

Subjective assessments of cognition and affect and their relationship with objective performance: Individuals with high levels of cognitive failures or negative affect miss more rare visual targets

Stephanie C. Goodhew and Mark Edwards

Research School of Psychology, The Australian National University

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Corresponding author: Stephanie C. Goodhew

Address: Research School of Psychology (building 39)

The Australian National University, Canberra, 2601

Email: Stephanie.Goodhew@anu.edu.au

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Author Note: Raw data are available at: <https://osf.io/kmdnv/>. Materials and analysis code for this study are available by emailing the corresponding author. This study's design and its analysis were not pre-registered.

Abstract

The detection of particular targets is critical in applied contexts, such as identifying cancers in diagnostic medical imaging and finding weapons in airport baggage security screening. Missed targets can have dire consequences in such contexts. These contexts are also typically characterized by low prevalence or rare targets, such that most searched-through images do not contain targets. A substantive body of evidence demonstrates that humans are much more likely to miss targets when they are rare. Therefore, it is critical to understand the factors that may mitigate or exacerbate this general tendency to miss rare targets. The present study considered the relative role of individual differences in cognitive failures, cognitive empathy, and negative affect (i.e., depression, anxiety, and stress) in predicting the detection of rare targets. Across two experiments, there was evidence that individuals experiencing elevated cognitive failures were more likely to miss the rare targets. In Experiment 1, negative affect was also related to performance, but it was only cognitive failures that made a unique contribution to explaining target-present accuracy when they were pitted against one another. There was no evidence that cognitive empathy was linked to performance. These findings have important theoretical implications and also highlight potential avenues for intervention to improve the detection of rare targets.

Keywords: low prevalence; visual search; negative affect; anxiety; attentional control; cognitive failures

1.0 Introduction

Visual search is the process of finding a target object amongst the clutter of distractor objects. The likelihood of correctly detecting a target varies dramatically according to the *prevalence* of the target (e.g., Horowitz, 2017; Van Wert et al., 2009; Wolfe et al., 2005; Wolfe et al., 2007). That is, often searches may occur not in isolation, but a sequence of searches is conducted. For example, a security professional searching through x-ray images of bags at airport security checkpoints could search through hundreds of bags in succession. In this context, when many searched-through images do not contain a target (e.g., a weapon), the likelihood of correctly detecting a target when it does appear is substantially reduced compared with the likelihood of detecting that same target if it appears in a higher prevalence context. In other words, the probability of missing the target is far higher under low prevalence (i.e., rare target) conditions. This change is thought to result from a shift in criterion to more conservative responding, rather than a change in sensitivity across prevalence conditions (e.g., Horowitz, 2017; Van Wert et al., 2009; Wolfe et al., 2007).

This detrimental effect of low target prevalence on visual search accuracy is observed even in trained professionals in real world settings, including cytologists involved in cervical cancer screening searching for abnormal cells in radiological images (Evans et al., 2011), radiologists examining breast-cancer screening images (Evans et al., 2013) and newly-trained transport security officers searching through simulated bag images (Wolfe et al., 2013). Thus, it is not just a laboratory phenomenon, but instead has important real-world implications for these kinds of professional visual search tasks, which are typically characterized by rare targets (e.g., most bags do not contain a weapon), and by dangerous consequences of failing to detect targets.

Given the importance of visual search accuracy under low-prevalence conditions, some research has focused on manipulations that mitigate the impact of prevalence on search

accuracy. For example, bursts of high prevalence targets with feedback (Wolfe et al., 2007), false feedback about missing targets on target-absent trials (Schwark et al., 2012), or identifying the stimulus most similar to the target, even if the target is absent (Taylor et al., 2022), have been found to improve rare target visual search accuracy. Another way of tackling this issue is to consider individual differences. That is, even under the identical low prevalence condition, some individuals perform better or worse than others. For example, individuals with high working memory capacity (Peltier & Becker, 2017; Schwark et al., 2013), and those less prone to certain everyday cognitive failures (Thomson & Goodhew, 2021) have been found to be more likely to correctly detect rare targets. This individual-differences approach has important implications, not only potentially for personnel selection for safety-critical professional visual search tasks, but also for identifying the cognitive processes implicated in visual search accuracy, which could then become the target of intervention. The focus of the present study was on distilling the individual difference variables that are associated with objective performance in detecting rare targets.

Visual search in general requires attentional processes such as effective shifts of attention, and visual search for rare targets in particular entails processes such as maintaining a top-down attentional set for a target with minimal scaffolding, reinforcement, or reminding about the searched-for target from the task context. Lapses in this kind of cognitive control are measured via the Cognitive Failures Questionnaire (CFQ), which asks respondents to indicate the frequency with which they experience everyday cognitive slips, such as forgetting appointments, daydreaming when ought to be listening, or forgetting what you came to the shops to buy (Broadbent et al., 1982). Individuals' CFQ scores predict their objective performance on cognitive tasks (Friedman & Miyake, 2004; Linden et al., 2005; Manly et al., 1999; Tipper & Baylis, 1987), brain activity during such tasks (Garavan et al., 2006; Garavan et al., 2002; Hester et al., 2004), and even white matter integrity in frontal and parietal areas

(Deprez et al., 2011). Scores are also associated with individual differences in important consequences of cognitive failures, such as risk of car crash (Wallace & Vodanovich, 2003).

The CFQ has often been treated as a unitary or monolithic construct, and the bulk of the evidence for CFQ's validity comes from studies that have treated it as such. While various factor structures have been proposed for the CFQ over its history, none has proved stable, showed qualitatively different relationships with objective performance metrics, or prevailed as the consensus understanding of CFQ's structure (Bridger et al., 2013; Larson et al., 1997; Pollina et al., 1992; Wallace et al., 2002).

In contrast to this historical backdrop, a recent factor analysis revealed an age-invariant CFQ structure consisting of three correlated factors, which have been found to have qualitatively different relationships with other variables: *Forgetfulness*, which is characterized by the forgetting things known or planned (e.g., Do you read something and find you haven't been thinking about it and must read it again?), *Distractibility*, which primarily relates to failures of social communication and emotion regulation (e.g., Do you say something and realize afterwards that it might be taken as insulting?), and *Goal Loss*, which relates to the inability to maintain goals or monitor for goal-relevant information (e.g., Do you fail to notice signposts on the road?) (Rast et al., 2009). While Rast et al. (2009) originally called this third factor *False Triggering*, Thomson and Goodhew (2021) recommend that *Goal Loss* is a more appropriate name for the content of this factor, and this is the name that will be used for it here.

Thomson and Goodhew (2021) found strong evidence that individuals prone to Goal Loss were more likely to miss visual search targets, and there was some evidence that those prone to Forgetfulness were more likely to detect visual search targets. These findings were observed under both low prevalence (2% target prevalence) and higher prevalence (50% target prevalence) conditions, but it is the low prevalence findings that are of particular relevance here. This suggests that individual differences in cognitive failures are an important source of

information in predicting visual search accuracy under low-prevalence conditions. Further, the fact that the factors had qualitatively different relationships with performance (i.e., relationships in different directions) supports the importance of distinguishing among the factors, rather than treating cognitive failures as unitary. In addition, a recent study found that the three CFQ factors also had qualitatively different relationships with other constructs measured via self-report, namely cognitive empathy (Goodhew & Edwards, 2022b), further supporting differentiation among these factors. However, while suggestive, these remain just two studies against a backdrop of compelling support for CFQ's validity when treated as a unitary concept. Therefore, the first goal of the current suite of experiments was to directly pit the three-factor versus one-factor models of CFQ against one another in predicting a meaningful performance metric – the detection of rare targets.

To summarize, cognitive failures predict rare target visual search performance. However, individual differences in cognitive failures do not occur in isolation. Instead, they are related to other individual difference factors as well. In particular, here we chose to focus on two variables in addition to cognitive failures: empathy and negative affect. These are not the only potential variables of interest, but we believe that they represent two important ones to test. This choice was motivated by two key considerations: (1) despite these two psychological processes appearing on the face of it quite distinct from cognitive failures, they both show meaningful associations with cognitive failures, (Goodhew & Edwards, 2022b; Simpson et al., 2005), and (2) there are logical reasons why they might impact rare target visual search performance in their own right, as we describe below. This means that it is possible that individual differences in one or both of these related variables is actually a stronger predictor of accuracy of visual search accuracy for rare targets, and the apparent association between cognitive failures and performance observed previously was actually due to the effect of one

of these unmeasured variables. This possibility for each of empathy and negative affect is discussed in more detail below.

Empathy cleaves into at least two dissociable components – cognitive empathy (also Theory of Mind), which is the ability to adopt and understand another’s perspective, and their thoughts, beliefs, and feelings, and affective empathy is the tendency to feel what another is feeling, and some authors emphasize the need to recognize the source of the emotion (de Vignemont & Singer, 2006; Goodhew & Edwards, 2021; Kanske et al., 2016; Preckel et al., 2018; Reniers et al., 2011; Shamay-Tsoory et al., 2009; Weisz & Cikara, 2021). It has been found that individuals prone to all types of cognitive failures are more likely to experience affective empathy, while individuals prone to distractibility-related cognitive failures score lower in cognitive empathy, and those prone to forgetfulness-related cognitive failures score higher in cognitive empathy (Goodhew & Edwards, 2022b). Given this shared variance between cognitive failures and empathy, it is possible that individual differences in empathy are the true driver of, or at least a more important predictor of the detection of targets in low-prevalence visual search. Cognitive (versus affective) empathy in particular stands out because it had qualitatively different relationships with the three CFQ factors, and because there is theoretical reasoning to support the notion of cognitive empathy’s involvement in cognitive performance. Firstly, rare target visual search performance is particularly likely to be sensitive to motivation to perform well at the task. This is because the speed at which participants complete the task is a strong predictor of target hits (e.g., Thomson & Goodhew, 2021). The speed at which participants complete the task is within their control, and likely strongly associated with their motivation to perform the task well. Motivation to perform well likely stems from multiple factors, and here we suggest that one of these factors could be cognitive empathy. This is because a participant high in cognitive empathy is more likely to appreciate that they are participating in another person’s (i.e., the researcher’s) research study, and may

reasonably assume that this other person is hoping that they will take the task seriously and perform well. In contrast, a participant low in cognitive empathy is more likely to focus exclusively on their own perspective and needs (e.g., desire to complete the experiment as quickly as possible to earn one's credit or payment). Therefore, it is possible that individuals with higher levels of cognitive empathy may spend more time on the task and thereby reduce their target miss rate relatively to those with lower levels of cognitive empathy. Secondly, improved task performance from those high in cognitive empathy could stem from the domain-general cognitive mechanisms that are thought to underpin cognitive empathy. This latter possibility is considered in more detail below.

Contemporary thinking espouses that domain-general mechanisms, such as attention and working memory, are implicated in social cognition, and that domain-specific processes may have often been proposed without foundational evidence and when the more parsimonious explanation of domain-general mechanisms would suffice (Ramsey & Ward, 2020). Indeed, functionally, the process of cognitive empathy has much in common with the process of working memory. Working memory is conceptualized and measured as the ability to store new information while also actively processing another source of information, and working memory is thought underscore the inhibition of prepotent or salient task-irrelevant information in the service of goals (Conway et al., 2005; Engle, 2018; Kane & Engle, 2003). To adopt another person's perspective requires the inhibition of a prepotent or salient perspective – one's own – to acquire new information from this shift in perspective. In addition to this flexibility, it also requires the maintenance of multiple distinct sources of information. That is, maintaining a cognitive distinction between self and other is considered integral to empathic process, because empathy is *not* about merging the self with other, but about being able to appreciate multiple distinct perspectives without merging them (Lamm et al., 2016; Preckel et al., 2018; Steinbeis,

2016). Thus, from a functional perspective, both the inhibition and multiple distinct sources of information aspects of working memory are implicated in cognitive empathy.

Consistent with this functional argument, empirical evidence demonstrates that an active working memory load, which diminishes the availability of these resources, impacts social-cognitive reasoning that calls upon cognitive empathy (McKinnon & Moscovitch, 2007) and also impacts perspective-taking (Navarro et al., 2020). In healthy adults, working memory capacity is associated with the extent to which a person reliably engages in perspective-taking (Wardlow, 2013). Similarly, in adolescents, intelligence, attention, and working memory correlate with individual differences in cognitive empathy (Gabriel et al., 2021), while among older adults with Alzheimer's Disease, the loss of executive functions are strong predictors of decline in cognitive empathy (Fliss et al., 2016).

Given the functional requirements of cognitive empathy, individuals who regularly engage in cognitive empathy may be more practiced at this process of inhibiting salient information. In the context of rare target visual search, the overwhelming preponderance of target-absent trials can be considered a source of salient information that needs to be inhibited in order to detect rare targets when they do occur. Therefore, individuals with high levels of cognitive empathy may be particularly well equipped to perform better in rare target visual search. In this way, cognitive empathy could be an individual difference factor that directly improves rare target visual search performance.

Alternatively, individuals scoring high in cognitive empathy could excel at rare target visual search because of the concomitant domain-general processes (e.g., higher working memory capacity) that underscore cognitive empathy may improve rare target visual search performance in their own right with no unique contribution from cognitive empathy. Therefore, if there is a relationship between cognitive empathy and rare target visual search performance in the present study, then it would be important to further differentiate whether cognitive

empathy or domain-general processes such as working memory is the primary or unique contributor via additional studies with measures of these domain-general cognitive processes.

Individual differences in cognitive failures are also linked to individual differences in negative affect, including depression, anxiety, and stress. Note that by *negative affect* and its subcomponents of *depression, anxiety, and stress*, we are referring to dimensions along which individuals in the general population vary in the extent to which they experience these affective states. While individuals with high levels of negative affect are more likely to qualify for formal clinical diagnoses (Brown et al., 1997), here our focus was on these dimensions of variation, rather than clinical categories. Individuals prone to cognitive failures tend to experience elevated negative affect (Castellon et al., 2004; MacQueen et al., 2003; Simpson et al., 2005). Thus, it is possible that negative affect is also a predictor of individual differences in visual search detection accuracy, or potentially even a stronger one than cognitive failures. Indeed, while it is well-established that individuals with high levels of trait anxiety can show biased attention toward negative or threatening stimuli (Bar-Haim et al., 2007; MacLeod et al., 1986; Onie & Most, 2017), it is increasingly evident that individuals with high levels of trait anxiety have poorer attentional control in general, even with neutral stimuli that do not have intrinsic emotional significance (Bishop, 2009; McNally, 2019; Moran, 2016; Shi et al., 2019). This link between poor attentional control and negative affect could be because superior attentional control provides protection against negative affect, for example via enabling an individual to engage in adaptive cognitively-flexible emotion regulation strategies, such as reappraisal, that reduce negative affect (Gross & John, 2003; McRae & Gross, 2020). Alternatively, there could be no intrinsic differences between in cognitive ability across different levels of negative affect, but individuals experiencing negative affect may have more of their available cognitive resources consumed by internal processes such as rumination, leaving fewer available for external tasks (e.g., Whitmer & Gotlib, 2013). Regardless of the causal direction, it is clear that

there is an inverse link between negative and attentional control, and therefore it is possible that negative affect is the most important unique predictor of rare target visual search accuracy, and that the apparent relationship between CFQ and rare target visual search accuracy is actually a consequence of shared variance between CFQ and negative affect. Therefore, the second goal of this project was to differentiate the association between CFQ and rare target detection from two viable candidate alternative predictors: cognitive empathy and negative affect.

1.1 Present Study

The present study sought to investigate the relationship between the accurate detection of rare targets on the one hand, and cognitive failures, cognitive empathy, and negative affect on the other. In particular, it sought to assess whether the relationship between cognitive failures and the detection of rare targets was better understood via a single-factor versus a three-factor framework for cognitive failures, and whether there was unique shared variance between cognitive failures and performance once individual differences in cognitive empathy and negative affect were accounted for. To this end, two experiments were conducted, which measured individual differences in cognitive failures, cognitive empathy, and negative affect, and participants' ability to detect rare targets.

2.0 Experiment 1

In Experiment 1, participants performed a visual search task for a prescribed rare target in arrays of alphanumeric characters. Participants also completed measures of cognitive failures, cognitive empathy, and negative affect. The goal was to determine whether cognitive failures provided a better fit for the objective data when it was treated as a single factor versus a three-factor structure, and whether cognitive failures still explained variance in performance once cognitive empathy and negative affect scores were accounted for.

2.1 Method

2.1.1 Transparency and Openness

For all experiments, we report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study, and we follow JARS (Kazak, 2018). Raw data are available at: <https://osf.io/kmdnv/>. Materials and analysis code for this study are available by emailing the corresponding author. All statistical analysis for this and subsequent experiments was performed in the Statistical Package for the Social Sciences (SPSS, Version 27). This study's design and its analysis were not pre-registered.

2.1.1 Participants

For this and subsequent experiments, recruitment was guided by a power analysis. G*Power indicates that to have 90% power of detecting a medium effect size in a bivariate correlation requires a sample of 109 (whereas $N = 82$ would provide 80% power). This effect size was chosen because it corresponds to the effect size of the bivariate correlation observed between the False Triggering / Goal Loss scale from the Cognitive Failures Questionnaire and target-present accuracy in a rare target visual search task used in previous research (Thomson & Goodhew, 2021). To account for potential exclusions, we therefore initially sought to recruit approximately $N = 120$ for each Experiment. However, following data analysis at this stage, we were concerned that the study was underpowered (e.g., not replicating previously observed relationships), and therefore intended the sample size was doubled to $N = 240$. Note for a medium effect in three-predictor multiple regression analysis, $N = 99$ is required for 90% power, and $N = 77$ for 80% power. Crucially, following exclusions, we met or exceeded the minimum N for 80% power for all these analyses in all experiments.

A total of 245 participants completed Experiment 1. Participants 1-182 were recruited via an Australian National University (ANU) research participation website, where participants self-selected into the study, and provided informed consent prior to participation (student

sample), while participants 183-245 were recruited via Testable Minds (general population sample) and offered \$15 for their participation¹. Participants were required to be 18 years of age or over. Participants' mean age was 23.19 years (SD = 8.49) (excluding five participants who did not report). A total of 82 participants reported their gender as male, 157 as female, 4 as other, and 2 did not report, while 21 participants reported being left-handed, 221 right-handed, 2 ambidextrous, and one did not report. With respect country of birth, 125 participants were born in Australia, 23 in China, 19 in India, and rest in other countries (and one non-report).

2.1.2 Stimuli

The stimuli in Experiment 2 consisted of 3 x 3 grids of alphanumeric characters. In the main experiment, the target (i.e., the number 7) was present on 16 out of 400 arrays (i.e., 4% target prevalence), and non-target stimuli were selected randomly for each array without replacement from: 1, 2, 3, 4, 5, 6, 8, 9, J, and L. A total of 400 search arrays were created prior to the experiment and used for all participants in a different random order. For the practice trials, eight images were used, two of which contained the target. All images were presented at 600 x 600 pixels, and consisted of black characters on a white background, presented in the center of the screen. While participants completed the experiment on their own computer, for reference, this corresponded to approximately 10.5 x 10.5cm on a Retina 5K 27-inch iMac following calibration. See Figure 1 for an example target-present image and Figure 2 for an example target-absent image.

Figure 1

¹ For both Experiment 1 and Experiment 2, analyses as a function of participant type are provided in the supplementary material. To summarize, in both experiments, target-present accuracy was higher and CFQ scores were lower in the general population participants compared with the student participants, and the relationship between CFQ and target-present accuracy appeared selective to the general-population participants.

An example target-present image in Experiment 1

L	1	3
4	J	7
5	2	8

Figure 2

An example target-absent image in Experiment 1

5	L	6
9	3	4
1	8	2

2.1.4 Materials

The Cognitive Failures Questionnaire (CFQ) consists of 25 items to which participants indicate the frequency with which they have experienced those errors or lapses (e.g., forgetting what came to the shops to buy) on a five-option response scale: Never (0); Very Rarely (1); Occasionally (2); Quite Often (3); and Very Often (4). We adjusted one word in two items (newspaper > phone; letters > emails). Responses are summed to yield scores, such that possible CFQ total scores range from 0 to 100, where higher scores indicate greater proneness to cognitive failures. The three factors identified by Rast et al. (2009) consist of eight items on each scale (with three items used for both Forgetfulness and Goal Loss), and thus possible

scores for each factor range from 0 to 32. Descriptive statistics for the scores on all measures in this sample are reported in Table 1.

The Questionnaire of Cognitive and Affective Empathy (Reniers et al., 2011) consists of 31 items total, 19 to measure Cognitive Empathy and 12 to measure Affective Empathy. Respondents indicate their level of agreement with statements such as, “I try to look at everybody’s side of a disagreement before I make a decision” (Cognitive Empathy) and “It affects me very much when one of my friends seems upset” (Affective Empathy), on a four-point response scale: strongly disagree (1); slightly disagree (2); slightly agree (3); and strongly agree (4). One Cognitive Empathy and three Affective Empathy items are reverse-scored. Responses are summed to provide scores, such that possible Cognitive Scores range from 19-76, while possible Affective Empathy scores range from 12-48, such that higher scores indicate greater empathy for both. Both the Cognitive and Affective factors can be further subdivided into additional factors (Reniers et al., 2011), however, we just focused on the division between Cognitive and Affective empathy as we have done previously (Goodhew & Edwards, 2021, 2022b) because (a) this is the distinction that is best supported theoretically by available evidence (Cox et al., 2012; Kanske et al., 2016; Shamay-Tsoory et al., 2009), (b) in the original factor analysis, the two-factor solution provided the best fit to the data (Reniers et al., 2011). We adjusted the wording of some items to make them gender neutral (e.g., fellow > person). QCAE scores have strong evidence for their validity, including that scores are inversely related to psychopathy and Machiavellianism (Reniers et al., 2011), and are associated with individual differences in gray matter density in brain areas implicated in cognitive versus affective empathy (Eres et al., 2015).

We used the Depression Anxiety and Stress Scales (DASS) (Lovibond & Lovibond, 1995) to gauge negative affect. We used the 21-item version, because it has at least as good if not superior psychometrics to the 42-item version (Antony et al., 1998). DASS can provide

separate measures of depression, anxiety, and stress, but the total score also provides a valid measure of negative affect in non-clinical samples (Henry & Crawford, 2005), and this is what we focused on here. DASS total scores have been found to be associated with a range of attentional and cognitive processes in general unselected (i.e., non-clinically recruited) samples (Goodhew & Edwards, 2022a, 2022b; Hajcak et al., 2004; Onie & Most, 2017).

When completing the DASS, respondents are presented with 21 items (e.g., “I found it hard to wind down”) and asked to indicate how much the statement applied to them over the past week, via four response options: Never (did not apply to me at all, 0), Sometimes (applied to me to some degree, or some of the time, 1), Often (applied to me a considerable degree, or a good part of the time, 2), and Almost Always (applied to me very much, or most of the time, 3). DASS scores are summed and then multiplied by two, such that possible DASS total scores range from 0 to 126, while for each subscale possible scores range from 0 to 42, such that higher scores indicate greater negative affect.

3.1.4 Procedure

Participants completed the study online remotely via Testable. To ensure that image size was constant across participants (despite them completing the experiment on different computers), we employed Testable’s inbuilt calibration option, which instructs participants to match a line onscreen to the physical size of a credit card. The study was set-up to only run on computers (i.e., tablets and phones were barred). Testable has been found to have a mean precision of 3.92ms in measuring response times (Bridges et al., 2020), and we have found it sensitive to contextual effects on response time (Goodhew & Edwards, 2022a). In addition, it should also be noted that here the primary dependent variable here was accuracy, which is not affected by any lag in gauging response times.

The study began with a Captcha (to prevent bots), followed by calibration, and then participants were shown the Information Sheet and hit one of two buttons (“Agree” or

“Disagree”) to indicate whether they wanted to participate. Those who hit Disagree did not progress to the experiment. Then, participants completed the four blocks (visual search task, CFQ, QCAE, and DASS) in an order randomly selected for each participant. Attention check items appeared in amongst the CFQ items (which instructed participants to select “Very Often”), and at the end of the QCAE items (which instructed participants to select “Slightly Disagree”).

For the visual search task, participants were presented with the following onscreen instructions: “Here you will see an array of nine digits and/or letters. Your task is to press the M key if you see the number 7 in the array, and to press the Z key if the array does not contain the number 7.” They then completed eight practice trials, which included onscreen feedback about the accuracy of each response (feedback was not provided in the main experiment). They were reminded of the task instructions again before proceeding to the main experiment. This consisted of 400 trials, of which 16 contained the target digit 7 (i.e., 4% target prevalence), randomly intermixed, with the constraint that the first 16 trials were target-absent. On each trial, the search array was presented until response, and there was an 800ms intertrial interval during which the screen was blank.

The specific instructions prior to each questionnaire are presented in the supplementary material. Two attention-check items were included, one of which appeared at the end of the CFQ and instructed participants to answer “Very Often” for the item, and the other appeared amongst the QCAE items and instructed participants to answer “Slightly Disagree”. For each questionnaire, all items were shown on the same page, and the response options were arranged vertically under the item, with a bubble next to each response option, where participants clicked to indicate their response.

2.2 Results

2.2.1 Exclusions

For all experiments, only data from participants who gave consent and reached the end of the study were analyzed, and participants were excluded from further analysis if they: (a) had missing data on any of the scales, (b) failed to respond as instructed to the attention-check items, (c) scored 0% accuracy on target-present trials, or (d) scored below 50% on target-absent trials, to facilitate analyzing only data from participants who had genuinely attempted to complete the experiment. Different exclusion rates were used for target-absent versus target-present trials, because in these rare target designs accuracy is typically much greater for target-absent trials (e.g., Thomson & Goodhew, 2021). In Experiment 1, 19 participants were excluded due to missing data, 17 due to failure to respond as instructed to the attention-check items, 1 due to 0% target-present accuracy, and 3 due to scoring below 50% on target-absent trials (screening was performed in this order, so any individuals meeting multiple criteria would be reported for the first criterion they met leading to their exclusion). This left a final sample of $N = 205$.

2.2.2 Descriptive statistics, reliability, and correlations

Table 1

Descriptive statistics for Experiment 1 ($N = 205$)

	Mean (SD)	Reliability
CFQ total	44.06 (15.46)	.92
CFQ Forgetfulness	15.31 (5.31)	.81
CFQ Distractibility	15.23 (5.39)	.80
CFQ Goal Loss	11.48 (5.64)	.83
QCAE Cognitive Empathy	59.28 (7.43)	.88
DASS Total	37.83 (22.15)	.93
Target-Present Accuracy	75.03% (19.43)	.75

Target-Present Median RT	794.23 ms (195.44)
Target-Absent Accuracy	99.76% (1.41)
Target-Absent Median RT	800.41 ms (297.69)

Note. No Response Time (RT) trial exclusions were applied given the small number of critical trials. Therefore, median RT was calculated for each participant, and the values shown here are the mean of those medians.

Note. All reliabilities reflected Cronbach's alpha. For target-present trial accuracy, each of the 16 trials was treated as equivalent to an item on a scale for this calculation.

All of the questionnaire-based measures (CFQ, QCAE, and DASS) yielded a substantive range of scores, in addition to adequate reliability. Histograms of the distribution of scores are available in the supplementary material. Notably, the CFQ scales Forgetfulness, Distractibility and Goal Loss mean scores were similar to those obtained previously where a relationship was shown with rare target visual search (15.4, 14.9, 11.7) (Experiment 1 of Thomson & Goodhew, 2021), and the SDs were all larger than those observed previously, (4.1, 4.0, and 4.2) (Thomson & Goodhew, 2021), indicative of meaningful range of CFQ scores in the present sample. Cognitive Empathy scores were similar to those obtained in previous work where Cognitive Empathy was found to be associated with other variables ($M = 59.48$, $SD = 8.22$) (Goodhew & Edwards, 2022b). DASS scores were also similar to that previous work ($M = 38.73$, $SD = 22.71$) (Goodhew & Edwards, 2022b) and ($M = 44.24$, $SD = 26.71$) (Goodhew & Edwards, 2022a) where associations between DASS scores and other variables were found.

Accuracy was significantly lower on target-present than target-absent trials (repeated-measures t -test: $t(204) = 18.59$, $p < .001$, Mean Difference = $-.25$, 95% CI of difference = $-.27$

to -.22), indicative of a low prevalence effect. This target-present accuracy is also similar to that seen in previous work ($M = 76.1$, $SD = 21.3$, Thomson & Goodhew, 2021).

Furthermore, the maximum observable magnitude of association between any two measures is fundamentally constrained by the measurement reliability of both (Parsons et al., 2019; Spearman, 1910). This means that for the present study, it is important to consider the measurement reliability of both the questionnaire-derived *and* experimentally-derived performance-based measures, even though the reliability of experimental measures has often been overlooked in the literature (for practical recommendations regarding reliability in cognitive psychology, see Goodhew & Edwards, 2019). Reliability tends to be lower for experimental effects than for questionnaire scales. Here, the reliability for target-present accuracy was substantively higher than that in previous research (.59 in Thomson & Goodhew, 2021). This may be a product of the increased homogeneity of the stimulus items in the present study (compared with images of different objects used in Thomson & Goodhew, 2021), and /or the larger sample size.

The primary planned analysis approach here was to compare the variance explained in target-present accuracy by cognitive failures, cognitive empathy, and negative affect. First, however, we examined the bivariate correlations between the predictor variables, and these are shown in Table 2.

Table 2

Bivariate correlations between predictor variables in Experiment 1 ($N = 205$)

	CFQ-F	CFQ-D	CFQ-GL	CE	NA
CFQ-Total	.90**	.89**	.88**	-.06	.49**
CFQ-F		.71**	.83**	-.02	.37**

CFQ-D	.66**	-.10	.49**
CFQ-GL		-.05	.43**
CE			.02

Note. Some of the variables were not normally distributed, and so Spearman's rho correlation coefficients are reported here.

Note. ** = $p < .01$, * = $p < .05$.

Note. CFQ-Total = Cognitive Failures Questionnaire (Total Score); CFQ-F = Forgetfulness; CFQ-D = Distractibility; CFQ-GL = Goal Loss; CE = Cognitive Empathy; NA = Negative Affect.

Note. AE was not a predictor in the models (because there is no theoretical reason to link it to target-present accuracy). However, it is worth noting that, CE and AE were related in ways consistent with previous literature, $r_s(203) = .24$, $p < .001$, (Goodhew & Edwards, 2021; Reniers et al., 2011).

The bivariate correlations between the predictor variables and target-present accuracy are shown in Table 3. Target-absent median RT was a significant predictor of target-present accuracy, $r_s(203) = .58$, $p < .001$, which is consistent with previous research showing that participants who respond more slowly on the majority absent trials are more likely to correctly detect rare targets when they do appear (Thomson & Goodhew, 2021). Notably, however, none of the predictor variables correlated with target-absent median RT (absolute value of $r_s \leq .11$, $ps \geq .133$).

Table 3

Bivariate correlations between predictors and target-present accuracy in Experiment 1 (N = 205)

	CFQ-total	CFQ-F	CFQ-D	CFQ-GL	CE	NA
Target-present accuracy	-.26**	-.19**	-.21**	-.23**	-.02	-.17*

Note. Some of the variables were not normally distributed, and so Spearman's rho correlation coefficients are reported here.

Note. ** = $p < .01$, * = $p < .05$.

Note. CFQ-total = Cognitive Failures Questionnaire (total score); CFQ-F = Forgetfulness; CFQ-D = Distractibility; CFQ-GL = Goal Loss; CE = Cognitive Empathy; NA = Negative Affect.

Table 3 shows a negative relationship between CFQ total and target-present accuracy, and between each of the CFQ sub-factors and target-present accuracy. Negative Affect was also similarly negatively associated with target-present accuracy. This means that individuals prone to elevated cognitive failures or negative affect were more likely to miss the rare targets. In contrast, Cognitive Empathy was unrelated to target-present accuracy.

2.2.3 Linear Multiple Regression

A linear multiple regression was performed, where the criterion was target-present accuracy, and the predictors entered were CFQ-total, Cognitive Empathy, and Negative Affect. This revealed a significant overall model, $F(3, 201) = 5.87$, $p = .001$, $R^2_{\text{adjusted}} = .07$. The regression

coefficients are shown in Table 4². A similar model except where the three CFQ factors were substituted for CFQ total was assessed. This model explained less overall variance ($R^2_{\text{adjusted}} = .06, p = .006$), and none of the three CFQ were significant, suggesting that they worked together to explain variance in target-present accuracy, and that there was no additional value in distinguishing among the factors. Details of this analysis are reported in the supplementary material.

Table 4

Regression coefficients predicting target-present accuracy in Experiment 1

	β weight
CFQ Total	-.21**
Cognitive Empathy	-.09
Negative Affect	-.10

Note. ** = $p < .01$, * = $p < .05$.

Note. To assess the impact of missing questionnaire responses, an additional analysis was conducted where the predictors were each individual's *mean* response score from the 25 CFQ items, mean score from the Cognitive Empathy items (following reverse scoring for relevant items), and mean score from the Negative Affect items. Assuming that all items measure the target process, taking an individual's mean response score for a questionnaire (rather than total additive score) means that scores are comparable across individuals with different numbers of responses (i.e., those with and without missing data, and those with different amounts of missing data). Cases with missing scale responses were also included in this analysis (total N

² The exclusion of two cases with extreme residual scores did not alter the pattern of results. The overall model was still significant ($R^2_{\text{adjusted}} = .09, p < .001$), and CFQ total remained the sole significant predictor ($\beta = -.25, p = .002$), while both Cognitive Empathy ($\beta = -.08, p = .216$) and Negative Affect ($\beta = -.11, p = .167$) remained non-significant. Even with these exclusion the residuals were not perfectly normally distributed, however, this should not compromise the regression model (Gelman & Hill, 2006).

= 222), and a linear multiple regression was performed where the predictors were Mean response score for CFQ, Cognitive Empathy, and Negative Affect, and the criterion was target-present accuracy. This showed a significant overall model ($R^2_{\text{adjusted}} = .05, p = .004$), whereby CFQ was the only significant predictor ($\beta = -.19, p = .015$), while neither Cognitive Empathy ($\beta = -.04, p = .535$) nor Negative Affect ($\beta = -.08, p = .296$) were significant unique predictors. This is consistent with the primary analysis, and indicates that missing responses did not distort the pattern of results.

This shows that individuals experiencing elevated Cognitive Failures were more likely to miss the rare target. Neither Negative Affect nor Cognitive Empathy contributed unique variance to explaining target-present accuracy. This same model applied to target-absent accuracy as the criterion also yielded a significant model ($R^2_{\text{adjusted}} = .04, p = .009$). However, none of the individual predictors were significant ($\beta \leq .13, p \geq .091$). This suggests that the unique effect of Cognitive Failures was selective to target-present trials. Further, exclusion of 13 cases with extreme residual scores led to the model become non-significant ($R^2_{\text{adjusted}} = -.004, p = .515$), indicating that the model was unstable, and that any predictive value is likely limited to target-present trials.

2.4 Discussion

While in Experiment 1 both Cognitive Failures and Negative Affect were negatively correlated with target-present accuracy at the bivariate level, the multiple regression analysis indicated that Cognitive Failures alone explained unique variance in target-present accuracy. This was such that individuals with elevated Cognitive Failures were more likely to miss the rare targets. The multiple regression analysis also suggested that the three CFQ factors did not

explain variance over and above CFQ total. Cognitive Empathy was unrelated to performance. The robustness of these results was tested in an additional experiment with different stimuli.

3.0 Experiment 2

In Experiment 2, the same research questions were addressed as in Experiment 1, but this time the rare targets occurred without the presence of distractors. That is, on each trial, a single stimulus appeared in the center of the screen, and the target was present on 4% of trials.

3.1 Method

3.1.1 Participants

A total of 243 participants completed Experiment 2. Participants 1-122 were recruited via ANU participation site, while participants 123-243 were recruited via Testable Minds. Participants' mean age was 26.14 years ($SD = 9.83$). A total of 100 participants reported their gender as male, 139 as female, and 4 as other, while 19 participants reported being left-handed, 219 right-handed, 4 ambidextrous, and one did not report. With respect to country of birth, 75 participants were born in Australia, 42 in India, 17 in South Africa, 17 in England or United Kingdom, 16 in China, and the rest in other countries (and one reported a year rather than a country and one only typed a single letter).

3.1.2 Stimuli

The stimuli in Experiment 2 consisted of nine digits (1-9), word versions of these numbers (one-nine). Targets were the word *seven* or the digit 7. Their size was approximately .5 x .5cm on a Retina 5K 27-inch iMac following calibration. They appeared in black font against a white background.

3.1.3 Materials

Experiment 2 used the same CFQ, QCAE, and DASS measures as Experiment 1.

3.1.4 Procedure

Participants completed the study online remotely via Testable. It began with a Captcha, followed by calibration, and then consent. Next, participants completed the demographic questions. Then, participants completed the four blocks (target detection task, CFQ, QCAE, and DASS) in an order randomly determined for each participant. Two attention check items were included, one appeared amongst the CFQ items and read “Please select “Very Often” for this statement”, while the other appeared at the end of the QCAE and read “Please select “Slightly Disagree” for this statement.

Prior to the target detection task, participants were presented with the onscreen instruction: “Here you will be presented with a number, either as a word (e.g., one) or a digit (e.g., 1). Your task is to press the M key if it IS seven (or 7), and to press the Z key if it IS NOT seven (or 7).” Participants then completed 10 practice trials, in which two targets (a ‘7’ and a ‘seven’) appeared, where they received onscreen feedback about whether their response was correct or incorrect on each trial (no feedback during the main experiment). They were reminded of the task instructions again before proceeding to the main experiment. This consisted of 400 trials, 16 of which contained a target seven/7 (i.e., 4% target prevalence), randomly intermixed, with the constraint that the first 16 trials were non-target trials, where each non-target option was used once. When the target was present, half of the time it was a digit, and half of the time it was a word. On non-target trials, a digit (1, 2, 3, 4, 5, 6, 8, or 9) or a word (one, two, three, four, five, six, eight, or nine) was presented, such that each distractor option occurred equally often across the experiment. On each trial, the stimulus was presented until response, and there was an 800ms intertrial interval during which the screen was blank.

3.2 Results

3.2.1 Exclusions

In Experiment 2, 24 participants were excluded due to missing data, 17 due to failure to respond as instructed to attention-check items, none due to the target-present criterion, and 2 due to the target-absent accuracy criterion, leaving a final sample of $N = 200$.

3.2.2 Descriptive statistics, reliability, and correlations

Table 5

Descriptive statistics for Experiment 2 ($N = 200$)

	Mean (SD)	Reliability
CFQ total	42.45 (16.76)	.93
CFQ Forgetfulness	14.81 (5.98)	.83
CFQ Distractibility	14.71 (5.76)	.81
CFQ Goal Loss	11.07 (5.74)	.83
Cognitive Empathy	59.42 (7.65)	.88
Negative Affect	36.06 (22.79)	.93
Target-Present Accuracy	72.00% (19.11)	.70
Target-Present Median RT	614.65ms (154.24)	
Target-Absent Accuracy	99.92% (0.17)	
Target-Absent Median RT	421.33ms (86.21)	

Note. No Response Time (RT) trial exclusions were applied given the small number of critical trials. Therefore, median RT was calculated for each participant, and the values shown here are the mean of those medians.

Note. All reliabilities reflected Cronbach's alpha. For target-present accuracy, each of the 16 trials was treated as equivalent to an item on a scale for this calculation.

Table 5 shows a target-present accuracy similar to that of Experiment 1, including a significant difference between target-present and target-absent trial accuracies ($p < .001$), indicative of a low prevalence effect. The measurement reliability was also excellent for the scales and adequate for target-present accuracy. Distributions of scale scores are provided in the supplementary material. The bivariate correlations between the predictor variables are shown in Table 6.

Table 6

Bivariate correlations between predictor variables in Experiment 2 (N = 200)

	CFQ-F	CFQ-D	CFQ-GL	CE	NA
CFQ	.93**	.91**	.91**	-.08	.66**
CFQ-F		.76**	.86**	-.05	.54**
CFQ-D			.74**	-.06	.70**
CFQ-GL				-.11	.60**
CE					-.06

Note. Some of the variables were not normally distributed, and so Spearman's rho correlation coefficients are reported here.

Note. ** = $p < .01$, * = $p < .05$.

Note. CFQ = Cognitive Failures Questionnaire (total score); CFQ-F = Forgetfulness; CFQ-D = Distractibility; CFQ-GL = Goal Loss; CE = Cognitive Empathy; NA = Negative Affect.

Note. AE was not a predictor in the models (because there is no theoretical reason to link it to target-present accuracy). However, here CE and AE were related in ways consistent with previous literature, $r_s(198) = .34, p < .001$, (Goodhew & Edwards, 2021; Reniers et al., 2011).

The bivariate correlations between the predictor variables and target-present accuracy are shown in Table 7. It should also be noted that target-absent median RT was strongly related to target-present accuracy, $r_s(198) = .69, p < .001$, but none of the predictors were associated with target-absent median RT (absolute value of $r_s \leq .13, p_s \geq .058$).

Table 7

Bivariate correlations between predictors and target-present accuracy in Experiment 2

	CFQ-total	CFQ-F	CFQ-D	CFQ-GL	CE	NA
Target-present accuracy	-.20**	-.18*	-.20**	-.18*	-.09	-.13

Note. Some variables were not normally distributed, and thus Spearman's rho correlation coefficient are reported.

Note. ** = $p < .01$, * = $p < .05$.

Note. CFQ total = Cognitive Failures Questionnaire (total score); CFQ-F = Forgetfulness; CFQ-D = Distractibility; CFQ-GL = Goal Loss; CE = Cognitive Empathy; NA = Negative Affect.

Table 7 shows that Cognitive Failures were associated with target-present accuracy. This was true for CFQ-total, and for each of the CFQ subscales.

3.2.3 Linear Multiple Regression

A linear multiple regression was performed, where the criterion was target-present accuracy, and the predictors were CFQ-total, Cognitive Empathy, and Negative Affect. This revealed a significant model ($R^2_{\text{adjusted}} = .05, p = .004$), and the predictor coefficients are shown in Table 8.

Table 8

Regression coefficients predicting target-present accuracy in Experiment 2

	β weight
CFQ Total	-.27**
Cognitive Empathy	-.08
Negative Affect	.03

Note. ** = $p < .01$, * = $p < .05$.

Note. The exclusion of two cases with extreme residual scores did not alter the pattern of results. That is, the overall model was still significant, ($R^2_{\text{adjusted}} = .06, p = .003$), and Cognitive Failures was the sole significant predictor ($\beta = -.24, p = .009$), whereas neither Cognitive Empathy ($\beta = -.17, p = .096$) nor Negative Affect ($\beta = -.01, p = .895$) were significant.

Note. To assess the potential impact of missing item responses, mean individual item response score was taken for the CFQ, Cognitive Empathy, and Negative Affect, and these predictors were used in a model where the criterion was target-present accuracy, and participants who had missing item responses were included as well (total $N = 218$). This model was significant ($R^2_{\text{adjusted}} = .04, p = .005$), and mean CFQ score was the sole significant predictor ($\beta = -.26, p = .004$), while neither Cognitive Empathy ($\beta = -.07, p = .325$) nor Negative Affect ($\beta = .03, p = .326$) were significant. This is consistent with the results of the primary analysis, suggesting the missing item responses did not distort the outcome of the primary analysis.

This suggests that individual differences in Cognitive Failures were uniquely associated with target-present accuracy, such that higher Cognitive Failures were associated with

increased target misses. Another model was applied to target-present accuracy, whereby the three CFQ factors were used instead of CFQ total. This model did not explain more variance than the model where CFQ was treated as unitary ($R^2_{\text{adjusted}} = .05, p = .016$), and none of the individual CFQ factors were predictive. This model is reported in full in the supplementary material.

Finally, another model where CFQ total, Cognitive Empathy, and Negative Affect were predictors was also applied to target-absent accuracy. This model was not significant ($R^2_{\text{adjusted}} = .002, p = .327$), suggesting that the associations were selective to target-present trials.

3.3 Discussion

The results of Experiment 2 implicated Cognitive Failures in explaining variance in target-present accuracy, such that individuals prone to greater cognitive failures were more likely to miss the rare targets. There was no evidence that differentiating among the three CFQ factors elucidated patterns that were not already captured by the unitary CFQ construct.

4.0 General Discussion

The purpose of the present experiments was twofold: (1) to determine whether a one-factor or three-factor structure for the CFQ provided a better fit for explaining variance in objective rare-target detection performance, and (2) to assess the relative role of three related factors in predicting performance in rare-target detection: cognitive failures, cognitive empathy, and negative affect. Experiment 1 had participants search for rare digit 7s (4%) amongst alphanumeric non-targets in 400 search arrays, and in Experiment 2, participants' task was to identify rare target 7/sevens (4%) that were presented in a single-item at a time stream of alphanumeric non-targets over 400 trials. Both experiments implicated the unique role of cognitive failures in predicting misses of rare targets, and they converged on the conclusion that there no value to differentiating among the factors. Instead, the evidence was in favor of treating CFQ as unitary. In Experiment 1 there was evidence that negative affect was related

to performance at the bivariate level, but this was not seen in Experiment 2. In contrast, both experiments were consistent in indicating no role of cognitive empathy in performance. We discuss the implications of these findings below.

The finding that individuals prone to cognitive failures are more likely to miss rare targets is consistent with previous literature (Thomson & Goodhew, 2021), but also extends on it and differs from it in some important ways. First, while Thomson and Goodhew (2021) found qualitatively different relationships between the three components of cognitive failures identified by Rast et al., (2009), the present study found no utility to differentiating among these factors. This is consistent with the broader CFQ literature according to which CFQ factors appears to be unstable. The CFQ is clearly associated with important outcomes, such as person's risk of car crash (Wallace & Vodanovich, 2003), through to their life satisfaction (Haslam et al., 2008). However, various attempts to identify factor structures have been contentious and inconsistent, and the present results can be considered as part of that narrative.

Why is this? It is possible that the CFQ is truly unitary. However, we believe that there may well be meaningful subcomponents of the CFQ, but current measurement tools are inadequate for this purpose. That is, CFQ total consists of just 25 items, and the factors identified by Rast et al. (2009) have only item 8 items per factor with three items shared between two factors. Even if these are meaningful components of CFQ, this may limit their ability to yield reliable measurement. Current work in our laboratory is therefore focused on extending the number of items in the CFQ and applying factor-analytic approaches to this to determine if a more stable factor structure where the factors are consistent in their relationships with performance can be obtained. If so, this may reveal enhanced associations between particular aspects of cognitive failures and task performance.

That said, however, it is clear that CFQ total scores here yielded reliable associations with the detection of rare targets, such that individuals prone to greater cognitive failures in

everyday life missed more rare targets. From an applied perspective, this means that the CFQ could be used as a screening tool for assessing prospective personnel for performing safety-critical rare-target visual searches such as baggage screening. However, the CFQ may be rather transparent in its intended measurement, and thus while it may be useful to screen out some individuals prone to missing rare targets, it may need to be used in conjunction with other less transparent measures for maximal effectiveness. Perhaps the greater applied utility of the present finding is that it identifies cognitive processes that could be the target of potential training programs or other interventions to improve the detection of rare targets. While the present findings did not support the unique role of the Goal Loss factor of the CFQ, a number of CFQ items clearly gauge difficulties with maintaining goals and monitoring for goal-related information. Given this, it is possible that scaffolding performance via reminders about the identity of searched-for target may mitigate the detrimental effect of propensity toward cognitive failures.

It should also be noted that the relationships between CFQ and target-present performance appeared to be most pronounced in the general population participants that we recruited, rather than in the participants who were students. While we have observed relationships between CFQ and rare target visual search in previous work with student participants (Thomson & Goodhew, 2021), this suggests that these relationships may be stronger in the general population. Alternatively, this may stem from greater measurement precision amongst the general population sample. Consistent with this, target-present accuracy was reliably greater in the general population samples in both experiments, which may indicate that these participants exerted greater effort at the task, and thus differences in performance may stem more intrinsically from cognitive control differences, rather than differences in motivation.

Experiment 1 indicated that there may be a relationship between negative affect and the detection of rare targets, albeit a weaker one than that between CFQ and performance. The relationship with negative affect may be stronger in samples selected for their high levels of negative affect. Here we consider some of the potential implications if future work confirms a robust relationship between negative affect and rare target visual search performance.

The link between attention and negative affect, particularly trait anxiety, has long been of interest. A large body of evidence indicates that anxious individuals tend to exhibit biased attention toward threatening or negative stimuli, and this has been suggested to be a factor in the development and maintenance of anxiety (MacLeod, 2019; MacLeod et al., 2002; Van Bockstaele et al., 2014). Alternatively, it has been considered whether these patterns of biased attention are not the hallmark of the disorder, but instead just one symptom of a broader impairment in attentional regulation and control, that is not limited to emotionally-salient stimuli (Bishop, 2009; Moran, 2016; Shi et al., 2019). The results of Experiment 1 are consistent with this notion of poorer attentional regulation and control associated with negative affect. There is presumably nothing intrinsically salient about alphanumeric characters, but participants with high levels of negative affect nonetheless had difficulty detecting the targets. This suggests that these individuals had poorer ability to control or regulate their attention to respond to these targets correctly. It should be acknowledged that negative affect is a superordinate construct that includes anxiety, but also other factors such as depression and stress (Lovibond & Lovibond, 1995; Watson & Clark, 1984; Watson & Tellegen, 1985). Thus, anxiety and negative affect cannot be treated as entirely synonymous when considering the link between the anxiety literature and the present study, since one is a subset of the other. However, it is worth noting that in the literature on attentional control issues in anxiety, other aspects of negative affect such as depression or stress are often not controlled for. Further, the State Trait Anxiety Inventory which is commonly used to gauge anxiety in such studies has been found to

be sensitive to both depressive and anxious symptomology (e.g., Andrade et al., 2001; Grös et al., 2007). This means that the attentional control deficits exhibited in anxiety may not be selective to anxiety at all, but may be present across multiple aspects of negative affect.

If we infer from the results of Experiment 1 that there is evidence that elevated negative affect impairs the detection of rare targets, then where did this deficit come from? There are at least two possibilities, and they are not mutually exclusive. On the one hand, negative affect is linked to rumination (e.g., Kirkegaard Thomsen, 2006; Moberly & Watkins, 2008). If the individuals experiencing higher levels of negative affect in the current experiment were ruminating during the task, then this task-unrelated thought could consume their cognitive faculties, leaving fewer available to maintain the task set and remain vigilant to the rare targets and undermining readiness to efficiently switch from the prepotent target-absent response. This possibility does *not* require that individuals prone to negative affect have intrinsically poorer attentional control compared with other individuals, and instead it espouses that negative affect and its associated consequences such as rumination are the culprit for poorer detection of rare targets. Therefore, according to this possibility, reducing negative affect for these individuals would improve their performance.

On the other hand, there is compelling evidence that engagement in cognitively flexible emotion-regulation such as reappraisal facilitate mental health and well-being (Gross & John, 2003; McRae & Gross, 2020; Preece et al., 2021; Preece et al., 2020; Shafir et al., 2016). Individuals also reliably differ in their attentional control capacities, such as working memory capacity (Conway et al., 2005; Engle, 2018; Kane et al., 2004). Therefore, individuals with reduced attentional control capacities may be less able or willing to engage in adaptive emotion regulation strategies (Schmeichel et al., 2008), thereby leaving them vulnerable to negative affect. Such individuals would be likely to report higher levels of negative affect in the current study, and then these individuals may also have had impaired ability to maintain the task set,

monitor for rare targets, and inhibit prepotent motor responses as a consequence of their impaired attentional control capacities, rather than as a direct result of negative affect. In other words, according to this possibility, both heightened negative affect and poor response inhibition are consequences of intrinsic individual differences in attentional control capacities, and only by improving their attentional control capacities could this rare target performance deficit be remedied.

These possible causal directions for the association between negative affect and more rare-target misses could be distinguished via future research. For example, could a positive mood induction mitigate the selective decrement in performance for those with negative affect observed here? Would a negative mood induction make an individual who is not prone to negative affect perform like one who is? If so, then this would be both theoretically informative, because it would suggest that affect itself is a driver of rare-target performance, as well as practically important, in that it would offer a means of improving rare target detection in important professional visual search tasks such as diagnostic medical imaging. In a similar vein, it would imply that workplace variables may be important in promoting rare target detection accuracy in professional visual search contexts – for example, excessively high workloads could induce negative affect (and/or encourage fast searches), thereby impairing performance.

Furthermore, while the goal of the present study was to differentiate between cognitive failures and negative affect, it should be noted that these were consistently positively related in both experiments ($r_s = .47$ and $r_s = .66$). That is, individuals prone to depression, stress, anxiety, were also more likely to make mistakes in everyday life. While we cannot determine the direction of causality from a correlation, one possibility is that the *ruminations* associated with negative affect may consume available cognitive resources, making individuals susceptible to these mistakes. If so, then the correlations observed here may be the product of

rumination, such that rumination is driving poorer detection of rare targets. This can be assessed in future research by testing whether rumination tendencies mediate the relationship between negative affect and cognitive failures, and by assessing the role of rumination directly in task performance. This could be done both via individual differences approaches, examining the association between self-reported rumination tendencies and task performance, and by experimental manipulations of a current cognitive load (e.g., information to remember) and examining how this impacts the detection of rare targets.

It will also be interesting to assess the extent to which different predictors are associated selectively with performance under low prevalence conditions versus across a range of prevalence conditions. Thomson and Goodhew's (2021) results suggested that the bivariate correlation between Goal Loss and target-present accuracy was eliminated when target prevalence was 50%, while the three factors together still predicted variance via a regression model. This is suggestive that the relationship may weaken under higher prevalence conditions, but further testing will be required to confirm that this applies to unitary CFQ models.

Turning now to cognitive empathy, despite the evidence from previous literature linking cognitive empathy to attentional control and working memory (Fliss et al., 2016; Gabriel et al., 2021; Goodhew & Edwards, 2021; McKinnon & Moscovitch, 2007; Navarro et al., 2020; Wardlow, 2013), here across two experiments, cognitive empathy was consistently unrelated to the detection of rare targets. This may seem surprising given previous evidence that working memory itself is implicated in the detection of rare targets (Schwark et al., 2013). This could mean that the shared variance between cognitive empathy and these executive functions is not also shared with the processes implicated in maintaining vigilance in searching for rare targets. Alternatively, it could be that the cognitive empathy as measured by the QCAE conflates two arguably distinct aspects of cognitive empathy – individual differences in the *ability* to perspective-taking and mentalize, and individual differences in the *propensity* or

tendency to do so (Keysar et al., 2003; Keysers & Gazzola, 2014). Some items appear to gauge ability (e.g., “Other people tell me I am good at understanding how they are feeling and what they are thinking”), whereas others appear to gauge propensity (e.g., “I try to look at everybody’s side of a disagreement before I make a decision). It is possible that the shared variance between working memory and cognitive empathy is selective to one of these aspects of empathy, and hence why general cognitive empathy may not be a strong predictor of performance when both aspects are measured. For example, working memory may be more strongly related to individual differences in ability, whereas propensity may be a product of multitude of factors not implicated in ability, including factors such as motivation, thus diluting any relationship with working memory. If the QCAE strongly represents individual differences in propensity, then this might explain the absence of relationship between it and rare target visual search which has been linked to working memory.

Finally, while cognitive failures were a strong negative predictor of performance in detecting rare targets across the multiple experiments here, a consistently strong positive predictor of performance was response time on the target-absent trials. That is, participants who took longer to respond on target-absent trials were more likely to correctly detect the target when it did appear on target-present trials. This suggests that encouraging participants to slow down might help to reduce rare-target misses. One early study found that issuing participants with ‘speeding tickets’ on trials where they went too fast had such temporary effects that it did not demonstrably improve target hit rate (Wolfe et al., 2007). However, it remains to be seen whether other manipulations can improve performance by inducing more enduring effects on response speed.

4.1 Conclusion

In conclusion, the present work demonstrated clear associations between subjective cognitive failures in everyday life and objective performance in rare target detection contexts.

There was also some more limited evidence that negative affect was also associated with impaired detection of rare targets. This has important implications both for theoretical models of the relationship between subjective assessments of cognition and task performance and for theoretical models of negative affect and attentional control, and also for potential intervention strategies to improve rare target detection in important real-world contexts such as airport baggage security screening and diagnostic medical imaging.

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