Forced unilateral nostril breathing affects lateralized cognitive functions
by David Phillip Arnott

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Psychology
Montana State University

Abstract:
Research in ultradian rhythms has shown a great many 70-120 min cycles in both physiological and cognitive variables. Of special interest is research pointing to an oscillation in hemispheric dominance. This research reports both electroencephalographic (EEG) data and performance on the presumably lateralized performance measures of verbal and spatial performance. The introduction of research correlating a nasal breathing cycle to EEG-measured dominance became of considerable interest when another study showed forced nostril breathing to unilaterally affect EEG. The possibility that verbal and spatial performance can be affected by forced unilateral nostril breathing is the topic of this thesis. A total of 60 subjects were given verbal and spatial performance tests after a period of forced nostril-breathing. This study reports a significant interaction of sex, nostril, and test. Males showed an ipsilateral effect to forced nostril breathing on both verbal and spatial performance, whereas females showed a contralateral spatial effect.

FORCED UNILATERAL NOSTRIL BREATHING AFFECTS LATERALIZED COGNITIVE FUNCTIONS

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Date May 31, 1985

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ABSTRACT

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INTRODUCTION

During the last twenty years a subcategory of the research on circadian rhythms has developed in which biological rhythms that oscillate at less than twenty-four hours (ultradian) are studied. Some of the cyclical changes studied are those yielding differences in cognitive measurements.

The research discussed here concerns ultradian cycles within the range of 70-120 min. Most of the research is aimed at approximately a 96-min cycle which appears to be largely theoretical. Some of the variables studied that oscillate with this cycle are: Gastric constrictions, oral activity, visual detection errors, spiral after-effect, rapid eye movements during sleep and sensory deprivation, psychotic episodes during sleep deprivation, heart rate, fantasy, spatial and verbal performance, and interhemispheric electrocortical arousal (see Kripke, 1982, for a review).

The research into periodicities during sleep has been the most extensive in terms of periodicities that affect cognition. Rapid Eye Movement (REM) cycles during sleep follow a fairly consistent 90-100 min cycle with a mean of 96 min (Bakan, 1978-1979). This figure reflects the onset-to-onset interval of the REM cycle, not its duration. REM sleep is characterized by a high level of elecrocortical arousal, extremely low muscle tonus, rapid eye movements, and the highest threshold for awakening due to external stimulation. Persons awakened from REM sleep have the highest propensity for reporting strong visual imagery, emotionally laden content, and strong symbolic psychological content. Persons awakened from non-REM sleep (characterized by delta and theta brain waves, higher muscle tonus, and absence of eye movements) have a greater tendency to report "thought-like mentation" which is usually undirected, drifting, and displaying the property of irrational or illogical interconnection.

Reported activity during non-REM sleep is frequently described as "mentation" and "sub-vocal" indicating language functions, whereas REM activity is usually reported as involving imagery, emotions, and "primary process" activity. Bakan (1978-1979) speculates that the different sleep stages are related to hemispheric functioning. Sub-vocal mentation and language are strongly associated with left hemispheric functioning; whereas imagery, emotions, and other primary mentation are strongly associated with the right hemisphere. This speculation suggests that there is a dominance oscillation between the hemispheres during sleep which would be indicated by electroencephalographic (EEG) activity. Research in the area has shown highly correlated brain waves between hemispheres during non-REM sleep and very little correlation during REM sleep (Burdick, Lazlo, & Goldstein, 1968). Correlation between hemispheres is not considered a measure of dominance but may be an indicator of inter-cerebral communication.

Periodic oscillations in consciousness during sleep are somewhat easier to detect on the biological level (in terms of EEG, eye movements, and muscle tonus) but relating the biological changes to cognitive functions is tenuous. Waking subjects to report cognitive processes yields valuable information, but the problem still exists that the subject is really reporting an interpretation of the previous state from a completely different one. When the subject is "in" either REM or non-REM sleep he or she is unable to report.

Oscillations in cognitive functions during waking states have been measured. Some of the variables that have been measured are perceptual motor skills, verbal and spatial performance, and fantasy. Kleitman (1969) first proposed a 24-hr cycle based on vigilance and perceptual-motor skills. Perceptual-motor performance peaks in accuracy and speed at around 1:00-2:00 p.m. and reaches its lowest levels at 1:00-3:00 a.m. This cycle reflects physiological and nervous system arousal levels and, especially, quantitative measures of alertness. Kleitman also reported that in addition to the 24-hr cycle there is a 90-100 min cycle affecting the same set of performance measures. Kleitman named this cycle the Basic Rest Activity Cycle (BRAC).

Klein and Armitage (1979) administered perceptual-motor performance tests to subjects every 15 min for a total of 8 hr. In addition to the performance measures that Kleitman (1969) had tested, Klein and Armitage also included the variable of spatial versus verbal performance. Their results showed that performance on both measures followed a 96-min cycle. The most striking aspect of their data is that, in accordance with their thesis, the performance peaks for spatial and verbal tasks are 180 degrees out of phase. In other words, dominance on spatial and verbal tasks seems to oscillate with spatial performance higher for one half of the cycle and then verbal for the other half of the cycle.

Kripke and Sonnenschein (1978, Experiment 1) tested subjects for fluctuations in qualitative cognitive content. Subjects deprived of normal environmental stimulation (but not subjected to complete sensory deprivation) were alerted every 5 min over a 10-hr period and asked to report a brief summary of their ongoing mental processes. Five days later subjects rated their own responses on a 5-point scale ranging from <u>Vivid dreamlike fantasies</u> to <u>Present-time perceptual scanning</u>. The operational function of the scale is described as "Stimulus Independent Mentation versus Stimulus Dependent Mentation." Their results showed a significant predisposition towards fantasy on a 90-min cycle. In a second experiment, Kripke and Sonnenschein (1978) found the same predisposition towards fantasy in the work setting, but at a much lower level of statistical significance. The apparent connection between Kripke and Sonnenschein's finding and the sleep cycle suggests that the fantasy cycle is a daytime extention of the REM cycle. This has not been empirically verified, however. Few of the daytime cycles have been found to be extensions of the sleep cycle.

The ultradian cycles that have been found to be an extension of the sleep cycle are electrocortical patterns. Globus, Destrooper, and Broughton (cited in Sterman, Lucas & McDonald, 1972) found a 96-min oscillation between slow and fast wave EEG activity in cats. Sterman et al. later found this cycle to be in phase with the REM cycle.

Electrocortical rhythms have also been demonstrated in humans. Goldstein, Stoltzfus, and Gardocki (1972) reported that brain wave amplitude is greater over the left cerebral hemisphere during non-REM sleep and greater over the right hemisphere during REM sleep. Manseau and Broughton (1984) also reported an in-phase 16 cycle per day (90 min) frequency relationship between the cerebral hemispheres over a 10-hr period. A "frequency relationship" can best be described as an oscillation from beta to alpha and theta activity. Beta is considered an indication of cortical arousal and alpha an indication of "idling." The Manseau and Broughton study supports the Klein and Armitage (1979) results indicating an oscillation in inter-cerebral dominance by yet another measure. Other EEG studies report 70-110 min cycles in EEG delta activity (Kripke, 1972) and EEG alpha (Kripke & Sonnenschein, 1978).

When interpreting EEG data it is important to understand that frequency data and amplitude data are not the same and should not be assumed to simply indicate cortical activation without qualification. Frequency refers to cycles of voltage change (positive to negative) per second. Amplitude refers to total voltage generated over time regardless of frequency. (For a more extensive analysis of this topic, see the discussion section.)

Research into periodic oscillations has also studied the topics of relative nare efficiency and forced nostril breathing. This represents more empirical investigations of the Yoga breathing traditions. The practice of Pranayama Yoga within the larger disciplines ot Yoga concentrates largely on breathing techniques, with a particular emphasis on nasal breathing. The morning exersises involve forced-nostril breathing in one nostril for a set number of breaths and then a shift to the other nostril. Often the exercises go in patterns, a typical pattern being: Left (25 breaths); Right (25); Left in, right out (25); Right in, left out (25); and so on. The exercises are founded on the belief that the two major "spiritual energies" (Ida and Pingala) enter through the two nostrils in a polar fashion (Vishnudevananda, 1960). Descriptions of the influence of the two energies on the mind can be loosely interpreted as the functions now attributed to the seperate hemispheres, although the ideas may have been formed as long as 2000 years ago. Energy entering the right nostril is described as "earth bound" and that which holds matter and events in place. Energy entering the left nostril is described as "spirit bound" or the influence that brings creativity, visions, and spiritual union. Texts on Yoga such as Vishnudevananda's assert that during the day, air intake normally oscillates between the two nostrils and that this reflects the give and take of two primary forces in nature. To some extent these beliefs may be a remarkable intuition about what is now thought to be physiological functioning.

Ornstein (1977-1978) reported a study in which recording electrodes were placed in the right and left amygdalas of three epileptics during surgical commissurotomy. He found that unilateral breathing produced "marked ipsilateral driving of the amygdala" (pp. 103-109), an organ to which the olfactory system is directly linked and which has been implicated in sexual-aggressive behavior as well as cortical arousal. Lonsdale (1983) also reported high amplitude EEG spikes to olfactory stimulation under deep hypnosis.

Werntz, Bickford, Bloom, and Shannahoff-Khalsa (1983) reported testing the assumption that air intake oscillates between nostrils in a cycle of 90-100 min. The phenomenon of an oscillation in relative nare efficiency was reported by Kaiser as early as 1895 (cited in Werntz, et al.) and has since been verified by Keuning (1968). This oscillation has been found to be regulated by sympathetic and parasympathetic branches of the autonomic nervous system in both humans (Keuning, 1968; Stoksted, 1952) and animals (Eccles & Lee, 1981). Werntz et al. (1983) also reported greater EEG amplitude over the left hemisphere when air intake has shifted to the right nostril and stated that this effect exists in a phase relationship. In other words, EEG amplitude is higher in the left hemisphere when nare efficiency (easier to breath through) is highest in the left nostril and vice versa for EEG amplitude in the right hemisphere. A subsequent study (Shannahoff-Khalsa, Bickford, & Werntz, 1984) tested the hypothesis that "Active alteration of the nasal cycle by forced breathing . . . can produce significant changes in the cortical activity of the EEG, such that the hemisphere contralateral to the previously congested nostril becomes the dominant one" (pp. 1-27). In this study they reported positive results in six subjects.

Because cerebral dominance should be indicated by changes in verbal and spatial performance as well as in EEG activity, the present study was designed to test the hypothesis that forced-nostril breathing can unilaterally drive specialized hemispheric functioning as revealed by spatial and verbal tests. This introduction has surveyed reports of in-phase oscillations in both EEG and verbal and spatial performance which indicate a cycle of inter-cerebral dominance. It has also reviewed evidence that the EEG cycle is correlated with a nare efficiency cycle and that EEG-measured dominance can be modified by forced-nostril breathing. This study proposes that there will be a shift in verbal and spatial performance with forced-nostril breathing. Subjects who breathe exclusively through the right nostril for 5 min are expected to show higher scores on verbal performance and lower scores on spatial performance than those breathing exclusively through the left. In other words, a test by nostril interaction is expected. The present study should also replicate the research indicating a sex by test interaction with males performing higher, overall, on spatial tests and females higher on verbal tests (Springer & Deutsch, 1981).

Previous research in the area of nostril breathing and cognitive oscillations has not examined variables separated by sex, so no such interaction with was expected. However, based on the literature reporting less lateralized cognitive abilities in females (Springer & Deutsch, 1981) it was expected that females would be affected to a lesser degree by the experimental conditions than males would be.

METHOD

Subjects and Design

An initial sample of potential participants was obtained from the population of students attending three introductory psychology courses at Montana State University. The participants were volunteers whose cooperation was obtained through the promise of experimental credit.

A total of 60 individuals, 30 males and 30 females, was studied. Individuals were screened for handedness; only right-handed persons were used. The design was a 2 x 2 x 2 factorial with two between-subjects variables (nostril and sex) and one within-subjects variable (verbal versus spatial performance). A total of 20 subjects was randomly assigned to the left nostril (open) condition, 20 to the right (open) condition, and 20 to an offset satellite control condition with no restrictions on breathing. An equal number (10 per condition) of each sex was represented in each of the three conditions. The order of test administration (verbal or spatial test taken first) was block randomized, as was the order of nostril condition.

Materials

Subjects were tested in a small room with six chairs. The spatial test utilized was Vandenberg and Kuse's (1978) paper-and-pencil adaptation of Shepard and Metzler's (1971) mental rotations task in which a three-dimensional graphic block design is compared with four highly similar designs. Two of the four choices have the same geometric structure as the original but are rotated in space, sometimes as much as 180°. The task is to rotate the original mentally and try to "fit" it with the correct two of the four choices. This task is believed to involve largely spatial abilities, although the task can be solved deductively at a much slower pace.

The verbal task was a consonant-vowel matching task designed for this experiment. In this task subjects were presented with a key word with either five or six letters, and four alternative words with the same number of letters. The task was to find the one word of the four alternatives with the same vowel-consonant sequence as the key word (Example: CIDER * APPLE, TABLE, RIPEN, QUICK; the correct answer is RIPEN). This task is considered to employ mainly left hemispheric abilities in both verbal (consonant and vowel distinction, letter recognition) and linear sequencing modes.

The spatial task consisted of 20 questions with a total of 40 correct answers. The verbal task had 20 questions with 20 correct answers.

Procedure

Participants were seated in a common waiting room upon their arrival. There they were requested to fill out a voluntary subject participation statement. The experimenter watched their handwriting to ensure that all subjects were right-handed. Left-handed writers were dismissed. After the subjects were seated they were read the following statement:

> The experiment you are involved with tests the effects of breathing through one nostril on performance measures. During the first five minutes of the experiment you will be asked to block your right [left] nostril with cotton and breathe through the other for a five minute duration. During this period close your eyes and relax. Please try not to breathe through your mouth or other nostril until I tell you to. Feel free to make yourselves comfortable in your chairs and clear your nostril with the tissue provided as often as you feel necessary. At the end of five minutes I will give you two tests to fill out which you should do to the best of your ability. During this time please keep your mouth closed until the experiment is finished. If at any time during the experiment you feel you have to leave, please oblige yourself.

Then experimental subjects were given tissues to clear their nostrils and were told to begin. Control subjects were instructed to sit for 5 min with their eyes closed and were then given the tests. No mention of breathing or nostrils was made to control subjects. At the end of 5 min the experimenter asked subjects to perform the first test and assisted them with pencils, facial tissue, etc. Subjects were given 2 min to read the instructions for each test--this was necessary since the spatial test has two pages of detailed instructions and sample questions--and 2.5 min to work on each test. The experimenter remained in the room to time the three phases of the experiment and to answer any questions.

RESULTS

The total number of correct answers on each test was calculated. Spatial test scores were aggregate since there were two correct answers per question. One point was given if only one of the two choices was answered correctly. The verbal task was non-aggregate with one correct answer per question.

Results of evaluation of assumptions of normality, linearity, and multicollinearity of the data were satisfactory following deletion of a single multivariate outlier.

An analysis using SPSS MANOVA reveals several significant multivariate effects without the control condition included. First, the spatial task (M = 8.9) is significantly more difficult than the verbal task (M = 12.9), $F(2, 23) = 10.13$, $p < .001$. Second, subjects also performed in accordance with the expected multivariate effect of sex, with males scoring relatively higher on the spatial task and females scoring relatively higher on the verbal task, $F(2, 53) = 10.37$, $p < .001$ (see Figure 1). This multivariate effect validates the use of the particular spatial and verbal tests in the present study, because it replicates other well accepted research results. Because the effect is stronger than expected it may also indicate that the tests used in this study are more specific measures of lateralized cognitive functioning than other commonly used tests. Third, the predicted main effect of nostril is not significant, $F(2, 25) = 2.17$, $p > .05$.

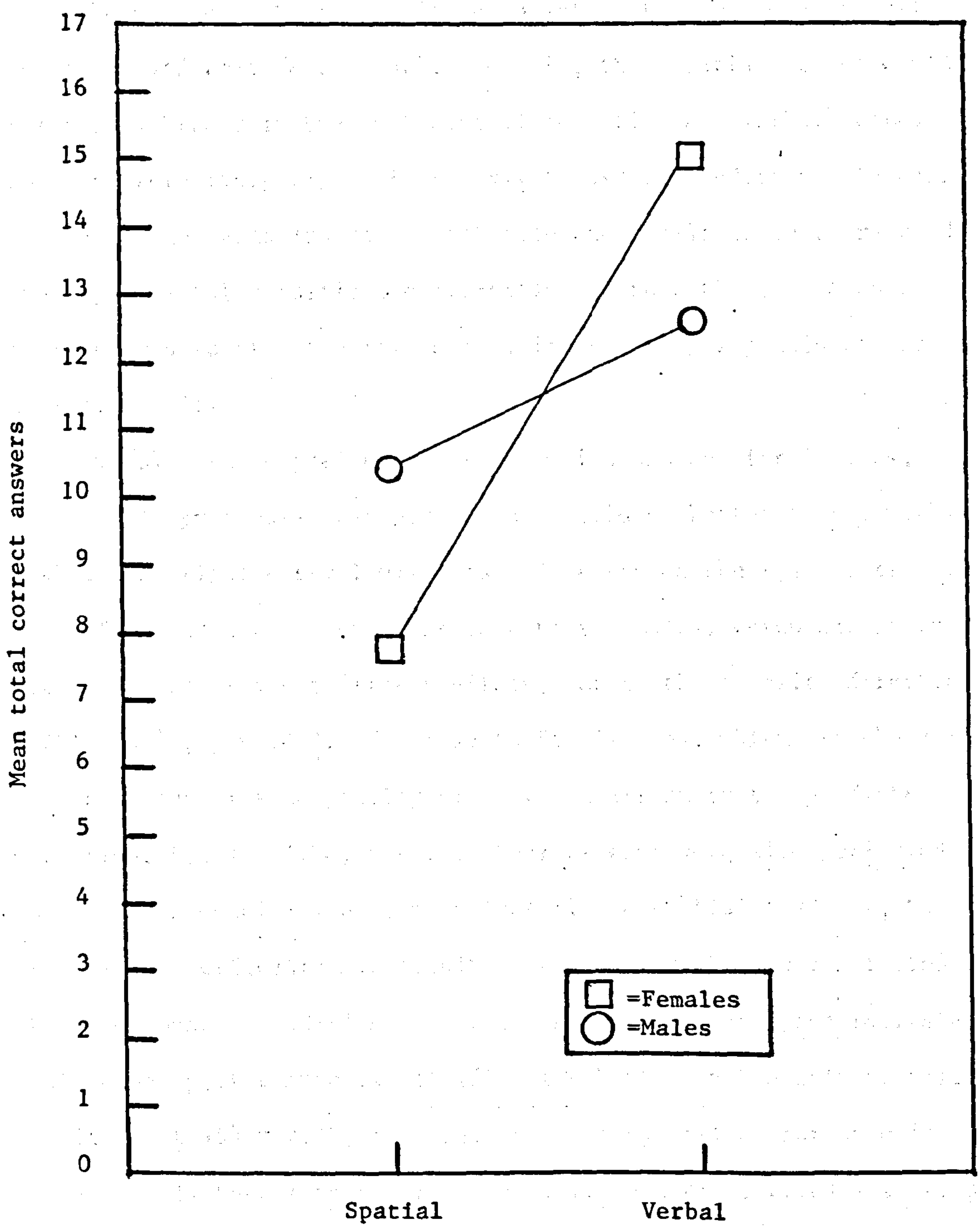

Figure 1. Spatial and verbal performance scores for males and females.

The main hypothesis predicted an interaction between nostril condition and test performance; that is, that spatial scores would be relatively higher in the left nostril condition and verbal scores would be relatively higher in the right nostril condition. An observation of the means indicates that male and female subjects reacted to the experimental conditions differently and that the summation of their scores to test the main effect is canceling any main effect of nostril condition.

Two planned comparisons, one for males and one for females, tested the hypothesis that performance would be better on the verbal task if the right nostril was open and better on the spatial task if the left nostril was open. The results for males, which are shown in Figure 2, reveal a significant effect, but in the opposite direction, $\underline{t}(36) = 3.40$, $\underline{p} < .002$. The results for females, which are shown in Figure 3, reveal a marginally significant effect in the predicted direction, $\underline{t}(36) = 1.30$, $\underline{p} < .2$. Four $\underline{t}$-tests were also performed, one for each combination of test (verbal and spatial) and sex, to determine specifically how cognitive performance had been affected by the experimental conditions. For the males these analyses indicate that verbal performance is significantly better in the left nostril condition, $\underline{t}(16) = 2.31$, $\underline{p} < .05$, and that spatial performance is significantly better in the right nostril condition, $\underline{t}(18) = 2.92$, $\underline{p} < .01$. For females the corresponding analyses indicates that spatial performance is better in the left nostril condition, $\underline{t}(16) = 2.18$, $\underline{p} < .05$, but that there is no difference between verbal scores in the two nostril conditions, $\underline{t}(16) = .068$, $\underline{p} > .05$.

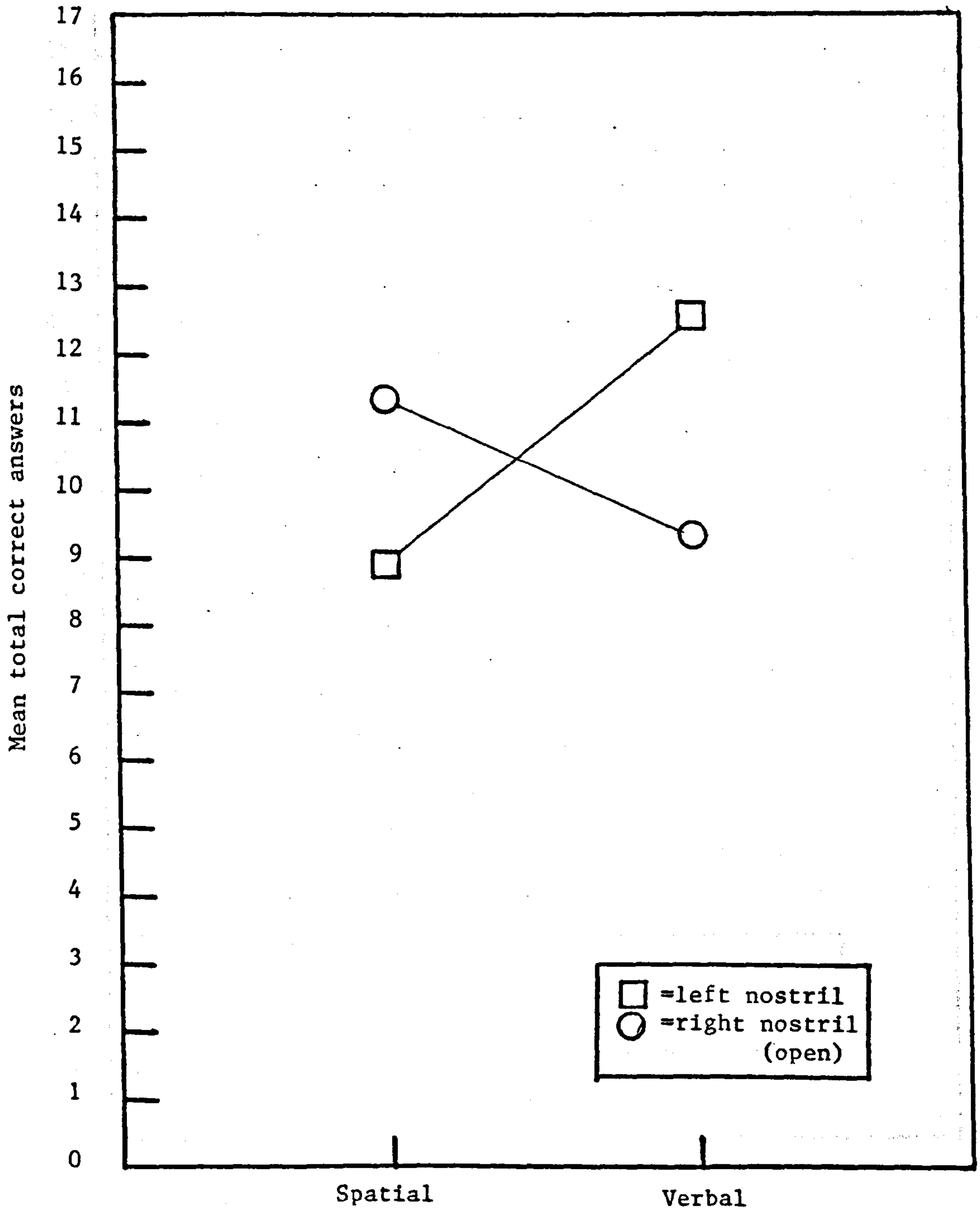

Figure 2. Spatial and verbal performance scores for males between experimental conditions.

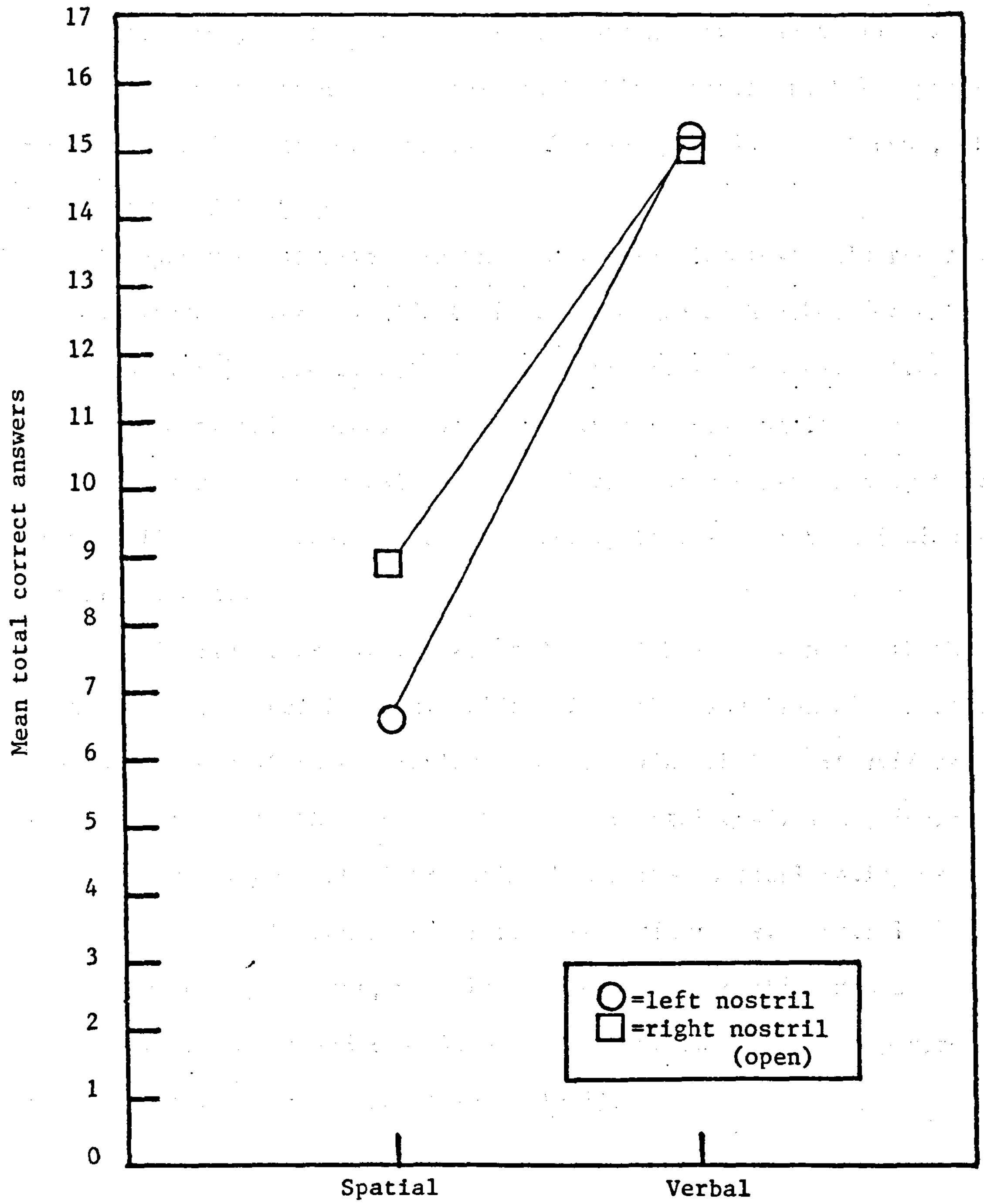

Figure 3. Spatial and verbal performance scores for females between experimental conditions.

A three-way multivariate analysis (Sex X Test X Nostril) was done to test the assumption that males and females reacted to the experimental conditions in opposite ways. The analysis is significant, $F(1, 25) = 11.40$, $p < .002$.

A separation of main effects from interaction residuals reveals the magnitude of various effects in relation to each other (Rosenthal & Rosnow, 1983). The effects are, in order of importance, differences between the overall verbal and spatial test scores, differences between the sexes on verbal and spatial test scores, the sex by test by nostril interaction, and the nostril by test interaction (which was not significant).

Originally no prediction was made about how the control (both nostrils open) condition would differ from the experimental conditions. The control condition was included to determine whether it differed significantly from the range of the experimental conditions, indicating that forced nostril breathing had either a facilitating or a deleterious effect upon measures of task performance. Control condition means, however, were between nostril condition means on spatial performance and roughly equivalent to the highest experimental means on verbal performance (see Table 1).

Table 1

Mean Performance in Control Condition

Sex	Test: Spatial	Test: Verbal	M
Male	10.6	12.6	11.6
Female	7.7	15.3	11.5
M	9.1	14.4	11.6

DISCUSSION

The present results indicate that forced-nostril breathing has a strong effect upon the verbal and spatial measures of cognitive performance in three ways. When breathing through the right nostril for five minutes prior to taking the test, males show higher scores on the spatial task than when breathing through the left nostril. They also show higher scores on the verbal task when breathing through the left nostril than when breathing through the right nostril. Females score higher on spatial performance when breathing through the left nostril but show no differences in verbal scores in the two nostril conditions. Based upon the assumptions in the literature that spatial processing is lateralized in the right hemisphere (in right-handed subjects) and that verbal processing is lateralized in the left hemisphere, these findings indicate that asymmetric hemispheric dominance in males can be significantly affected by forced-nostril breathing. Spatial processing can also be affected to a lesser extent in females. Perhaps the most surprising finding in these data is the apparently inverse reaction to the experimental conditions on spatial processing between the sexes. Both sexes showed significant differences in spatial performance between nostril conditions. Spatial scores for males, however, are higher in the right nostril condition, whereas for females they are higher in the left nostril condition. Also interesting is the fact that the male verbal scores are significantly affected by the nostril conditions, whereas females show no effect whatsoever. Assuming, once again, that spatial processing is lateralized in the right hemisphere, the male data indicate that relative cerebral dominance is produced by forced-nostril breathing in the ipsilateral nostril. The female data indicate that relative cerebral dominance is produced in the contralateral nostril.

Thus, significant measured effects are invoked by forced unilateral nostril breathing, but not in the way originally predicted by this thesis or by the conclusions drawn by Werntz et al. (1983) and Shannahoff-Khalsa et al. (1984). Originally it was predicted that performance on spatial tasks would be better in the left nostril condition than in the right nostril condition and vice versa for verbal performance. No differential predictions were made for the two sexes. Essentially a contralateral effect was predicted based on the assertion that "relatively greater integrated EEG value in one hemisphere correlates with predominant airflow in the contralateral hemisphere" (Werntz et al., 1983, p. 41) and the assertion that "forced nostril breathing produces a relative increase in EEG amplitude in the contralateral hemisphere" (Shannahoff-Khalsa et al., 1984, p. 12). The discrepancy between the prediction and the present findings may be the result of the misinterpretation by both Werntz et al. and Shannahoff-Khalsa et al. of their EEG data, combined with their use of largely male subject populations in one study. (No indication of subject sex is given in the forced-nostril experiment.) Both studies reported using EEG amplitude as the measure of hemispheric activation. Although interpretation of EEG data is considered difficult, one of the most basic assumptions in the field is that slow wave (e.g., alpha or theta) activity is an indication of "idling" or non-activation and is positively correlated with greater amplitude. Higher frequency (i.e., beta) waves are positively correlated with lower levels of absolute amplitude, which leads to the assumption of "Low Voltage Activity for the alert or aroused subject" (Thompson, 1975, p. 122). In an almost identical conflict of interpretation, Galin and Ornstein (1972) reported that EEG "power" (total amplitude generated over time) was greater in the right hemisphere during verbal tasks than during spatial tasks, leading them to report a conclusion diametrically opposed to the research paradigms on hemispheric asymmetry. Springer and Deutsch (1981) conclude that "an analysis of Galin and Ornstein's results showed that the predominant rhythm in their EEG records was alpha. Since alpha reflects a resting brain state, less alpha activity would be expected to follow greater involvement in a particular task" (p. 87).

Werntz et al. (1983) reported that of their 19 subjects, 14 were male, 2 of the 5 females were left-handed, and 2 of the remaining 3 right-handed females yielded some of their least significant data. "The clinical evidence pointing to greater bilaterality in left handers" (Springer & Deutsch, 1981, p. 85) would also fit the present data showing an ipsilateral effect in males. Had Werntz et al. used a predominantly right-handed female subject population, the present data suggest that their conclusions would have been entirely different.

To some extent Werntz et al. may have been aware of the discrepancy between amplitude and activation as they state that "increased amplitude has generally but not exclusively been considered a reflection of mental inactivity. Therefore, future correlative studies of the nasal cycle in relation to spatial and verbal performance is required to resolve this question" (p. 42).

Anatomically, the olfactory system is an anomaly as the only perceptual system with primarily ipsilateral input. Some contralateral pathways have been mapped through the anterior commissure to the olfactory bulbs. These are believed to originate in the contralateral olfactory bulb "and in all probability, other areas as well" (Netter, 1983, p. 27). These contralateral pathways are afferent and inhibitory and cannot be regarded as "input" except in the way they affect input.

The present research shows clearly that males and females react quite differently to the two cognitive tasks used here. Males and females reacted inversely to the nostril conditions on spatial processing, whereas females were not affected by the nostril conditions on verbal performance at all. The latter phemomenon is easier to account for. Research by Landsdell (1962) and McGlone (1978) comparing verbal and spatial performance after unilateral brain damage concluded that such abilities are much less highly lateralized in females than in males. Based on these data a prediction might be made that females would simply be affected by the present experimental conditions to a lesser degree. Statistically this holds in the present study but does not account for the fact that females react to the experimental condition on spatial processing opposite from males. Spatial processing in females may depend more upon inter-cerebral communication than it does in males.

Shannahoff-Khalsa et al. (1984) concluded that "these results suggest the possibility of a non-invasive approach in the treatment of states of psychopathology where lateralized cerebral dysfunction have been shown to occur" (p. 9). The study makes no specific recommendations as to which nostril to breathe through for specific disorders. Their conclusion--"on the whole we find a contralateral effect on EEG activity" (p. 9)--and their summary of various lateralized dysfunction disorders suggests that imbalances in cerebral dominance could be rectified by forced nostril breathing in the nostril ipsilateral to the dominant hemisphere. The present research suggests that in males such a practice is seriously ill-advised and in females it may have negligible effects.

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