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Resting EEG in alpha and beta bands predicts individual differences in attentional breadth

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ABSTRACT

Whether individuals focus their attention on the global level (the forest), or local elements that make up the stimulus (the trees) remains relatively stable over a period of at least 10 days in multiple global/local measures. Greater attentional approach tendencies and vigilance, which are likely reflected by lower alpha and higher beta power, are associated with narrowed attentional breadth. The current study investigated whether individual differences in the propensity for individuals to focus on the global or local levels (attentional breadth) can be predicted based on EEG power in alpha and its neighbouring frequency bands during a preceding rest period. Greater levels of posterior alpha and preponderance of alpha-to-beta power at rest were associated with greater attentional breadth during the subsequent Navon letters task. These results suggest that neural indices of attentional approach when not engaged in a goal-orientated task are associated with individual differences in attentional breadth.

1. Introduction

1.1. Global and local attentional processing

Visual stimuli can be perceived at a global level (e.g., the forest), or as local elements that make up the stimulus (e.g., the trees). There are reliable individual differences in the inclination to attend to the global features (referred to as a global bias), or to the local elements (local bias; Dale & Arnell, 2013). Navon (1977) letters such as a large "H" made up of many smaller "T's" are often used to measure global/local processing. Individuals with a global bias are faster to detect a target letter at the global level than at the local level (e.g., Gable & Harmon-Jones, 2008), show greater interference from the global level when needing to attend to the local level (Dale & Arnell, 2013; Navon, 1977), and are more likely to report seeing the global level over the local level such as when they identify a triangle made of squares as more similar to a triangle made of triangles than to a square made of squares in the hierarchical shape task (e.g., Dale & Arnell, 2013; Fredrickson & Branigan, 2005; Kimchi & Palmer, 1982).

Individual differences in the propensity to attend to either the local or global aspects of visual stimuli (i.e., measures of their attentional breadth) have been shown to remain stable over a period of at least 10 days in multiple global/local tasks (Dale & Arnell, 2013), are resistant to exposure to high and low spatial frequencies (Dale & Arnell, 2014), and can predict individual differences in the magnitude of the attentional blink – a phenomenon of temporal attention that has previously been related to both global/local processing and oscillatory neural activity (Dale & Arnell, 2010, 2015; Hanslmayr, Gross, Klimesch, & Shapiro, 2011; Klimesch, 2012; MacLean, Arnell, & Cote, 2012).

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1.2. Electrophysiological measures of attention

Spectral frequency oscillations, both at rest, and pre-trial, have been examined to better understand the mechanisms underlying global/local bias. Human EEG activity during rest can reflect cortical operations in the absence of sensory input. Posterior alpha activity decreases with input of visual sensory information such as when individuals open their eyes relative to having them closed (Berger, 1929), and posterior alpha can also be attenuated by greater attentiveness (Niedermeyer, 1997). According to the idling hypothesis of alpha activity, greater alpha activity recorded in EEG signal is thought to reflect idling of cortical areas in an awake but unoccupied state (Pfurtscheller, Stancak, & Neuper, 1996). A more recent hypothesis suggests that alpha activity acts as a mechanism for increasing the signal to noise ratio by inhibiting competing functions or processes while completing goal-related tasks (Händel, Haarmeier, & Jensen, 2011; Hanslmayr et al., 2011; Klimesch, 1999; Knyazev, Levin, & Savostyanov, 2008; Palva & Palva, 2007; van Dijk, Schoffelen, Oostenveld, & Jensen, 2008). High alpha power may be indicative of an inhibitory attentional filter which can help keep relevant target information activated, allowing for more efficient anticipatory attention before completing a cognitive task (de Vries, van Driel, & Olivers, 2017; Klimesch, 2012; Sadaghiani et al., 2010; Thut, 2006).

Oscillations in alpha and other frequency waves (e.g., beta, theta), recorded both at rest and before the presentation of a visual stimulus, are most likely due to thalamo-cortical feedback loops and can be examined to better understand the fluctuations between individuals' internal and external brain states and how they correlate with perceptual and cognitive performance (Hanslmayr et al., 2011). During rest, alpha reductions accompanied by increases in beta band fluctuations can indicate increases in vigilance, while decreased alpha activity as well as increased theta wave activity can indicate greater drowsiness (Belyavin & Wright, 1987; Laufs et al., 2006). Decreased alpha activity and increased beta activity predict greater metabolic activity in frontal-parietal areas of the cortex responsible for top-down attention, and could indicate greater engagement in mental activity and information processing (Laufs et al., 2003, 2006). Alpha power at rest has been previously found to positively correlate with activation in default mode network regions, but alpha power recorded at occipital sites can negatively correlate with the dorsal attention network, perhaps suggesting that visual alpha activity can be suppressed by the dorsal attention network (Zumer, Scheeringa, Schoffelen, Norris, & Jensen, 2014).

Power in EEG bands at rest can predict temporal attention during a subsequent cognitive task. For example, MacLean et al. (2012) used an attentional blink (AB) task, whereby participants are less accurate in reporting a second target when it is presented less than 500 msec following a first target, relative to when the two targets are separated by a longer time interval (Raymond, Shapiro, & Arnell, 1992). Greater alpha activity and lesser beta activity, which likely indicated lesser attentional engagement at rest, were associated with greater AB magnitude. In another experiment, greater event-related desynchronization (ERD) of alpha activity preceding the presentation of a visual stimulus correlated with the size of individuals' AB magnitudes, further suggesting the important role of alpha activity in temporal attention (MacLean & Arnell, 2011).

There is some evidence that lateralized alpha power while participants are completing a cognitive task can predict individual differences in attentional breadth. When preparing to respond to either a global or local stimulus, fast local responses were accompanied by greater alpha activity in the right centro-parietal cortex whereas fast global responses were accompanied by greater alpha activity in the left centro-parietal cortex, and this pattern was reversed when examining slow responses to global and local targets (Volberg, Kliegl, Hanslmayr, & Greenlee, 2009). These findings are consistent with the widespread view in the literature that local processing and global processing are preferentially processed in the left and right hemispheres respectively, whereby the representations in one hemisphere may be inhibited to prepare for processing of the cued target level (Robertson & Lamb, 1991; Robertson, Lamb, & Knight, 1988).

Asymmetrical hemispheric activity as indexed by differences in alpha activity has also been shown to have a causal influence on attentional breadth. In a previous experiment, participants squeezed a ball in either their right or left hand. Alpha activity decreased in the contralateral hemisphere of the hand they squeezed the ball in resulting in faster behavioural responses when viewing the target level that is preferentially processed in that hemisphere, such that a greater local bias was observed after activating the left hemisphere and a greater global bias was observed after activating the right hemisphere (Gable, Poole, & Cook, 2013; Harlé & Sanfey, 2015). Differential alpha activity recorded at right and left frontal-central electrodes has also been shown to correlate with attentional breadth when viewing images of desserts such that greater left frontal cortical activity related with faster responses to local targets and greater right frontal cortical activity related with faster responses to global targets (Harmon-Jones & Gable, 2009).

Despite the above findings, no one has yet shown that naturally occurring individual differences in relative alpha activation at rest can predict individual differences in attentional breadth. Instead, researchers have tended to examine ERP differences under conditions of global or local bias, or examine whether asymmetry in alpha activation across left and right hemispheres predict global/local bias. Although asymmetrical alpha activity, recorded either at rest or pre global/local stimulus, has previously been associated with event-related potentials (ERPs) to global/local stimuli, asymmetrical alpha activity has not been found to relate to behavioural measures of attentional breadth in the absence of appetitive stimuli (Boksem, Kostermans, Tops, & De Cremer, 2012; Harmon-Jones & Gable, 2009; Pitchford & Arnell, 2019).

1.3. The current study

There is extant literature suggesting that oscillatory activity in alpha frequencies, as well as beta and theta frequencies to a lesser extent, serve a role in visual perception and attention. Greater power in alpha frequencies and lesser power in beta frequencies recorded at rest may indicate a mind that is less engaged in mental and information processing, less vigilant, and less attentionally invested, which is supported by the desynchronization of alpha often encountered with higher task demands (Klimesch, 1999;

MacLean et al., 2012). Individuals' attentional breadth has been associated with attentional approach tendencies whereby lesser urgency and vigilance can result in broader visual attention whereas greater urgency to approach toward visual stimuli is associated with narrowed attentional breadth (Gable & Harmon-Jones, 2008). Previous experiments have found that individual differences in asymmetrical alpha activity at rest do not predict individual differences in behavioural measures of attentional breadth (e.g., Boksem et al., 2012; Pitchford & Arnell, 2019). However, there has not yet been an examination of the relationship between individual differences in alpha power at rest when accounting for power in other frequencies (e.g., beta, theta) and individual differences in global/local processing. The purpose of the current study was to examine whether individual differences in attentional breadth would be predicted by individual differences in power in alpha, beta and theta frequency bands at rest while controlling for power in the other two bands. Based on past studies examining the relation between power in alpha and neighbouring frequency bands (i.e., theta, beta) at rest and attentional performance (MacLean et al., 2012; van Dijk et al., 2008), we hypothesized that bilateral EEG activity at rest will predict attentional breadth on a subsequent attentional breadth measure such as the Navon letters task such that greater relative alpha power and less relative beta power at rest would predict greater attentional breadth. The relationship between alpha and attentional breadth was expected to be particularly strong at posterior sites where alpha is maximal. Based on findings by MacLean et al. (2012) which suggested that theta activity did not modulate the relationship between alpha and beta power with temporal attention, there was no expectation that theta activity at rest would predict individual differences in attentional breadth, although some previous findings have suggested that the relationship between alpha and other cognitive measures could potentially be moderated depending on levels of theta activity at rest (Klimesch, 1999; Laufs et al., 2006).

2. Method

2.1. Participants

Forty-eight right-handed undergraduate students participated in this study for partial course credit (*Mage* = 20.98, *SDage* = 6.58; 43 females). All participants in this study reported normal (or corrected-to-normal) vision and that they had no history of neurological or cardiac conditions and were not taking psychoactive medications.

2.2. Procedure

The experiment took place in a dimly lit, shielded, sound attenuated room. Visual stimuli were presented on a 17-inch CRT monitor and controlled by E-prime software running on a Dell desktop computer. After completing informed consent, the electrode cap and electrodes were prepared. Participants first completed questionnaires – the results of which will not be discussed here. Participants were then instructed to sit in the chair and try to relax as much as possible during eight 60-second resting blocks that alternated between eyes open (EO) and eyes closed (EC) (i.e., either in one of the following orders: COOCOCCO or OCCOCOOC). A tone signaled the end of each block. They then performed a block of Navon letter trials where they were instructed to indicate which of two target letters had been presented ("H" or "T") by pressing designated keys on the keyboard as quickly and accurately as possible. Target letters were shown randomly at the global or local level. Participants completed 64 trials of the Navon task including 32 trials where the target letter was presented in the global level and 32 trials where the target letter was presented in the local level.

2.3. Stimuli

Navon stimuli were large letter stimuli (global; visual angle of 3.82° by 2.39°) composed of smaller (local; visual angle of 0.19° by 0.19°) letter stimuli. Each stimulus was black and was presented centrally on a white-background screen. All hierarchical stimuli were incongruent where the identity of the global letter differed from the local letter. On half of the trials, a target letter (H or T) was presented in the global level while a distractor letter (F or L) was presented in the local level. This was reversed for the other half of trials whereby the target was presented in the local level while the distractor letter was presented in the global level. All combinations of target letters, distractor letters, and target levels were equally likely and presented randomly trial-to-trial. On each trial a fixation cross was presented for 500 ms, followed by a blank screen for 1000 ms, then a Navon letter which remained on the screen until a response was made indicating which of the two target letters had been presented. Each trial was followed by an inter-trial interval of 1000 msec.

2.4. Resting EEG acquisition

EEG was recorded continuously using 29 tin electrodes embedded in an Electro-cap © (Electro-cap International Inc., Eaton, Ohio) distributed according to the international 10–20 system. An electrode placed anterior to Fz was used as ground, while linked left and right earlobes were used as a reference. EEG data was amplified and acquired using a 32-channel NeuroScan SynAmps and Neuroscan acquisition software (Compumedics USA, Charlotte, North Carolina). EEG data was sampled online at a rate of 500 Hz. Electrooculogram (EOG) electrodes were placed on the outer canthus of each eye and on the infra- and supra-orbital regions of each eye to record horizontal and vertical eye movements, respectively. Impedance was maintained below 10 kohms.

2.5. Resting EEG analysis

EEG data were analyzed offline using EEGLAB v14.1.1b (Delorme & Makeig, 2004) and custom routines written in MATLAB R2017a (The Mathworks, Natick, MA). The data were band-pass filtered with the default EEGLAB filter (pop_eegfiltnew) excluding activity below 0.1 Hz and above 60 Hz and the default filter order (i.e., 2 Hz transition bandwidth). All activity ± 100 μV in the vertical electrooculogram and horizontal electrooculogram was rejected from analysis. Afterward, epochs with artifacts (i.e., signals due to muscle movement, eye movements and eye blinks) were manually removed using visual inspection and rejected from analysis.

Eyes closed and eyes open data were separately epoched into 1.024 s segments extracted through a hamming window where consecutive epochs overlapped by 50%. Theta power density, (V^2Hz; 4–8), alpha power density (V^2/Hz; 8–13 Hz) and beta power density (V^2Hz; 13–35) in each epoch were extracted using the pwelch() function and averaged across epochs of the same condition (i.e., eyes open and eyes closed) for each site. Power values were log-transformed to obtain normalized values before statistical analysis. Similar to MacLean et al. (2012), we averaged power across sites in four regions of interest which included frontal (F3, F7, FZ, F4, F8), central (C3, CZ, C4), parietal (P3, PZ, P4), and occipital (O1, OZ, O2). Analyses presented here were focused on data recorded during the eyes closed condition since recorded alpha power was much greater relative to the eyes open condition, as expected (Berger, 1929).

3. Results

3.1. Navon letter task

All correct global/local RTs that were less than 2000 ms were extracted (*M*reject = 2.63%, *SD*reject = 2.40%). These were subjected to a two-stage recursive outlier elimination procedure where RTs were removed if they were greater or less than 2 standard deviations from the mean for each combination of participant and level (global, local) (*M*reject = 8.60%, *SD*reject = 1.74%). Attentional breadth was calculated by taking the difference between RTs to global and local Navon stimuli (local RTs – global RTs) whereby greater values represented greater attentional breadth. There were large differences across individuals in mean RTs and attentional breadth estimates (see Table 1).

3.2. Spectral EEG power at rest

A 3 × 4 × 2 repeated measures ANOVA was performed on power values, with frequency range (theta, alpha, and beta), ROI (frontal, central, parietal, and occipital) and hemisphere (left, right) as factors. The ANOVA indicated a significant main effect of frequency band, $F(2, 94) = 455.76$, $p < .001$, such that power was greatest in the alpha band, and least in the beta frequency band. A significant main effect of ROI, $F(3, 141) = 59.84$, $p < .001$, as well as a significant main effect of hemisphere, $F(1, 47) = 52.58$, $p < .001$ were found such that greater power in all frequencies was observed in the left hemisphere and posteriorly. There were significant interactions of ROI × hemisphere, $F(3,141) = 23.93$, $p < .001$, and frequency × ROI, $F(6,282) = 165.61$, $p < .001$, and a significant frequency × ROI × hemisphere interaction, $F(6, 282) = 2.78$, $p = .01$, such that alpha and theta power were greater in the left hemisphere than the right hemisphere when examining the more anterior regions, but this difference decreased closer to the posterior regions, and power decreased from occipital to frontal ROIs in the alpha and beta bands but was similar across ROIs for the theta band (see Fig. 1). The interaction of frequency × hemisphere did not attain significance, $F(2,94) = 0.572$, $p = .57$.

Absolute power values in the different frequency bands were highly positively correlated with absolute power in the other frequency bands for each ROI, *r*'s ranging from 0.51 to 0.78. The high correlations between power values in the three different frequency bands suggests there were individual differences in overall power. Variability in overall power can obscure individual differences in the unique contributions of alpha, beta and theta power and their relationships with other variables of interest. To circumvent this issue, following MacLean et al. (2012), we regressed power in each frequency band on power in the other two frequencies for each ROI which resulted in three residualized measures for each ROI (i.e., theta controlling for beta and alpha, beta controlling for alpha and theta, alpha controlling for beta and theta). Residualized measures better reflect the unique contributions of power in each of the three frequencies independent of overall power across the entire band from 4 Hz to 35 Hz.

Residual power values in each of the three frequency bands were negatively correlated with residual power values in each of the other bands at all ROIs, *r*'s ranged from −0.23 to −0.61. This coincides with previous findings that low alpha power at rest relates with high beta power at rest or high theta power at rest, and high beta power at rest tends to relate with low theta power at rest (Laufs et al., 2006; MacLean et al., 2012).

Table 1
Descriptive statistics for Navon RTs (ms).

	Mean	*SD*	Minimum	Maximum
Local RT	737	135	535	1061
Global RT	705	126	522	1032
Local – Global RT Difference	32	104	−196	288

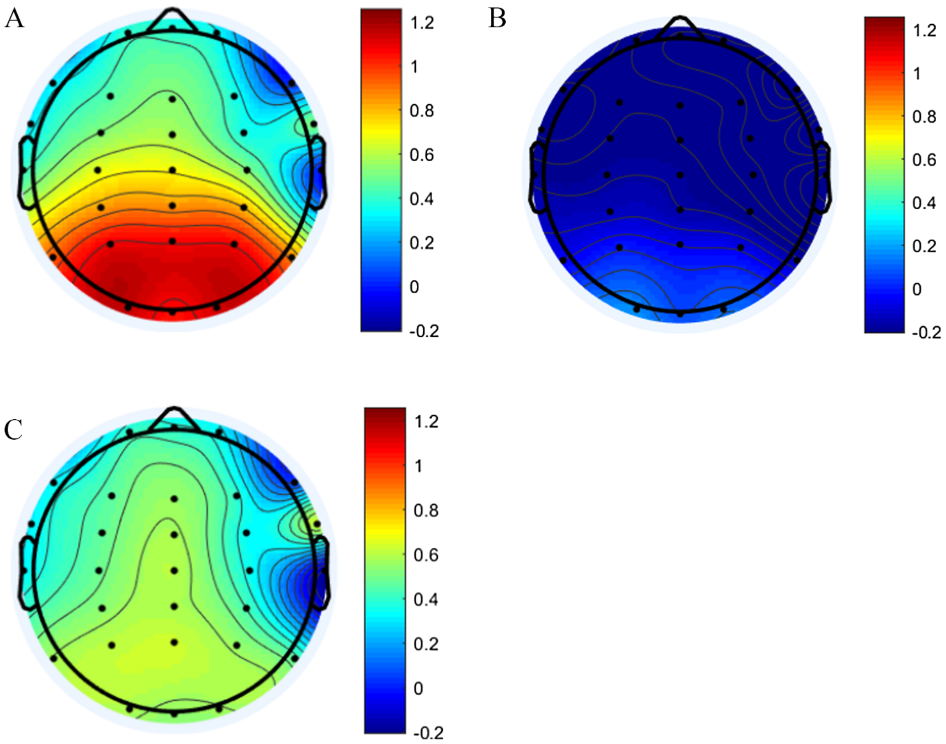

Fig. 1. Scalp topographies of average (A) alpha (V^2/Hz; 8–13 Hz) power, (B) beta (V^2Hz; 13–35) power and theta (V^2Hz; 4–8) power for all participants ($n = 48$) at rest. All power values are shown as log power densities across frequency bands.

Table 2
Correlations between alpha, and residual alpha when controlling for both beta and theta power, at each ROI with attentional breadth.

	Local RT – Global RT (ms)
Alpha (Frontal)	0.15
Alpha (Central)	0.03
Alpha (Parietal)	0.11
Alpha (Occipital)	0.33*
Resid. Alpha (Frontal)	0.16
Resid. Alpha (Central)	0.11
Resid. Alpha (Parietal)	0.19
Resid. Alpha (Occipital)	0.28

Note: $^*p < .05$.

3.3. *Predicting attentional breadth by resting EEG*

We first examined whether absolute alpha power recorded from each of the ROIs correlated with subsequent attentional breadth. These results are presented in Table 2.[1] Absolute alpha power recorded from the occipital sites (where alpha was maximal) was significantly correlated with greater attentional breadth, $r = 0.33$, $p = .02$. We then examined the relationship between absolute beta and theta power and attentional breadth at each of the ROI's and found that in neither frequency did absolute power significantly relate to attentional breadth at any of the ROIs (p's $> .10$; see Tables 3 and 4).

The relationships between residual alpha, beta and theta power and attentional breadth are presented in the bottom halves of Tables 2–4. There was a trend toward less residual beta power at the parietal and occipital sites predicting greater attentional breadth, $rs = -0.26$ & -0.25, $ps = .07$ & $.09$, and greater residual alpha power at the occipital sites, $r = 0.28$, $p = .05$, predicting greater attentional breadth. Greater residual alpha power recorded from the right occipital site significantly predicted greater

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[1] Due to the difference in power values recorded from the left and right hemispheres, we also examined power values separately at the left and right sites. Relationships between power in each frequency and attentional breadth remained in the same direction when examining power recorded only from left, or only from right, electrode sites. Therefore, power recorded at the left, right and midline sites for each ROI were averaged together. Any relationships that were significant when examining left or right electrodes only are noted within the text.

Table 3
Correlations between beta, and residual beta when controlling for both alpha and theta power, at each ROI with attentional breadth.

	Local RT – Global RT (ms)
Beta (Frontal)	0.06
Beta (Central)	−0.07
Beta (Parietal)	−0.07
Beta (Occipital)	−0.04
Resid. Beta (Frontal)	−0.02
Resid. Beta (Central)	−0.16
Resid. Beta (Parietal)	−0.26
Resid. Beta (Occipital)	−0.25

Note: *$p < .05$.

Table 4
Correlations between theta, and residual theta when controlling for both alpha and theta power, at each ROI with attentional breadth.

	Local RT – Global RT (ms)
Theta (Frontal)	0.06
Theta (Central)	0.01
Theta (Parietal)	0.13
Theta (Occipital)	0.23
Resid. Theta (Frontal)	−0.07
Resid. Theta (Central)	0.05
Resid. Theta (Parietal)	0.13
Resid. Theta (Occipital)	0.07

Note: *$p < .05$.

attentional breadth, $r = 0.31$, $p = .03$, while greater residual beta power recorded from the right parietal, $r = -0.31$, $p = .03$, and right occipital, $r = -0.29$, $p < .05$, sites predicted narrowed attentional breadth. None of the other residual measures were significant predictors of attentional breadth, p's > .20. These results indicate that greater resting alpha power was related to greater attentional breadth while greater resting beta power was related to narrowed attentional breadth. Residualized theta power at rest did not relate with attentional breadth (see Table 4).

Because residual beta and alpha power negatively correlated with each other and both measures predicted attentional breadth in opposite directions, we further examined whether the trade-off between alpha and beta power predicted attentional breadth. We followed the same procedure as MacLean et al. (2012) and subtracted individuals' beta power from their alpha power to get a measure of relative preponderance of alpha relative to beta power for all individuals. The trade-off between alpha-to-beta power was most clearly seen at the posterior regions of the scalp (see Fig. 2). There was a significant relationship between individuals' occipital preponderance of alpha relative to beta power and their attentional breadth, such that greater alpha relative to beta power predicted greater attentional breadth, $r = 0.41$, $p < .001$ (see Fig. 3). There also appears to be an increase in the variability of attentional breadth as the preponderance of alpha relative to beta power increases, such that low occipital alpha minus beta power was associated with a neutral or modest local bias relative to individuals with greater alpha minus beta scores. Higher alpha minus beta scores were associated with more variable attentional breadth, except perhaps at the highest occipital alpha – beta levels where scores have a predominantly global bias. These changes in variability were observed when plotting the difference in power but not when plotting

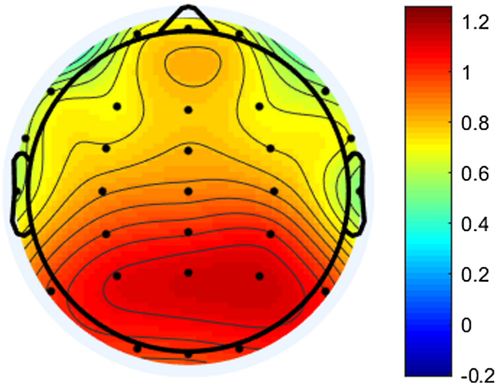

Fig. 2. Scalp topography of average alpha minus beta power for all participants ($n = 48$) at rest. All power values are shown as log power density.

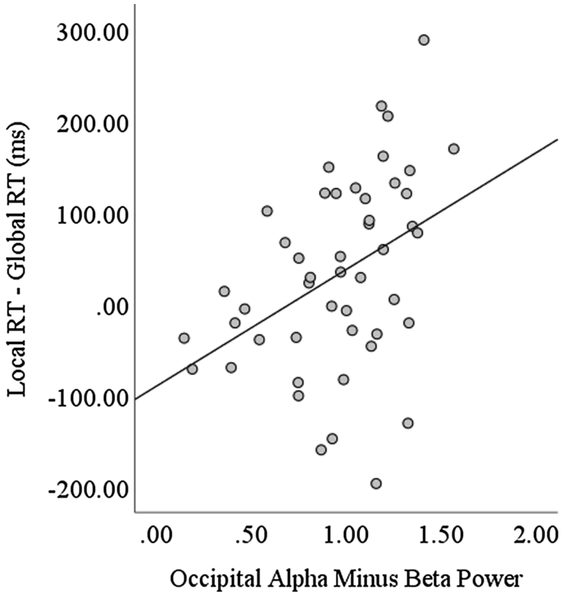

Fig. 3. Scatterplot delineating the relationship between occipital alpha minus beta power and attentional breadth (local RT – global RT).

Table 5
Correlations between alpha–beta at each ROI, and overall alpha–beta with attentional breadth.

	Local RT – Global RT (ms)
Alpha – beta (Frontal)	0.15
Alpha – beta (Central)	0.13
Alpha – beta (Parietal)	0.22
Alpha – beta (Occipital)	0.41**
Alpha – beta (Overall)	0.28

Note: $^*p < .05$, $^{**}p < .001$.

either alpha or beta power separately. The difference in alpha relative to beta power recorded from the other ROIs did not significantly predict attentional breadth, p's $> .13$, but there was a trend in that alpha-beta power averaged across all of the ROIs predicted greater attentional breadth, $r = 0.28$, $p = .06$ (see Table 5). These results suggest that the greater the preponderance of resting alpha is relative to beta, the greater the attentional breadth during the subsequent global/local task.

We then split participants into two groups based on whether they had higher occipital alpha relative to beta power ($n = 24$), or lower occipital alpha relative to beta-power ($n = 24$).[2] Greater resting occipital alpha power was recorded for the higher alpha-to-beta power group, $M = 1.33$, $SD = 0.29$, relative to the lower alpha-to-beta power group, $M = 0.82$, $SD = 0.27$, $t\ (46) = 6.49$, $p < .001$, but there was no difference in resting occipital beta power between the higher, $M = 0.12$, $SD = 0.22$, and lower, $M = 0.12$, SD = 0.23, groups, $t(46) = 0.07$, $p = .94$, suggesting that the difference was likely more driven by greater resting alpha power within the group. The higher alpha-to-beta power group showed significantly greater attentional breadth when completing the subsequent Navon letters task than the lower alpha-to-beta group, $t(46) = 2.55$, $p = .01$, $d = 0.74$ (see Fig. 4). Individuals with greater resting occipital alpha-to-beta power were significantly more global-focused such that the mean difference, $M = 68.91$, $SD = 112.12$, between their local and global RTs were significantly > 0, $t(23) = 3.01$, $p < .01$. In contrast, the lower alpha-to-beta power group showed neutral attentional breadth such that the mean difference, $M = -3.93$, $SD = 83.39$, between their local and global RTs was not significantly different than 0, $t = 0.23$, $p = .82$.

4. Discussion

The purpose of this study was to investigate whether individual differences in power in EEG bands at rest could predict individual differences in attentional breadth during a subsequent Navon letter task. Specifically, we hypothesized that greater alpha power at rest would predict greater attentional breadth and greater beta power at rest would predict narrowed attentional breadth. These

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[2] Our independent-groups analysis was intended to function as a median-split approach to a continuous variable (amount of alpha and beta within an individual). We do not suggest that there is something qualitatively different between the two groups, as defined by the threshold used here.

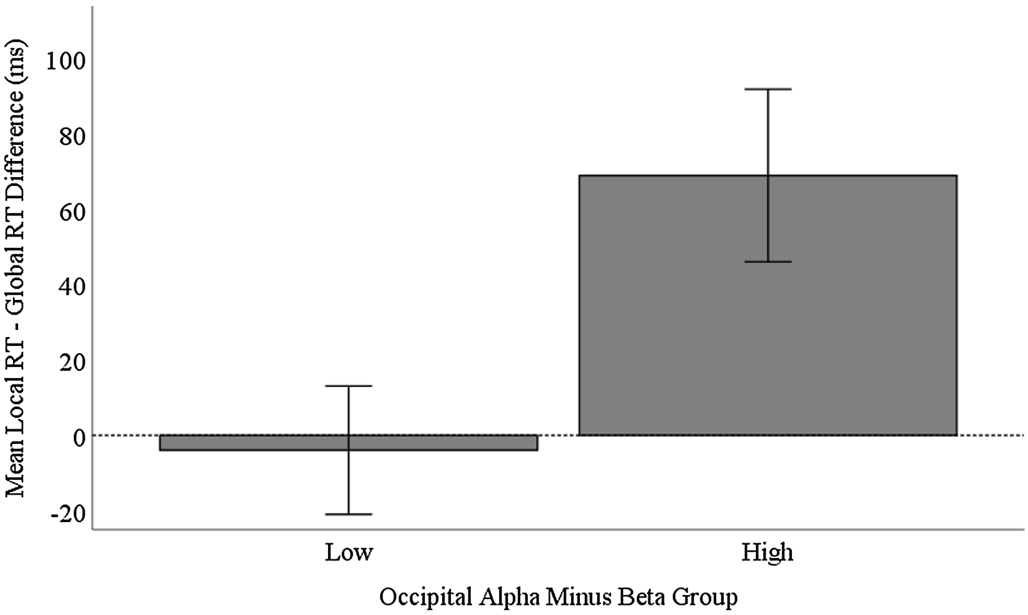

Fig. 4. Mean attentional breadth (local RT – global RT) for the low and high occipital alpha-beta groups. Error bars denote ± 1 SEM.

predictions were based on previous findings that greater attentiveness, engagement, and approach tendencies, are thought to be reflected in less alpha relative to beta power (e.g., Laufs et al., 2006; Niedermeyer, 1997), and greater approach tendencies have been shown to relate to narrowed attentional breadth (Gable & Harmon-Jones, 2008, 2011; Harmon-Jones & Gable, 2009; Pitchford & Arnell, 2019). Furthermore, when lateral hand contractions were used to manipulate activation differentially in the two hemispheres during a global/local task, relatively less alpha in the left versus right hemisphere led to faster RTs to the local level of Navon stimuli, whereas relatively less alpha in the right versus left hemisphere led to faster RTs to the global level (Gable et al., 2013). Similarly, Volberg et al. (2009) showed that fast local responses were accompanied by greater pre-trial alpha activity in the right centro-parietal cortex, whereas fast global responses were accompanied by greater pre-trial alpha activity in the left centro-parietal cortex. Furthermore, resting alpha power, resting beta power, and the preponderance of alpha relative to beta, have been shown to predict performance on temporal attentional tasks such as the attentional blink (MacLean et al., 2012).

The current findings provide evidence that individual differences in resting alpha power recorded from posterior sites predict individual differences in attentional breadth during a subsequent Navon letter task in the manner hypothesized, where greater alpha, and a greater preponderance of alpha relative to beta, predict greater global bias. Although the preponderance of alpha relative to beta predicted greater global bias, there was an increase in variability in attentional breadth with increased preponderance of alpha relative to beta, which was not seen when examining either alpha or beta power alone. Individuals with the lowest alpha – beta power all showed a neutral or modest local bias. However, alpha – beta power was less predictive of attentional breadth at higher levels of alpha – beta power except perhaps at the highest levels where scores have a predominantly global bias. This could suggest that a local or neutral bias may be expected when beta levels approximate those of alpha, perhaps because a threshold of vigilance has been reached (e.g., Laufs et al., 2006). Alternately, if there is a predominant global bias for those with the highest alpha relative to beta values, then the current results suggest that alpha relative to beta power can predict attentional breadth for those with more extreme low or high alpha-beta values (where greater preponderance of alpha is associated with greater attentional breadth), but that it is a less useful predictor for those with more average alpha-beta values.

When split into groups, we found that individuals with higher alpha-to-beta power showed a bias toward the global level whereas individuals with lower alpha-to-beta power did not show a bias toward either the local or global levels. These findings are in line with previous findings reported above and might suggest that greater “idling” or inhibition of early visual areas during rest can predict greater subsequent attentional breadth.

Differing levels of power in the two bands most likely reflect different attentional states whereby greater beta power and lesser alpha power reflect greater engagement and attentiveness during rest (Laufs et al., 2003, 2006; MacLean et al., 2012). Diffuse attention is generally experienced when individuals are in a calm or restful state relative to when they are in a high-approach-motivated-state (Gable & Harmon-Jones, 2008, 2011; Harmon-Jones, Price, & Gable, 2012; Price & Harmon-Jones, 2010). Greater alpha activity has generally been associated with disengagement of task-irrelevant cortical areas and suppression of sensory information processing, but can also signal increased creative ideation and memory processes, especially in the frontal areas (Fink & Benedek, 2014; Händel et al., 2011). Greater creative ideation has been previously associated with greater attentional breadth whereby a greater focus on the “big picture” when viewing hierarchical visual stimuli can predict greater cognitive flexibility and divergent thinking (Zmigrod, Zmigrod, & Hommel, 2015), and greater alpha activity at rest may be conducive to both diffuse attentional breadth and creative thinking.

This is the first study to examine whether bilateral power in EEG bands at rest can predict individual differences in attentional breadth. Most examinations of the relationship between alpha power and attentional breadth observe alpha power while individuals are completing the task and investigate differences in the relative level of alpha in the two hemispheres (e.g., Volberg et al., 2009). Contrary to measuring power when participants are completing a cognitive task, there is no explicit goal when completing a resting procedure; participants are simply instructed to close their eyes and to relax as much as possible. We do not assume that the resting procedure is the same for all individuals as some participants may be engaging in extraneous mental processes which is most likely reflected in their electrophysiological output (e.g., mental activity would suppress alpha activity during rest). This pattern of behaviour may continue while they are completing the subsequent global/local task whereby attention to these internal states and less attention to external sensory information may promote greater attentional breadth while the opposite pattern could promote narrowed attentional breadth, perhaps due to greater attentiveness and engagement as indicated by lesser alpha and greater beta power (MacLean et al., 2012).

There could be important state-like contributions to how alpha power at rest can predict attentional breadth such that experimental conditions influence resting EEG power. These possible conditions could be investigated in subsequent work. However, previous findings suggest that alpha power remains relatively stable within individuals over a period of at least a month (Winegust, Mathewson, & Schmidt, 2014), as does global/local bias (Dale & Arnell, 2013). It is possible that the relation between EEG power at rest and attentional breadth is due to trait-like characteristics such that individuals with naturally-high alpha power at rest show more attentional breadth generally. One hypothesized mechanism for how EEG power at rest can influence later task performance is by activation or deactivation of the cortex. There is a general consensus in the literature that greater alpha activity reflects cortical inhibition and/or "idling" of goal-irrelevant areas. Individuals showing engagement of cortical areas, as indicated by lesser alpha activity and greater beta activity at rest, may have greater chronic cortical activation generally (both on-task and off-task), thereby allowing for enhancement of stimulus processing when completing the cognitive task (Hanslmayr et al., 2005; Klimesch, Vogt, & Doppelmayr, 2000). This increased activation of relevant cortical areas may facilitate visual discrimination and perceptual ability relative to less cortical activation. This could potentially aid local processing to a greater extent than global processing during a subsequent global/local task and result in narrowed attentional breadth.

Although multiple studies have found that global/local processing is lateralized such that local stimuli are preferentially processed in the left hemisphere while global stimuli are preferentially processed in the right hemisphere (e.g., Gable et al., 2013; Robertson et al., 1988), we did not find different associations between resting power values in alpha and beta frequency bands and attentional breadth when examining left versus right electrode sites. For example, we might have predicted based on previous literature that greater resting alpha power in the left hemisphere would predict greater attentional breadth and greater resting alpha power in the right hemisphere would predict lesser attentional breadth. Previous findings have suggested that lateralized power measures can predict attentional breadth when observing pre-trial power (e.g., preparatory alpha power), but not when examining EEG power at rest (Boksem et al., 2012; Harmon-Jones & Gable, 2009; Pitchford & Arnell, 2019; Volberg et al., 2009). Therefore, the findings here coincide with a growing body of literature suggesting that lateralized EEG measures (e.g., frontal alpha asymmetry, alpha asymmetry) observed at rest do not predict behavioral measures of attentional breadth when individuals are not viewing appetitive images before viewing global/local stimuli. Although lateralized power in alpha and beta bands at rest have not been found to predict attentional breadth, we have provided evidence here for a relationship between bilateral resting power in the alpha and beta bands and individual differences in attentional breadth, suggesting that bilateral resting power may be a better predictor of individual differences in attentional breadth than lateralized resting power.

5. Conclusion

In summary, these results suggest that there are individual differences in neural measures at rest that predict individual differences in attentional breadth such that greater resting alpha-to-beta power recorded at posterior electrode sites predicts subsequent broad attentional breadth. These results suggest that greater attentional breadth is mirrored in neural functioning of the primary visual area such that greater inhibition of the visual area at rest predicts greater breadth during a subsequent attentional breadth task. This relationship may also be due to greater attentiveness at rest predicting narrowed attentional breadth which would coincide with past findings suggesting a relationship between power in EEG bands at rest and temporal attention. Ultimately these results provide evidence that measuring neural activity at rest can be informative in better understanding individual differences in attentional breadth, and that one need not look at relative differences in alpha across the hemispheres to find EEG predictors of global/local bias.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concog.2019.102803.

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