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Auditory attentional capture: Implicit and explicit approaches

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ABSTRACT

The extent to which distracting items capture attention despite being irrelevant to the task at hand can be measured either implicitly or explicitly (e.g. Simons, 2000). Implicit approaches include the standard attentional capture paradigm in which distraction is measured in terms of reaction time and/or accuracy costs within a focal task in the presence (vs. absence) of a task-irrelevant distractor. Explicit measures include the inattention paradigm in which people are asked directly about their noticing of an unexpected task-irrelevant item. Although the processes of attentional capture have been studied extensively using both approaches in the visual domain, there is much less research on similar processes as they may operate within audition, and the research that does exist in the auditory domain has tended to focus exclusively on either an explicit or implicit approach. This paper provides an overview of recent research on auditory attentional capture, integrating the key conclusions that may be drawn from both methodological approaches.

1. INTRODUCTION

We live in a busy and complicated world, so the ability to focus on relevant stimuli at the expense of irrelevant ones is essential in allowing us to avoid distraction. However, it is also important that our attention can be captured by stimuli that, although irrelevant to the task at hand, may nevertheless provide information about important changes to the environment. Attentional allocation thus relies on a delicate balance between, on the one hand, voluntary prioritisation of currently-relevant stimuli, and, on the other hand, a more involuntary capture of attention whereby attention is disengaged from the focal task and directed instead towards the salient, yet task-irrelevant, capturing stimulus. Whereas the study of attentional capture now has a long tradition within the field of visual attention, auditory attentional capture has until recently received relatively little research interest. However, over a decade of research on this topic has now accumulated to a point at which we hope it will be useful to provide an overview of the current knowledge.

A range of different experimental approaches has been used for investigating auditory attentional capture. Studies using the *implicit* approach infer that a task-irrelevant item has captured attention if the item's presence (compared with its absence) affects performance of an ongoing relevant task. By contrast, studies using the *explicit* approach ask participants directly about their awareness of the task-irrelevant item, and thus measure the item's ability to capture attention in terms of the extent to which it is explicitly noticed (Simons, 2000). Here we review both implicit and explicit approaches, with the aim of providing a fuller overall perspective on the determinants of auditory attentional capture. We focus mainly on behavioural evidence because the important neuroscientific (e.g., event-related potential-based) contributions to this research area have been reviewed in detail elsewhere (e.g., Näätänen, 1990; Sussman, 2007).

2. THE MAIN EXPERIMENTAL APPROACHES

2.1 Implicit measures of auditory attentional capture

One widely-used implicit approach to studying auditory attentional capture is the reaction time (RT)-based oddball paradigm. Here, the time taken to respond to a target stimulus (or a particular dimension of a target stimulus) is compared in the presence (vs. absence) of a rare deviation (or ‘oddball’) within a sequence of irrelevant stimuli (or an irrelevant dimension of the target). For example, Schröger (1996) asked participants to respond according to the intensity of a sound presented to one ear, while ignoring a preceding sound presented to the other ear. Reaction times in the intensity task were slowed by up to 26 ms and accuracy was also reduced when the preceding irrelevant sound was of deviant frequency compared with trials where it was of standard frequency, suggesting that the irrelevant deviants might have captured attention. An increasingly utilised variant of this approach involves measuring RTs to a visual stimulus (e.g., judging whether a digit is odd or even) each one of which is preceded by either a standard tone or, on rare occasions, a rare deviant (e.g., frequency) tone (e.g., Escera, Alho, Winkler, & Näätänen, 1998; Parmentier, Elford, Escera, Andres, & San Miguel, 2008; Parmentier & Hebrero, 2013). Again, responses to the visual target stimulus are slowed in the presence of the deviant sound.

One of the key theoretical conclusions drawn from such studies is that it is the initiation of the processing of the target stimulus that is delayed by an auditory deviant rather than some post-initiation target-processing stage (e.g., phonological, semantic, or response-decision process; Parmentier et al., 2008). Another key conclusion is that when the deviant sound is speech, the capture of attention by the deviant is followed by its involuntary semantic processing, in line with the notion that the function of attentional capture is the extensive evaluation of the capturing stimulus’ significance (for a comprehensive review, see Parmentier, this volume).

However, another feature of the capture effect in the RT-based oddball paradigm seems to limit the generality of its implications: Recent evidence indicates that the sounds in this paradigm (in both unimodal and crossmodal variants), whilst nominally irrelevant to the task and hence to-be-ignored, are in fact used as a basis for responding in a timely fashion to the target stimulus. That this is the case is evident from the fact that the presence of the standard sounds facilitates RTs compared to a no-sound condition (cf. Hackley, 2009; Wundt, 1880). Thus, the nominally task-irrelevant stimuli are effectively task-relevant, making the setting one of divided not selective attention. More importantly, when the standard sounds are stripped of such *informational value*—that is, when they no longer reliably signal the imminent occurrence of a target stimulus—a deviant sound no longer exerts a disruptive effect (Parmentier, Elsley, & Ljungberg, 2010). The prevailing interpretation of this observation is that the informational value of non-deviant sounds "is a fundamental prerequisite of behavioral deviance distraction" (Li, Parmentier, & Zhang, 2013, p. 260; see also Parmentier, this volume). However, an alternative interpretation is that the reliance of the effect on the informational value of the non-deviant sounds—rather than being a universal characteristic of auditory attentional capture—is an artefact of the features of the particular paradigm. In this view, the use of speeded performance as the key dependent measure endows the to-be-ignored stimuli with a utility so long as they reliably predict the imminent occurrence of targets. Thus, the behavioural deviation effect in this paradigm may be reliant entirely on the fact that the supposedly task-irrelevant stimuli happen to (usually) facilitate performance in the context of this particular dependent measure. Indeed, if auditory attentional capture were contingent generally on the informational value of task-irrelevant sounds, the usual story regarding the alerting function of audition would need to be substantially revised: Deviant sounds would lack the capacity to capture attention in situations in which there is no coupling between relevant and irrelevant information, as well as in the many contexts in which cognitive processing takes place in the absence of external 'target' stimuli (e.g., thinking, reasoning, rehearsing). This seems implausible from a functional point of view as well as counter-intuitive.

There is also empirical evidence from other implicit approaches that the informational value of non-deviant sounds is not a general pre-requisite for auditory attentional capture. For example, Dalton and Lavie (2004) created brief sequences of auditory stimuli in which participants searched for targets defined on a particular dimension (e.g., duration). They measured attentional capture in terms of the performance cost associated with the presence (vs. absence) of an irrelevant auditory 'singleton' that was unique on a task-irrelevant dimension (e.g., frequency). Importantly, the target's position in the sequence was varied and in some experiments it even remained absent on half of the trials. Thus its occurrence was unpredictable from trial-to-trial and the non-singletons did not provide precise information about its likely onset. In addition, the singletons were only present on a proportion of the trials and could also occur either before or after the target sound, such that they did not reliably predict the occurrence of the target and were thus genuinely task-irrelevant. Nevertheless, the task-irrelevant singletons interfered significantly with search performance, causing an average response-slowing of around 30 ms across all ten experiments. These effects were consistent across four different auditory singletons (high frequency, low frequency, high intensity and low intensity), three different target dimensions (intensity, frequency and duration) and two different auditory search tasks (requiring either target detection or target discrimination) and were thus argued to reflect attentional capture by unique items in general.

Dalton and Lavie (2004) also found that the task-irrelevant singleton feature of high frequency interfered with a duration search task when it coincided with a distractor sound but improved search performance when it coincided with the target. Interestingly, these findings contrast directly with those of the RT-based oddball paradigm (discussed earlier) which has typically demonstrated interference (rather than facilitation) when a target sound contains a singleton feature. For example, Schröger and Wolff (1998) found that performance on a duration judgement task was impaired when the target sound was of a low-probability, deviant, frequency, compared with trials in which the target was of a standard frequency. This might be taken as further evidence that the effects observed within the oddball paradigm rely on the deviant items receiving deliberate attentional allocation rather than genuinely capturing attention. More specifically, Schröger and Wolff's task required judgement of successively-presented target sounds, such that attention could be paid to each target in turn. These circumstances would not provide much scope for attentional capture towards the target to elicit performance improvements, because each target would presumably be fully attended anyway. The interference associated with the presence of a deviant feature under these circumstances might arise because this deviant draws attention to an irrelevant feature of the target sound. By contrast, in Dalton and Lavie's task, the occurrence of the target was unpredictable, because it could occur at one of several positions within the search sequence. These circumstances allow attentional capture towards the target to elicit clear performance advantages, in reducing the time taken to identify the target among the competing nontargets. It seems likely that the search advantage associated with attentional capture towards the target item would outweigh any impairment associated with momentarily drawing attention towards an irrelevant feature.

However, although the singletons used by Dalton and Lavie (2004) were irrelevant to the task and thus should not have been targets for deliberate attentional allocation, they nevertheless occurred within an attended sequence. Thus the observed interference associated with the singletons may have arisen because the singletons received some deliberate attentional allocation by virtue of appearing within an attended stream (Hughes, Vachon, & Jones, 2005). By contrast, in several studies, Hughes and colleagues have demonstrated significant interference from deviant sounds presented in an entirely task-irrelevant auditory stream on serial recall of a sequence of simultaneously-presented visual items, such that the mean percentage of correctly-recalled items can be reduced by up to 10% (e.g., Hughes, Vachon, & Jones, 2007; Lange, 2005). They argued that this constituted stronger evidence for involuntary attentional capture by deviant auditory stimuli, because the entire auditory stream was irrelevant to the task at hand. These findings also support the claim that the informational value of non-deviant sounds is not a general precondition for auditory attentional capture (cf. Parmentier, this volume). The temporal relationship between relevant and irrelevant stimuli is typically very opaque in this paradigm; the auditory stimuli are not paired systematically with each to-be-remembered item and hence are unlikely to be used as cues to aid task-performance. Furthermore, even when the temporal relationship between relevant and irrelevant stimuli changes from trial to trial, a robust deviation effect is still found in this setting (Hughes et al., 2005, Exp. 3). Finally, unlike the case in the RT-based oddball paradigm, the presence of non-deviant sounds does not facilitate performance of the focal task compared to a no-sound condition (Hughes et al., 2005, 2007), again suggesting that auditory attentional capture in general is not contingent on the non-deviant sounds having informational value.

Another key contribution of the study of attentional capture in the context of serial recall is that it has served to distinguish between two fundamentally distinct forms of auditory distraction. The susceptibility of serial recall to attentional capture by an auditory deviation has been shown to be unrelated to the long established ‘changing-state effect’ whereby a continuously changing sequence (e.g., “A, B, A, B, A…”) is found to be much more disruptive of serial recall than a steady-state sound (e.g., “A, A, A, A…”; Jones & Macken, 1993). For example, the changing-state effect is focal-task sensitive: it is only found in tasks such as serial recall that involve or encourage a serial rehearsal strategy whereas deviation effects have been found across a range of qualitatively distinct tasks. For example, an auditory deviation effect is found in the context of a missing-item task in which, say, eight of the nine digits from the set 1-9 are presented in random order and the task is to identify the item missing from the given list. This task is not thought to involve serial rehearsal (Klapp, Marshburn, & Lester, 1983) and, accordingly, is immune to a changing-state effect. It is, however, like serial recall, susceptible to a deviation effect (Hughes, Vachon, & Jones, 2007). Thus, it has been argued that there exists a form of auditory distraction that is caused by a specific conflict between the processing of the sound and the processing involved in the focal task (*interference-by-process*). In the serial recall setting, the critical process is that of the deliberate organisation and retention of events in serial order (or serial rehearsal). The presence of continuous changes in an irrelevant sound sequence also yields information about serial order as a by-product of the preattentive (and hence obligatory) organization of sound into streams (cf. Bregman, 1990). This involuntary processing of order within the sound interferes specifically with the similar process of serially rehearsing the to-be-remembered items (e.g., Jones & Macken, 1993; for further discussion, see Hughes, in press; for evidence of interference-by-process beyond serial recall, see, e.g., Marsh, Hughes, & Jones, 2008, 2009).

Although the focus of the current review is on behavioural rather than electrophysiological approaches to the study of auditory attentional capture, it is important to acknowledge the large and influential body of electroencephalography-based research that has investigated neural responding to auditory deviants (or ‘oddballs’) forming a change in an otherwise repetitive sequence. Such deviants typically elicit the mismatch negativity (MMN) component of the ERP. The MMN is thought to reflect basic registration of the deviation (presumably based upon the extraction of ongoing patterns within the scene and the derivation of a predictive model based upon these patterns; e.g. Näätänen, 1990) and is thus often characterised as a ‘call for attention’. However, research has also identified a later component known as P3a which is thought to reflect a subsequent, functionally discrete, process of switching attention to the deviant in order to evaluate its potential significance (an “*answer* to the call for attention”; Escera, Alho, Schröger, & Winkler, 2000). It is worth noting, however, that such ERP components have often been studied in the context of the RT-based oddball task discussed at the beginning of this sub-section (e.g., Escera et al., 1998). Pertinent to our earlier discussion of the generality of the role of informational value to auditory attentional capture, a recent study showed that the P3a to deviant sounds is produced regardless of whether the non-deviant sounds can be used as cues to predict the occurrence of target stimuli and hence in the absence of behavioral distraction (Wetzel, Schröger, & Widmann, 2013). It is possible to interpret such findings as indicating that the P3a is not after all closely related to behavioural attentional capture (see Parmentier, this volume). However, another interpretation, in line with the suggestion we made earlier, is that the P3a does indeed reflect behavioural auditory attentional capture but that the deviation effect produced within the RT-based oddball paradigm is not a true attentional capture effect.

2.2 Explicit measures of auditory attentional capture

Within the visual domain, some of the most striking demonstrations of the potential power of selective attention have come from studies of inattentional blindness (e.g. Mack & Rock, 1998), which have typically demonstrated that the absence of attention can cause people to fail to notice visual stimuli that are clearly detectable under normal viewing (e.g. a person dressed as a gorilla; Simons & Chabris, 1999). In contrast to the more implicit measures of attentional capture discussed above, in which the task-irrelevant stimuli are presented throughout the experiment (and might thus be deliberately attended to some extent), the inattention paradigm investigates people’s explicit awareness of stimuli that are not only unexpected but also one-off stimuli in an otherwise quiet background and therefore genuinely unattended. This complete absence in this paradigm of any expectation of the task-irrelevant stimulus (and thus of any deliberate attentional allocation towards it) has the advantage of avoiding any longer-term strategic responses to potential distraction that participants are likely to develop throughout a longer and more repetitive experiment. The lack of expectation may explain the apparent strength of the effects observed, whereby highly noticeable stimuli can fail to reach participants' awareness. Indeed, the very term 'inattentional blindness' (or deafness) clearly refers to the likelihood that the unexpected stimulus in this paradigm will *fail* to capture attention. However, research investigating the determinants of inattentional blindness and deafness can of course alternatively be characterised as investigating the factors that influence whether a stimulus succeeds in capturing attention.

Similar findings have recently been reported in the auditory domain, through demonstrations of the phenomenon of inattentional deafness. Mack and Rock (1998, chapter 10) reported a brief investigation using this approach. They asked participants to listen to a sequence of five spoken letters, presented to one ear, with the task of detecting the letter 'A' whenever it occurred, as well as remembering all five letters for subsequent recall. Following several of these trials, the 'critical trial' was presented, containing the letter stimuli in the attended ear, but also an unexpected tone to the unattended ear. As with the visual version of the task, large numbers of participants (ranging from 33% to 100%, depending on the stimulus intensity) failed to notice this 'critical stimulus' despite being able to identify it in a subsequent 'full attention' control trial (see also Murphy et al., 2013). Macdonald and Lavie (2011) have extended the paradigm to a crossmodal context, demonstrating that a high (vs. low) level of demand in a visual discrimination task reduced people's ability to detect an unexpected auditory tone.

Although the findings from inattention experiments of this type are often discussed in terms of the failures of the unexpected 'critical' stimuli to capture attention, they can alternatively be used to highlight the conditions under which these stimuli are successful in eliciting attentional capture. For example, Murphy et al. (2013) found that 20-31% of participants (depending on the experimental conditions) were 'inattentionally deaf' to an unexpected spoken word presented against a background of white noise. The critical stimuli thus successfully captured the attention of 69-80% of participants in these experiments. The fact that attentional capture can be demonstrated to this extent, despite the critical stimuli containing no obvious informational value with respect to the focal task, might be taken as further evidence against the claim that the task-irrelevant stimuli must possess informational value in order for deviants to capture attention (e.g., Parmentier, this volume).

Whereas Mack and Rock's (1998) design presents short, transient critical stimuli within a single, brief critical trial, stimuli in the real world rarely appear for such short periods of time, and it has thus been important to investigate whether longer-lasting stimuli can also be missed in the absence of attention. In the visual domain, it is now well-known that inattentional blindness can indeed occur over sustained periods of time (e.g., Most et al., 2005; Simon & Chabris, 1999). However, until very recently this type of sustained inattentional neglect had not been demonstrated in hearing. In order to address this issue, Dalton and Fraenkel (2012) used binaural recording and presentation methods to create a three-dimensional auditory scene containing a conversation between two women presented at the same time as a different conversation between two men. Halfway through the conversations, an additional male character walked through the scene without any warning, continually repeating the phrase "I'm a gorilla" for 19 seconds. 70% of participants attending to the women's conversation failed to detect the gorilla under these conditions (despite the fact that the same participants all noticed it in a subsequent 'full attention' control trial, indicating that it was clearly detectable). By contrast, only 10% of the participants attending to the men's conversation failed to notice the gorilla, presumably because in this case the gorilla fell within the attended category of men's voices (and he also passed closer in space to the men's conversation than to the women's). Another demonstration of sustained inattentional deafness is reported by Koreimann, Vitouch and Gula (this issue; see also Koreimann, Strauß, and Vitouch (2009). They find that even expert musicians can fail to notice an unexpected electric guitar solo presented without warning within a piece of classical music, while they are engaged in a task that draws attention to another aspect of the music. Along similar lines, Dehais et al. (2013) recently demonstrated significant levels of inattentional deafness to auditory alerts in experienced pilots under high workload conditions.

3. MECHANISMS OF AUDITORY ATTENTIONAL CAPTURE

3.1 Expectancy-violation

One area of recent investigation into the mechanisms of auditory attentional capture has asked whether stimuli that capture attention do so because they are novel or, instead, because they violate participants' expectancy concerning the likely pattern of stimulation. Evidence in favour of the violation of expectancy account was provided by Vachon, Hughes, and Jones (2012). They found that a change in speaker gender in a stream of task-irrelevant speech only caused interference (to serial recall of concurrently-presented visual items) when participants had been able to build up an expectancy for a particular voice, and not at the start of the trial when, although the sounds would have had a high level of novelty, no such expectation would have been in place. Interestingly, this disruption declined across the experimental session, presumably as participants began to expect the voice changes. Vachon and colleagues concluded that behavioural attentional capture is driven by violations of expectation, rather than the simple detection of novelty (see also Hughes, Vachon, & Jones, 2007, Exp. 3; Nöstl, Marsh, & Sörqvist, 2012; Parmentier, Elsley, Andrés, & Barceló, 2011).

The expectancy-violation account enjoys further support from the finding that attentional capture by auditory deviants can be reduced if participants are forewarned about the potential distraction. For example, Hughes et al. (2013) found that the impact of an auditory deviant on serial recall performance was eliminated when participants were warned about the auditory deviation just before the trial in which it occurred (see also Horváth, Sussman, Winkler, & Schröger, 2011; Parmentier & Hebrero, 2013; Sussman, Winkler, & Schröger, 2003). Furthermore, Shelton, Elliott, Eaves, and Exner (2009) found that participants performing a visually-presented lexical-decision task recovered more quickly from disruption by an irrelevant mobile phone ring when they had been pre-warned that the phone might ring at some point during the task. Taken together, this research agrees that prior warning of likely auditory distraction can reduce or even eliminate auditory attentional capture by task-irrelevant deviants. It seems likely that the prior knowledge of the imminent occurrence of a deviant stimulus can be represented within the ongoing task set, such that it no longer violates expectations and performance can thus be shielded from its effects to some extent (e.g. Hughes, in press).

3.2 Level and type of task-engagement

Researchers now agree that the elicitation of the MMN component of the ERP (reflecting registration of deviant auditory stimuli) is not normally modulated by the demands of an ongoing task (e.g., Alho, Woods, Algazi, & Näätänen, 1992; Muller-Gass, Macdonald, Schröger, Sculthorpe, & Campbell, 2007; see Sussman, 2007, for review). However, the later P3a component—thought to reflect subsequent attentional allocation towards the deviant—can be modulated by the demands of an ongoing task, such that the P3a is reduced as the task demands increase (Harmony, Bernal, et al., 2000; Muller-Gass, Stelmack, & Campbell, 2006; but see Muller-Gass et al., 2007). Thus the ERP research broadly agrees that attentional allocation towards auditory deviants is dependent on concurrent task demands, such that capture is reduced when resources are engaged more strongly elsewhere.

This conclusion is in line with a range of behavioural findings. For example, Hughes et al. (2013) demonstrated that increased difficulty in a visual serial recall task (implemented, for example, by reducing the perceptual discriminability of the visual items) reduced attentional capture by concurrently-presented auditory deviants. In addition, recall that Macdonald and Lavie (2011) found that explicitly-measured attentional capture by an unexpected auditory tone was reduced by increases in the perceptual demands of a concurrent visual discrimination task. However, Murphy, Fraenkel, and Dalton (2013) found no evidence of modulation of explicitly-measured auditory attentional capture by the level of demand in an ongoing auditory task (see also Gomes et al., 2008). Thus, it is possible that different mechanisms operate within crossmodal and unimodal contexts. More specifically, it is likely to be easier to separate relevant from irrelevant stimuli when they are presented in different modalities than when they are both presented auditorily. Thus, under situations of high demand in the crossmodal set-up, processing resources can be allocated efficiently to the relevant items, reducing processing of irrelevant items and thus reducing attentional capture. By contrast, assuming that separation is less straightforward in purely auditory contexts, it will therefore be harder to allocate processing resources specifically to the relevant items and attentional capture will be less open to modulation by the relevant task demands.

Whereas the above research examined the influence on auditory attentional capture of the *extent* to which participants are engaged by the focal task, one additional study investigated the importance of the *way* in which participants are engaged. Dalton and Lavie (2007) examined the extent to which auditory attentional capture might depend on the search strategy adopted by the listener. They asked participants to search for targets defined by frequency and make discrimination responses according to the target's duration. Attentional capture by high intensity singletons was eliminated both when the nontargets were made heterogeneous on the dimension of frequency (Experiment 2) and when more than one target was included in the search array (Experiment 3). These manipulations would both have prevented the target from being a unique feature singleton, thus preventing the use of a singleton-detection search strategy. Thus auditory attentional capture was only observed when participants adopted a search strategy that emphasises singleton detection, providing further evidence that the phenomenon is open to influence by a range of top-down factors.

3.3. Auditory versus visual attentional capture mechanisms

Another interesting issue concerns comparisons between attentional capture in vision and in audition. Because of the fundamental differences in the way in which information is registered and processed in the two modalities, one would not necessarily expect similar mechanisms to be implicated. For example, whereas the spatial selectivity of the visual system provides a strong selection mechanism, the auditory system does not appear to allow such an extreme focus. Instead, auditory selection relies upon the perceptual organisation of a scene into 'streams' upon which attention can be focused (Bregman, 1990; Shinn-Cunningham, 2008). The experimental paradigms used to investigate attentional capture have taken on different formats reflecting the different processing priorities of the different sensory modalities, with much of the visual research concerning spatial attentional capture (see, e.g., Simons, 2000, for a review) while the auditory research tends to examine attentional capture occurring within sequences of auditory stimuli. For this reason, the debates surrounding the mechanisms underlying attentional capture have differed across the two modalities, with auditory researchers focusing more on the impacts of expectancy, prediction and novelty detection. Nevertheless, some interesting overlaps have emerged between the auditory and visual debates. In particular, claims that attentional capture might not be purely stimulus-driven but is instead likely to be open to a range of top-down influences have been made based on both visual and auditory research.

4. SUMMARY

Recent years have seen an increasing focus on research into the determinants of auditory attentional capture, using both implicit and explicit approaches. The evidence outlined above clearly agrees that a range of top-down factors, including expectation, task demand and search strategy, can all modulate the strength of auditory attentional capture. Thus it seems that auditory attentional capture does not operate in a purely stimulus-driven manner but is instead open to influence by cognitive control. This conclusion is in line with the overall finding from the inattentional deafness paradigm: that distinct and surprising auditory stimuli can fail to capture people's attention despite being present for extended periods of time. However, the critical role often attributed to the informational value of non-deviant sounds to behavioural auditory attentional capture (cf. Parmentier, this volume) can, in our view, be questioned. Behavioural auditory attentional capture effects have been demonstrated in the absence of such informational value using implicit (e.g., Dalton & Lavie, 2004; Hughes et al., 2005), explicit (e.g., Mack & Rock, 1998; Murphy et al., 2013) and EEG-related measures (Wetzel et al., 2013).

This review has integrated both implicit and explicit approaches to the study of auditory attentional capture. The implicit approach involves repeated presentation of the potentially-capturing stimuli throughout the experiment, allowing very precise measurements of their effects on performance. However, it is rare in naturalistic contexts to encounter such frequently-repeated critical capturing stimuli. Instead, attentional capture in the real world is more likely to involve a one-off stimulus that occurs 'out-of-the-blue', as investigated using the explicit 'inattentional deafness' approach. The 'one-shot' approach of this paradigm also has the advantage of avoiding any longer-term strategic responses to potential distraction that might develop within the longer and more repetitive experiments required for the implicit measures. However, the explicit approach faces its own challenges, most notably from the fact that each participant can only be asked once about their noticing of the unexpected stimulus, thus only one trial can be gathered per participant, reducing the experimental reach of the paradigm. It therefore seems that future research on auditory attentional capture will benefit from a combination of the implicit and explicit approaches.

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