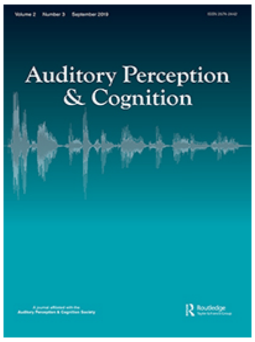

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Dissociating Two Forms of Auditory Distraction in a Novel Stroop Serial Recall Experiment

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ABSTRACT
We report a dissociation of two forms of auditory distraction within a single repeated-measures experiment using a novel Stroop serial recall task in which participants were oriented either to serially recall six color-words (low task-load condition) or the incongruent colors in which those words were presented (high task-load condition). The disruption of serial recall due to a single deviation in the voice delivering a sequence of task-irrelevant speech tokens (the deviation effect) was replicated in the low task-load condition but eliminated in the high task-load condition. In contrast, the disruption of serial recall by continuously changing compared to a repeating sound (the changing-state effect) did not differ according to task-load. The results provide further support for a duplex-mechanism account of auditory distraction: Disruption due to attentional diversion (cf. the deviation effect) is modulated by levels of focal task-engagement whereas interference-by-process (cf. changing-state effect) – in which the processing of the sound conflicts with seriation processes involved in task performance – is not.

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Auditory distraction; serial recall; Stroop; interference-by-process; attentional diversion; task-load

The auditory modality is our sentinel of the senses: it is always "on guard", picking up information about objects and events from all directions, even in darkness, and even to some extent during sleep (e.g., Davis, 1965; Golob & Holmes, 2011; Hapeshi & Jones, 1992; Hughes & Jones, 2001; Miller, 1974). This essential permeability of the auditory modality, however, renders us particularly vulnerable to distraction. The obligatory processing and organization of the auditory scene means that sound that is irrelevant to current mental processing often impinges on focal task performance. Of theoretical interest in the present article is the debate as to whether auditory distraction is a unitary phenomenon (e.g., Elliott, 2002; Röer, Bell, & Buchner, 2015) or whether there are two distinct classes of such distraction, one of which is contingent on the type of processing deployed to perform the focal task and one of which is contingent on the level of engagement in the focal task (e.g., Hughes, 2014; Hughes, Hurlstone, Marsh, Vachon, & Jones, 2013; Marsh et al., 2018).

On the duplex-mechanism account of auditory distraction (e.g., Hughes, 2014), the obligatory processing of sound can lead to two distinct forms of auditory distraction:

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Interference-by-process occurs when the processing of the sound conflicts with a similar process being deployed to perform the prevailing cognitive activity (e.g., Hughes & Marsh, 2017; Jones & Macken, 1993; Jones & Tremblay, 2000). In contrast, *attentional diversion* occurs when something within the auditory scene is either unexpected or is endowed with some particular interest or relevance to the individual and thereby draws attention away from the prevailing activity (Hughes, 2014; Hughes & Marsh, 2020). The hypothesized distinction between these two mechanisms of distraction has been based primarily on studies of auditory distraction during short-term verbal serial recall (e.g., Colle & Welsh, 1976; Jones & Macken, 1993; Salamé & Baddeley, 1982). In a typical experiment in this paradigm, around 5–8 verbal items (e.g., words, digits, letters) are presented one-by-one on the screen and must then be recalled in serial order. Interference-by-process is said to be witnessed in this setting in the form of the *changing-state effect* (Jones, Madden, & Miles, 1992): An irrelevant sound sequence whose elements are changing acoustically from one segmentable element to the next (e.g., "G, R, Q, B … "; or a succession of different-frequency tones changing in frequency) is more disruptive than a sequence in which the same sound is repeated ("steady-state" sound; e.g., "G, G, G, G … ", or a repeating tone; Jones & Macken, 1993). The interference-by-process account posits that the involuntary processing of the acoustic changes in a changing-state sequence yields information pertaining to the order of its elements and that this order information interferes with the similar but deliberate process of seriating the to-be-remembered items within a motor-plan assembled in support of serial recall (e.g., Jones & Tremblay, 2000).

According to the duplex-mechanism account, a second form of auditory distraction that can also be witnessed in the context of verbal serial recall (but also in other tasks; e.g., Hughes, Vachon, & Jones, 2007; Marsh et al., 2018; Parmentier, 2008) is attentional diversion. The most prominently studied example of attentional diversion is the disruptive effect of an unexpected deviation with the sound sequence. For instance, verbal serial recall is disrupted if one of the stimuli in an irrelevant speech sequence is presented in a different voice from, or presented out of time with, the other stimuli in that sequence (Hughes et al., 2013; Hughes, Vachon, & Jones, 2005; Hughes et al., 2007). In short, then, interference-by-process occurs when the processing of the irrelevant sound conflicts with a process being deployed to perform the focal task whereas attentional diversion occurs due to a temporary disengagement from the focal task (Hughes, 2014).

One key line of evidence that interference-by-process and attentional diversion are functionally distinct mechanisms is that their most prominently studied empirical referents – the changing-state effect and the deviation effect, respectively – are differentially amenable to top-down cognitive control: The deviation effect is attenuated or eliminated when encoding the to-be-remembered material is relatively difficult whereas the changing-state effect is not (Hughes et al., 2013; Marsh, Campbell, Vachon, Taylor, & Hughes, 2020).[1] We have suggested that such an increase in encoding-load leads to a top-down boost in task-engagement which acts to shield against the task-disengagement usually caused by an unexpected event. The changing-state effect, in contrast, is not affected because an increase in encoding-load would not be expected to reduce reliance on the process (serial rehearsal) that is thought to make serial recall vulnerable to that effect (Hughes et al., 2013).

In contrast to the duplex-mechanism account stands a unitary account in which the changing-state effect and the deviation effect are both attributed to attentional diversion (e.g., Cowan, 1995; Röer et al., 2015). In this view, a sound that differs from its immediate predecessor (i.e., each sound in a changing-state sequence) draws attention away from the focal task more than a sound that is a repetition of its predecessor, just as a deviant is more likely to divert attention compared to the preceding succession of non-deviating sounds (e.g., Bell, Röer, Marsh, Storch, & Buchner, 2017). If this was the case, however, it is not clear why the changing-state effect should not also be diminished when attention must remain more steadfast on the focal task (i.e., under high task-load). However, a criticism that has been leveled at the duplex-mechanism account is that the dissociation between the two main empirical referents of the two putatively different mechanisms – the deviation effect and the changing-state effect – "is rarely tested directly within a single experiment. Instead, almost all evidence in favor of [the] dissociation … relies on comparisons across studies" (Bell et al., 2017, p. 360). Körner, Röer, Buchner, and Bell (2017) raise the same issue:

"A recurring problem is that the arguments in favor of a dissociation of the changing-state effect and the deviation effect more often than not rely on comparisons across different experimental setups that do not allow one to compare the two phenomena directly. This is not ideal for drawing conclusions because dissociations might have been produced by methodological differences between experiments rather than by differences between the changing-state effect and the deviation effect per se" (p. 123).

And indeed, this is the case in relation to the effects of the task-load manipulations just described: In Hughes et al. (2013, Experiment 1), increased task-engagement was promoted by embedding the visually-presented to-be-remembered items in visual noise and this was found to eliminate the deviation effect. However, the fact that the changing-state effect was immune to this increase in task encoding-load was shown in a separate experiment (Hughes et al., 2013; Experiment 3a). Similarly, Marsh et al. (2020) showed that promoting task-engagement by orienting participants to attend to and recall the local dimension of hierarchical Navon letters (Navon, 1977; high load task) compared to the global dimension (low load task) eliminated the deviation effect (Experiment 1) but again the demonstration that the changing-state effect was not modulated by which dimension of the Navon stimuli needed to be recalled relied on a separate experiment (Experiment 2).

In the present study, therefore, we sought for the first time to demonstrate a dissociation between the deviation effect and changing-state effect in terms of the impact of focal task-load within a single experiment. We also took the opportunity to expand the range of ways in which task-load has been manipulated. Specifically, we deployed the Stroop paradigm to manipulate task-load (Stroop, 1935). One of the most famous discoveries in the canon of psychology is that naming the color in which a word appears is more difficult when that word is a different color-word (e.g., "Red" presented in blue; the "incongruent" condition) than when the word is not a color-word (the "neutral" condition) (for a review, see Macleod, 1991). Critical for present purposes is that, unlike the task of naming the color, the task of reading the word is not affected by a lack of correspondence between the word and its color (e.g., reading "Red" is not impaired if it is presented in blue compared to red; Macleod, 1991). There is broad agreement that such asymmetry arises from the fact that word-reading is faster or more automatic than naming a color (Macleod, 1991). We capitalized on this asymmetry in the present study to vary task-load in the presence of irrelevant auditory stimuli. Specifically, participants were required to serially recall a list of six color-words, each of which was presented in a color different from that signified by the word (see Figure 1). Critically, in the low load condition, participants were to undertake the easier of two tasks: They had to encode and recall the order of the six words (the colors in which they were presented being irrelevant). In the high load condition (or harder task), participants had to encode and recall the order of the six colors in which the words were presented (the identities of the words being irrelevant). Thus, the correct recall response to the list shown in Figure 1 in the low load condition would be *Red, Blue, Purple, Orange, Yellow*, and *Green* whilst in the high load condition the correct response would be *Blue, Yellow, Orange, Green, Red*, and *Purple* (if reading a monochrome print version of this article, please consult the online electronic version of the article to view this figure in color). The set of to-be-remembered stimuli was post-categorically identical regardless of load, therefore, and hence we made the assumption that even though the encoding of the to-be-remembered information would be more demanding in the high load condition, participants would likely engage in (covert) verbal serial rehearsal regardless of load condition.

It is worth noting also that orienting participants to one or another dimension of the *same* physical stimulus as was done here is considered to be a better method of promoting different degrees of top-down task-engagement (Marsh et al., 2020) than varying the nature of the stimulus itself across load conditions. This is because the latter method, as used by Hughes et al. (2013; see also, e.g., Halin, Marsh, Hellman, Hellström, & Sörqvist, 2014; Marsh, Sörqvist, & Hughes, 2015) may, at least in part, cause changes in

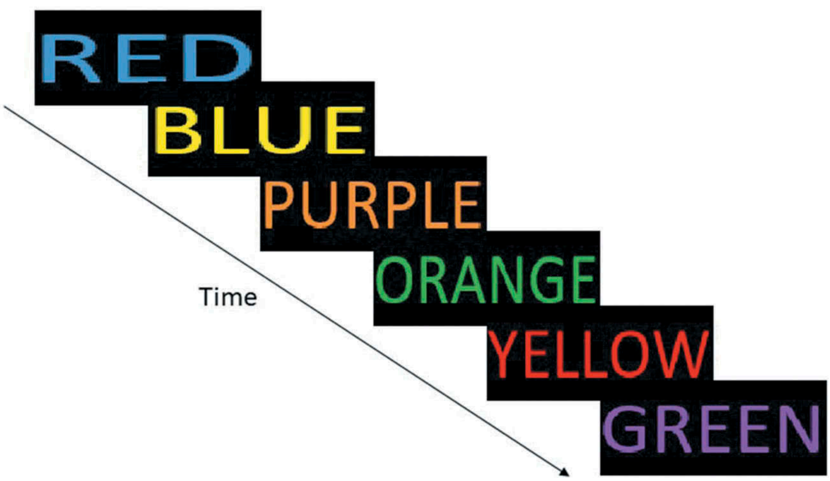

Figure 1. A schematic of the to-be-remembered stimuli. In the low load condition, participants were required to recall the order of the words (i.e., Red, Blue, Purple, etc.) while in the high load condition, they were required to recall the order of the colors (i.e., Blue, Yellow, Orange, etc.). Each stimulus was presented for 1500 ms with no interstimulus interval (see text for further details). If reading a monochrome print version of this article, please consult the online electronic version of the article to view this figure in color.

performance due to data limitations rather than cognitive limitations (e.g., Lavie & de Fockert, 2003; Norman & Bobrow, 1975).

During the presentation of the to-be-remembered stimuli, one of three types of irrelevant auditory sequence was also presented: A steady-state sequence in which one letter-name spoken in a female voice was repeated (e.g., "J, J, J, J, J, J), a changing-state sequence, again all spoken in the same female voice (e.g., "A, Q, J, C, K, M"), or a steady-state sequence in which one stimulus was presented in a different (male) voice from the remaining, female-spoken, stimuli (e.g., steady-state+deviation; "J, J, J, **J**, J, J" where the item in bold signifies the male-spoken stimulus). We predicted that when participants had to recall the words (low load condition), performance would be poorer in the Steady-state+deviation condition than in the Steady-state condition but that this deviation effect would be attenuated when participants had to, instead, recall the colors (high load condition). In contrast, we predicted that the amount of disruption produced by a changing-state sequence compared to the steady-state sequence (i.e., the changing-state effect) would not differ as a function of load.

Method

Participants

The participants were eighty undergraduate students (33 males, 47 females; mean age = 20.7 years, SD = 1.13) at Royal Holloway, University of London, who took part in the study in exchange for entry into a prize draw. The study was granted ethical approval by Royal Holloway, University of London's ethics committee. All participants reported normal hearing and normal or corrected-to-normal vision.

Apparatus and Materials

To-be-Remembered Lists

The visual to-be-remembered lists consisted of six color-words, each of which was presented in a different color from that signified by the word. These were "RED" presented in blue, "BLUE" presented in yellow, "YELLOW" presented in red, "GREEN" presented in purple, "PURPLE" presented in yellow, and "ORANGE" presented in green. Thus, note that each of the six colors (red, blue, yellow, green, purple, and orange) played the role of both word and actual color across the six word/color pairings. Moreover, in constructing the stimuli, the word and color in a given word/color pairing were never simply switched to play opposite roles (e.g., "RED" was presented in blue but "BLUE" was not presented in red). Each word was presented in capital letters, Calibri (Body) font, within a black-background rectangle, 4.97 cm in width and 2.09 cm in height, within the center of the screen. The words in a list were presented one at a time for 1500 ms each, with no interstimulus interval.

Auditory Sequences

Two sets of eight spoken letter-names ("A", "C", "J", "K", "L" "M", "Q" and "S") were recorded to generate the irrelevant auditory sequences, one set recorded in a female voice and the other in a male voice. All items within each voice were spoken at approximately the same pitch and each had a duration of 250 ms. There was a 1250 ms interval between each spoken letter in an irrelevant sequence. Using these stimuli, three types of irrelevant auditory sequence were generated: For the steady-state sequences, a single letter-name, chosen randomly from the eight possible letter-names on each trial, was repeated six times in a female voice (e.g., "A, A, A, A, A, A"). A steady-state+deviant sequence was identical to a steady-state sequence except that the fourth instance of the letter-name was presented in a male voice. For the changing-state sequences, a different random selection and ordering of six of the eight letter-names was presented in the female voice on each trial (e.g., "A, L, K, J, S, M"). For all three types of auditory sequence, the onset of each of the six spoken items coincided with the onset of each of the six to-be-remembered items. All 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

The experiment had a 2 (Load: low vs. high) × 3 (Auditory condition: steady-state, steady-state+deviant, changing-state) fully repeated-measures design. There were two blocks of 30 trials, a recall-words block (n = 43 receiving this first) and a recall-colors block (n = 37 receiving this first). For 12 trials in each block of 30, the irrelevant auditory sequences were "steady-state", for another 12 they were "changing-state" and the remaining 6 were "steady-state+deviant" sequences. The steady-state+deviant sequences were presented on trials 5, 9, 12, 18, 24 and 29 in block one and on trials 3, 9, 15, 19, 23 and 28 in block two.

Procedure

A trial commenced when the participant clicked on a "begin trial" button on the screen, after which a fixation cross appeared for 1500 ms before the onset of the first to-be-remembered item (and the onset of the auditory sequence). Following the last to-be-remembered item, participants were to recall the list in forward serial order by writing either the words or the names of the colors (depending on load condition) from left to right on a response sheet featuring six horizontally-arranged boxes for each trial. Participants were encouraged to try to provide a response in each of the six boxes but could leave a box blank if they wished. Regardless of load condition, participants were allowed to abbreviate their responses, particularly for the colors with longer names, suggestions for which were provided on an instruction sheet and again at the top of the response sheet (e.g., "ora" for "orange" and "yel" for "yellow"). There was no time-limit on responding, however. Participants were informed that any sound presented over the headphones was irrelevant to the memory task and that they should ignore it the best they could. There were 2 practice trials without an auditory sequence before each block. The responses to the practice lists were checked by the Experimenter to ensure that the participant had understood which dimension of the stimuli was to be recalled in the block of trials they were about to undertake. With an optional 5 min break inbetween blocks, the experiment lasted approximately 40 min.

Results

The raw data were scored according to the standard strict serial recall criterion whereby a recalled item is only scored as correct if its output position corresponds to its position in the list as presented. Figure 2 shows the proportion of items correctly recalled, collapsed across the six serial positions, according to auditory condition and task-load. The data can be accessed from https://doi.org/10.17030/uclan.data.00000232.

An initial Analysis of Variance (ANOVA) showed that block-order did not exert a main effect nor interact with any other factor (all *p*s >.12) and so it was not included in the following analysis. A 2 (Load) × 3 (Auditory condition) repeated-measures ANOVA showed a reliable main effect of Auditory condition, $F(2, 158) = 8.34$, $MSE = .006$, $p < .001$, $\eta_p^2 = .095$, where performance was poorer overall in the steady-state+deviant and changing-state conditions than in the steady-state condition, and a main effect of Load, $F(1, 79) = 5.83$, $MSE = .011$, $p < .02$, $\eta_p^2 = .069$, whereby recall was poorer overall under high load. The interaction between Load and Auditory condition was also reliable, $F(2, 158) = 4.65$, $MSE = .004$, $p < .02$, $\eta_p^2 = .056$. A simple effects analysis of the interaction showed that under low load, recall was significantly poorer in the presence of a deviation than without, $p < .01$, but under high load, there was no reliable deviation effect ($p = .85$). In contrast, the changing-state effect was reliable under both low and high load ($p < .01$ in both cases).

Given the concern that some have expressed over the strength of inference that can be drawn from an ordinal interaction (e.g., Wagenmakers, Krypotos, Criss, & Iverson, 2012), we supplemented the foregoing null-hypothesis significance testing approach with a Bayesian analysis (following Masson, 2011) of the data obtained in the high load condition. This showed that the posterior probability that the data favored the null

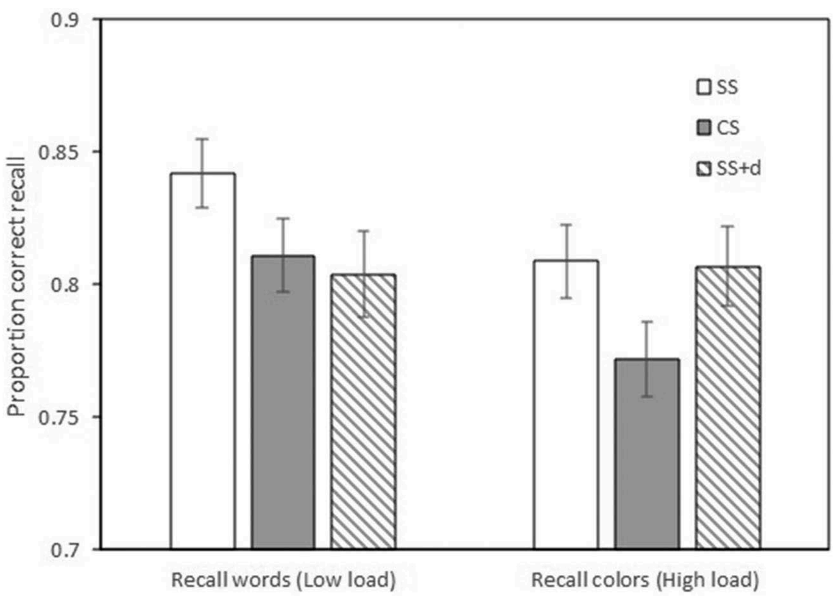

Figure 2. Proportion correct recall (collapsed over serial positions) in the Recall words (Low load) and Recall colors (High load) conditions as a function of auditory condition. Note: SS = Steady-state; CS = Changing-state; SS+d = Steady-state+deviation. Error bars show the standard error of the mean.

hypothesis that there was no difference between the steady-state and steady-state+deviant conditions (i.e., a deviation effect), pBIC (H0|D), over the alternative hypothesis (that there was a difference) was .86. In contrast, the posterior probability that the data favored the null hypothesis that there was no difference between the steady-state and changing-state conditions (i.e., a changing-state effect), pBIC (H0|D), over the alternative hypothesis (that there was a difference) was .003.

Discussion

The present study demonstrated, for the first time within a single experiment, a dissociation between the deviation effect and the changing-state effect as a function of task-load, in contrast to previous studies in which the dissociation was only shown across separate experiments. Moreover, this was done using a novel Stroop task in which, again unlike most previous studies (e.g., Halin, Marsh, Hellman, Hellström, & Sörqvist, 2014; Hughes et al., 2013; Marsh, Sörqvist, & Hughes, 2015; Vachon, Marsh, & Labonte, 2019), a physical change between stimulus displays across low and high load conditions was avoided by requiring participants instead to recall one or another dimension of the same set of stimuli (cf. Marsh et al., 2020). The study has therefore addressed a key criticism raised by proponents of a unitary account of auditory distraction (e.g., Bell et al., 2017; Röer et al., 2015) for which a dissociation between the two distraction effects clearly poses a challenge.

In line with our previous theorizing (e.g., Hughes, 2014; Hughes et al., 2013), we argue that the greater task-difficulty in the recall-colors condition triggered a top-down boost in task-engagement which served to block attentional diversion to the deviant sound. An alternative possibility suggested to us during the review process, however, is that the word dimension in the recall-colors condition may itself have diverted attention and this effectively passively diluted any attentional-diversion effect that the deviant may otherwise have had. This certainly seems plausible although, to our knowledge, no model of Stroop interference makes reference to the kind of attentional diversion mechanism invoked in accounts of the auditory deviation effect. It is worth pointing out also that this suggestion would not affect the conclusion that the present data show a dissociation between the deviation effect and the changing-state effect; rather, it offers an alternative mechanism by which that dissociation arose. Moreover, the account is not necessarily mutually exclusive with our own task-engagement account: it could be that it is the diversion of attention to the word, or the threat of such, that boosts task engagement which in turn is, ultimately, the mechanism by which attentional diversion to the sound is blocked. Finally, one reason for favoring the task-engagement account (one that would not invoke the notion of attentional diversion to the word) is the similarity between the effects of the current Stroop (and Navon; Marsh et al. 2020) manipulation on the deviation effect to that of other ways of manipulating task-load. For example, it seems unlikely that presenting the to-be-remembered items in static visual noise (cf. Hughes et al., 2013) would cause attentional diversion and yet doing this has, ostensibly, the same effect on the deviation effect as the current Stroop manipulation (Hughes et al., 2013).

It should be acknowledged that the present study has only shown a within-experiment dissociation between the two forms of distraction in relation to task-load specifically, and so only goes some way to address the general charge that "*almost all evidence* in favor of a dissociation between the deviation effect and the changing-state effect relies on comparisons across studies" (Bell et al., 2017, p. 360, emphasis added). However, we would question whether this characterization of the literature is accurate. Even before the criticism was raised, one of the most compelling lines of evidence for a dissociation between the two effects had already come from within a single experiment: Experiment 2 of Hughes et al. (2007) focused on the fact that the interference-by-process account of the changing-state effect assumes, by definition, that the qualitative nature of the focal processes engaged to perform the task is, along with the nature of the sound, a joint determinant of that effect. That is, only if the focal task engages a seriation process is performance vulnerable to a changing-state effect (e.g., Jones & Macken, 1993). The view that the deviation effect is due, in contrast, to a more general task-disengagement mechanism predicts that any (non-automated) task should be vulnerable to a deviation effect. Hughes et al. (2007) demonstrated, in a single experiment, a deviation effect in a missing-item task – in which adoption of a seriation strategy (specifically, serial rehearsal) is relatively infrequent – while there was no evidence of a changing-state effect in this task (see also Elliott et al., 2016; Hughes & Marsh, 2020; Jones & Macken, 1993; Vachon, Labonté, & Marsh, 2017). Thus, it should be possible, using a combination of the approach taken in Hughes et al. (2007) and the kind taken in the present study, to demonstrate a double dissociation between the two forms of distraction in a single experiment: The deviation effect should be eliminated under high load but not when removing the involvement of focal seriation processes while the opposite should be the case for the changing-state effect.[2]

Further within-experiment evidence of a dissociation between the deviation and changing-state effects comes from the finding that the two effects are additive. The unitary account would predict that if attention is already being diverted from the focal task by changing-state sounds (e.g., "A, L, K, J, S, M") then a deviation in the context of that sequence ("A, L, K, **J**, S, M") should have less effect than if the sounds within which the deviant is embedded are steady-state ("J, J, J, **J**, J, J") and hence not already diverting attention (or not diverting attention as much; cf. Bell, Röer, Lang, & Buchner, 2019). That is, the two effects should interact in an under-additive manner. However, Hughes et al. (2005; Experiment 1), Hughes et al. (2007, Experiment 1), and Marois, Marsh, and Vachon (2019) all showed that the deviation effect is as large in a changing-state context as it is in a steady-state context. Marois et al. (2019) also reported a further within-experiment dissociation between the two effects: They found that a deviant sound elicited a pupillary dilation response – a well-established index of attentional orienting – while changing-state sounds did not. Moreover, echoing the behavioral evidence for an additive effect of the two types of distraction, this pupillary response was of the same magnitude whether the deviant was embedded in a steady-state or a changing-state sequence.

The additivity of the two distraction effects also helps to address a point raised by a reviewer of an earlier version of this article, namely, whether the presence of changing-state (compared to steady-state) sound itself could be conceptualized as an increase in task-load. If so, this would predict, incorrectly, that the deviation effect should be reduced when the deviant is embedded in a changing-state sequence compared to a steady-state sequence. But it would nonetheless be fair to ask why the presence of a changing-state sound sequence does not constitute an increase in task-load (or at least not one that boosts task engagement). One testable hypothesis is that the participant may need to be meta-cognizant of the increase in task-load (or whatever factor may trigger a boost in task-engagement) for it to instigate a boost in task engagement. The available evidence suggests that participants show little or no subjective awareness of the degree to which changing-state irrelevant sound disrupts their performance (Ellermeier & Zimmer, 1997), in line with the notion they are not aware of changing-state sound incurring an increase in "load". Indeed, the idea that the participants are unaware of the changing-state effect is in line with the interference-by-process account of that effect but sits uncomfortably with an attentional-diversion based account of the effect. In contrast, we would speculate that participants are typically aware that the word in the color-word Stroop task interferes with their performance, consistent with the observation that the Stroop effect is markedly reduced or eliminated if the word is presented in such a way that participants do not show awareness of the word's meaning (e.g., Logan & Zbrodoff, 1982; Sand & Nilsson, 2017; Severance & Dyer, 1973). A potentially informative extension of the current study, therefore, would be to include measures of participants' awareness of the interference produced by the word-dimension in the high load condition and of disruption by the two forms of auditory distraction. We would expect that participants would be consciously aware of Stroop interference and disruption by a deviant sound but they would show less awareness of the degree of disruption caused by changing- compared to steady-state sound.

Another dissociation between the two effects that has indeed only been examined thus far across experiments is that produced when manipulating foreknowledge of the imminent distractor sequence. When participants are given a forewarning that the auditory sequence on the upcoming trial will contain a deviant, the deviant is no longer disruptive (Hughes et al., 2013, Experiment 2). However, providing a forewarning that the upcoming auditory sequence will contain a changing- as opposed to a steady-state sequence does not influence the changing-state effect (Hughes et al., 2013, Experiment 3b). This is again consistent with the duplex-mechanism account's position that the deviation effect results from attentional disengagement due to a violation of expectancies: when the deviation is made expectable through the provision of foreknowledge, it is no longer disruptive. In contrast, there is no reason to expect foreknowledge to alter the degree to which the obligatory processing of order in a changing-state sequence should disrupt seriation processes within the focal task. Although Bell et al. (2017) failed to replicate the attenuation of the deviation effect by foreknowledge, the deviation effect in that study was already very small in the no-foreknowledge condition (for reasons that are not entirely clear), making it not altogether surprising that an interaction between the deviation effect and the presence of foreknowledge was not observed.

While a within-experiment dissociation between the changing-state and deviation effects has not yet been shown in the context of the manipulation of foreknowledge, a dissociation between the different mechanisms that we argue underpin the two effects has indeed been shown in that context. To elaborate, it has been argued that the attentional diversion mechanism within the duplex-mechanism account has, in turn, two possible causes: an unexpected violation of expectancies (such as witnessed in the deviation effect) or the presence of stimulus-specific relevance or interest for the participant (Hughes, 2014; Vachon, Hughes, & Jones, 2012). Hughes and Marsh (2020) showed within a single experiment that disruption of performance by an irrelevant unfamiliar spoken sentence (a different one on each trial) – which they suggested could plausibly produce stimulus-specific attentional diversion – was attenuated by foreknowledge but disruption by a relatively simple changing-state sequence was not (see also Marsh et al., 2018).

It should be acknowledged that there is at present less clarity as to whether the two mechanisms of distraction are dissociable in relation to individual differences in susceptibility to auditory distraction. For example, Joseph, Hughes, Sorqvist, and Marsh (2018) found that children (mean age: 8.2 years) were more vulnerable to the deviation effect than adults whereas, within the same experiment, no such age-difference was found in relation to the changing-state effect. However, Röer, Bell, Körner, and Buchner (2018) subsequently failed to conceptually replicate this result. There is also a lack of consistency across studies with respect to whether or not there is a dissociation between the deviation and changing-state effects as a function of working memory capacity, a construct typically measured in terms of the ability to temporarily retain and process information simultaneously (e.g., Engle, 2002). A prominent account of individual differences in working memory capacity is that they reflect differences in the ability to remain task-engaged, especially in the presence of task-irrelevant inputs (Engle, 2002; Engle & Kane, 2004). That working memory capacity has been found to correlate negatively with susceptibility to the deviation effect but not the changing-state effect (Hughes et al., 2013; Marsh, Vachon, & Sörqvist, 2017; Sörqvist, 2010; Vachon, Marsh, & Labonté, 2019; see also Beaman, 2004) is clearly in line with the argument within the duplex-mechanism account that the deviation effect, but not the changing-state effect, is related to task-engagement level. However, a highly-powered study by Körner et al. (2017) failed to observe a reliable correlation between working memory capacity and either distraction effect. A concern about the data from the Körner et al. (2017) study, however, is that a large proportion of the participants did not show a deviation effect at all (based on inspection of their Figures 2, 4, and 6). This clearly would have reduced the likelihood of detecting a correlation between differences in the size of the effect across participants and differences in their working memory capacity scores. Further high-powered within-experiment research is needed therefore to determine whether a dissociation in relation to working memory capacity exists when both distraction effects are demonstrated by the majority of the participant sample.

Despite the rather inconclusive state of play relating to whether interference-by-process and attentional diversion dissociate in relation to participant-age or working memory capacity, we argue that the evidence that there are indeed two mechanisms – evidence to which the present study now adds – is compelling. This is especially the case as the dissociation between the changing-state effect and effects associated with attentional capture is increasingly being demonstrated within the context of a single experiment and in a growing number of ways. This now includes the effects of task-type, foreknowledge, the lack of an interaction between the two effects themselves, the qualitatively different physiological responses that deviant compared to changing-state sounds invoke, and the effect of task-load, whether the latter is manipulated in terms of the readability of the focal-task stimuli (e.g., Hughes et al., 2013), or by capitalizing on the asymmetric nature of Navon (Marsh et al., 2020) or Stroop interference (present study).

Notes

1. Others, using a different paradigm, have shown that the deviation effect is also attenuated under increased memory load (Berti & Schroger, 2003).
2. We thank Maciej Hanczakowski for this suggestion.

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