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Domain-specific and domain-general processes underlying metacognitive judgments

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ABSTRACT

Metacognition and self-awareness are commonly assumed to operate as global capacities. However, there have been few attempts to test this assumption across multiple cognitive domains and metacognitive evaluations. Here, we assessed the covariance between "online" metacognitive processes, as measured by decision confidence judgments in the domains of perception and memory, and error awareness in the domain of attention to action. Previous research investigating metacognition across task domains have not matched stimulus characteristics across tasks raising the possibility that any differences in metacognitive accuracy may be influenced by local task properties. The current experiment measured metacognition in perceptual, memorial and attention tasks that were closely matched for stimulus characteristics. We found that metacognitive accuracy across the three tasks was dissociated suggesting that domain specific networks support an individual's capacity for accurate metacognition. This finding was independent of objective performance, which was controlled using a staircase procedure. However, response times for metacognitive judgments and error awareness were associated suggesting that shared mechanisms determining how these meta-level evaluations unfold in time may underlie these different types of decision. In addition, the relationship between these laboratory measures of metacognition and reports of everyday functioning from participants and their significant others (informants) was investigated. We found that informant reports, but not self reports, predicted metacognitive accuracy on the perceptual task and participants who underreported cognitive difficulties relative to their informants also showed poorer metacognitive accuracy on the perceptual task. These results are discussed in the context of models of metacognitive regulation and neuropsychological evidence for dissociable metacognitive systems. The potential for the refinement of metacognitive assessment in clinical populations is also discussed.

1. Introduction

Just as the accuracy of objective performance varies substantially among individuals (Kirchhoff & Buckner, 2006; Song et al., 2011), so too does the accuracy of metacognitive judgments that self-evaluate performance (Rounis, Maniscalco, Rothwell, Passingham, & Lau, 2010). Metacognition has been conceived as self-directed control processes that guide

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everyday decision making (Flavell, 1979; Koriat & Goldsmith, 1996; Nelson & Narens, 1990). For example, a lack of confidence following one's own memory retrieval often redirects behavior, such as reallocation of study time during learning and changes of retrieval strategy (Nelson & Narens, 1990). Metacognition and awareness are often considered to be global phenomena (Shimamura, 2000). One way that metacognition is widely measured is through Retrospective Confidence Judgments (RCJs) of performance and are elicited by asking an individual to give an additional report or commentary over their initial task response. Recent research has demonstrated a distinct relationship between accuracy in retrospective judgments of performance in perceptual decision making and the anatomical structure of the anterior prefrontal cortex (Baird, Smallwood, Gorgolewski, & Margulies, 2013; Fleming, Weil, Nagy, Dolan, & Rees, 2010). Similar neuroanatomical regions have also been implicated in error monitoring processes, research has implicated the dorsal ACC, rostral ACC, posterior medial frontal cortex, anterior medial frontal cortex and prefrontal cortex in error awareness (Taylor, Stern, & Gehring, 2007).

Furthermore, covariation between metacognitive accuracy across different tasks has lent support to a domain general account (McCurdy et al., 2013; Song et al., 2011). Sherer et al. (1998) found that the number of brain lesions rather than the volume or location was predictive of the degree of Impaired Self Awareness (ISA) in a sample of 91 participants with Acquired Brain Injury (ABI). However, recent research (Fleming, Ryu, Golfinos, & Blackmon, 2014) showed that patients with lesions to the anterior prefrontal cortex (aPFC) showed a selective deficit in perceptual metacognitive accuracy but that metacognitive capacity on a memorial task remained unimpaired. In a similar vein, McCurdy et al. (2013) reported that grey matter volume in the aPFC predicted individual differences in the accuracy of decision confidence judgments in a visual discrimination task. Metacognitive accuracy in a memory recognition task on the other hand, was predicted by grey matter volume in a neuroanatomically distinct region in the medial parietal cortex. However, the extent to which domain specific metacognitive processes can be separated in studies employing psychophysical tasks with differential types of stimuli and paradigms is unclear. Convergent evidence from recent structural and functional imaging studies in support of the role of aPFC in metacognitive ability utilized tasks that permit the comparison of results across research. One possibility is that differences between the tasks could be potentially orthogonal to the domain in question. For example, Kao, Davis, and Gabrieli (2005) found that Judgments of Learning (JOLs) were associated with activation in left ventromedial prefrontal cortex. A Judgment of learning elicits a belief during learning about how successful recall will be for a particular item on subsequent testing and is commonly used in metamemory research. On the other hand, Do Lam et al. (2012) observed an association with activation in medial PFC, orbital frontal, and anterior cingulate cortices and JOLs. Although ventromedial cortex activation was common to both studies, additional areas of activation were observed by Do Lam et al. (2012). Differences in activation may be due to underlying procedural differences across the two studies. Kao et al. (2005) had participants make JOLs on scenic images for eventual recognition whereas Do Lam et al. (2012) had participants make JOLs on photographs of faces for eventual cued recall of names. Thus, variations in task design meant JOLs were based on different sources of information and thus different areas of brain activation.

Here, we compared intraindividual variability in metacognitive capacity for perceptual decisions, memorial judgments and awareness of errors controlling the nature of the stimuli across tasks in order to isolate metacognitive accuracy from changes in primary task performance. A central aim of this study was to investigate metacognition and awareness across three different cognitive paradigms, which require participants to evaluate the accuracy of their perceptions, actions and memories separately. In order to achieve this aim, novel tasks were designed to measure subjective confidence judgments for perceptual and memorial decisions, and to measure awareness of simple action errors. Each task drew upon the same set of verbal stimuli to ensure that the 'object of awareness' was constant across domains. In addition, the tasks had built in staircases applied to control for accuracy and dissociate task performance from the meta-level judgment. Furthermore, for our decision confidence tasks, we also employed a signal detection measure, the theoretic measure meta-d'/d' (Maniscalco & Lau, 2012). Meta-d'/d' quantifies the efficiency with which confidence ratings discriminate between correct and incorrect trials in each task domain separately (visual and memory). Using this measure of metacognition effectively eliminates performance and response bias confounds that typically affect other measures (Barrett, Dienes, & Seth, 2013).

Researchers have begun to investigate the metacognitive processes in decision making, focusing in particular on both confidence judgments and error monitoring (Yeung & Summerfield, 2012). This research will investigate the relationship between two important metacognitive evaluations-error detection and confidence judgments. Both aspects of metacognition have been studied however; very little research has focused on looking at the relationship between these two evaluations. A recent electroencephalography (EEG) study conducted by researchers Boldt and Yeung (2015) observed a clear graded modulation of error related EEG activity by confidence, suggesting that shared mechanisms underlie both aspects of metacognition. Yeung and Summerfield (2012) put forward the hypothesis that there are crucial points of convergence between these two related aspects of metacognition- error monitoring and confidence judgments. The researchers suggest that common principles govern metacognitive judgments of confidence and accuracy. In particular, a shared reliance on post decisional processing within the systems responsible for the initial decision (see Figs. 1–3).

Laboratory tests to assay metacognition may prove to be useful in the assessment of impairments of awareness in brain injury patients or older adults at risk of dementia. An important question is whether our capacity to evaluate different cognitive processes in the laboratory is associated with our awareness in daily life. A final aim was therefore to assess