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Prestimulus alpha-band power biases visual discrimination confidence, but not accuracy

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ABSTRACT

The magnitude of power in the alpha-band (8–13 Hz) of the electroencephalogram (EEG) prior to the onset of a near threshold visual stimulus predicts performance. Together with other findings, this has been interpreted as evidence that alpha-band dynamics reflect cortical excitability. We reasoned, however, that non-specific changes in excitability would be expected to influence signal and noise in the same way, leaving actual discriminability unchanged. Indeed, using a two-choice orientation discrimination task, we found that discrimination accuracy was unaffected by fluctuations in prestimulus alpha power. Decision confidence, on the other hand, was strongly negatively correlated with prestimulus alpha power. This finding constitutes a clear dissociation between objective and subjective measures of visual perception as a function of prestimulus cortical excitability. This dissociation is predicted by a model where the balance of evidence supporting each choice drives objective performance but only the magnitude of evidence supporting the selected choice drives subjective reports, suggesting that human perceptual confidence can be suboptimal with respect to tracking objective accuracy.

1. Introduction

Excitability of the visual cortex has been directly linked to fluctuations in the power of alpha-band (8–13 Hz) oscillations in human electroencephalographic (EEG) recording (Brandt & Jansen, 1991; Rajagovindan & Ding, 2010; Romei, Brodbeck, et al., 2008; Romei, Rihs, Brodbeck, & Thut, 2008; Samaha, Gosseries, & Postle, 2016). Accordingly, recent work has found that variability in the detection of near-threshold visual stimuli is explained by variability in alpha-band power just prior to stimulus onset. A now-typical finding is that the probability of detecting a visual stimulus increases when prestimulus alpha power is low (Babiloni, Vecchio, Bultrini, Romani, & Rossini, 2006; Busch, Dubois, & VanRullen, 2009; van Dijkq, Schoffelen, Oostenveld, & Jensen, 2008; Ergenoglu et al., 2004; Mathewson, Gratton, Fabiani, Beck, & Ro, 2009; Romei, Gross, & Thut, 2010). From a Signal Detection Theory (SDT) framework, however, an increased probability of detection (i.e., hit rate) could result from a change to either perceptual sensitivity (i.e., d') or to response criterion (Green & Swets, 1966). That is, when alpha power is low, although it could be that observers can better discriminate a visual stimulus from

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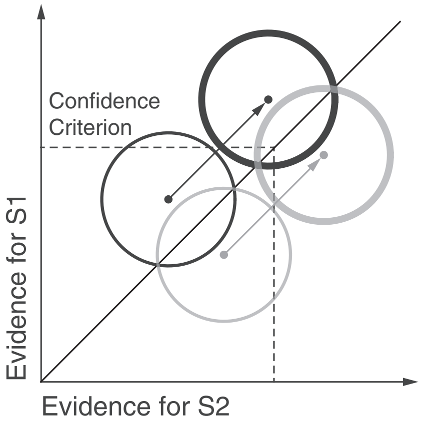

Fig. 1. In the two-dimensional SDT model for discrimination, a decision is made regarding which of two stimuli was presented (S1 or S2; black and grey lines, respectively) using evidence sampled from bivariate Gaussian distributions. The diagonal line represents the optimal decision criterion: if evidence on a given trial falls to the left of the diagonal, S1 is chosen, otherwise, S2. Thus, discrimination accuracy is determined by the separation between the black and grey distributions with respect to the diagonal. Rating confidence according to the amount of evidence for the chosen stimulus, rather than the balance of evidence for both, results in confidence criteria (dashed lines) marked at various points along the x and y axes. We hypothesize that during states of high cortical excitability both evidence distributions are translated diagonally (thick lines), reflecting increased evidence for both S1 and S2. The dissociation between confidence and accuracy emerges because the two pairs of distributions are identical with respect to the decision boundary (diagonal), but not with respect to the confidence criterion. This predicts higher confidence when visual cortical excitability is high (i.e., alpha is low), but no change in accuracy. For a more detailed treatment and empirical evidence in support of this model, see Maniscalco et al. (2016) and Iemi et al. (2017). Note that the choice of a single confidence criterion and its location is arbitrary and used here only for illustration.

noise, it could also be that they are simply more likely to report stimulus presence, regardless of whether one was actually shown.

Recent experiments confirm the latter scenario. Limbach and Corballis (2016) performed a SDT analysis of detection performance as a function of prestimulus alpha levels. They observed that response criterion, and not d', was related to prestimulus alpha, such that observers adopted a more conservative criterion when alpha power was high. The same pattern emerged from a recent paper applying a SDT model to single-trial responses (Iemi, Chaumon, Crouzet, & Busch, 2017). However, these findings leave open the question of how prestimulus alpha changes subjective and objective responses in a discrimination task with equally probable stimuli, where criterion is presumably balanced (Macmillan & Creelman, 2004). Because changes in criterion have been linked to changes in subjective awareness reports (Peters, Ro, & Lau, 2016; Rahnev et al., 2011), we hypothesize that prestimulus alpha may impact confidence ratings in a discrimination task, but should not affect discrimination accuracy. This hypothesis is motivated by the idea that when cortical excitability is non-specifically increased, neurons representing the presented stimulus (correct choice) as well as those representing the non-presented alternative (incorrect choice) should both increase their firing rates by the same amount, leaving discriminability between the two unaffected. However, if confidence is driven primarily by evidence in favor of the decision, rather than the balance of evidence for both possible choices (e.g., Maniscalco, Peters, & Lau, 2016), then confidence will be systematically higher when cortical excitability is higher (e.g., when alpha is low), despite no change in accuracy. This hypothesis is depicted within a SDT framework in Fig. 1.

Recent psychophysical studies have borne out the proposal that confidence is disproportionality affected by evidence in favor of a decision, rather than the balance of evidence between alternatives. For example, Zylberberg, Barttfeld, and Sigman (2012) continuously varied the luminance of two stimuli as observers decided which was brightest. Their findings show that, whereas choice accuracy was determined by relative difference in luminance between the two stimuli, confidence was insensitive to fluctuations in luminance for the non-chosen stimulus but was driven by the absolute luminance of the chosen stimulus. Subsequent work found that proportionally increasing the contrast of a target as well as the contrast of noise (or a non-target, e.g., Koizumi, Maniscalco, & Lau, 2015; Expt 1A) led to increased confidence despite no change to accuracy (Koizumi et al., 2015; Samaha, Barrett, Sheldon, LaRocque, & Postle, 2016). Here, we measured prestimulus alpha power as a trial-by-trial index of cortical excitability while observers judged the orientation of a grating and provided subjective confidence ratings. We found a robust negative relationship between prestimulus alpha power and confidence ratings, but no relationship to accuracy, suggesting that states of high visual cortical excitability are associated with an enhanced sense of subjective confidence despite no change in actual performance. We view this finding as providing support for models of subjective awareness according to which the absolute value of evidence in support of a decision underlies confidence (Maniscalco et al., 2016; Paz, Insabato, Zylberberg, Deco, & Sigman, 2016; Zylberberg, Roelfsema, & Sigman, 2014; Zylberberg et al., 2012).