THE EFFECT OF ENDOGENOUS ALPHA ON HEMISPHERIC ASYMMETRIES AND THE RELATIONSHIP OF FRONTAL THETA TO SUSTAINED ATTENTION

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SUMMARY

Data are presented which suggests that degree of hemispheric alpha asymmetry (for tasks hypothesized to induce such asymmetries) is related to resting eyes closed endogenous alpha activity. Also, it is demonstrated that frontal theta activity varies with difficulty level of an addition task. Both results share a common emphasis on electrophysiological individual differences.

EEG recordings from 54 right-handed subjects (P3,P4,F3,F4 referenced to linked ears) performing 5 cognitive tasks were collected and quantified using period analysis. The subjects were rank ordered on the basis of their hemispherically averaged (P3+P4/2) alpha activity during an Eyes Closed (lights off) baseline condition. Subjects comprising the top, middle and lower thirds of this ranking were ascribed the status of HIGH, MIDDLE or LOW alpha generators. A similar procedure was performed for frontal theta to distinguish theta generators. Before the experiment the tasks were ordered <u>a priori</u> for their hypothesized hemispheric involvement. The tasks, ordered from right to left hemisphere involvement, were: 1) FOCUSING, 2) STRUCTURED FOCUSING, 3) COUNTING ARTICLES, 4) COUNTING NOUNS, and 5) CONTINUOUS ADDITION. The addition contained trials with varying levels of difficulty. All tasks were performed with eyes closed and lights off.

Utilizing a L-R/L+R asymmetry index the results indicate that HIGH and MIDDLE alpha generators displayed the hypothesized asymmetry relationship (ie. increasing right hemisphere alpha activity for the <u>a priori</u> ordered tasks) whereas the LOW alpha generators did not. This implies that low alpha generating subjects may negatively affect EEG laterality studies. Results from the addition task indicate that hemispherically averaged (F3+F4/2) theta activity varies curvelinearly as a function of increasing task difficulty (ie. theta increases and then decreases as difficulty increases). Subjects displaying higher performance scores on the addition task also demonstrate higher frontal theta values, suggesting theta is associated with sustained focused attention or higher order cognitive processes (or both).

INTRODUCTION

This study addresses two research issues. The first investigates the effect, on EEG, of tasks chosen to differentially engage the cerebral hemispheres. The second concentrates on an hypothesized relationship between frontal theta activity and sustained focused attention. Both issues share a common emphasis on electrophysiological individual differences. Not to be confused with the psychophysiology of individual differences (see 9), this study demonstrates the need to pay greater attention to electrophysiological differences among individuals, and the degree to which these differences influence results in EEG research.

<u>Hemispheric Asymmetries</u>:

The theoretical basis for laterality research has its origin in research from a number of disciplines: anatomical studies (e.g., 16, 38), commissurotomy, hemispherectomy and lesion studies (e.g., 14, 27, 40, 41) and behavioural studies (e.g., 3, 42). Efforts to investigate laterality using EEG, however, has yielded many inconsistent and conflicting results. For example, when measuring EEG laterality during task performance some studies have found that females are more lateralized than males (e.g., 4, 7, 21, 31), others that males are more lateralized than females (e.g., 2, 35, 36, 44), and still other have found no sex differences at all (e.g., 12, 20, 22, 30). The issue of whether

EEG is sensitive and robust enough to reflect asymmetrical cognitive processes is highlighted by well a known controversy. In 1979, Gevins and his colleagues published a series of papers asserting that EEG hemispheric asymmetries during cognitive tasks (specifically chosen to induce such asymmetries) were due to efferent activity, stimulus characteristics and performance related factors, rather than to cognitive differences among the tasks (17, 18, 19). Their results challenged a cognitive interpretation of hemispheric EEG asymmetry supported by the research of Galin, Ornstein and their colleagues (6, 10, 11, 12, 13, 33, 34). Among the many factors used to explain the conflict include: electrode montage, type of quantification procedure, statistics, methodology and task type. One factor which has not been addressed, however, is the effect due to electrophysiological individual differences.

The present study was prompted by the results of a pilot study in which the authors found that if the subjects were divided (post hoc) into high and low alpha generators, high alpha generators showed the hypothesized asymmetries during task performance whereas low alpha generators did not. The groups did not differ on task performance scores, nor did they differ demographically. It was also demonstrated that tasks could be ordered a priori with respect to the amount of asymmetry each task was expected to produce. However, because the pilot study suffered from too few subjects (N=13) and too many tasks (seven), an attempt to replicate these important findings seemed necessary.

Theta Activity and Attention:

In an excellent review of theta and psychological phenomena, Schacter (39) isolated two "grossly different" psychological processes associated with theta activity: 1) active and efficient information processing during problem solving due to the selective and intensive components of attention (e.g., 1, 6, 24), and 2) apparently the opposite, theta associated with sleep onset (hypnogogic) and low level of pre-stimulus alertness (e.g., 26, 32). The latter is a common phenomenon and is used as a criterion to define stage 1 sleep (37). The former is less well established but frontal midline theta has received attention from researchers in Japan. Ishihara and Yoshii (24) reported frontal midline theta activity during continuous arithmetic addition and performance on an intelligence test. In a straightforward and convincing study, Mizuki, Tanaka, Isozaki, Nishijima and Inanaga (29) demonstrated that 19 out of 30 subjects exhibited prominent frontal midline theta activity during continuous arithmetic addition. Mizuki, Takii, Nishijima and Inanaga (28) demonstrated a relationship between theta and focused attention in a memory task. The results from these studies along with Schacter's review suggest that theta activity, especially at frontal sites, is associated with sustained focused attention.

The present experiment manipulated difficulty level among trials of a continuous addition task to investigate the relationship between frontal theta activity and sustained focused attention. It was hypothesized that as difficulty level increases theta would increase due to the heightened attentional demands of the task. As the task becomes too difficult, and thus focused attention lapses, theta should decrease (overall, an inverted U shaped function). Prompted by the alpha results of our pilot study (mentioned above), the possibility that endogenous levels of theta could influence the results was also investigated.

METHOD

Subjects:

Seventy subjects were tested; however, due to equipment malfunction, the data for 16 subjects were omitted. Of the remaining 54 subjects, 21 were males with a mean age of 22.8 yrs, and 33 were females with a mean age of 23.6 yrs. The subjects were either paid volunteers or introductory Psychology students given course credit for participation. All subjects were functionally and familially right-handed, as determined by questionnaire. One subject's data were deleted from the study because she fell asleep during the FOCUSING task.

Apparatus:

Four electrodes, P3, P4, F3 and F4 referenced to linked ears, were secured using Grass EC2 electrode paste and headbands. Bipolar EOG and ground were secured using tape. The EEG and EOG were amplified using Grass EEG pre-amplifiers (Model P511J) with 60 Hz notch filters, and was simultaneously recorded on a Beckman type Rm dynograph and an 8 track Vetter Model A FM tape recorder running at 3 3/4 ips with flutter compensator. A real time clock activated by the experimenter while the subjects performed the tasks generated an electrical signal lasting 10 seconds. These signals were recorded on the 8 track tape and demarcated single or successive 10 second EEG 'epochs'. Electrophysiological data reduction was performed using a dual channel band pass filter (A.P. Circuit Corp. 24 db/octave rolloff for each channel) and a DEC LSI 11/23 micro-computer with A/D converters, real time clock and mass storage (floppy and hard discs). The EEG amplifiers and the dual channel filter were counterbalanced across hemispheres for the frontal and parietal sites. All stimuli for the experiment were pre-recorded on audio tape.

Tasks

The FOCUSING and COUNTING ARTICLES tasks were chosen because they exhibited the largest alpha asymmetries in the pilot study. A second version of each task was created to induce greater left hemisphere activation.

FOCUSING, a meditative type task, was designed to require very little verbal-analytic-serial processing. It was intended to elicit a spatial-holistic experience. The structure of the task, in comparison to the counting tasks, contained fewer well defined task objectives and did not include requirements for serially placed responses. While minimally changing the spatial-holistic characteristics of the task, the second version of the FOCUSING task (i.e. STRUCTURED FOCUSING) included serially placed responses as well as a greater number of well defined task objectives. It was expected that the added structure would engender greater left hemisphere activation (relative to the FOCUSING task).

The COUNTING ARTICLES task involved counting the number of 'a's and 'the's in aurally presented text. During the pilot study it was suspected that the subjects may have adopted an auditory matching strategy for word detection instead of cognitive recognition. To control for this a second version of the task (i.e. COUNTING PROPER NOUNS) was included requiring the detection of proper nouns. A semantic evaluation is needed to identify proper nouns; simple auditory matching cannot be used. It was expected that the added verbal component would require greater left hemisphere activation (relative to the COUNTING ARTICLES task).

Although two versions of the ADDITION task were used, both versions were identical. The two versions simplified counterbalancing task presentations across subjects.

A more detailed description of the tasks follow. Note the order of the tasks reflect the (a priori) hypothesized right to left hemisphere influence of the tasks.

FOCUSING: Recorded instructions were given which attempted to elicit a self-directed internal focusing of attention designed to heighten bodily awareness (the instructions for this task were derived from Gendlin (15). Part of the instructions asked the subject to create a 'handle', a word or image, reflecting the present state of their internal bodily feelings (see appendix A for a transcript of the instructions). EEG was recorded in five 45 sec blocks (a total of 3.75 min) between which instructions were given to increase subject motivation and elucidation of the experience. At the end of the task the subject was asked to report their 'handle' and give a brief summary of their experience of the task.

STRUCTURED FOCUSING: Recorded instructions were given which attempted to elicit an internal focusing of attention to specific body parts. For each of the five 45 sec blocks the subject was requested to mentally focus on a particular (predetermined) part of the body. At the end of each 45 sec block the subject was asked to rate on a scale from 1 to 5 where 1 is 'not successful' and 5 is 'very successful' his ability to focus on that body part. As with the FOCUSING task a total of 3.75 min of EEG was recorded during five 45 sec blocks. Although similar to the FOCUSING task from a visual, spatial and holistic perspective, this task was designed to incorporate a sequentially ordered and less ambiguous set of instructions requesting temporally spaced responses (see appendix A).

COUNTING ARTICLES: A task similar to that described by Moore (30) was used in which a pre-recorded 2 minute nonfiction, simple, historical passage was played over the speaker. The subject was instructed to mentally count the total number of 'a's and 'the's (taken together) uttered in the passage. This was repeated for a second 2 min passage. EEG was recorded during both 2 min passages.

COUNTING PROPER NOUNS: Also using pre-recorded nonfiction, simple, historical passages, the subject was instructed to mentally count to total number of proper nouns uttered in the passage. The task was simplified by instructing the subject to treat proper nouns such as 'Jacques Cartier' or 'United States of America' as 1 instead of 2 or 3 respectively. As in the COUNTING ARTICLES task EEG was recorded during both 2 min passages. It was anticipated that recognizing and counting proper nouns would require more verbal-analytic cognitive processing than COUNTING ARTICLES where an aural pattern matching strategy could be used.

ADDITION: The subject, with eyes closed was asked to mentally add numbers presented aurally for 10 sec. Eight numbers were presented per trial, 1 number every 1.24 sec, for a total of 24 trials. For each trial, difficulty level was manipulated by controlling the magnitude of the numbers to be added. For each trial, numbers from one of six difficulty levels were presented. They are:

EASY	Level 1:	1, 2
	Level 2:	2, 3, 4, 5, 6
	Level 3:	4, 5, 6, 7, 8
	Level 4:	6, 7, 8, 9, 12
	Level 5:	8, 9, 12, 13, 14
DIFFICULT	Level 6:	12, 13, 14, 15, 16

Each trial involved a random presentation (with replacement) of the set of numbers at a single difficulty level. Presentation order of the trials with respect to difficulty level was pseudo-random; that is, level of difficulty was chosen randomly (without replacement) within blocks of 6 trials. Hence, with 24 trials each of the 6 difficulty levels was presented 4 times. At the end of each trial the subject was asked for the following information:

1. the total
2. a subjective estimate of confidence concerning the correctness of their total, on a scale from 1 to 6 where 1 is 'very sure' and 6 is 'not sure'
3. a subjective estimate of the level of difficulty, on a scale from 1 to 6 where 1 is 'easy' and 6 is 'difficult'.

EEG was recorded only during the 10 second period for each trial the subject was counting, not during the subject's response.

Procedure:

Each subject was seated in an electrically shielded anechoic chamber with his head positioned in a chin-rest/head-restraint device to reduce involuntary head movements. Instructions and tasks were presented through a speaker situated 1 meter in front of the subject. Four EEG baselines were recorded before the tasks: 5 ten second epochs each for resting with eyes open lights on, eyes open lights off, eyes closed lights on and eyes closed lights off. During the experiment all tasks were performed in darkness, with the eyes closed.

The tasks were presented in counterbalanced order with the provision that no task's two versions were presented successively. The experimental session lasted approximately 40 minutes.

EEG Analysis:

Before the recorded EEG was computer quantified, the signal was bandpass filtered. EEG from the parietal leads were bandpass filtered from .5 to 60 Hz and the frontal leads from 4 to 60 Hz (to reduce the effect of eye movements). The event signal recorded on the FM tape by the experimenters during the experiment demarcated 10 sec epochs for EEG period analysis. From the polygraph tracings, any 10 second epoch of EEG which showed clear movement artifact was deleted from further analysis. The filtered EEG was A/D converted at 1000 samples per sec. Period analysis was performed on the digitized data producing 3 measures for each of 5 EEG bandwidths (delta .5-4 Hz, theta 4-8 Hz, alpha 8-12 Hz, sigma 12-16 Hz and beta 16-60 Hz). The 3 measures are: 1) zero-cross, 2) first-derivative, and 3) power. Briefly, a zero-cross analysis checks for a change in the sign of the voltage passing through zero. A measurement of the elapsed time between two zero-crossing events yields an estimate of the wave's frequency. First-derivative analysis checks for negative inflections in the EEG voltage; that is, a change from a decreasing voltage to an increasing one. The time between two such events provides an estimate of faster frequencies superimposed on the main waveform. A 7 uV threshold criteria was adopted for the first-derivative measure in order to eliminate very low amplitude high frequency activity which is often a consequence of equipment noise. The power measure is calculated by cumulatively adding the absolute voltage values between zero-cross events. For a more complete description of this period analysis see

Hoffmann et al. (23). Finally, for each frequency bandwidth and period analysis measure, an asymmetry index was calculated --- (Left-Right/Left+Right) x 100.

RESULTS

Less than 1% of the EEG was deleted due to artifact.

Alpha zero-cross values (i.e. percent alpha) at the parietal sites of each hemisphere during the eyes closed (dark) baseline condition were summed and averaged producing a mean parietal alpha measure for each subject. The subjects were rank ordered from highest to lowest on this measure and were divided evenly into high, middle and low alpha generators, 18 subjects per group. The subject who was deleted from the experiment for falling asleep was a high alpha generator, hence that group contained 17 subjects. When alpha power was used create the groups, all but 4 subjects were in the same groups and these subjects were borderline between low and middle, and middle and high. Table 1 displays the distribution of sex and mean age for each alpha group. A similar _post hoc_ procedure was used with theta zero-cross values to produce high, middle and low theta generators (see table 2). The two factors (i.e., alpha and theta generators) were treated independently for hypothesis testing because the same subjects made up both conditions. Table 3 illustrates the distribution of subjects on both factors. Notice that similar high, middle or low groups in each factor share few subjects. Separate ANOVAs were performed on the ages of the alpha and theta groups. There was no significant difference among the mean ages for the alpha groups. A significant difference was found, however, among the theta groups (F=3.92, df=2,50, p <.026). High theta generators were younger than low theta generators.

The average alpha zero-cross values for Eyes Closed baseline (dark), Focusing (both versions), Counting (both versions) and Addition (all levels) are shown in figure 1. Using repeated measures ANOVA with tests for trends (i.e. orthogonal polynomial contrasts) there is a significant decreasing linear trend in alpha from the baseline condition to the Addition task (F=47.95, df=1,50, p <.0000). There was also a significant interaction between task and alpha generators (F=5.06, df=6,150, p <.0001) showing the expected pattern: low alpha generators show no decreasing trends, middle alpha generators show a marked decreasing trend and high alpha generators show a prominent decreasing trend.

A 3 between (alpha groups) by 2 within (Focusing vs Counting) by 2 within (version 1 and version 2) mixed design ANOVA was performed on the alpha asymmetry index (zero-cross) at the parietal location. A main effect for task (F=13.46, df=1,50, p <.0006) and more importantly a significant interaction between type of task and type of alpha generator (F=3.83, df=2,50, p <.028) was found. The interaction is shown in figure 2 and supports the hypothesis that Focusing and Counting show relative hemispheric differences in alpha production only for alpha generators. To test whether the tasks were correctly ordered _a priori_ for their presumed ability to induce left of right hemisphere activation a 3 between (alpha groups) by 4 within (FOCUSING, STRUCTURED FOCUSING, COUNTING ARTICLES, COUNTING PROPER NOUNS) ANOVA was performed with tests for polynomial trends. There was a significant linear interaction between alpha generators and the tasks (F=7.48, df=2,50, p <.0014) for the alpha zero-cross asymmetry index. A similar interaction was found with alpha power (F=3,25, df=2,50, p <.047). The interactions are shown in figure 3 and 4. This effect is specific to the parietal site; similar analyses performed at the frontal site showed no significant results. Separate trend analyses for each alpha group on the same tasks showed a significant linear trend for high alpha generators (F=8.78, df=1,16, p <.0092), a significant linear trend for middle alpha generators (F=11.76, df=1,17, p <.0032) and non-significant trends for low alpha generators. There were no significant trends or interactions for the other EEG frequencies.

There were no significant main effects or interactions with alpha generators for the alpha power or alpha zero-cross asymmetry indices over the 6 difficulty levels in the ADDITION task, either at the parietal or frontal positions. To compare the amount of asymmetry induced by the Addition task (with respect to Focusing and Counting), a mean alpha zero-cross asymmetry index was calculated for each subject (collapsed across difficulty levels). The results are shown in figure 5. The Addition task produces an alpha asymmetry value more similar to Counting than to Focusing, as expected. However, there was no significant interaction between task and alpha groups, only a (linear) main effect for the tasks (F=24.1, df=1,50, p <.0000). As can be seen from figure 5 the inconsistent (compared to Focusing and Counting) asymmetry result in the Addition task for low alpha generators essentially eliminated any interaction. Within the Addition task asymmetrical alpha activity did not vary as a function of difficulty level for any of the alpha groups.

		SEX	AGE
ALPHA GENERATORS	HIGH	MALES = 8 FEMALES = 9	23.2 yrs
	MIDDLE	MALES = 7 FEMALES = 11	22.7 yrs.
	LOW	MALES = 6 FEMALES = 12	23.9 yrs.

TABLE 1. Distribution of sex and mean age across the alpha groups.

		SEX	AGE
THETA GENERATORS	HIGH	MALES = 8 FEMALES = 9	20.53 yrs.
	MIDDLE	MALES = 7 FEMALES = 11	22.72 yrs.
	LOW	MALES = 7 FEMALES = 11	26.39 yrs.

TABLE 2. Distribution of sex and mean age across the theta groups.

		THETA GENERATORS		
		HIGH	MIDDLE	LOW
ALPHA GENERATORS	HIGH	2	7	8
	MIDDLE	9	2	7
	LOW	6	9	3

TABLE 3. Distribution of subjects on both factors.

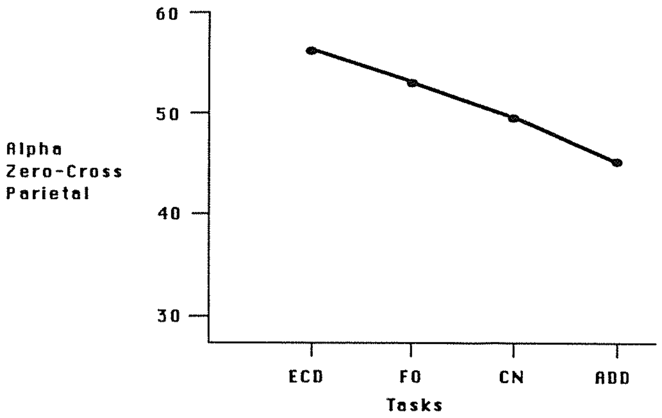

Figure 1: Hemispherically averaged alpha zero-cross for all subjects.
ECD = Eyes Closed Dark; FO = Focusing (mean of both versions);
CN = Counting (mean of both versions); ADD = Addition (mean of all levels).

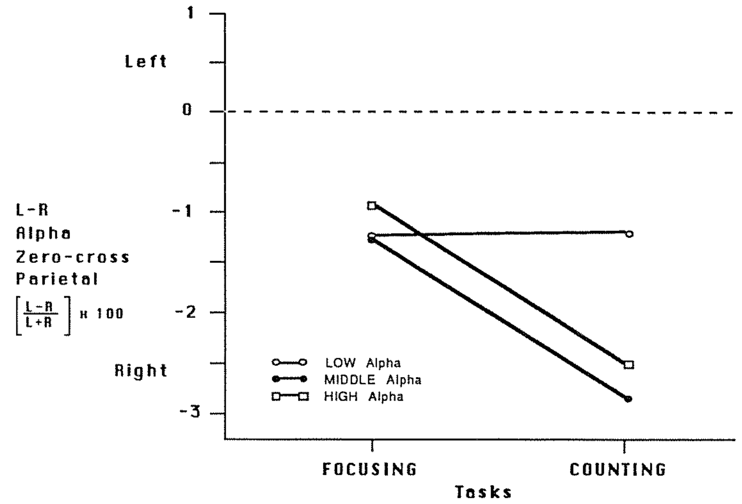

Figure 2: Alpha asymmetry index (zero-cross parietal) for means of both versions of the Focusing and Counting tasks for each type of alpha generator.

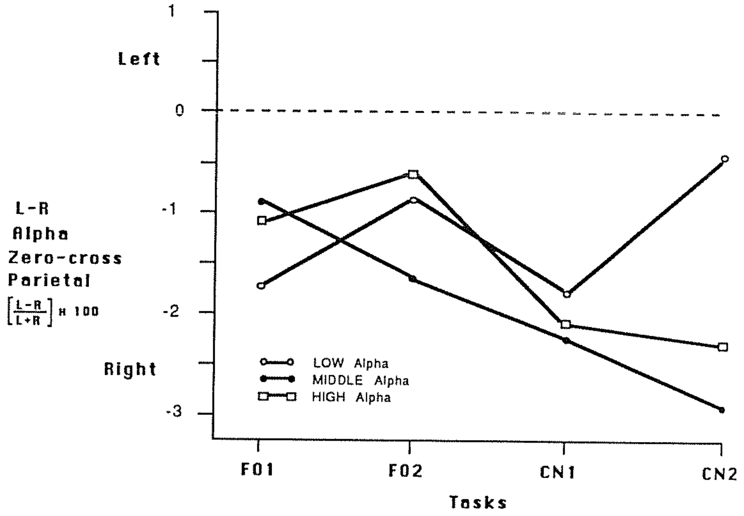

Figure 3: Alpha asymmetry index (zero-cross parietal) for the hemispherically ordered tasks for each type of alpha generator.
FO1 = Focusing; FO2 = Structured Focusing;
CN1 = Counting Articles; CN2 = Counting Proper Nouns.

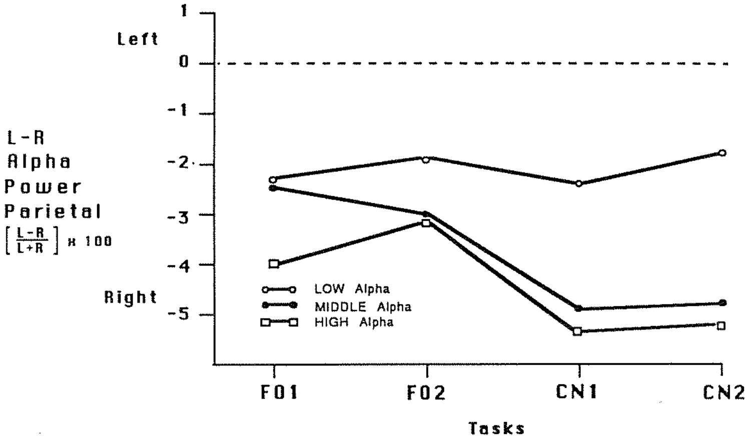

Figure 4: Alpha asymmetry index (power parietal) for the hemispherically ordered tasks for each type of alpha generator.
FO1 = Focusing; FO2 = Structured Focusing;
CN1 = Counting Articles; CN2 = Counting Proper Nouns

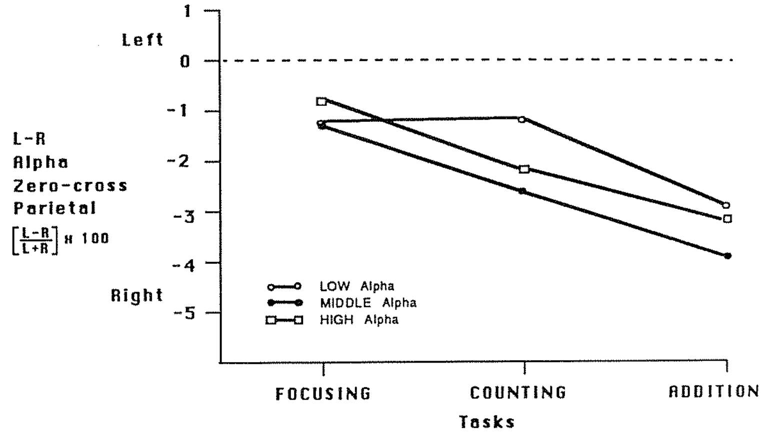

Figure 5: Alpha asymmetry index (zero-cross parietal) for the means of both versions of the Focusing and Counting tasks and the mean of all levels of the Addition task for each type of alpha generator.

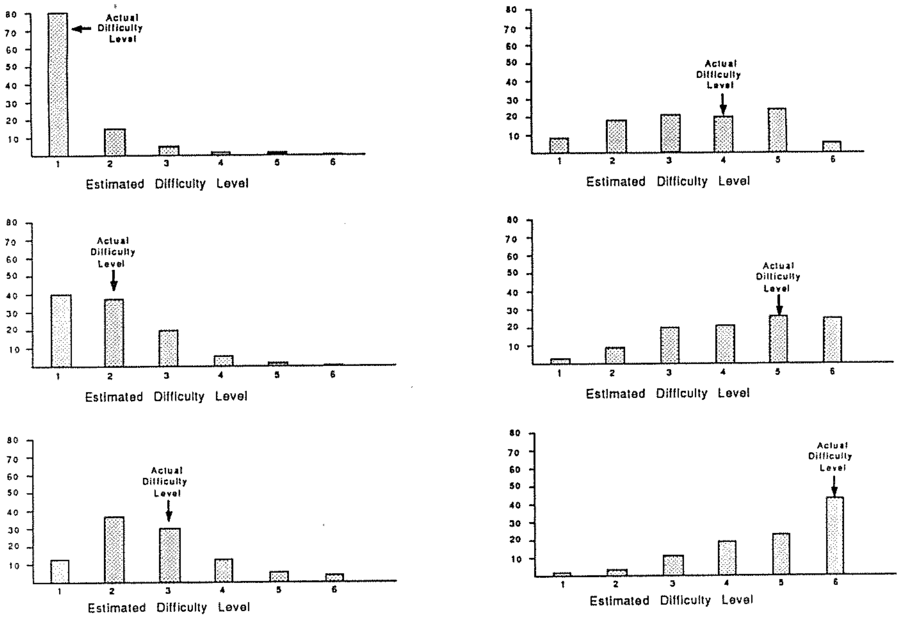

Figure 6: Percent frequency histograms of subjective difficulty with actual difficulty level for the Addition task.

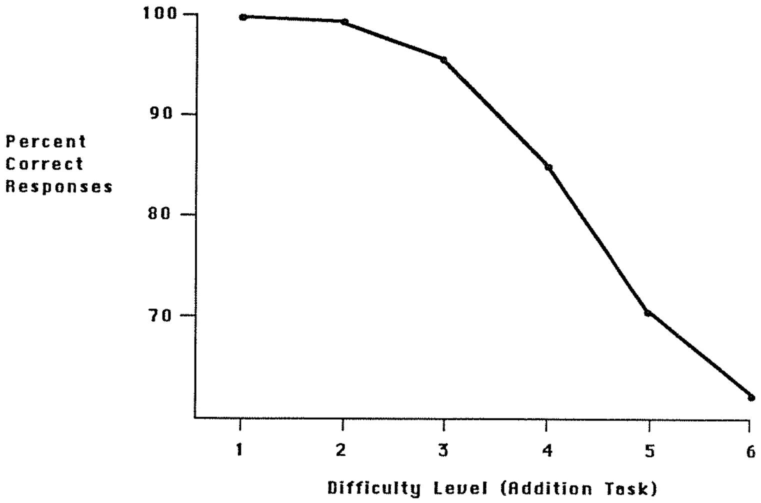

Figure 7: Percent correct responsese (subject answer/correct answer) x 100 for each difficulty level of the Addition task.

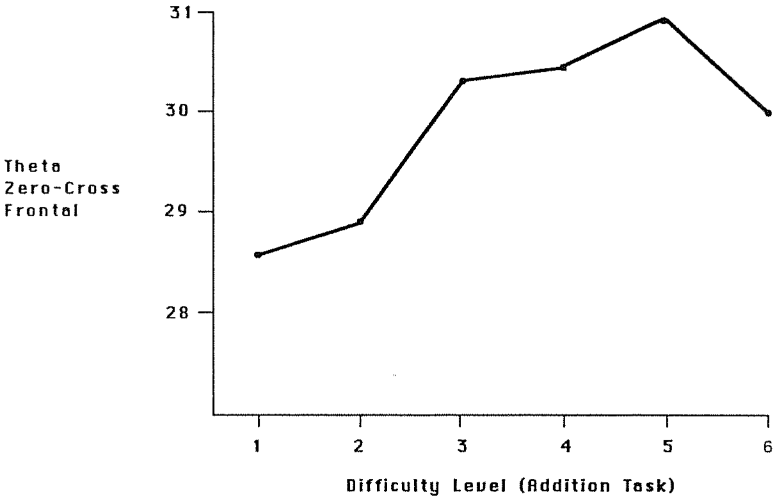

Figure 8: Hemispherically averaged theta zero-cross frontal for each difficulty level the Addition task.

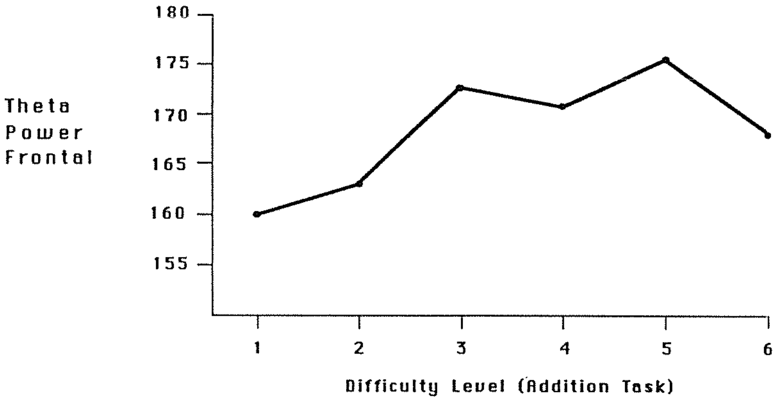

Figure 9: Hemispherically averaged theta power frontal for each difficulty level of the Addition task.

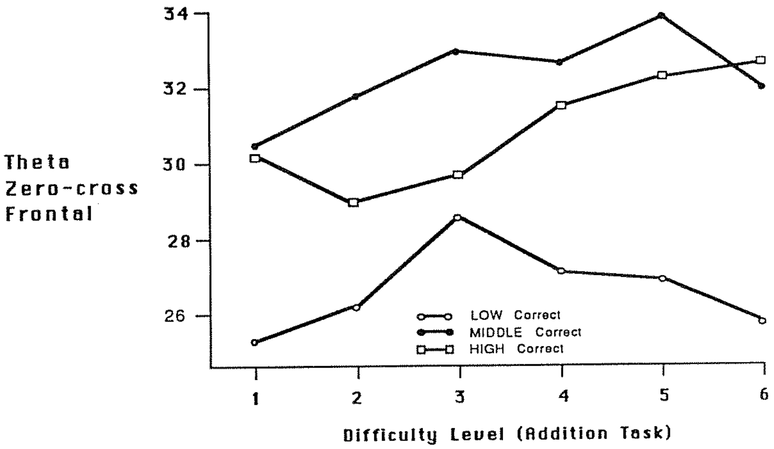

Figure 10: Hemispherically averaged theta (zero-cross frontal) for the three percent correct groups at each difficulty level of the Addition task.

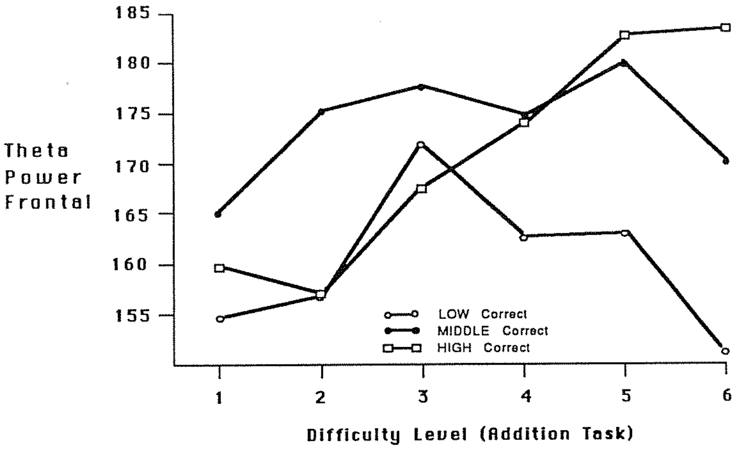

Figure 11: Hemispherically averaged theta (power frontal) for the three percent correct groups at each difficulty level of the Addition task.

Two analyses evaluated whether the ADDITION task indeed varied with difficulty level. First, the subjective responses of difficulty level for each trial with respect to the actual difficulty level were graphed and are shown in figure 6. It demonstrates that as actual difficulty level increased the subjects' estimate of difficulty also increased, with a correlation of r=.755. Second, the subjects' addition answers for each trial were divided by the correct answer and multiplied by 100 to produce a percent-correct estimate for each level of difficulty. As can be seen in figure 7 there is a clear decreasing trend from the easiest level to the most difficult (significant with F=73.34, df=1,50, p <.0000), demonstrating that as difficulty increased the subjects' percent correct scores decreased.

To test whether theta is related to difficulty level by an inverted U shaped function, theta zero-cross and theta power were averaged across hemispheres for each subject at each level of the Addition task. In figures 8 and 9 the results for each measure are plotted. There were significant linear main effects for difficulty level; that is, as difficulty increased theta increased. More importantly, however, there were also quadratic main effects both for theta zero-cross (F=4.57, df=1,50, p <.037) and theta power (F=4.96, df=1,50, p <.031). There were no significant differences among alpha or theta generators.

Although figures 8 and 9 are not inverted U shaped, they are curved. The results may have been influenced by individual differences in abilities to perform the Addition task. The subjects were rank ordered on the basis of their overall performance scores (i.e., percent-correct measure). The top, middle and bottom thirds were divided into 3 groups: high-correct, middle-correct and low-correct performers. ANOVAs (3 groups x 6 levels of difficulty) yielded a significant linear interaction for theta power (F=3.55, df=2,50, p <.036) and a significant quadratic interaction for theta zero-cross (F=4.18, df=2,50, p <.021). High and middle-correct performers maintain a higher level of theta activity than do low-correct performers (see figures 10 and 11).

These theta results were specific to the frontal site. Also, no hemispheric differences were detected.

DISCUSSION

It is well known that individuals differ with respect to the amount of alpha activity they produce. However, the effect of this individual difference has not been investigated in asymmetry research. Low alpha generators did not exhibit EEG asymmetries for tasks designed to induce such asymmetries whereas middle and high alpha generator did. The results suggest that past conflicts in the literature concerning EEG and asymmetry may be due partly to individual differences in EEG. For instance, studies demonstrating hemispheric asymmetries may have had subjects who were predominantly alpha generators. Ornstein, Herron, Johnstone and Swencionis (34) chose subjects on their ability to display alpha asymmetry during a screening session. Subjects displaying "negligible or reversed specialization (p.399)" were excluded. It is likely that subjects passing this test were high alpha generators. On the other hand, studies finding no hemispheric EEG differences may have had a sample of low alpha generators. Our pilot study, mentioned earlier, yielded non-significant asymmetry results when the data from both high and low alpha generators were taken together (N=13). When the two groups were separated a significant interaction was obtained.

It may be argued that the observed asymmetries were due to task difficulty and not hemispheric processing. Indeed figure 1 shows decreasing levels of alpha activity across the tasks, a result often seen for tasks of increasing difficulty (e.g., 45). But in the addition task, a task specifically designed to vary difficulty, asymmetries in alpha activity were not observed, even among middle or high alpha generators. It could also be argued that the focusing and counting tasks contained different stimulus characteristics: specifically, silence during focusing, and verbally presented text during counting. However, it is difficult to imagine a mechanism by which the physical presence or absence of an auditory signal could induce left hemisphere activation without also assuming asymmetrical cognitive processing. Even Jutai's (25) theory that the attentional demands of the right hemisphere may dominate the left during "...interoception, sustained attention, and early (primarily feature extraction and identification) stages of information processing" (p.224), would predict greater activation (i.e., less alpha) in the right hemisphere during the presence of a stimulus. Also the *a priori* ordering of the four tasks (i.e. both versions of Focusing and Counting) did produce a linear relative change in hemispheric alpha activity. That is, adding more 'left hemisphere' qualities to both tasks did produce an effect.

The most important result for this part of the study is that hemispheric shifts in alpha occur in high and middle alpha subjects only. As such, it suggests that the organization of brain activity and its relation to cognition could vary greatly in the population. Such variation could be related to characteristics such as preferred cognitive strategy, personality variables, cognitive skills, etc. Recently De Pascalis and Silveri (5) demonstrated that (alpha) biofeedback regulation of hemispheric asymmetry could augment the amount of alpha asymmetry observed during cognitive processing. This implies that hemispheric asymmetries can to some extent be learned. Furthermore, Townsend, Lubin and Naitoh (43) have found that by sinusoidally modulating light at the alpha frequency, EEG alpha can be augmented and stabilized. They suggested that this method may phase-lock scalp recorded alpha by influencing subcortical alpha generators. Using this technique, it may be possible for low alpha generators to produce larger amounts of alpha. It would then be interesting to determine if these individuals exhibit the asymmetries high and middle generators show. The issue is important because it would help determine whether low alpha generators are, or are not, lateralized.

The behavioural and subjective results from the ADDITION task demonstrate that level of difficulty was successfully manipulated in this study. Concomitant changes in theta activity as a function of increasing difficulty level suggests a relationship between theta and attention. An overall inverted U shaped relation was not observed due to individual differences during task performance. Subjects receiving higher performance scores produce more theta activity when task difficulty increases. Low performance subjects exhibit a peak in theta production at medium levels of difficulty and then show a decline with greater difficulty. It is assumed that theta varied in these individuals due to variable attention requirements, but this interpretation is not conclusive. The difficulty continuum in the addition task confounded attention with cognitive processing. However, indirect evidence supporting an 'attention' explanation is the significant difference in ages among the theta groups (determined during baseline). Assuming that younger and more naive university subjects experience greater anxiety or excitement at the beginning of an experiment they may, as a result, exercise greater attention during the baseline condition. Older, experienced subjects may relax more and therefore produce less theta. This effect was limited to the baseline condition. During task performance no differences among (baseline determined) theta generators were observed, suggesting that theta reflects relatively immediate processes.

Mizuki et al. (29) did not observe frontal midline theta activity in any of their subjects during baseline conditions. Also they found no performance differences between subjects exhibiting theta during the task and subjects not generating theta. Their results however, are likely due to the visual EEG scoring technique they used, which ignored important background theta activity.

In summary, endogenous levels of alpha activity effects the likelihood of detecting hemispheric asymmetries during the performance of tasks presumed to induce such asymmetries. From a methodological perspective this may account for some of the conflicting results in the literature. Differences in frontal theta activity seem to reflect immediate changes in attention, although more research is necessary to conclusively determine whether attention alone or cognitive processing (which includes attention) is the primary correlate.

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APPENDIX A

FOCUSING Task Instructions

1. If the instructions for this task seem vague, don't worry about it. From time to time I'll give you further instructions. There will be periods when I won't be saying anything and you'll be carrying out the instructions. Alright... When you are ready just sense into your body and ask yourself, "How am I inside right now?" and don't answer. Make a space for whatever comes up. Listen to your body. Don't put words on it... Just put all your attention on what is going on inside your body and see how it is.

>>> 45 seconds of silence <<<

2. Perhaps you are listening to several parts of your body. Choose the main one and go with it. Focus all your attention on that one feeling or sensation. You don't do anything except let it come up and be with it.

>>> 45 seconds of silence <<<

3. If this sensation changes or moves, let it do that. Whatever it does, follow the feeling and pay attention to it.

>>> 45 seconds of silence <<<

4. Now take what is fresh or new in the feel of it <u>now</u>, and as you feel it, try to find a word or two, or a picture which captures what your present feeling is all about. The word or picture is a handle on your experience and doesn't have to make sense to anyone but you.

>>> 45 seconds of silence <<<

5. Now match the handle to the feeling and see if the work or picture is just right in capturing your feelings. Change the image to match the feeling till they are a good fit.

>>> 45 seconds of silence <<<

STRUCTURED FOCUSING Instructions

1. For this task you'll be asked to direct your attention inward, to specific parts of your body. At each step I will direct you to which body part you should attend. There will beperiods when I won't be saying anything and you'll be carrying out the instructions. At the end of these periods I'll ask how successful you were in attending to that body part. Try not to let your mind wander. Try to 'experience' that body part. Remember, the purpose of this task is to focus on specific parts of your body and then tell me how successful you were, after I ask you. Alright... Relax and keep your eyes closed. Take a few deep breaths... When you are ready, just sense into your body and locate both your ankles. Focus all of your attention on your ankles. Ask yourself "How do they feel?" but don't answer. Just sense them.

>>> 45 seconds of silence <<<

2. On a scale from 1 to 5 where 1 is 'not successful' and 5 is 'very successful', rate your ability to focus on your ankles. (SUBJECT'S RESPONSE)... Now focus all of your attention on both your knees... Locate one feeling or sensation in them and go with it.

>>> 45 seconds of silence <<<

3. On a scale from 1 to 5 where 1 is 'not successful' and 5 is very successful, rate your ability to focus on your knees. (SUBJECT'S RESPONSE)... Now go from your knees to your stomach. Again locate one feeling or sensation. If this sensation changes or moves, let it do that. Whatever it does, follow the feeling and pay attention to your stomach.

>>> 45 seconds of silence <<<

4. On a scale from 1 to 5 where 1 is 'not successful' and 5 is very

successful, rate your ability to focus on your stomach. (SUBJECT'S REPONSE)... New, focus your attention on your heart. Take what is fresh or new in the way your heart feels now, and focus on it.

>>> 45 seconds of silence <<<

5 On a scale from 1 to 5 where 1 is 'not successful' and 5 is very successful, rate your ability to focus on your heart. (SUBJECT'S RESPONSE)... From your heart, switch your attention to the inside of your head. Try to visualize and feel the inside of your head.

>>> 45 seconds of silence <<<

6. On a scale from 1 to 5 where 1 is 'not successful' and 5 is very successful, rate your ability to focus on your heart. (SUBJECT'S RESPONSE).