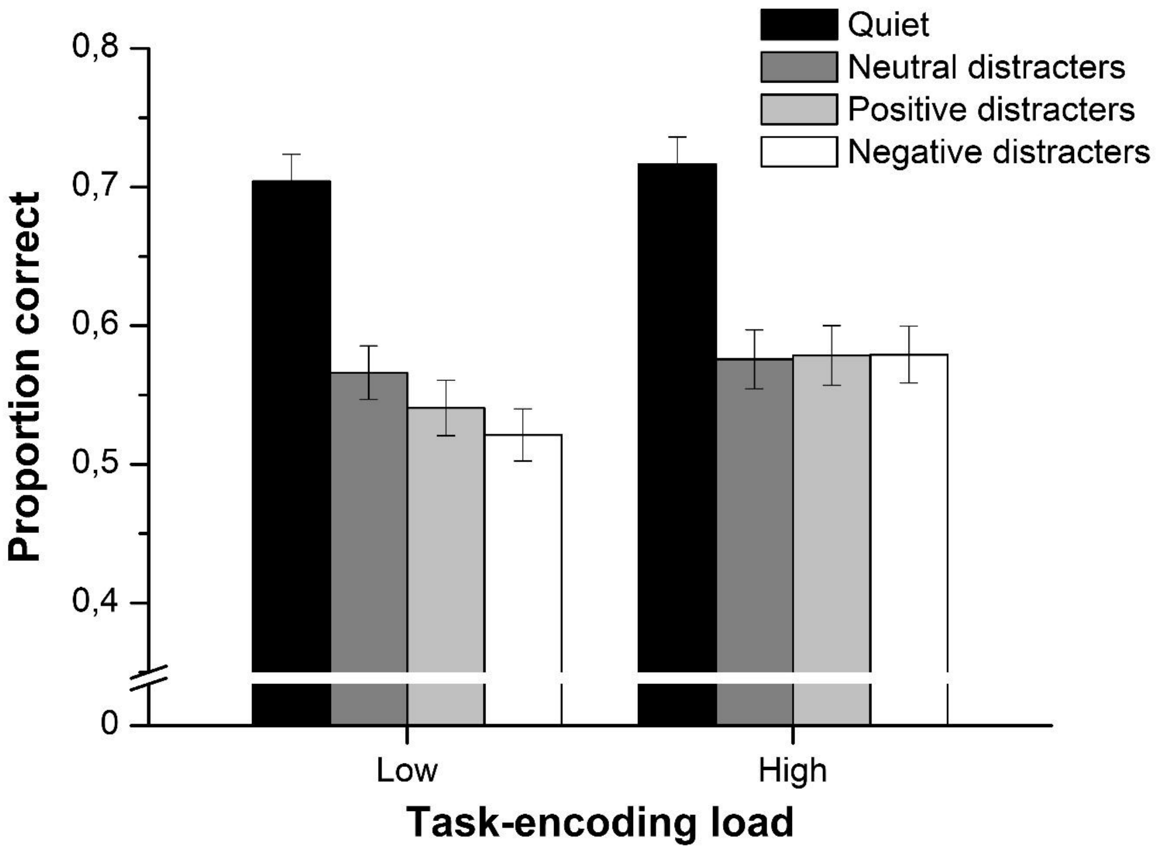
Quiet
Neutral distracters
Positive distracters
Negative distracters
0,8
0,7
0,6
0,5
0,4
0
Proportion correct
Low
High
Task-encoding load

Figure 3.

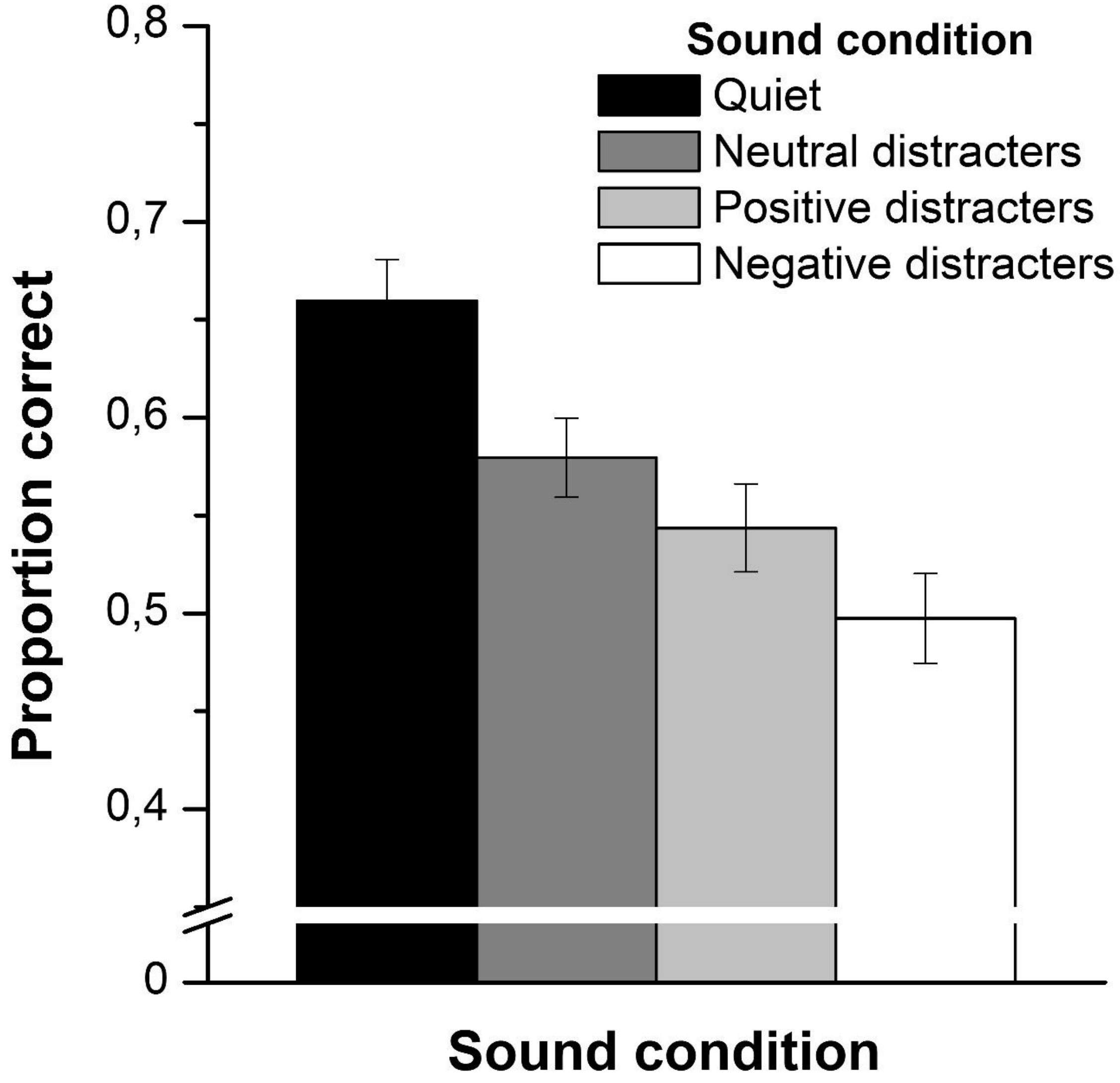
0,8
0,7
0,6
0,5
0,4
0
Proportion correct
Sound condition
Quiet
Neutral distracters
Positive distracters
Negative distracters
Sound condition

Table 1/Appendix

Social Threat distracters

No.	Word	Valence	Concreteness	K-freq	Letter	Syllable	T-freq
1	Hate	2.12	335	42	4	1	456
2	Tease	4.84		6	5	1	105
3	Coward	2.74		8	6	2	71
4	Insane	2.85		13	6	2	81
5	Stupid	2.31	351	24	6	2	144
6	Lonely	2.17		25	6	2	203
7	Neglect	2.63	282	12	7	2	192
8	Inferior	3.07	311	7	8	3	40

Social Positive distracters

No.	Word	Valence	Concreteness	K-freq	Letter	Syllable	T-freq
1	Hope	7.05	261	178	4	1	1180
2	Loyal	7.55		18	5	1	91
3	Admire	7.74	296	10	6	2	257
4	Engage	8.00		14	6	2	424
5	Gentle	7.31	322	27	6	2	242
6	Virtue	6.22	243	30	6	2	126
7	Passion	8.13	300	28	7	2	236
8	Intimate	7.61	281	21	8	3	172

Physical Threat distracters

No.	Word	Valence	Concreteness	K-freq	Letter	Syllable	T-freq
1	Hurt	1.90	368	37	4	1	725
2	Pinch	3.83		6	5	1	86
3	Robber	2.61	545	2	6	2	27
4	Coffin	2.56	595	7	6	2	50
5	Cancer	1.50	615	25	6	2	27
6	Damage	3.05	406	33	6	2	156
7	Assault	2.03	410	15	7	2	46
8	Mutilate	1.82			8	3	8

Physical Positive distracters

No.	Word	Valence	Concreteness	K-freq	Letter	Syllable	T-freq
1	Safe	7.07	376	57	4	1	550
2	Greet	7.00		7	5	1	238
3	Cuddle	7.72			6	2	15
4	Dazzle	7.29		1	6	2	79
5	Lively	7.20		26	6	2	103
6	Secure	7.57		30	6	2	353
7	Protect	7.29		34	7	2	383
8	Carefree	7.54		9	8	3	42

Neutral distracters

No.	Word	Valence	Concreteness	K-freq	Letter	Syllable	T-freq
1	Deer		631	13	4	1	47
2	Sheep		622	23	5	1	86
3	Donkey			1	6	2	20
4	Turtle		644	8	6	2	21
5	Badger		566	9	6	2	64
6	Rabbit	6.57	635	11	6	2	96
7	Hamster		599		7	2	
8	Elephant		628	7	8	3	144