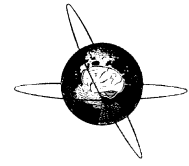




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Asymmetry in alpha power predicts accuracy of hemispheric lexical decision

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Abstract

Objective: Previous work has shown that individual differences in resting alpha asymmetry are associated with efficacy on a variety of cognitive tasks. Still unresolved is how ongoing alpha asymmetry relates to behavioral asymmetry, explored here using lateralized lexical decision.

Methods: Alpha power immediately preceding lexical decision trials was measured to assess cognitive engagement during word recognition. This was compared with behavioral performance for the task, measured by accuracy and latency of the lexical decision response.

Results: Greater relative left hemisphere alpha power (i.e. higher asymmetry) immediately before presentation of a word led to reduced likelihood for its successful identification. Greater alpha asymmetry was also associated with reduced performance for identifying stimuli lateralized to the right visual field.

Conclusions: Word recognition is facilitated by decreased asymmetry in cognitive engagement in the two cerebral hemispheres, particularly when the stimuli are lateralized to the left hemisphere (right visual field).

Significance: Results address the role of cognitive engagement in the two cerebral hemispheres, and its relationship with lexical access. © 2004 International Federation of Clinical Neurophysiology. Published by Elsevier Ireland Ltd. All rights reserved.

Keywords: Alpha; Laterality; Electroencephalography; Hemispheric specialization

1. Introduction

Ever since oscillatory patterns were first observed in the human electroencephalogram (EEG), a link with cognitive processing has been sought. For example, the observation of low-frequency alpha rhythms (9–11 Hz) in approximately 95% of healthy adults during rest with eyes closed (Nunez, 1981) has led many to suggest that such rhythms indicate cortical deactivation. The attenuation of these oscillations by cognitive demands has further supported this view. Conversely, higher frequency EEG response (gamma band, > 30 Hz) has been linked with effortful cognitive processing such as temporal binding (Joliot et al., 1994) and short-term memory rehearsal (Tallon-Baudry et al., 1997, 1998, 1999). These associated patterns of electrophysiological response and cognitive state have led to continuing speculation

regarding the link between physiological processes underlying rhythmic brain activity and behavior.

Inhibitory and excitatory postsynaptic potentials of pyramidal cells in the neocortex form the primary basis of the EEG signal (Birbaumer et al., 1990; Fisch, 1999; Hari and Lounasmata, 1989; Pulvermuller et al., 1997). Because any electrode is influenced by several square centimeters of cortical space, the signal may result from the firing of up to 10^8 neurons (Lutzenberger et al., 1987). However, the actual number of neurons influencing each EEG electrode will be much smaller due to the effect of neural synchrony on the signal. The greatest contribution of the EEG signal comes from synchronized neural activity (Nunez, 1995, 2000), so increases in EEG oscillatory response provide a useful indicator of underlying phase-locked neural firing.

The description of alpha activity as representing cortical deactivation or an 'idling system' (Adrian, 1942, 1947) belies the important role of low-frequency EEG activity in

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human cognition. Consider the example of coherence, which is a measure of correlation between pairs of signals in a particular frequency band. Coherence is often strong in the peak alpha frequency range over large distances between electrodes, even though coherence in other frequencies over the same distances is much smaller (Nunez, 2000; Nunez et al., 1997). This has led some to suggest that alpha activity provides important large-scale neocortical dynamic functions (Nunez, 2000). Thus, the view of alpha activity as an absence of cortical activation may be better stated as a replacement of locally driven activity with global top-down modulated activation (von Stein and Sarnthein, 2000).

As suppression of low-frequency EEG activity is associated with cognitive engagement, it provides a useful means for measuring task-related demands in cognitive processing. This tool becomes even more useful through comparisons of the two cerebral hemispheres, as it allows for identifying relative hemispheric asymmetries in cognitive engagement and resources. A long history of research has demonstrated links between cognition and alpha asymmetry (see Glass, 1984 for review). For example, McKee et al. (1973) observed greater alpha suppression over the left hemisphere for linguistic compared to musical tasks, and Davidson et al. (1990) observed a relative alpha depression over the left hemisphere during verbal processing and over the right hemisphere during dot localization.

More recently, alpha asymmetry has been linked with individual differences in cognitive performance. Davidson and Hugdahl (1996) measured alpha asymmetry in 44 subjects by subtracting left hemisphere log alpha power from right hemisphere log alpha power. The same subjects were administered a dichotic listening task months after EEG data collection. Most demonstrated a right-ear advantage. Greater right-ear advantages were observed for subjects with smaller relative left hemisphere pre-frontal alpha response, as well as for subjects with greater relative posterior left hemisphere alpha response. The authors interpret these results as indication of multiple processes distributed over diverse locations within the cortex during dichotic listening, and also support for the view that alpha asymmetry provides a useful tool for examining hemispheric specialization for simple cognitive tasks.

Left hemisphere suppression of alpha activity has also been correlated with more complex cognitive tasks not directly associated with left hemisphere specialization. Cicek and Nalcaci (2001) observed that lower left frontal alpha power correlated with better performance on the Wisconsin Card Sorting Task. The differentiation between frontal and posterior alpha asymmetry mirrored that of Davidson and Hugdahl (1996), with alpha attenuation associated with improved performance only in frontal areas. Alpha suppression may play an important role in frontal areas due to its special relationship with attention allocation and involvement with the dorso-lateral pre-frontal cortex.

Hoptman and Davidson (1998) examined alpha asymmetry during simple cognitive tasks, but used factor analysis to determine the relationship between anterior and posterior patterns of activation. Their results showed that lower relative left hemisphere alpha response over central electrodes was related to improved performance on a verbal fluency task, and that greater right hemisphere alpha response was also associated with better performance on Corsi's Recurring Blocks task. Factor analysis revealed 3 different eigenvectors independently linked with anterior, posterior, and central electrodes, with the different eigenvectors holding different correlations with cognitive task performance. Thus, there exists some indication that alpha asymmetries may result from different underlying processes in different brain locations.

While low-frequency EEG asymmetries have been linked with individual differences in task-long cognitive performance, less is known about how electrophysiological asymmetries are associated with performance for subjects on a trial-by-trial basis. Specifically, subjects possessing greater relative right hemisphere alpha activity perform better on a given linguistic task, it is possible that individual variation in performance on that task as a whole may also depend on trial-by-trial short-term variation of that resting alpha asymmetry. The goal of the current experiment is to examine the role of low-frequency EEG activity immediately prior to presentation of a lexical stimulus on subjects' ability to identify the lexical category of that stimulus. The influence of previous trial characteristics is also explored, as low-frequency asymmetries may play an important role in previous trial effects often observed for lexical decision (Iacoboni et al., 1997; Kaplan and Zaidel, 2001). Further, we examine the relation between physiological and behavioral asymmetry. To our knowledge, no previous studies have examined alpha asymmetries on lateralized lexical decision and no studies have examined alpha activity immediately prior to stimulus presentation.

2. Methods

2.1. Participants

Eighteen paid volunteers participated in the experiment, 5 males and 13 females. Data from two females had to be discarded due to excessive artifact from eye blink during the target epochs, leaving 16 subjects remaining for the analysis. All were right-handed native speakers of English with no history of neurological illness. Handedness was assessed using a modified version of the Edinburgh Handedness Inventory (Oldfield, 1971). This 17-item survey includes questions regarding preferred handedness for simple daily tasks (e.g. drawing, writing, throwing, etc.), as well as questions regarding family sinistrality. All subjects reported possessing strong right-handed dominance.

2.2. Materials

A list of 144 words and 144 non-words was modified from the list used by [Iacoboni and Zaidel \(1996\)](#). All stimuli were between 3 and 5 letters in length. Words were divided into high-frequency and low-frequency categories based on the frequency of written use norms developed by [Francis and Kucera \(1982\)](#). High-frequency words were defined as those occurring greater than 100 times per million and low-frequency words were defined as those occurring fewer than 20 times per million. Words were also divided into two categories based on their orthography (regular and irregular). Non-words were divided into two categories, pronounceable and unpronounceable. The pronounceable 'pseudo-words' were selected from the list of [Iacoboni and Zaidel \(1996\)](#), while the unpronounceable non-words were constructed from consonants with letter frequency matched with letter frequency in the word list.

2.3. Design and procedure

Participants were seated at a fixed distance of 57.3 cm from a 16 in. ViewSonic A70f color monitor with their chins in a chin-rest and eyes aligned with a black fixation cross in the center of the screen. Subjects were instructed to maintain their gaze on the fixation point throughout the experiment. Each trial began with presentation of the lexical stimulus one degree of visual angle from fixation and subtending between 3 and 6 degrees in length, followed by subject response. The stimuli, which were black words or non-words on a white background, were displayed either to the left or right of the fixation point for 171 ms (9 refresh cycles of the monitor). This duration was chosen to minimize the possibility of scanning eye movements ([Pirrozolo and Rayner, 1980](#)). Subjects responded manually using a response box placed at midline and aligned vertically. Subjects were instructed to depress one button if the target was a word and another button if it was a non-word, using their index and middle fingers, respectively. Subjects responded with the hand ipsilateral to the side in which the stimulus was shown. Consequently, subjects responded with their left hand for LVF trials and with their right hand for RVF trials. The next trial began 3 s after the previous stimulus was shown.

Stimuli were presented in 6 120 trial blocks. Brief rest periods were provided between blocks to reduce subject fatigue, with breaks lasting between 2 and 5 min. Stimuli were repeated either once or twice for purposes unrelated to the current experiment. Half of the stimuli were repeated once in the same visual field as first presentation, and half were presented twice in the same visual field. Word frequency and orthography, as well as stimulus length and non-word pronounceability, were matched between visual fields and repetition conditions.

Subjects were also given a 24 trial practice in which to familiarize themselves with the response box mechanism

and the EEG recording apparatus. Testing lasted approximately 3 h.

2.4. EEG recordings and analysis

Electrical responses were recorded using a 32 channel Neuroscan quik-cap with tin electrodes and a nose reference, and amplified using a Synamps amplifier. Horizontal and vertical eye movements were monitored using two bipolar electrode pairs, one pair placed on both sides of the head adjacent to the eyes and one pair placed above and below the left eye. All trials with eye blink or other artifacts ($> 80 \mu\text{V}$ deflection) were excluded. All impedances were kept below 5 k Ω , and data was sampled at a rate of 500/s. Eleven electrodes over each hemisphere were targeted for study: FP1/2, F3/4, F7/8, FC3/4, FT7/8, C3/4, T7/8, CP3/4, TP7/8, P3/4, P7/8. Recordings were also collected over midline electrodes, but data from these electrodes were not the focus of the current study and are not discussed.

Electrophysiological response was recorded in the 512 ms immediately prior to stimulus onset and stored for later examination. Data collected from each electrode in this time-window was converted to the frequency domain between 0.5 and 55 Hz and passed through a bandpass filter of 0.5–35 Hz. The alpha band was chosen to be of primary interest, defined as the frequency range from 7.8 to 11.7 Hz. Activity responses in the theta (3.9–7.8 Hz) and beta (11.7–18.5 Hz) bands were also examined, although these were not the focus of this study and are addressed in Section 4. Power in the alpha band was found using Neuroscan software and the log value of the reading was taken to approximate a more normal distribution of responses. The difference between homotopic electrodes was recorded for each electrode pair for each trial, leading to separate readings for each of the 11 electrode pairs.

Frontal electrodes (FP1/FP2, F3/F4, F7/F8, FT7/FT8, FC3/FC4), central (C3/C4, CP3/CP4), parietal (P3/P4, P7/P8), and temporal (T7/T8, TP7/TP8) were grouped together to simplify the analysis. Results were analyzed using a 4-way ANOVA with the following factors: electrode group (frontal, central, parietal, temporal), wordness (word, non-word), visual field (LVF, RVF), and trial accuracy (correct, incorrect). Thus, asymmetry, which was calculated as the difference between left and right hemisphere activity, acted as the dependent variable and trial target wordness, visual field, electrode group, and accuracy served as the independent variables. Because right hemisphere activity is subtracted from left hemisphere activity, positive asymmetry readings represent greater left hemisphere activation and negative asymmetry readings represent greater right hemisphere activation.

Additional analyses examined separate aspects of intra- and inter-subject differences in EEG asymmetry. Intra-subject asymmetry differences examined accuracy and latency under various visual field, target wordness,

and asymmetry conditions. An additional factor of EEG asymmetry was added to the analysis, which was treated as another within-subjects ANOVA factor with two levels: high and low asymmetry. For each target wordness by visual field ANOVA cell, the median asymmetry score acted as the dividing point for creating two sub-cells termed ‘high-asymmetry trials’ and ‘low-asymmetry trials.’ Using this form of analysis EEG asymmetry is transformed to become a dichotomous independent variable and accuracy and latency of performance become the two dependent variables. Separate target wordness by visual field by asymmetry ANOVAs were conducted for each electrode group (central, parietal, frontal, temporal) and for each dependent variable (accuracy and latency), leading to a total of 8 separate analyses. This was termed a ‘state’ analysis because it examines behavioral performance based on the physiological state of the subject, in this case the asymmetry reading immediately preceding the trial.

Inter-subject differences in EEG asymmetry were also analyzed. First, subjects were divided into two groups: high and low asymmetry. The 9 subjects with the highest mean asymmetry readings in the alpha band were grouped together and the 9 subjects with the lowest asymmetry readings were grouped together, thus adding an additional between-groups ANOVA factor: subject EEG asymmetry (high or low). This analysis was termed the ‘trait’ analysis because it compares behavioral performance for subjects with different physiological traits, specifically mean EEG asymmetry.

In order to assess the influence of previous trials over any observed EEG asymmetries, an examination of previous trial effects was included. It is well established that not only does lexical category of preceding lexical decision trials affect performance on the current trial (Iacoboni et al., 1997), but monitoring of previous trial correctness also influences performance (Kaplan and Zaidel, 2001). Such factors may be especially important when the focus of interest is EEG asymmetry immediately preceding presentation of the stimulus, as lingering asymmetries from previous trials may still be evident. In order to determine if such influences may be important contributors to the observed effects, the effect of previous trial wordness, previous visual field, and previous correctness was included.

3. Results

Fig. 1 presents overall spectral response (power) in alpha and other frequency bands for sample electrodes over the left and right hemispheres. A main effect of electrode group ($F_{3,45} = 44.03$, $P < 0.001$) showed different patterns of asymmetry for different locations over the scalp. Significantly greater left hemisphere alpha was observed for central ($t_{15} = 4.58$, $P < 0.0005$), frontal ($t_{15} = 17.65$, $P < 0.0001$), and temporal ($t_{15} = 6.08$, $P < 0.0001$) electrodes (positive asymmetry scores), whereas greater right

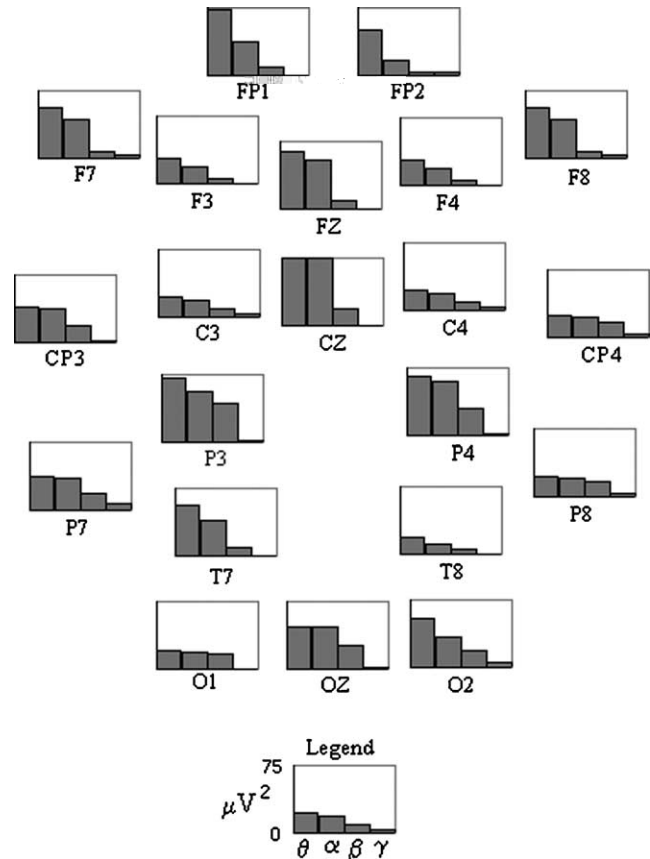


Fig. 1. Mean spectral response (power) for theta (4–8 Hz), alpha (8–12 Hz), beta (12–16 Hz), and gamma (28–42 Hz) frequency bands, by electrode.

hemisphere alpha was observed for parietal ($t_{15} = 5.10$, $P < 0.0001$) electrodes (negative asymmetry scores; see Fig. 2).

A significant interaction between target wordness and accuracy ($F_{1,15} = 5.95$, $P < 0.05$) signaled an effect of alpha asymmetry on lexical decision performance. Although no significant differences were observed between alpha asymmetries for correct and incorrect responses during non-word trials, significantly greater alpha asymmetry was associated with incorrect word trials, compared to correct word trials ($F_{1,15} = 5.05$, $P < 0.05$; see Fig. 3).

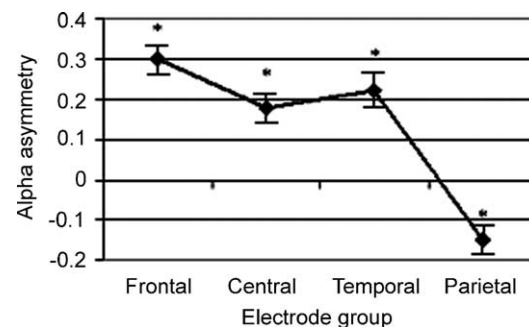


Fig. 2. Alpha asymmetry in activity by electrode group. Because log right hemisphere activation is subtracted from log left hemisphere activation, positive numbers represent greater left hemisphere response. * $P < 0.0001$.

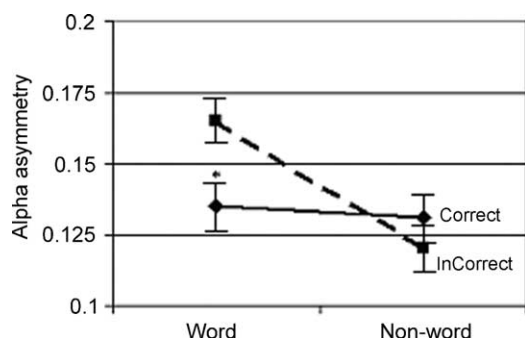


Fig. 3. Alpha asymmetry for correct and incorrect responses by word type. * $P < 0.05$.

The direction of the asymmetry was positive in all cases, indicating greater left hemisphere activity, so reduced asymmetry preceding correct trials meant reduced left hemisphere alpha compared to the right.

An interaction between hemisphere and accuracy ($F_{1,15} = 10.98$, $P < 0.005$) was also observed, as shown in Fig. 4. For LVF trials there were no differences in alpha asymmetry between correct and incorrect trials. However, for RVF trials greater asymmetry (more left hemisphere alpha compared to the right) was associated with incorrect trials, compared to correct trials ($F_{1,15} = 10.22$, $P < 0.01$).

3.1. Intra-subject 'state' analysis

Intra-subject 'state' analysis investigated the effect of EEG asymmetry on behavioral indices of performance. Trials in each visual field by target wordness cell were divided into high- and low-asymmetry groups based on a median split. Therefore, this analysis included 3 independent variables (visual field, target wordness, EEG asymmetry) and two dependent variables (accuracy, latency). Asymmetry in frontal, central, temporal, and parietal electrode groups were examined separately.

The only result involving asymmetry to reach significance was an interaction between central asymmetry and visual field for response latency ($F_{1,17} = 7.08$, $P < 0.05$). Although neither difference reached significance individually, for the left hemisphere high-asymmetry trials were associated with faster responses (649 and 660 ms), and for

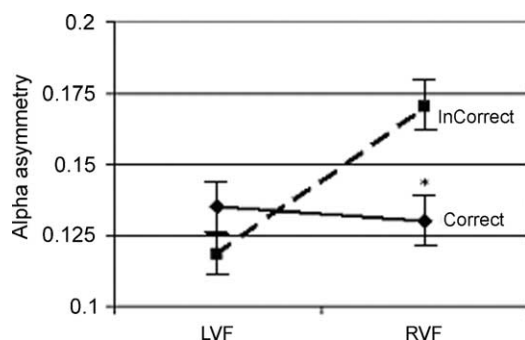


Fig. 4. Alpha asymmetry for correct and incorrect responses by visual field. * $P < 0.01$.

the right hemisphere high-asymmetry trials were associated with slower responses (698 and 688 ms). However, this result must be interpreted cautiously due to the risk of type one error. Because so many analyses were conducted, the likelihood of observing this result by chance is great.

3.2. Inter-subject 'trait' analysis

For inter-subject 'trait' analysis, subjects were divided into high- and low-EEG asymmetry groups, with EEG asymmetry acting as a between-groups variable. Results failed to reveal any trait differences in either accuracy or latency performance. Consequently, high-asymmetry and low-asymmetry subjects did not show any behavioral differences in the lexical decision performance.

3.3. Previous trial analyses

3.3.1. Behavior

Although behavioral results from the current experiment are discussed in full separately (Weems et al., in preparation), previous trial effects were examined here to explore the influence of subject testing history on current trial performance. Three separate analyses were conducted. First, ANOVAs with factors previous trial wordness, previous trial visual field, and previous trial correctness were performed to examine the effect upon current trial accuracy and latency. Although no main effect reached significance, a previous wordness by previous visual field interaction was observed for response accuracy ($F_{1,15} = 5.73$, $P < 0.05$). The lowest accuracy was observed following pseudo-words previously displayed to the RVF, leading to a previous wordness effect for the RVF (words = 94.1%, pseudo-words = 91.2%; $F_{1,15} = 5.19$, $P < 0.05$) and a previous visual field effect for pseudo-words (LVF = 94.4%, RVF = 91.2%; $F_{1,15} = 7.37$, $P < 0.05$).

Although the above analyses provided effective means for measuring lingering effects from previous trials, they did not measure the influence of previous trial on current trial performance. Two separate analyses were performed to examine this effect. The first used previous visual field and current visual field as independent variables to identify any 'momentum effects' involving visual field of presentation. A main effect of previous visual field revealed faster responses following previous LVF trials, compared to RVF trials (LVF = 689.9 ms, RVF = 701.2 ms; $F_{1,15} = 9.65$, $P < 0.01$). Similar analysis of previous wordness effects, with previous trial wordness and current trial wordness as independent variables, revealed a main effect of previous trial wordness, with faster responses for previous word trials compared to previous pseudo-word trials (words = 685.7 ms, pseudo-words = 705.8 ms; $F_{1,15} = 9.52$, $P < 0.01$). Interestingly, these same effects were explored in the previous wordness by previous visual field by previous correctness analysis without significant results, although it

is likely power to detect these effects was reduced in that case due to the larger number of factors and therefore fewer observations per cell.

3.3.2. EEG correlates

The same analyses identified above were conducted with EEG asymmetry as a dependent variable for each electrode group. Incorrect previous trials led to greater alpha asymmetries, compared to correct trials, over parietal electrodes (incorrect = -0.20 , correct = -0.15 ; $F_{1,15} = 9.93$, $P < 0.01$). Greater alpha asymmetry was also observed for preceding LVF trials in central electrodes (LVF = 0.18 , RVF = 0.23 ; $F_{1,15} = 7.40$, $P < 0.05$), and for preceding RVF trials over parietal electrodes (LVF = -0.20 , RVF = -0.15 ; $F_{1,15} = 4.90$, $P < 0.05$), although asymmetry readings in these two electrode groups acted in opposite directions (greater over the left hemisphere for central electrodes and over the right hemisphere for parietal electrodes).

No previous trial effects reached significance in either of the previous visual field or previous wordness ‘momentum’ analyses, for any of the electrode groups.

4. Discussion

The current experiment showed that the resting state of a subject prior to identification of a lexical stimulus has significant impact over his or her performance. It has been well documented that individual differences in resting alpha power asymmetries are correlated with performance on complex tasks such as dichotic listening (Davidson and Hugdahl, 1996) and the Wisconsin Card Sorting Task (Cicck and Nalcaci, 2001). However, while macro-level alpha variation between subjects demonstrates the importance of overall resting state, it provides little information regarding trial-by-trial performance. The current study measured alpha power before each lexical stimulus was shown, and consequently identified how variation in the asymmetries for engagement in the two hemispheres predicts future performance.

One assumption upon which this and other related work is based is that alpha asymmetries provide indirect measures of cognitive engagement. Alpha power has historically been synonymous with a resting or idle state, although we now know such a description is overly simplified. A reduction in alpha power is thereby taken as an increase in engagement, and cognitive tasks that lead to attenuation of alpha activity are characterized as highly demanding of attentional resources. This assertion is supported not only by work that shows gross changes in alpha activity during the transition from rest to work, but also by highly specific and controlled experiments that manipulate various levels of cognitive engagement and yield negative correlations with alpha activity of participants (for review, see Glass, 1984).

Examining asymmetries in alpha power requires one further logical assumption: that differences in alpha activity over the two hemispheres are associated with asymmetries in engagement. Whereas previous studies showed that intrinsic asymmetries in resting states for the two hemispheres are linked with overall cognitive performance, the current results show that engagement differences at the time of the task also affect immediate performance. Specifically, although alpha activity was generally greater over the left hemisphere, words were identified more accurately with decreased differences in left and right hemisphere alpha activity. It should be noted that separate post-hoc analyses of the same data did not reveal any relationships between performance and engagement in any single hemisphere alone. This suggests that asymmetric engagement patterns, and not hemisphere-specific engagement, mediate this result. It is noteworthy that this result did not interact with visual field, indicating that the benefit of having a more engaged left hemisphere for word processing is independent of whether the lexical stimulus is sent directly to the left or the right hemisphere.

Since left hemisphere alpha power was greater over frontal, central and temporal electrodes, this suggests that immediately preceding the lexical stimulus the right hemisphere was more highly engaged. Decreases in asymmetry therefore represent increased relative left hemisphere engagement. Is improved performance due to decreased asymmetry and therefore more equivalent engagement in both hemispheres, or simply to increases in relative left hemisphere engagement? The former explanation appears more plausible given the absence of a relationship between performance and left hemisphere alpha activity alone. Strong support for the joint hemispheric processing of words has been provided elsewhere (Iacoboni and Zaidel, 1996; Mohr et al., 1994; Zaidel and Rayman, 1994), further supporting this explanation.

Even though visual field of stimulus presentation did not interact with alpha asymmetry for word engagement, an interaction between visual field and overall accuracy was observed. Specifically, alpha asymmetries were smaller for correct RVF trials compared to incorrect RVF trials, indicating that increased relative left hemisphere engagement led to improved performance. The same pattern of results approached significance for LVF trials, with greater accuracy related to increased relative right hemisphere engagement. It follows that both hemispheres benefit from having the target hemisphere engaged at time of presentation.

Asymmetries in spectral response over different scalp areas provides an additional way in which cognitive engagement may be studied. Although electrode location did not interact with any of the results described above, in the alpha band anterior electrodes showed greater left hemisphere activation whereas parietal electrodes showed greater relative right hemisphere activation. This difference between frontal and parietal areas has been observed

elsewhere (Hoptman and Davidson, 1998) and may indicate possible effects of loci of attention in the brain. As a major center for decision making, frontal area activation may be most relevant in the current analysis. Nonetheless, the parietal lobe is the location of important language centers in the brain and both areas are involved in attention. Unfortunately, the lack of interactions involving electrode location limit our ability to support anatomical models of cognitive engagement.

Previous trial effects provide an additional tool for examining differences between cortical areas. The parietal electrodes were most consistently influenced by previous trials, with incorrect trials leading to increased subsequent relative right hemisphere alpha activity, and therefore increased left hemisphere engagement. Such a result is in contrast to previous behavioral examination of implicit monitoring that showed increased right hemisphere monitoring following incorrect lexical decision trials (Iaconi et al., 1997). It is possible that alpha asymmetry provides different indices of implicit monitoring than behavioral measures. Indeed, perhaps engagement is inversely related to monitoring efficacy, such that reduced engagement following unsuccessful identification leads to greater resources available for processing of the next stimulus. This would explain greater capacity for implicit monitoring from the right hemisphere, and increased right hemisphere performance following incorrect trials as observed by Iaconi and Zaidel (1996).

The lack of previous trial ‘momentum’ effects in EEG asymmetry is disappointing but not surprising. We term momentum effects as those involving successive trials of the same type (e.g. LVF trials followed by LVF trials or word trials followed by word trials). One could suppose that if a hemisphere is engaged by a trial, it might be more (or, conversely, perhaps even less) capable of being engaged by the same type of stimulus in the following trial. However, such was not the case and it appears that the hemispheres are not more or less prepared for a specific type of trial based on previous experience. However, we did observe some lingering effects of previous trial visual field on alpha and beta asymmetry. Specifically, the right hemisphere was less engaged (i.e. greater relative right hemisphere activity) following LVF trials. This might suggest that a negative momentum was observed; tasking a hemisphere lowered engagement for the following trial. However, interpretation of this result is complicated by the fact that greater relative right hemisphere beta activity following LVF trials was observed. Typically, alpha activity is inversely related to engagement, but the relationship between beta activity and engagement is less clear and perhaps even opposite to that of alpha. The effect might be a product of increased overall activity and not necessarily indicative of the level of engagement.

Perhaps the most important observation regarding previous trial effects is that behavioral and electrophysiological measures revealed very different results. For example, a previous trial wordness effect was observed for response latency, and interacted with previous trial visual field for response accuracy. However, these same results did not reach significance for EEG asymmetry. It is possible that some lingering stimulus processing remained following pseudo-word presentations, particularly RVF pseudo-words. However, such processing did not reveal itself in EEG asymmetry, possibly due to joint presence in the two hemispheres. However, error monitoring, revealed by previous correctness effects, were evident in low-frequency EEG asymmetry but not behavioral measures. Alpha asymmetry was greater following incorrect trials (parietal electrodes only), compared to correct trials. Perhaps these electrophysiological measures are more sensitive for revealing error monitoring effects, and that error monitoring occurs asymmetrically in the two hemispheres.

The lack of significant effects in the ‘state’ and ‘trait’ analyses is disappointing, although not very surprising. If the effects described above are due primarily to reduced asymmetry preceding incorrect trials, this difference may become ‘washed out’ when asymmetry readings are averaged across half the trials within a given experimental cell (e.g. LVF words). The failure to relate subjects’ behavioral asymmetry to their physiological asymmetry is a little more surprising given that this result would more closely match the previous literature. However, previous studies typically involved measuring alpha power during an extended resting state rather than during relatively short periods during the task itself, making connections with the previous literature more tenuous. On the other hand, alpha power just before decision should have a more immediate effect on performance than alpha power during an unrelated resting state.

Finally, one cautionary note must be included for the current study. Although stimuli were lateralized and shown only briefly, accuracy for the task was overall very high (approximately 90%). As a result, far more trials were responded to correctly, compared to those that elicited incorrect response. The results must therefore be interpreted with the understanding that number of trials may be low for some of the experimental cells (e.g. RVF incorrect word trials). However, there is no reason to expect a confound to be introduced by this limitation, and in fact the most likely interpretation is that experimental power to detect differences should be reduced by having fewer incorrect trials. Thus, our results are conservative. Also, even under the ‘optimal’ circumstances in which equal numbers of trials are correctly and incorrectly identified, theoretically no differences should be observed in alpha asymmetry since this accuracy represents pure guessing. As a result, the best experimental data base is somewhere in-between excellent and at-chance performance, a goal which the current study hopefully approximated.

Acknowledgements

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