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Ear-catching? Real-world distractibility scores predict susceptibility to auditory attentional capture

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Although many of the everyday distractions we encounter are auditory, most research on distractor processing to date has been focused on the visual domain. A common measure of everyday distractibility is the Cognitive Failures Questionnaire (CFQ; Broadbent et al., 1982), which has previously been successfully linked with performance on controlled visual attention tasks (e.g. Forster & Lavie, 2007; Kanai et al., 2011; Tipper & Baylis, 1987), such that high scorers tend to display greater distractor interference than low scorers. We examined whether the same relationship would hold in hearing. Participants performed an auditory attentional capture task, responding to a target sound whilst ignoring an irrelevant singleton distractor (presented on half of the trials). We found that CFQ score successfully predicted distractor interference, as participants who reported being more distractible in everyday life produced more errors in the presence of the irrelevant singleton than did low scorers on the CFQ. This finding is the first to demonstrate a relationship between auditory distractor interference and everyday distractibility and confirms that performance on this type of laboratory-based attentional capture task can successfully be related to behaviour outside the laboratory.

Introduction

From a car alarm going off outside the office to a screaming baby on an aeroplane, we live in a world full of potential auditory distractors which can at times seem almost impossible to ignore. The consequences of such distraction can vary from minor, albeit irritating outcomes – such as being distracted from work due to a conversation between two colleagues – to more serious ones – such as failing to notice the person crossing the street right in front of you as your attention is captured by your mobile phone ringing. However, despite the prevalence of these potential auditory distractions, the majority of the research to date has focused on visual distraction.

One important question on this topic has concerned whether individuals differ in the frequency with which they experience distraction, and if so what factors underlie this variation in distractibility. This has typically been measured using the Cognitive Failures Questionnaire (Broadbent et al., 1982), which lists 25 examples of common cognitive slips such as "Do you find you forget what you came to the shop to buy?" and "Do you daydream when you ought to be listening to something?". Participants indicate the frequency with which they have experienced each scenario over the past six months, creating an index of everyday distractibility. The higher the score, the more prone to these cognitive slips the person reports to be. It has been demonstrated that the score on the questionnaire remains constant over time, indicating the reliability of the measure (Broadbent et al., 1982).

Relationships specifically between auditory distraction and the CFQ have never been investigated. However, scores on the questionnaire have been linked with more general real life occurrences whereby distractibility is likely to have been the main cause of the incident. For example, a positive correlation has been demonstrated between CFQ score and the occurrence of lost computer work due to failure in remembering to save files (Jones & Martin, 2003). Furthermore, it has also been reported that high scorers on the CFQ were more likely to have a history of causing traffic accidents than were low scorers (Larson & Merritt, 1991). A similar pattern of findings has been found in

workplace situations with positive correlations identified between the number of work accidents and CFQ score (e.g. Day et al., 2012; Wallace & Vodanovich, 2003).

Thus overall the CFQ measure has been shown to relate to everyday cognitive functioning in a range of different contexts, which makes it likely that the CFQ score reflects a general characteristic such as executive control capacity. If so, CFQ score should also relate to performance on more controlled attention tasks that assess attentional focus through measures that are less directly related to the kinds of cognitive slips listed in the questionnaire.

In line with this prediction, within the visual domain the CFQ has already been linked with the ability to sustain attention on a repetitive task, known as the sustained attention to response test (SART) (e.g. Manly et al., 1999; Roberston et al., 1997; Smilek et al., 2010). For example, Robertson et al. (1997) presented participants with a visual stream of single digits and the task was to make a button press response to all digit identities but one (which required response to be withheld). There was a positive correlation between CFQ score and the failure to withhold a response (as required by the task parameters), with higher scorers demonstrating a higher occurrence of false alarms than lower scorers. Furthermore, the CFQ has also been linked with performance on selective attention tasks measuring distractor interference through response competition. For example, Forster and Lavie (2007) investigated whether everyday distractibility could affect the extent to which irrelevant distractors were processed within a letter search task, which involved identifying a target letter in a circle surrounded by nontarget letters whilst ignoring a distractor letter in the periphery which was either of the same (congruent) or the opposite (incongruent) identity as the target. Participants who scored higher on the CFQ displayed greater distractibility than low scorers, as indicated by slower RTs in the presence of an incongruent distractor (vs. a congruent distractor). Furthermore, CFQ score was positively correlated with the magnitude of the congruency effect (incongruent RTs – congruent RTs) with higher scorers exhibiting greater congruency effects. Similarly, Tipper and Baylis (1987) found slower RTs for high CFQ scorers than for low scorers when categorising a target word in the

presence of a semantically related distractor word, in comparison to a distractor consisting of a random string of letters. In a second experiment where the irrelevant distractor became the relevant target on the following trial (i.e. measuring negative priming), low scorers were significantly slower than high scorers. In fact, the low scorers were the only group demonstrating negative priming (i.e. slower responses when the distractor subsequently became the target), which suggests that they successfully inhibited the distractor, while the high scorers processed the distractor. A more recent visual study used an attentional capture task to investigate whether the cost associated with the presence of a salient singleton distractor differed depending on reported distractibility on the CFQ (Kanai et al., 2011). They demonstrated an increase in attentional capture by the presence of the singleton (versus singleton absent trials) for high scorers compared with low scorers. Thus despite a small number of discrepant findings (Broadbent et al., 1986; Ishigami & Klein, 2009), the weight of evidence suggests a clear link between the CFQ measure and controlled visual selective attention.

However, if the CFQ reflects failures of a more general executive control capacity, it follows that the same relationship should be reflected in a task involving a different sensory modality. As all previous findings have exclusively investigated this question within the visual domain, it is important to examine whether the same relationship would emerge using an auditory task. The present study thus set out to investigate the relationship between CFQ score and performance on an auditory attentional capture task. Any positive relationship would be particularly interesting given that only two out of 25 items on the questionnaire ask directly about auditory distractor processing. Additionally, the findings will contribute to recent discussions concerning whether auditory distraction may be less open to modulation by attention than visual distraction (Gomes et al., 2008; Murphy et al., submitted). This research also provides an important test of whether laboratory measures of auditory selective attention can reflect everyday behaviour, despite in many cases bearing little resemblance to everyday tasks. This would be an important finding as it would validate the auditory attentional capture task that we used as a measure of distractibility which extends to behaviour outside the laboratory.

We employed the auditory attentional capture task designed by Dalton and Lavie (2004). Over a range of experiments, they consistently found a cost in performance on a search task in the presence of a singleton sound which was unique in respect to both targets and nontargets on one feature. Participants were presented with a rapid stream of tones and responded to a target feature while ignoring an irrelevant sound which could also appear within the sequence. If the CFQ genuinely relates to individual differences in people's ability to stay focused on a relevant task due to variations in executive control capacity, then the same positive relationship between CFQ score and distractor processing should occur in the present study using auditory stimuli as has been found in visual tasks. Thus, an increase in CFQ score should predict a greater cost on task performance in the presence of the irrelevant singleton distractor (versus its absence).

Method

Participants. 57 participants (11 males) were recruited at Royal Holloway, University of London, either voluntarily or in exchange for course credits. The average age was 20, ranging from 18 to 27 years. However, these figures exclude nine participants (one male) whose ages were not documented due to an error in recording (but who all came from within a very similar age demographic). All participants reported normal hearing and normal or corrected-to-normal vision, and 3 (1 male) were left-handed. Informed consent was obtained from all participants and all testing protocols were approved by the Departmental Ethics Committee.

Apparatus and stimuli. The experiment was run on a PC using the PST E-prime 2.0.8.90 software. Auditory stimuli were created using the Audacity software. Sounds were presented on Sony SRS – A201 loudspeakers at an average level of approximately 70 dB SPL. Speakers were positioned on a surface approximately 45 cm. below the participants' ear position, 50 cm. to either side of the participant's midline. Target and nontarget tones were all of the same frequency of 440 Hz, while the singleton tone was presented with a frequency of 520 Hz. The duration of the nontarget and singleton tones were 100 ms, while the target was either 50 or 150 ms.

Procedure. The experiment was carried out in a quiet testing room. Participants were asked to identify the duration of the target and they were also informed that there might be an odd sound appearing at a different frequency from the rest of the tones, and that failure to ignore it could impair task performance. At the start of each trial, the word "Ready" appeared at the centre of the screen for 500 ms. Subsequently, the sequence of five tones was presented. The interstimulus interval (ISI) varied according to the duration of the target sound. More specifically, the duration of each sound plus the subsequent ISI was equivalent of 185 ms, in accordance with Dalton and Lavie's (2004) Experiments 5 and 6. The target appeared in position 3 or 4 of the sequence with equal likelihood, and was equally likely to be of short duration as of long duration. Directly following the sequence, a question mark appeared for 500 ms. Half of the participants pressed 1 for short targets and 2 for long targets with the index finger and the middle finger of their right hand on the numeric keyboard respectively. For the other half of the participants, the response keys were reversed. Following the response, or if no response had occurred within 3000 ms, visual feedback appeared on the screen for 1500 ms. Participants performed a practice block of 24 trials, followed by 3 experimental blocks of 48 trials in each. The CFQ was administered prior to the experiment for half of the participants, while the other half completed the questionnaire after the experiment.

Results. Nine participants were excluded from the analysis: two failed to complete the full questionnaire; four performed at chance (with error rates $\leq$ 50%) in at least one experimental condition (suggesting that they were not able to successfully discriminate between the two target identities); and three had average RTs (M = 620 ms; 678 ms; 772 ms) more than 2 SDs above the group mean (M = 358 ms; SD = 123 ms). For the remaining participants, mean RTs and accuracy were calculated as a function of singleton condition (present vs. absent). For illustrative purposes, Table 1 presents performance in each singleton condition separately for high and low scorers on the CFQ (based on a median split: median = 48, range = 17 – 72). However, because of the many negative consequences associated with the dichotomization of individual differences measures (e.g. Cohen,

1983; MacCallum, Zhang, Preacher & Rucker, 2002), our main analyses consisted of simple linear regressions rather than relying on the median split approach.

Table 1. Mean RTs and errors of low and high scorers on the CFQ as a function of singleton condition (absent vs. present).

	Singleton Condition			
	Absent		Present	
CFQ Group	RTs	% Errors	RTs	% Errors
Low CFQ	316	12	369	20
High CFQ	286	14	346	24

Errors.

Auditory attentional capture task. A one-way repeated measures ANOVA with the factor of singleton condition (present vs. absent) revealed a significant effect, $F(1,47) = 54.95$, $MSE = .004$, $p < .001$, $\eta_p^2 = .539$. More errors were evident in the presence of a singleton distractor (M = 28%) compared with its absence (M = 13%), providing further support for the suggestion that a unique, salient event is difficult to ignore even when completely irrelevant to the task at hand (e.g. Dalton & Lavie, 2004)

CFQ and task performance. A linear regression analysis was carried out to investigate whether the CFQ score would predict performance cost on the attentional capture task. Cost was calculated by subtracting singleton absent errors from singleton present errors. CFQ score was a significant predictor of performance, $\beta = .306$, $t(46) = 2.18$, $p < .05$, accounting for 9.3% of total variance ($R^2 = .093$, $F(1,46) = 4.74$, $p < .05$). Thus, there is a clear and significant relationship between CFQ score and susceptibility to auditory attentional capture, such that participants with higher CFQ scores suffer more interference from irrelevant distractor singletons (see Figure 1). Note that the

means presented in Table 1 suggest that the increased singleton cost exhibited by the high CFQ scorers relates to higher error rates in the presence of the singleton (as would be expected if these participants were genuinely exhibiting higher distractability) rather than reduced error rates in the absence of the singleton (which would have been logically possible given our use of a difference cost but would have been much harder to explain in terms of distractability).

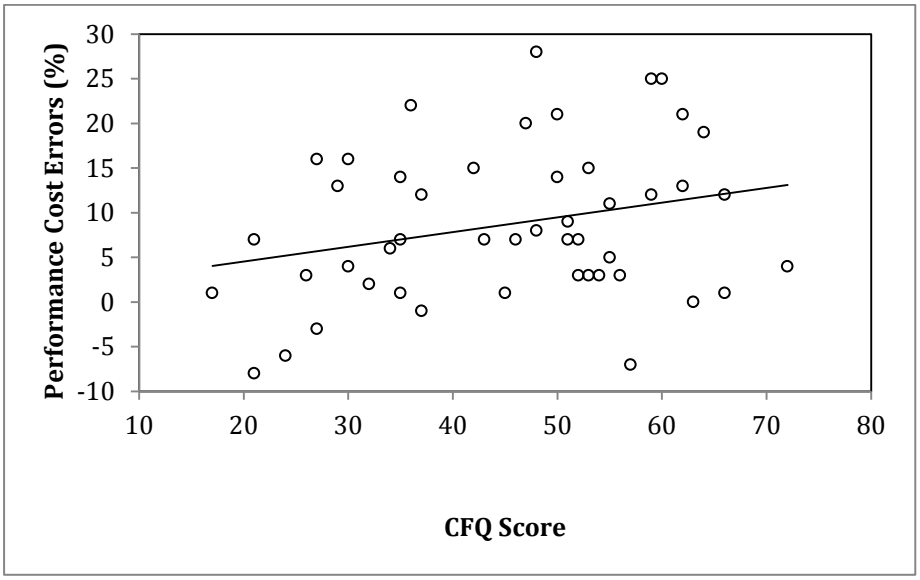

Figure 1. Linear regression displaying the relationship between CFQ score and performance cost (singleton present – singleton absent) in the error rates.

RTs.

Auditory attentional capture task. A one-way repeated measures ANOVA on singleton condition (present vs. absent) revealed a significant main effect, $F(1, 47) = 56.41$, $MSE = 1367.11$, $p < .001$, $\eta_p^2 = .546$. In line with the error data, performance was worse when the singleton was present (M = 358 ms) than when it was absent (M = 301 ms).

CFQ and task performance. As in the error analysis, a linear regression analysis was conducted to determine the extent to which score on the CFQ would predict performance cost on the attentional capture task. Cost was calculated by subtracting singleton absent RTs from singleton

present RTs. CFQ score did not successfully predict reaction time costs on the auditory attentional capture task, $\beta = .127$, $t < 1$, accounting only for 1.6 % of the variance, $R^2 = .016$, $F(1,46) < 1$ (see Figure 2).

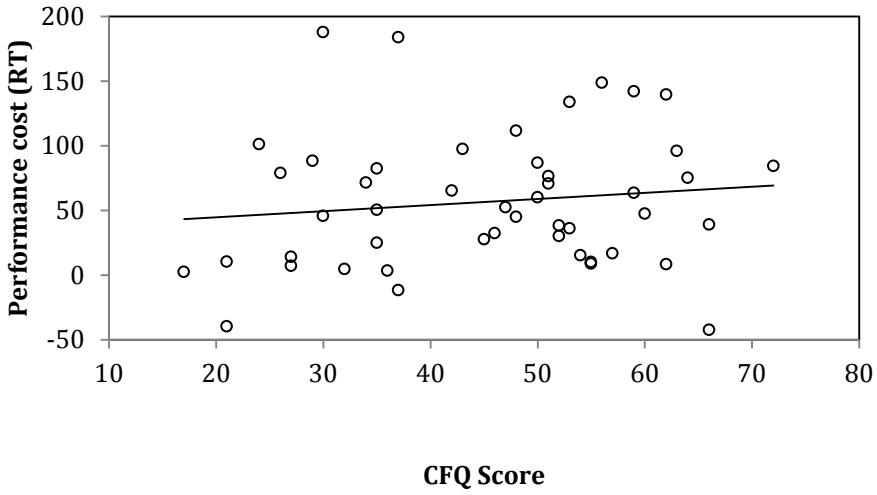

Figure 2. Linear regression displaying the relationship between CFQ score and performance cost (singleton present – singleton absent) in the RTs.

Discussion

We set out to investigate whether scores on the CFQ could predict people's susceptibility to auditory distraction as measured using an auditory attentional capture task. There was a direct relationship between the reported CFQ score and the cost related to the presence (vs. absence) of the unique yet irrelevant singleton distractor, such that participants who reported being more distractible in everyday life suffered more interference from the irrelevant singleton sound than did participants scoring lower on the CFQ.

This study is the first of its kind to demonstrate a relationship between reported everyday distractibility and performance on an auditory selective attention task, as previous findings have all used visual stimuli (e.g. Forster & Lavie, 2007; Kanai et al., 2011; Tipper & Baylis, 1987). This is a

particularly important finding as it suggests that the auditory attentional capture task we used does indeed relate to real life behaviour, even though the setting is far removed from everyday behaviour (e.g. due to the repetitiveness of the task, the sparseness of the sounds presented and the artificial nature of the responses required). Furthermore, the fact that the relationship between CFQ score and attention performance within the laboratory can be generalised in this way to a different sensory modality provides additional evidence to suggest that the CFQ relates to general executive control functions rather than any more modality-specific cognitive functions. This claim is strengthened by the fact that only two out of 25 items on the questionnaire are directly related to auditory distraction, demonstrating that the CFQ can predict attention performance even on tasks that are markedly different from the particular instances of cognitive slips referred to in the questionnaire.

Interestingly, whereas we found the correlation between laboratory-based distractibility and CFQ score in the error rates, some previous studies have reported a positive relationship in the RTs (e.g. Forster & Lavie, 2007; Kanai et al.,2011; Tipper & Baylis, 1987; although note that the latter two articles did not report correlation analyses for the error rates). It seems likely that the response measure with which CFQ score correlates in each example is determined by the specific parameters of the task. For example, it could be that a unique singleton distractor of the kind used in the present experiment is particularly salient and might thus distract participants to a greater extent than a visual singleton (as used by Kanai et al., 2011) or a task-related distractor (as used by Forster & Lavie and Tipper & Baylis). It could be this high level of salience that caused the distractor in the present experiment not only to produce a slowing in responses (which was seen to the same degree between participants) but also to lead to errors of commission, and particularly more so for participants reporting to be more prone to everyday cognitive slips. Indeed, we would suggest that the ultimate consequence of a distracting event would be an erroneous response rather than simply a slowing in response. Thus variation observed in error rate interference might be more strongly related to cognitive failures occurring in everyday life than variation observed in RT interference.

In line with Gomes et al. (2008), we have recently proposed that auditory distraction may be less open to modulation than visual distraction (Murphy, Fraenkel, & Dalton, submitted). In both studies, auditory attentional selection was investigated within the framework of perceptual load theory. Converging evidence across a range of task modulations of perceptual load failed to support the prediction that increasing perceptual load in a relevant task should reduce processing of task-irrelevant distractors (e.g. Lavie, 1995). Thus, we proposed that the auditory system is more likely than the visual system to retain some spare processing capacity at all times, regardless of the perceptual demands of the task at hand. The present findings are important in relation to this suggestion, as they demonstrate that, although auditory distractor processing appears to remain relatively constant for each participant across varying task demands, there is nevertheless significant variation between participants in the extent to which irrelevant sounds tend to interfere with task performance.

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