Bilateral Finger Temperature Differences

under

Hemisphere-Specific Cognitive Activation

by

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Thesis

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Abstract

Bilateral finger temperature differences in response to hemisphere-specific cognitive activation were investigated. Sixty, right-handed, introductory psychology students were randomly assigned to the experimental and control conditions. The schedule for the experimental group was: baseline, numerical task, vocabulary task, spatial manipulation, musical memory and final baseline. Each phase was 4 minutes in duration and tasks were presented in a randomized order with a rest period between each task. For the control group finger temperatures were recorded while the subjects relaxed with eyes closed for 36 minutes.

The results showed that hemisphere-specific cognitive activation did not produce lateralized differences in temperature responses. Under stress both hands exhibited similar decreases in temperature. However, for the experimental subjects the right hand was consistently warmer than the left while for control subjects the reverse was true. This finding was interpreted as evidence for right hemisphere activation in emotion.

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The purpose of this thesis is to examine bilateral finger temperature differences in response to differential hemispheric activation. Although the two hemispheres at times function as a unit, certain tasks -- such as those tapping verbal, numerical, musical or spatial skills -- engage primarily one hemisphere. It has been shown that bilateral differences exist in electrodermal activity in response to activation of either hemisphere. However, other lateralized psychophysiological indices, such as hand temperature, have not been thoroughly studied to date.

Hemispheric Specialization

Since the time of the ancient Greek physicians, researchers have been interested in the symmetry between the right and left sides of the body. Descartes noted that the two halves of the brain were identical in anatomical structure with the pineal gland being the only unduplicated structure. Researchers in more recent times became interested in whether brain function was also duplicated in the two hemispheres or whether each hemisphere served unique purposes.

Language and mathematical activity -- which employ a logical and analytical mode of problem solving -- are primarily localized in the left cerebral hemisphere. The right hemisphere operates in a global or gestalt mode utilized in activities dealing with spatial manipulation, musical appreciation and emotion. Studies investigating the above can be categorized as follows:

(1) commissurotomy studies

(2) lateralized input studies

(3) mapping of function studies

(4) lateralized eye movement studies.

Subjects who have had their corpus callosum surgically severed provide an opportunity to study the function of each hemisphere in isolation from the other. The left hemisphere is primarily suited for language, calculation, arrangement in order and logic whereas the right hemisphere is superior to the left in spatial perception, recognition of maps and musical appreciation (Gazzaniga and Sperry, 1967; Young, 1978). Gazzaniga and Hilyard (1971) examined the right hemisphere's capacity for speech in commissurotomy patients disconfirming previous studies by finding that the right hemisphere has little or no ability to perform syntactic functions.

Lateralized input studies utilizing such techniques as dichotic listening and tachistoscopic presentations of stimuli have been a source of information regarding hemispheric function in an intact brain. Dichotic listening studies have shown a right ear (left hemisphere) advantage for language and a left ear (right hemisphere) advantage for musical stimuli (Kimura, 1973; Sidtis and Bryden, 1978). Umilta, Bagnara and Simion (1978) found a left visual field advantage for complex geometric figures presented tachistoscopically.

Mapping of function in normal subjects has also been studied by various other techniques. Risberg, Halsey, Wills and Wilson (1975) used the Xenon inhalation technique -- a replacement for the Wada test -- to study bilateral simultaneous regional cerebral blood flow. They used verbal and spatial tasks and manipulated subject motivation by varying monetary reinforcement. In motivated subjects, blood flow increased to the left hemisphere for verbal tasks and increased to the right hemisphere for spatial tasks. The unmotivated subjects showed similar patterns but the differences were not statistically significant.

Electroencephalograph (EEG) data have provided support for hemispheric specialization. Doyle, Ornstein and Galin (1974) exposed subjects to language, mathematical, spatial and musical tasks resulting in asymmetrical EEGs. Galin and Ellis (1975) recorded flash evoked potentials and background EEG from the left and right temporal and parietal areas while subjects engaged in verbal and spatial tasks. Both records showed asymmetries reflecting hemispheric specialization for the tasks presented.

Reflective or lateral eye movements (LEMs) have been used as another tool to study hemispheric specialization. It is assumed that the hemisphere being activated is contralateral to the direction of gaze. Galin and Ornstein (1974) gave verbal and spatial problems to lawyers and ceramicists. In both groups of subjects the verbal task produced more rightward and more downward moves than did the spatial task. The fact that more upward deflections were produced by the ceramicists went unexplained and no doubt contributed to the statement made by the authors that LEM data is often conflicting because it is a poorly defined measure. Several studies have looked at the effects of psychological stress on hemispheric activation as indicated by LEMs. More frequent leftward deflections suggest activation of the right hemisphere (Schwartz, Davidson and Maer, 1975; Tucker, Roth, Arneson and Buckingham, 1977).

A comprehensive critique of LEM studies has been carried out by Ehrlichman and Weinberger (1978). They stated that interpretation of LEM studies is clouded by inconsistencies in experimental situations and scoring of eye movements. Some of the data does not fit the hemispheric activation theory and goes unexplained. For example, questions presumed to engage the right hemisphere tend to produce upward deflections and stares. The significance of vertical eye movements in relation to hemispheric asymmetry has not been determined. Ehrlichman and Weinberger conclude that further research is needed to define the relationship between the direction of eye deflection and cognitive-affective processes. Without a thorough understanding of this relationship and a consistent and accurate method of scoring responses, LEMs cannot be relied upon to make inferences about hemispheric activation.

Hemispheric Interaction

With continuing research the absolute dominance of one hemisphere over a specific function is coming into question. Luria (1966) noted that the degree of dominance of the hemispheres varies among subjects and among functions. Galin (1979) suggested that there are several ways in which the hemispheres can interact, namely:

(1) by alternating,

(2) by the dominant hemisphere utilizing some functions of the other hemisphere and inhibiting the rest,

(3) by the dominant hemisphere totally inhibiting the other hemisphere, and

(4) by both hemispheres being fully active and integrated through resolution by speed or by motivation.

The interaction of the hemispheres in emotion is considered by Tucker (1981) and it is suggested that the left hemisphere serves as a censor in personality by controlling and inhibiting the loose ideation of the right hemisphere.

Approaching matters from a different perspective, Marshall (1973) suggested the need to tease out the nature of individual differences in approaches to cognitive, hemisphere-specific tasks. Neiderbuhl (1976) attempted to show that hemispheric asymmetries do not depend upon the inherent nature of tasks used but upon the strategy a subject takes in dealing with them. The stimulus materials were kept constant while the subject's cognitive strategy was varied through the nature of instructions given prior to stimulus presentation. The results confirmed the hypothesis that the approach a subject takes in solving a task determines which hemisphere is activated or if the two function in a unitary fashion.

Sex Differences in Cerebral Organization

Studies have been conducted comparing males and females on performance of various cognitive tasks to determine the extent of hemispheric activation. Witelson (1976) gave children a spatial task and found that males at 6 years of age show right-hemisphere specialization whereas females -- age 6 to 13 -- evidence bilateral representation. Adult females also show less hemispheric functional asymmetry (Bakan, 1974). The results, however, are not totally unequivocal as Kimura (1973) could find no evidence that males and females differ in lateralization when presented with a verbal task.

Ray, Morell, Frediani and Tucker (1976) looked for sex differences using left and right hemisphere tasks that were more typical of 'real life'. They asked subjects to construct sentences, multiply, listen to music and visualize according to given instructions. EEG recordings taken from the temporal lobes showed sex differences in hemispheric functions. These results are further supported by Tucker (1976) where an EEG analysis showed right hemisphere specialization in males for a synthetic, visuospatial task and both hemisphere engagement in females during analytic and vocabulary tasks. McGlone (1980) presented a survey of the research examining brain asymmetry and sex differences with the conclusion that in light of the controversial nature of the data it is premature to conclude that there is sexual dimorphism.

Handedness and Cerebral Organization

About 89% of the population appear to be dextrals of whom 99.6% have left hemisphere dominance for language function (Dimond and Beaumont, 1974). Furthermore, of the 11% non-dextrals, about 56% have language functions dominated by the left hemisphere and 44% are right-hemisphere speech dominant. Kinsbourne (1978) supported the findings of Blakemore, Iversen and Zangwill (1972) that sinistrals are more variable than dextrals regarding which hemisphere is superior for language. In addition, dextrals are more lateralized and sinistrals have larger between subjects and within subject variability on measures of manual preference. Sinistrals have also been described as more field dependent with more primitive defense mechanisms and a non-differentiated global style of perceiving when compared to dextrals (Silverman, 1979).

Studies comparing dextrals to sinistrals have yielded conflicting data concerning cerebral lateralization of function. Miller (1971) pointed out that this is to a large extent a result of testing sinistrals which are mixed-handed since 'pure' sinistrals comprise such a small fraction of the entire population. Familial history concerning handedness is another important factor to be considered when studying sinistrals. Hecaen and Sauguet (1971) found that cerebral ambilaterality is present only in sinistrals having a family history of left-handedness.

Laterality of Electrodermal Activity

Fisher (1958) was one of the first researchers to study bilateral differences in electrodermal activity (EDA). He found that right handed subjects with a clear body image distinction between right and left produced a left galvanic skin response (GSR) which was more reactive than the right GSR. This did not apply to sinistrals or to subjects having no clear body image distinction. Fisher (1962), in a methodological note, pointed out that the body side producing the larger GSR is actually the less reactive which is in opposition to what most previous studies assumed to be the case.

Several other methodological issues need to be considered before examining research conducted using EDA. Lykken and Venables (1971) concluded that skin conductance bears a simpler and more linear relationship to psychological processes than does its reciprocal, skin resistance. Different finger sites for placing electrodes have been found to yield significantly different skin potential values (Christie and Venables, 1972). In addition, a distinction needs to be made between tonic and phasic EDA. Kilpatrick (1972) found that phasic EDA increased with psychological and physical stress and considered it to be a good indicator of autonomic emotional arousal. Tonic skin conductance, on the other hand, changed mainly as a function of cognitive activity. This supports the finding of Katkin (1965) that basal skin resistance and GSR nonspecific responses are two indices reflecting different phenomena.

A number of studies have shown no evidence for bilateral differences in EDA. Wyatt and Tursky (1969) exposed 12 right-handed and 12 left-handed males to light, noise and shock and found that for both groups, irrespective of conditions, significantly higher skin potentials were found on the right side of the body. The fact that unilateral stimuli did not produce unilateral changes in skin potential levels was considered as evidence for communication between the two sides. In another study, 59 subjects were given the tasks of listening to music, listening to paragraphs and a quiet period (Ketterer and Smith, 1977). These tasks were designed to be hemisphere specific and the results indicated that stimulation of one hemisphere did not produce greater EDA in the opposite hand. However, these researchers noted that sex and genetic handedness significantly influenced the pattern of responding. Gross and

Stern (1980) presented subjects with a visual recognition task consisting of words and shapes and found that these stimuli did not elicit asymmetric tonic or phasic EDA.

The above negative findings have been outweighed by the research evidence showing both naturally occurring asymmetry and hemispheric arousal related asymmetry. Varni, Doerr and Franklin (1971) pointed out that asymmetry in autonomic activity is typical in normal subjects and also noted that basal skin resistance had both static and dynamic aspects. Bull and Gale (1975) also found bilateral differences but noted that the activity from one hand is strongly related to the activity recorded simultaneously from the other hand.

Visual-imagery and verbal-numerical tasks were found to produce clear electrodermal lateral asymmetry (Myslobodsky and Rattok, 1975). In the right handed subjects, higher EDA values were present in the right hand during verbal tasks while the visual task produced higher left-hand skin conductivity. These researchers replicated this finding in 1977 and concluded that there is little doubt that EDA asymmetry is a reflection of the functional specialization of the two brain hemispheres. In addition they pointed out the contradictory or negative results may be due to the indifferent nature of the stimuli used to evoke EDA orienting responses (eg. tone and light).

Two studies by Lacroix and Comper (1979 and Note 1) add further evidence in support of bilateral differences. The former consisted of 3 experiments exploring bilateral differences in skin conductance as a function of hemisphere-specific tasks. Verbal and spatial (Experiment 1) and numerical and musical (Experiment 2) tasks were used to activate the left and right hemispheres respectively. The third experiment replicated the second but used sinistrals rather than dextrals. In dextrals, both experiments produced smaller response amplitudes in the hand contralateral to the more activated hemisphere than in the ipsilateral hand. In sinistrals the bilateral differences did not vary systematically with hemisphere activation. The ipsilateral activation found in these studies are in opposition to the research indicating contralateral activation (Myslobodsky and Rattok, 1975 and 1977).

Varni (1975) states that it is not surprising that recent studies are revealing bilateral differences in autonomic balance. As early as 3,000 B.C. Chinese physicians compared pulses from the two wrists as a means of disease detection. Varni's present research suggests that bilateral differences in autonomic function can be learned through classical conditioning or differential habituation.

In short, research evidence has established the existence of bilateral differences in EDA. Wexler (1980) agrees with this statement but points out that researchers still disagree if greater EDA on one side of the body is indicative of activation of the ipsilateral or contralateral hemisphere. Further work is required to define such things as the nature of stimulus systems establishing the asymmetries and the neurophysiological mechanism responsible for the lateralized differences.

Hand Temperature as a Psychophysiological Measure

DuToit (1956) compared GSR and skin temperature measures looking at temporal variations under a stressful condition. He found differences in reaction time, relative amplitude of reaction and recovery rate in the two measures. The conclusion was made that vascular reactions reflect an imbalance between the parasympathetic and the sympathetic divisions of the autonomic nervous system, whereas skin conductance reactions give an indication of varying activity in the sympathetic division only. This provides a likely explanation for the poor correlations found between these two psychophysiological measures.

A more recent investigation into unilateral temperature responses under stress was conducted by Boudewyns (1976) showing that hand temperature decreases under stress and increases under relaxation. The temperature measures taken from the nondominant hand did not correlate significantly with frontalis muscle tension (EMG), GSR or pulse rate taken also from the nondominant hand. It did correlate significantly with self-report of internal arousal. A difference between the sexes was found in that most of the subjects with low temperatures — irrespective of time — were female. It is suggested that finger temperature is a reliable measure to use when studying arousal over prolonged time periods rather than second-to-second changes in internal states as the speed of temperature reactions are relatively slow.

The Law of Initial Values

Wilder's Law of Initial Values (LIV) states that the magnitude of a physiological response to a given stimulus is related to the prestimulus level of the system being measured. For example, in relation to hand temperature, the warmer the temperature to begin with the greater will be the decrease in response to a stressful stimulus. Hord, Johnson and Lubin (1964) carried out a study to determine whether the LIV is applicable to all autonomic responses. They concluded that the LIV operates for heart rate, GSR and respiration rate but not for finger temperature. On the other hand, Boudewyns (1976) found that under conditions of relaxation, subjects with low initial finger temperatures showed greater increases in temperature than did subjects with initially warmer hands. Jamieson (Note 2) demonstrated that the LIV is only weakly applicable to skin temperature.

The LIV can be a confounding variable in studies examining the effects of hemispheric activation on autonomic responses. If the LIV is in effect and statistical analyses are carried out which do not take into consideration initial response levels, erroneous conclusions may be drawn.

Laterality of Temperature Responses

Meiners and Dabbs (1977) recorded the temperature from each ear canal near the tympanic membrane of 20 college students. A greater blood flow on the left side was observed during verbal tasks and a greater right flow for spatial tasks. The researchers concluded that tympanic temperature may provide a simple and flexible measure of hemispheric functioning. Bennett and Suter (1980) tried to replicate evidence that facial skin temperature asymmetries develop during hemisphere-specific activity. They were not able to establish such a relationship.

Jamieson, Ghannam and Papsdorf (Note 3) reported that when test anxious subjects listened to a tape describing test-taking situations only the left hand showed a significant decrease in finger temperature. A greater decrease in the left hand, compared to the right, significantly correlated with higher trait anxiety and a poorer feeling of well being. In a similar study, bilateral hand temperature responses under stress were utilized in an attempt to differentiate high and low test anxious subjects (McCann and Papsdorf, Note 4). Only left hand differences in temperature could be used as a criterion to discriminate between high and low test anxious subjects. The researchers suggested that this may be an indication of greater right hemisphere involvement in emotional arousal.

van Houten and Chemtob (Note 5) studied bilateral differences in response to visual stimulation. Male subjects were given slides of landscapes, female nudes and mutilated bodies while bilateral GSR and temperature recordings were being made. The researchers predicted that the side of the body with the lower temperature is the more reactive because vasoconstriction accompanies autonomic nervous system arousal. Although there were large individual differences in patterns of bilateral responding, clear differences between the two sides of the body were evident for both temperature and GSR measures. The researchers also noted that of the two measures temperature differences were considerably more stable.

Voluntary Control of Hand Temperature

Hadfield (1920) showed that it was possible to produce dramatic asymmetries in hand temperature using direct suggestions. The sole subject of the study initially had hand temperatures of $94^{o}F$. After a half hour the right hand temperature was $68^{o}F$ while the left hand temperature remained unchanged. After an additional 20 minutes the right hand resumed its initial baseline temperature. Roberts, Kewman and Macdonald (1973) successfully used hypnosis and auditory feedback to change the temperature of one hand relative to the other in a specified direction. Other research has suggested that changes in hand temperatures can be attained by hypnotized subjects and not by waking controls (Maslach, Marshall and Zimbardo, 1972). Dugan and Sheridan (1976) did not confirm the above in a study where imagery instruction alone enabled the subjects to change at least one hand temperature in a specified direction.

The ability of normal subjects to vary digital skin temperature with the aid of biofeedback was investigated by Surwit, Shapiro and Feld (1976). Vasodilation was more difficult to achieve than vasoconstriction which was readily accomplished. The researchers found that simply leaving the subject alone for a long baseline period seemed to be as effective as feedback training to produce vasodilation. No sex differences existed in the ability to control temperature but heart rate data suggested that males and females differ in the physiological mechanisms used to warm the hands. Males slow down heart rate when increasing hand temperature whereas females increase heart rate to accomplish the same temperature effect. The researchers pointed out that this data needs to be replicated before further inferences can be made.

In short, bilateral temperature differences have been produced by various techniques indicating that asymmetrical control of autonomic functions is possible.

Hemispheric Activation and Emotion

Several studies have been undertaken to examine the role that each hemisphere plays in emotional arousal. Galin (1974) reviewed hemispheric specialization and its usefulness in providing a framework for research and theory in psychiatry. Parallels were noted between aspects of mental processing in the disconnected right hemisphere and primary process thinking and repression. Galin hypothesized that in normal, intact subjects mental events can become functionally disconnected and continue to exist repressed in the right hemisphere. This line of thought is continued by Tucker (1981) who suggested that the left hemisphere acts as a censor in personality by controlling and inhibiting the loosely structured ideation of the right hemisphere. In addition, it was found that subjects who are more emotionally responsive display a preference for right hemisphere processing.

The relationship between psychological stress and LEMs has also been examined (Tucker, Roth, Arneson and Buckingham, 1977). An increased frequency of leftward deflections during stress conditions was interpreted as reflecting greater right than left hemisphere activation under emotional arousal. EEG activation asymmetry in the frontal lobes for positive and negative emotions has also been reported with the right hemisphere being activated for aversive affect (Shearer and Tucker, 1981). This study also found that subjects tended to report imaginal and global ideation (right hemisphere) when asked to facilitate emotional arousal while analytic and verbal thinking (left hemisphere) was reported when subjects were asked to inhibit emotion. In summary, although hemispheric interaction does occur, it is generally held that the right hemisphere becomes more activated than the left during emotional arousal especially when the emotions are negative.

Summary of Literature Reviewed

In summation, studies involving commissurotomy patients, lateralized input, mapping of function and lateralized eye movements found evidence in support of hemisphere-specific cognitive activation. Language and mathematical activity are primarily localized in the left cerebral hemisphere whereas spatial manipulation and musical appreciation are operations which primarily engage the right hemisphere. With continuing research, the absolute dominance of one hemisphere over a specific function is coming into question. Furthermore, the nature of the stimulus materials used, the sex and handedness of the subject, as well as the approach a subject takes in solving a task affect which hemisphere is activated or if the two function in unison. All of these factors along with inconsistent methodology in recording and scoring physiological responses contribute to the lack of cohesiveness prevalent in this area of psychophysiological research.

Researchers have examined the effect of hemisphere-specific tasks on electrodermal activity. The results support the existence of bilateral differences but disagreement exists if greater EDA on one side of the body is indicative of activation of the ipsilateral or contralateral hemisphere. Investigations into unilateral temperature responses under stress have showed that hand temperature decreases under stress and increases under relaxation. Bilateral hand temperature responses under stress have also been studied. A greater temperature decrease in the left hand, compared to the right, significantly correlated with higher trait anxiety scores. This finding may be a reflection of the generally held view that the right hemisphere becomes more activated than the left during emotional arousal especially when the emotions are negative.

Techniques such as hypnosis, biofeedback and direct suggestion have produced bilateral temperature differences indicating that asymmetrical control of autonomic functions is possible. Few studies exist, however, which examine bilateral finger temperature responses under hemisphere-specific cognitive activation. A possible confounding variable in such studies could be the Law of Initial Values which states that the magnitude of a physiological response to a given stimulus is related to the prestimulus level of the system being measured. If this law is in effect, statistical analyses which take into consideration initial response levels should be carried out in order to avoid drawing erroneous conclusions.

Present Study

Research has shown that hemisphere-specific cognitive activation produces lateralized differences in such autonomic responses as GSR and that stressful stimuli produce decreases in finger temperature. To date few studies exist which examine the effect of differential hemispheric activation on finger temperature recorded bilaterally.

In the present study subjects were exposed to several hemisphere-specific tasks with bilateral finger temperature continuously being recorded. A control group of subjects were asked to relax -- for a time period equivalent to the experimental group -- while bilateral temperature recordings were taken. An anxiety score and other personal data was obtained for all subjects.

It was hypothesized that each hemisphere-specific stressor would produce a decrease in temperature of the contralateral hand. Males, being more lateralized than females, should show this effect to a greater degree. In addition, the more anxious subjects should have colder temperatures from the outset and would produce greater left hand decreases regardless of the hemisphere being activated since emotional arousal in the right hemisphere would have an overshadowing effect. Whether or not the Law of Initial Values applies to hand temperature was also looked at.

Method

Subjects. Sixty, right-handed, introductory psychology students were randomly assigned to the experimental and control groups. An equal number of males and females were used. Mean age for the entire sample was 22.9 years. Table 1 provides the descriptive statistics for the subjects.

Apparatus. All subjects were asked to fill out a questionnaire (see Appendix A) and the IPAT Anxiety Scale. An eight channel Beckman polygraph was used with Yellow Springs Thermistors being attached to the volar surface of the distal phalanx on the middle finger of each hand. The machine was calibrated to produce a 1mm. pen deflection for each 0.2C^{o} temperature change. The paper speed was set at 2.5mm per second with the pens centered at 31^{o}C. The experimental subjects were also given a post-session questionnaire to complete (see Appendix B). Room temperature was maintained at approximately 24^{o}C.

Procedure. Upon completion of the initial questionnaire and the IPAT, experimental subjects were told that different cognitive tasks would be presented while control subjects were told to relax with their eyes closed for about half an hour. Thermistors were then attached and a 4 minute baseline was taken while subjects reclined in a padded chair. Tasks for the experimental subjects were presented in a random order and for all subjects polygraph channels were randomly varied as to which channel was recording which hand.

Table 1. Descriptive Statistics for Subjects

Statistic	Sex	Experimental Group	Control Group
Number of Cases	Male	15	15
	Female	15	15
Age* (Years)	Male	25.5 (9.0)	21.5 (4.4)
	Female	23.1 (8.2)	21.7 (5.0)
IPAT Anxiety Score* (Percentile)	Male	50.5 (33.6)	51.9 (26.9)
	Female	50.3 (33.7)	49.3 (32.7)

*Values are means and (standard deviations)

Table 2 indicates the hemisphere-specific tasks that were used. The computation task consisted of 40 items involving the four simple arithmetic operations (eg. 80124÷6; answers: A-13254, B-13347, C-13354, D-13396, E-none of these). The verbal tasks, consisting of 60 items, required the subject to form pairs of synonyms or antonyms out of a list of 4 words (eg. a-haughty, b-uncouth, c-dominant, d-humble). The 40 items of the spatial task required the subject to visualize folding a flat piece of metal along dotted lines which indicated where the metal was to be bent. Each item offered 4 completed constructions from which the subject was to choose the correct construction. All of these stimulus materials were printed in a booklet which was placed on the subject's lap. The Seashore Musical Memory Subtest was a tape-recorded exercise in tonal memory. Each trial contained a series of notes played twice requiring the subject to decide which note of a series was changed between the first and second playing.

The duration of each task was limited to 4 minutes with a 4 minute rest period separating the tasks. The subject was informed each time an error was made with the number of items completed and the number of items correctly answered being recorded. A final 4 minute baseline was also taken. Upon completion of the above, the experimental subjects completed the post-session questionnaire and all subjects were debriefed as to the purpose of the study. Any questions posed by the subjects were also answered.

TABLE 2. Cognitive Tasks Presented

Hemisphere to be Activated	Task Presented	Source of Task
Left	Computation	GATB* Part 2 Items 10 and up
Left	Vocabulary	GATB Part 4 Items 1 and up
Right	Spatial Manipulation	GATB Part 3 Items 1 and up
Right	Musical Memory	Seashore Measures of Musical Talents Tonal Memory

*GATB=General Aptitude Test Battery

<u>Data Analysis</u>. Polygraph records for each hand were scored and temperatures at the end of each 4 minute phase were utilized in the statistical analyses. Raw scores on the IPAT were transformed into percentiles, performance scores on experimental tasks were determined by converting the number of items correctly answered into a percentage and menstrual data was coded according to phases in the cycle as follows:

Code	Phase	Days
1	Menstrual	1-5
2	Follicular	6-13
3	Ovulation	14
4	Luteal	15-28.

Results

Figure 1 illustrates the mean digit temperature for the experimental group of subjects. In (a) the temperatures recorded at the end of the spatial (S), numerical (N), verbal (V), and musical (M) stressors are depicted while (b) represents the temperatures recorded during rest periods. The mean temperatures upon which these figures are based are provided in Appendix C. Repeated measures analysis of variance was performed for temperatures during tasks and also for resting temperatures (sex x task x hand/sex x rest x hand). There was a significant difference between the two hands with the right hand being consistently warmer than the left ($F(1,28)=5.94$, $p<.05$ experimental tasks/$F(1,28)=4.86$, $p<.05$ rest periods). For the experimental task temperatures there was no significant task by hand interaction indicating that hemisphere-specific activation did not produce lateralized differences in hand temperatures ($F(3,84)=.35$, n.s.). In addition, neither the hand by sex nor the hand by task by sex interaction was significant ($F(1,28)=.76$, n.s. hand x sex/$F(3,84)=2.52$, n.s. hand x task x sex). The nonsignificance of the latter interaction indicates that males and females did not differ in degree of laterality displayed to each task.

Figure 2 depicts the mean digit temperatures for males and females separately during experimental tasks. Although females had consistently

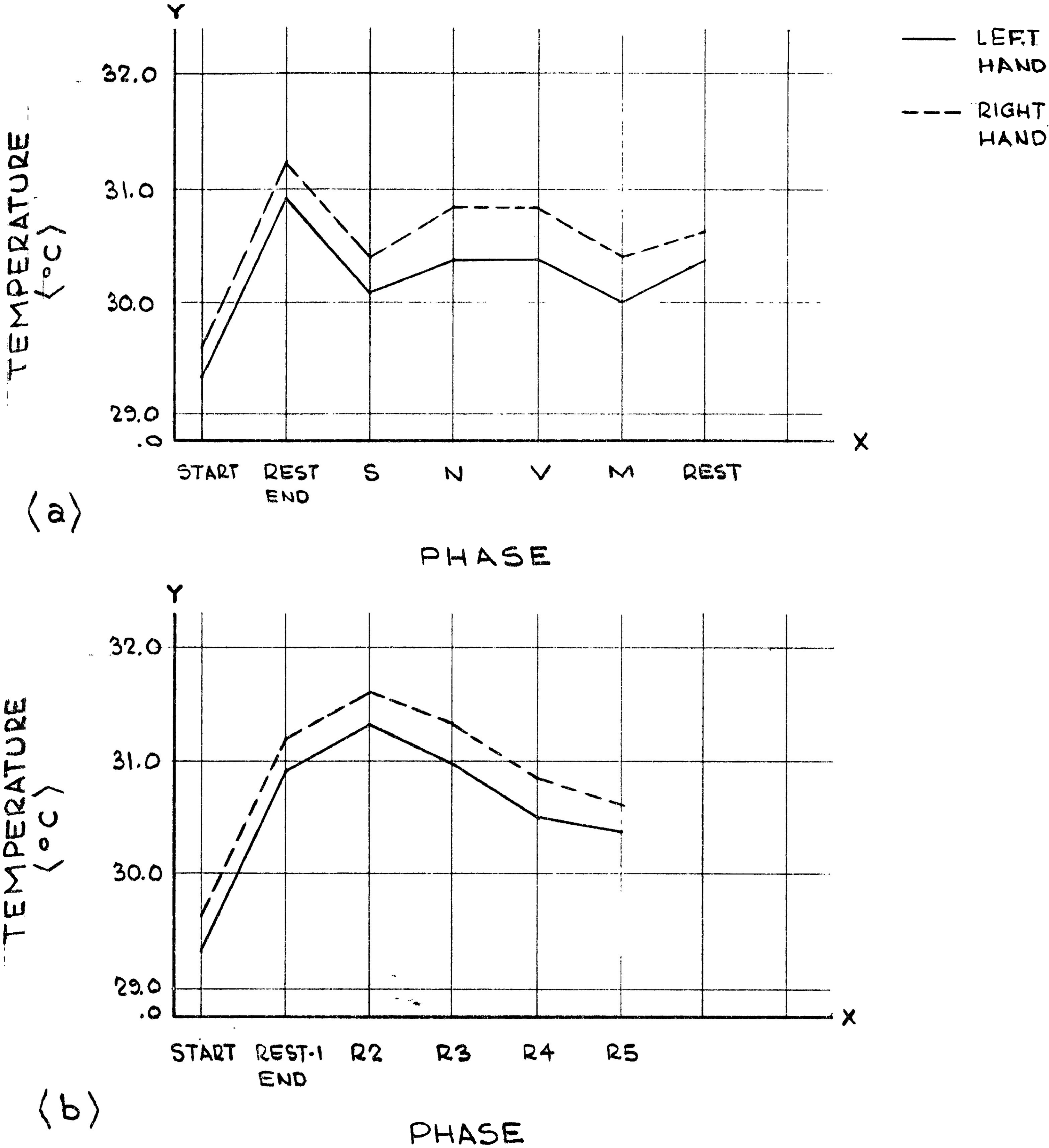

Figure 1. In (a) the mean digit temperature for each of the experimental stressor is represented. In (b) mean digit temperatures are shown for the same group of subjects during rest periods.

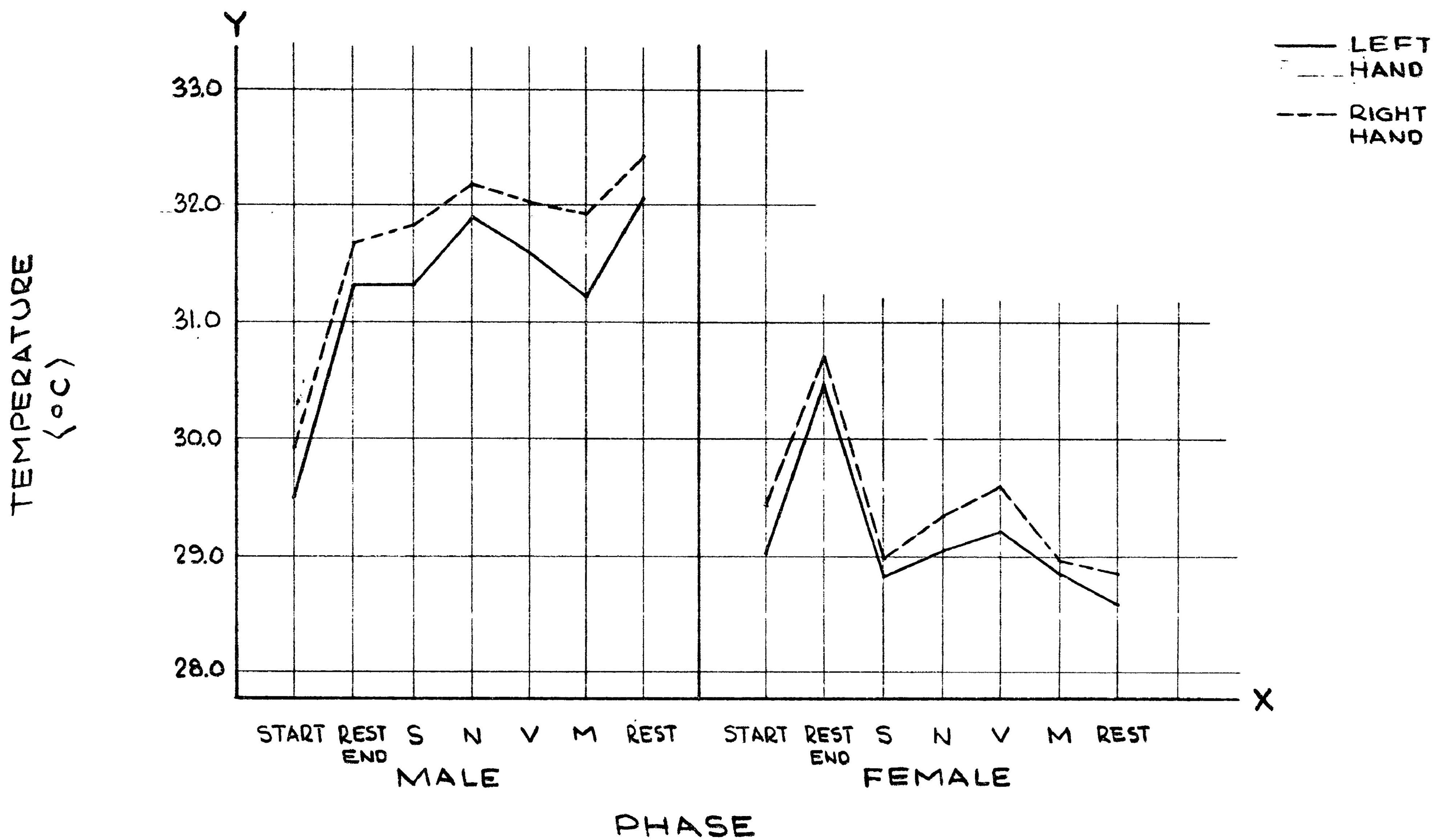

Figure 2. The mean digit temperature is illustrated for males and females in the experimental phases.

colder temperatures than males ($F(1,28)=6.52$, $p<.05$), repeated measures analysis of variance showed no significant task by sex interaction indicating that the sexes did not respond differently to the stressors presented ($F(3,84)=.34$, n.s.).

Table 3 provides comparisons between task temperatures and immediately preceding rest temperatures. Both hands showed significant decreases in temperature under the numerical, verbal, and musical tasks while no significant decreases occurred when subjects were exposed to the spatial task. In order to further examine temperatures recorded from the two hands, analyses were carried out using left minus right (L-R) change scores for experimental subjects. When L-R scores for the tasks were compared to L-R scores at the end of initial baseline no significant differences were found (see Table 4).

Figure 3 illustrates the mean digit temperatures for the control subjects as a group and subsequently for each sex separately. The mean temperatures upon which these figures are based are provided in Appendix D. A repeated measures analysis of variance was performed (time x sex x hand) showing a significant effect of time with both hands warming up over the course of the session ($F(3,84)=15.08$, $p<.001$). A significant time by sex interaction was also found indicating that the sexes differed in their temperature records over the course of the experimental session ($F(3,84)=5.48$, $p<.01$). Males generally increased temperatures of both hands over

Table 3. Comparisons Between Task Temperatures and Preceding Rest Temperatures

Hand	Phase	Mean Temperature	T Value (df=29)	Prob.
Left	Spatial	30.08	-1.26	.22
	Rest	30.37		
Right	Spatial	30.37	-1.28	.21
	Rest	30.66		
Left	Numerical	30.46	-2.76	.01*
	Rest	30.96		
Right	Numerical	30.76	-2.70	.01*
	Rest	31.26		
Left	Verbal	30.39	-4.27	.001*
	Rest	31.22		
Right	Verbal	30.79	-4.01	.001*
	Rest	31.51		
Left	Musical	30.00	-5.14	.001*
	Rest	31.10		
Right	Musical	30.37	-5.39	.001*
	Rest	31.41		

* = significant
Temperatures = ^{o}C

Table 4. Comparisons Between Task L-R Scores and Baseline L-R Scores

Task	Mean Differences Compared	(C^o)	T Value (df=29)	Prob.
Spatial	Spatial	-.29	.49	.63
	Baseline	-.36		
Numerical	Numerical	-.31	.33	.74
	Baseline	-.36		
Verbal	Verbal	-.37	-.07	.95
	Baseline	-.36		
Musical	Musical	-.41	-.30	.77
	Baseline	-.36		

* = significant

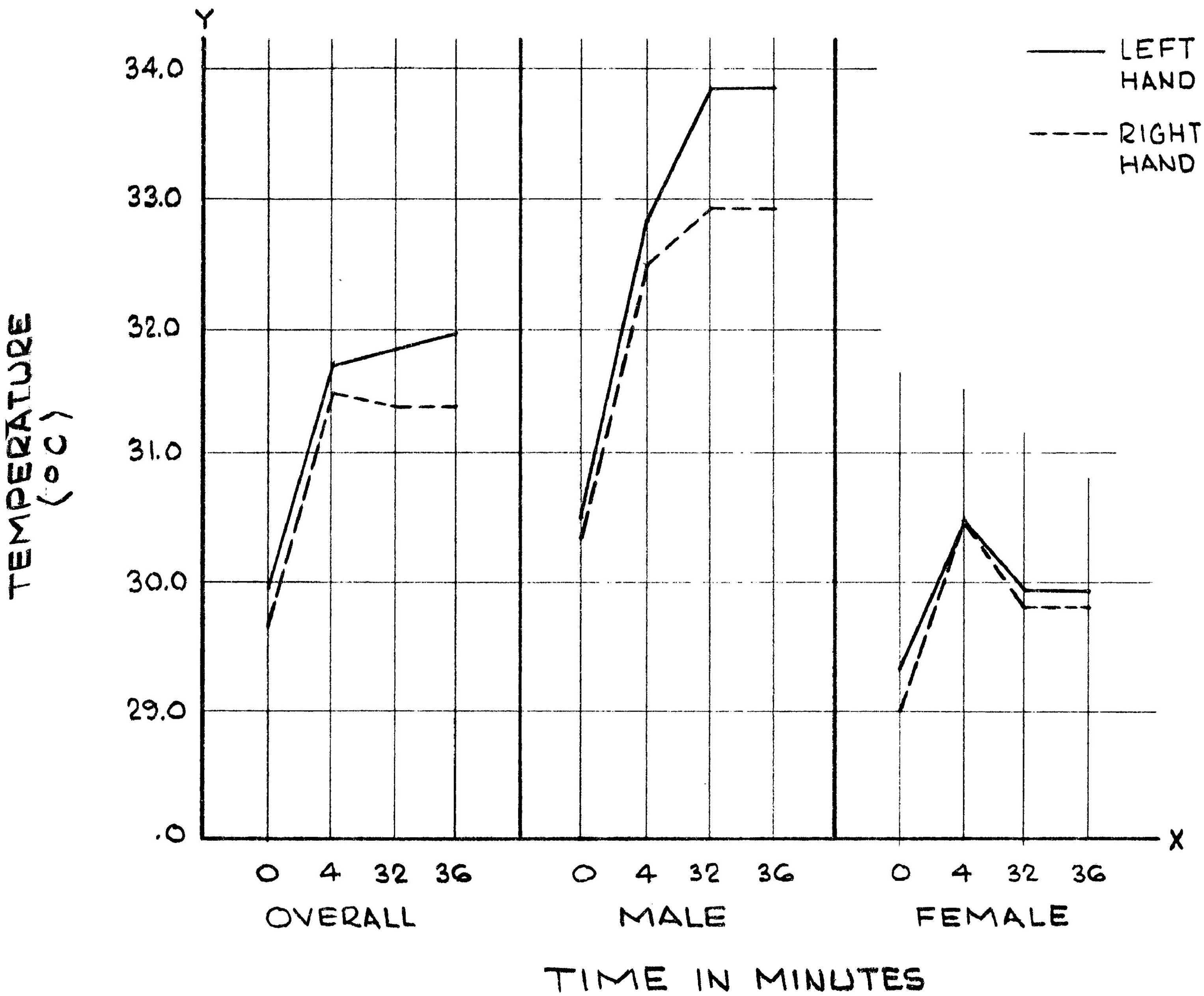

Figure 3. The mean digit temperatures for the control subjects are illustrated first for the entire group and subsequently for males and females separately.

the session with the increase levelling off over the final 4 minute baseline. Females tended to show a decline in temperature during the final portion of the session with the final baseline temperatures being generally lower than temperatures recorded at the 4-minute mark.

In order to examine resting differences in temperature responses between subjects expecting cognitive stressors and subjects instructed to relax, a repeated measures analysis of variance (group x time x hand) was performed comparing experimental and control subjects on temperatures recorded at times 0, 4 and 36 (ie. start of first rest, end of first rest and end of last rest). There was a significant effect of time reflecting the increase in temperatures over the first 4 minute baseline ($F(2,116)=21.63$, $p<.001$) and a significant hand by group interaction ($F(1,58)=4.58$, $p<.05$) indicating that the resting differences between the left and right hands differed according to which group the subject was in. Experimental subjects showed greater right hand temperatures throughout the experiment whereas control subjects showed warmer left hand temperatures.

In order to test whether the Law of Initial Values is applicable to hand temperature two analyses were done; the first used L-R change scores while the second looked at the left and right hands separately. For the former the following computations were carried out:

(1) computed L-R scores for initial rest and for tasks

(2) L-R for initial rest was subtracted from L-R for each task

(3) correlated value from (2) with L-R at end of initial rest period.

Table 5 presents the results of the above analysis for experimental subjects while Table 6 presents the correlations for the control group of subjects. For experimental males all correlations were negative and significant ($p < .05$) while for females no values were significant. No L-R values were significant for either sex in the control group. Therefore, for experimental males the greater the difference in temperatures between the two hand to start with the smaller the difference when under stress. When each hand is looked at in isolation, experimental males show the Law of Initial Values to hold for both hands while control males show this to be significant only for the left hand. The change in temperature from initial rest to task negatively correlated with initial resting temperature. Females in both groups showed no significant correlations.

Experimental males and females were also compared in terms of performance on cognitive stressors. No significant differences were found for the following:

(1) percentage of items correctly answered on a task,

(2) rating of difficulty of task, and

(3) subject's rating of amount of effort put forth to answer items correctly.

Table 5. Correlations of Baseline Temperatures with Task-Baseline Temperatures for Experimental Subjects

	SEX							
	MALE				FEMALE			
	S	N	V	M	S	N	V	M
Right Hand	-.45*	-.47*	-.45*	-.53*	-.24	-.31	-.30	-.22
Left Hand	-.53*	-.56*	-.51*	-.55*	-.16	-.25	-.30	-.16
L - R	-.49 *	-.83*	-.93*	-.86*	-.36	-.14	-.13	-.37

* $p < .05$

Table 6. Correlations of Baseline Temperatures with Final-Baseline Temperatures for Control Subjects

	SEX	
	MALE	FEMALE
Right Hand	.43	-.24
Left Hand	-.80 *	-.23
L - R	.43	.32

*$p < .05$

Pearson correlations were computed for demographic and questionnaire data and temperature scores. A finding was considered significant if the probability fell below .05 (two-tailed). For both groups the two hands were significantly correlated in the positive direction for all temperatures recorded (r's from .64 to .99). The stage in the menstrual cycle did not correlate with any measure (r's from -.48 to .25). Scores on the IPAT Anxiety Scale did not correlate significantly with any temperature measures but for the experimental group it was found that higher anxiety scores were obtained from subjects who smoked (r=.39) and from subjects rating the numerical task as difficult (r=.47). Task difficulty ratings correlated negatively with the number of items answered correctly (r's from -.35 to -.74) and musical training was negatively correlated with perceived difficulty of the musical task (r=-.36). Positive correlations were also obtained between the number of verbal items answered correctly and the number of numerical (r=.36) and spatial (r=.59) items answered correctly.

Discussion

The hypothesis that hemispheric activation would produce a contralateral decrease in hand temperature was not supported. For the experimental subjects the right hand was consistently warmer than the left and both hands showed significant decreases in temperature during the numerical, verbal and musical tasks. The finding that both hands showed temperature decreases for 3 of the 4 tasks suggests that the tasks were stressful to the subjects but that the stress response was manifested bilaterally.

There are several issues that need to be considered in exploring why hemispheric activation did not produce contralateral decreases. Previous studies have shown that numerical and verbal tasks primarily activate the left hemisphere while spatial and musical tasks primarily activate the right hemisphere (Doyle, Ornstein and Galin, 1974; Young, 1978). Without having directly recorded brain function in the present study, hemisphere-specific activation is assumed to have occurred on the basis of previous studies using similar stimulus materials.

The possibility exists that hemispheric dominance over a specific function is less well lateralized than is generally assumed. For example, Daniel (1981) found that although spatial tasks engaged the right hemisphere, when the complexity of the tasks was increased cooperation with the left hemisphere took place. Bever and Chiarello (1974) found that cerebral dominance for recognition of simple melodies differed between musicians and nonmusicians. Subjects with musical training used a strategy of musical apprehension that involved left hemisphere function.

Subject motivation may also have been a factor contributing to the temperature responses obtained. If a subject was not concentrating on the stimulus material presented then differential hemispheric activation would not have taken place. However, records of the number of items answered correctly and perceived task difficulty suggest that generally subjects were concentrating on the materials presented and were trying to answer the items correctly.

The present study is not consistent with EDA research which has found evidence in support of bilateral differences. Myslobodsky and Rattok (1975, 1977) found hemisphere-specific activation to produce contralateral activation in EDA while Lacroix and Comper (1979 and Note 1) reported ipsilateral activation. This inconsistency is to be expected in light of the poor correlations between various psychophysiological measures which have been reported in previous studies (DuToit, 1956; Boudewyns, 1976). The present study is, however, consistent with that of Jamieson (Note 2) which reported no task related asymmetry in hand temperature.

It was also hypothesized that males and females would differ in the degree of laterality displayed. This hypothesis was not supported in that the hand by task by sex interaction was nonsignificant. Females consistently showed colder temperatures than males for both hands; a finding previously reported by Boudewyns (1976).

As expected, control subjects increased their hand temperatures over the session indicating the effect of relaxation. A significant time by sex interaction indicates that females generally showed a decrease in temperature after the 4 minute baseline whereas males continued to increase hand temperature. Without further data from the present study or from previous research the reasons for this sex difference can only be speculated upon. It is possible that females found it more difficulty to relax and to remain relaxed for the entire experimental session. Further research is necessary in order to establish the reliability of this sex difference and to gain insight as to why it occurs.

Differences between experimental and control subjects were found when resting temperature differences between the left and right hands were compared. The right hand was consistently warmer than the left for experimental subjects while the left was warmer than the right for control subjects. The warmer right hand found in experimental subjects could be explained by a difference in blood supply to the hands due to dextrality. Carmon and Gombos (1970) pointed out that blood pressures were higher on the right side of the body for right handed subjects and higher on the left side for left handed subjects. This handedness hypothesis is not appropriate as the control subjects -- who were also dextrals -- showed the left hand to be warmer than the right.

A more plausible explanation is that the colder left hand temperatures in the experimental subjects may reflect right hemisphere emotional arousal due to stress whereas the control subjects, being relaxed, did not display this phenomenon. This explanation is supported by EEG data which shows right hemisphere activation in aversive, emotional arousal (Shearer and Tucker, 1981). The fact that this difference between experimental and control subjects was present in the initial temperatures recorded indicates that the preliminary instructions — informing experimental subjects of the cognitive stressors to follow the rest period — served to induce anticipatory stress reflected in lower left hand temperatures. Control subjects who were informed that they were control subjects and were asked to relax for the next half hour did not exhibit an anticipatory stress response as evidenced by warmer left hand temperatures.

The Law of Initial Values was seen to hold for experimental males but not experimental females when the analysis was performed on L-R change scores. The greater the difference between left and right temperatures to begin with the more this difference was reduced under stress. When hand temperatures were analyzed separately the Law of Initial Values was in effect for both hands in experimental males, the left hand for control males and neither hand for both groups of females. For both hands in experimental males, the warmer the baseline temperature the greater the decrease produced by the cognitive stressor. In control males, subjects with lower left hand temperatures at baseline showed greater increases in left hand temperatures during relaxation. No significant relationships between baseline and subsequent temperatures were obtained for the right hand of control males or for either hand in both groups of females. This contradicts Hord, Johnson and Lubin (1964) who found the law not applicable to hand temperature. Further research is required to determine why the law is only sporadically applicable to temperature responses.

No sex differences were found when experimental subjects were compared in terms of performance on cognitive stressors. This was unexpected in view of previous studies which reported male superiority for spatial tasks and female superiority for verbal tasks (Kimura, 1973). In a critical review, Petersen (1980) concluded that males seem to be better at spatial and quantitative skills while females are better at verbal skills.

The hypothesis that the more anxious subjects would have colder temperatures to start with and would show greater decreases under stress was not supported. Scores on the IPAT Anxiety Scale did not correlate significantly with any temperature measures. This is in opposition to studies which reported significant positive correlations between IPAT scores and such physiological measures as frontalis EMG, blood pressure and peripheral vascular resistance

(Smith, 1973; Pilowsky, Spalding, Shaw and Korner, 1973). Several early studies have also reported significant correlations between psychometric measures of anxiety (Taylor Manifest Anxiety Scale) and measures of autonomic nervous system arousal (Goldstein, 1964; Haywood and Speilberger, 1966).

The present study is consistent, however, with the findings of Crabbs and Hopper (1980) who looked at the extent and direction of relationships between EMG, finger temperature and scores on the State-Trait Anxiety Inventory and found no relation among the 3 measures. Jamieson (Note 2) reported that trait anxiety did not correlate significantly with left-right differences or temperature changes. Kelly, Brown and Shaffer (1970) also found that self ratings of anxiety did not correlate with any of the following: forearm blood flow, heart rate, EDA, EMG and cutaneous vasomotor status.

The finding that ratings of task difficulty were negatively correlated with the number of items answered correctly was expected as was the finding that musical training decreased the perceived difficulty of the musical task. Positive correlations between the number of items answered correctly on the verbal, numerical and spatial tasks could reflect inter-subtest correlations inherent in the GATB. Alternatively, verbal, numerical and spatial tasks could reflect intellectual abilities which require convergent, analytical thinking whereas the musical task could be measuring a different ability requiring divergent, synthetic thinking.

Future research could be directed toward gaining insight into what circumstances involving hemispheric activation produce differences in bilateral responses. Replication of this study using sinistral subjects and various clinical populations would enable the generalization of present findings to a wider population. Gur (1978) reported that schizophrenia is associated with both left hemisphere dysfunction and overactivation. Newlin and Golden (1980) studied manic-depressive patients and found the following: right-sided abnormalities and hyperarousal in affective illness, left-sided hemispheric specialization for positive affect and right-sided specialization for negative affect.

Research concerned with the effect of ageing on hemispheric asymmetry has also been carried out. Charman (1981) examined the relationship between age and processing of verbal stimuli. Results showed that the amount of information processed decreased with age and that the elderly have opposite hemispheric asymmetries to the young. It would be of interest to determine whether stimuli involving other cognitive functions also show this reversal in asymmetry with increased age. Clinical application of results from laterality studies may be of assistance in providing objective diagnostic criteria while research into the origins of differences in hemispheric activation and bilateral autonomic responses could provide insight into strategies for ameliorating pathological dysfunctions.

In conclusion, hemisphere-specific cognitive activation did not produce lateralized differences in temperature responses in the present study. Regardless of which hemisphere was activated, similar temperature decreases were found in both hands. Differences in resting temperatures recorded from the two hands were found between the experimental and control groups with the right hand being consistently warmer than the left for experimental subjects and the left hand being warmer for control subjects. This finding may reflect greater right hemisphere activation -- in comparison to the left hemisphere -- under stress.

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APPENDIX A

Pre-Session Questionnaire

1) Name:

2) Age:

3) Sex:

4) If FEMALE:

   Start of next period:

   Number of days between periods:

5) Are you a smoker? (Circle)

   Yes No

   If YES; time of last cigarette? ____________minutes ago

6) Did you take any drugs before this session (eg. coffee, prescriptions etc)?

   Yes No

   If YES; what? when?

7) Do you have any musical training?

   Yes No

   If YES; please elaborate:

****

Date Tested:

Time of Testing:

Room Temperature: Pre Post

APPENDIX B

Post-Session Questionnaire

1) How difficult did you find each of the tasks?

Mathematics

1	2	3	4	5	6	7
Not at all Difficult			Somewhat Difficult			Very Difficult

Vocabulary

1	2	3	4	5	6	7
Not at all Difficult			Somewhat Difficult			Very Difficult

Spatial Manipulation

1	2	3	4	5	6	7
Not at all Difficult			Somewhat Difficult			Very Difficult

Musical Memory

1	2	3	4	5	6	7
Not at all Difficult			Somewhat Difficult			Very Difficult

2) Briefly describe what you did to come up with an answer for each of the following:

Mathematical Questions

Vocabulary Questions

Spatial Questions

Musical Questions

3) How hard did you concentrate upon answering the questions correctly?

1 2 3 4 5 6 7

Not at all Some Very Hard

APPENDIX C

Mean Digit Temperatures for Experimental Subjects*

Experimental Phase	SEX			
	Male		Female	
	Left Hand	Right Hand	Left Hand	Right Hand
Start of Rest 1	29.5	29.9	29.0	29.4
End of Rest 1	31.3	31.7	30.4	30.7
End of Spatial	31.3	31.8	28.8	28.9
End of Rest 2	32.4	32.7	30.2	30.4
End of Numerical	31.9	32.2	29.0	29.3
End of Rest 3	32.3	32.7	29.7	29.8
End of Verbal	31.6	32.03	29.2	29.6
End of Rest 4	32.2	32.5	28.8	29.0
End of Musical	31.2	31.9	28.8	28.9
End of Rest 5	32.1	32.4	28.6	28.8

*Temperature=^{o}C