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## Lateral Differences in the Latency Between Finger Tapping and the Heart Beat

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### ABSTRACT

Based upon suggestions that the two cerebral hemispheres may be differentially involved in the perception and regulation of autonomic activity, three studies were designed to explore differences in the relationship between left versus right hand finger tapping and the heartbeat. In each study, right-handed subjects were asked to tap with either their left versus right forefingers regularly at the rate of approximately once per second. When the time from the R-spike immediately preceding their tap to the tap was examined, a significant difference between the two hands was obtained in two of the studies, with the left hand tapping closer to the last R-spike compared with the right. A variety of additional conditions in the experiments suggest that this effect may depend upon tapping rhythmically. The implications of these findings for the differential role of the left and right hemispheres in the perception and regulation of cardiac activity are considered.

**DESCRIPTORS:** Hemispheric specialization, Cardiac activity.

A number of investigators (e.g. Dimond, in press; Hecaen, 1969; Luria, 1973; Luria, Simeritskaya, & Tubylevich, 1970) have recently suggested that the two cerebral hemispheres may be differentially involved in the perception of interoceptive and proprioceptive feedback. For example, Hecaen (1969) has suggested that focal lesions of the right hemisphere, specifically in the parietal region, result in disturbances of the normal sensation of the patients' own body seven times more frequently than comparable lesions of the left hemisphere. On the basis of these and other observations, Luria (1973) suggested that "the right hemisphere is di-

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rectly concerned with the analysis of direct information received by the subject from his own body and which, it can be easily understood, is much more closely connected with direct sensation than with verbally logical codes" (p. 165).

If the right hemisphere is more involved in the perception of interoceptive and proprioceptive feedback, then one might argue that modulation of cortical tone through cardiac afferent feedback should be more demonstrable in the right compared with the left hemisphere. Walker and Sandman (1979, 1980) have recently presented data consistent with this suggestion. These investigators (Walker & Sandman, 1979) recorded visual evoked potentials (EPs) to light flashes during slow, fast and midrange level heart beats. They reported that the EPs recorded from the right hemisphere during slow, mid-range, and fast level heart beats could be differentiated from each other, but those recorded from the left hemisphere could not. Presumably, the differential afferent feedback associated with these three levels of heart rate influenced cortical process-

ing more in the right hemisphere. Consistent effects were presented at a conference cycle (Walker & Sandman, 1978) found that right hemisphere subjects were significantly more efficient in producing heart rate changes than left hemisphere subjects.

While one study has shown differential contributions of afferent control of heart rate, others directly bear on this issue (Walker & Sandman, 1978) found that right hemisphere subjects were significantly more efficient in producing heart rate changes than left hemisphere subjects. It is unclear from afferent or efferent control of heart rate.

Given the various studies regarding a differential role of the cerebral hemispheres in interoceptive and proprioceptive feedback, we sought to explore simple motor behavior control and cardiac activity. The available evidence reviewed here suggests that right hemisphere subjects compared with left hemisphere subjects when asked to tap their fingers, subjects who used their right hand to tap showed a shorter latency between the R-spike and the tap than subjects who used their left hand. We checked since a large body of research has found significant differences between the hemispheres in interoceptive and proprioceptive feedback (e.g., Filbeck, 1970; White, 1969).

**Subjects.** Thirteen right-handed subjects with no fainting history participated in an experimental procedure that correlated motor behavior with heart rate.

**Procedure.** The subjects performed three phases. In Phase I, a circular silver disk, with the index finger on the right hand, was rotated at one revolution per second. They were instructed to tap the other hand.

In Phase II, the subjects were aware of their heart rate and were instructed to sit silently. They were asked to tap immediately following each heart rate change. They were then repeated with the other hand.

During Phase III, the subjects were only when they were instructed to tap. They were instructed to try as hard as they could to detect the heart rate change. They were then instructed to tap with each hand.

The subjects were

ing more in the right than in the left hemisphere. Consistent effects were also obtained when stimuli were presented at different phases of the cardiac cycle (Walker & Sandman, 1980).

While one study may have bearing on the differential contributions of the two hemispheres to the efferent control of cardiac activity (Greenstadt, Schuman, & Shapiro, 1978), no data exist which directly bear on this question. Greenstadt et al. (1978) found that right ear monaural feedback was significantly more effective than left ear feedback in producing heart rate increases in a biofeedback paradigm. It is unclear whether this result emerged from afferent or efferent effects or both.

Given the various suggestions in the literature regarding a differential involvement of the two cerebral hemispheres in certain cardio-behavioral processes, we sought to explore the relation between a simple motor behavior under contralateral cortical control and cardiac activity. Based upon the perceptual evidence reviewed above suggesting a greater right compared with left hemisphere involvement in cardio-behavioral processes, we hypothesized that when asked to tap in synchrony with their heart beats, subjects would tap more quickly after an R-spike when using their left hand compared with their right hand. We chose speed as a dependent measure since a large body of behavioral data which has found significant functional asymmetries between the hemispheres is based upon reaction time evidence (e.g., Filbey & Gazzaniga, 1969; Gazzaniga, 1970; White, 1969).

### Method

#### Experiment I

*Subjects.* Thirteen female and 7 male subjects, all right-handed with no familial sinistrality, were recruited to participate in an experiment "designed to examine physiological correlates of movement."

*Procedure.* The experiment was divided into three separate phases. In Phase I, the subjects were asked to tap a circular silver disk, which triggered a pulse when tapped, with the index finger of one hand at a rate of about one tap per second. They were then asked to repeat the task with the other hand.

In Phase II, the subjects were asked to become as aware of their heart beat as possible. After being given 3 min to sit silently and become aware of their heart beat, they were asked to tap the disk with one index finger immediately following each beat of their heart, whether or not they felt they were tapping accurately. This task was repeated with the index finger of the other hand.

During Phase III, the subjects were instructed to tap only when they were "relatively certain" that their taps would be in synchrony with their heart beat. They were instructed to try as hard as possible to tap only when a beat was detected. Again, they were instructed to perform this task with each hand.

The subjects were required to tap 100 times with each

hand during Phases I and II and 75 times in Phase III. The hand used first was counterbalanced across all subjects and phases.

*Apparatus and Recording Procedure.* Heart rate was recorded from lead plate electrodes placed on each arm and amplified and displayed on a Grass Model 7 polygraph. A digital logic program obtained the time between the R-wave of the cardiac cycle and the next tap, if one occurred, during each interbeat interval (IBI). In addition, the IBI was printed out after each heart beat.

Additionally, two electrodes were placed across the frontalis muscle of the forehead. No data, however, were collected from these electrodes. They were used solely to mask the nature of the experiment until it was revealed by instructions.

#### Experiment II

The purpose of this experiment was twofold: 1) to replicate Experiment I in a different laboratory (Psychophysiology Laboratory, Bedford VA Hospital) and with a new set of subjects; and 2) to examine the effects of instructions to tap aperiodically with no reference to the heart beat. This condition was included as a control for Phase III where subjects were instructed to tap only when "relatively certain" that their taps would be in synchrony with their heart beat since this latter instructional set resulted in aperiodic tapping.

*Subjects.* Ten male and 10 female subjects with an age range of 18-32 were recruited for an experiment on "the physiological correlates of movement." As in Experiment I, all subjects were right-handed with no familial sinistrality.

*Procedure.* Phases I, II and III as described in Experiment I were presented in Experiment II. In addition to these three phases, a fourth phase, called Phase 0, was included and preceded Phase I. In Phase 0 the subjects were required to tap 25 times with each hand at a random rate. As in Experiment I, they were required to tap 100 times with each hand during Phases I and II and 75 times during Phase III. The instructions to the subjects during Phases I, II and III remained unchanged from Experiment I. Hand use was again counterbalanced across phase and subjects.

*Apparatus and Recording Procedure.* A microswitch which triggered a pulse of the sense input of a computer was employed in place of the silver disk trigger used in Experiment I. In this experiment, the phases were controlled by a DEC PDP/12 computer which also collected data on-line for subsequent analysis.

Heart rate was recorded as in Experiment I. In addition, electrodes were placed on the frontalis region as in Experiment I.

#### Experiment III

The purpose of the third experiment was to determine whether any effects of Phase on tap latency (i.e., changes in the time since an R-spike to a tap as the experiment progressed from one phase to the next) were a function of fatigue developing over the course of the experiment or were more associated with the differences in instructional set of the various phases. Accordingly, Experiment III included an identical number of trials as was contained in Experiment II. However, instead of presenting subjects

with different phases following one another, this experiment consisted of the presentation of three blocks of Phase I. In this way, we were able to equate the length of Experiments II and III while independently varying the instructional set given to the subjects.

**Subjects.** Seven female and 6 male right-handed volunteers with no familial sinistrality, aged 18–25 yrs, were recruited in a manner identical to that for the previous two experiments. Subjects employed in this experiment had not participated in either of the previous two experiments.

**Procedure.** Subjects were given instructions to tap at the rate of "about one tap per second" with each hand, as in Phase I of Experiments I and II. This was repeated three times until three blocks of 100 taps with each hand were completed. The hand used first was counterbalanced across all trials and subjects.

**Apparatus and Recording Procedure.** Heart rate was recorded from lead plate electrodes placed on both arms and digital logic equipment obtained the same information as in Experiment I. Miniature electrodes from which no data were recorded were again placed across the frontalis muscle of the forehead.

## Results

The major dependent measure obtained in each experiment was tap latency—the time in msec between a tap and the immediately preceding R-spike. The mean tap latency was obtained for each Hand-Phase combination, separately for each subject. Analyses of variance with Hand and Phase as repeated factors were performed separately for each experiment.

### Experiment I

The ANOVA on the tap latency data revealed no significant main effect for Hand ( $\bar{X}$  for the right hand = 449.84 msec; left hand = 445.69 msec) or for Phase, nor was there a significant Hand  $\times$  Phase interaction.

The variability of tap latency was examined by obtaining the standard deviation of tap latencies for each Hand-Phase combination, separately for each subject and then performing an ANOVA on the tap standard deviation data. This ANOVA revealed a significant main effect for Hand ( $F(1/18) = 12.64, p = .002$ ) with the left hand showing more variability in tap latency compared with the right ( $\bar{X}$  tap stand-

ard deviation for the left hand = 243.53; for the right hand = 229.21). No other significant effects for tap standard deviation were obtained.

The interbeat interval data were examined in a manner identical to that for the other dependent measures. No significant main effects or interactions were obtained. IBI variability was examined by obtaining the standard deviation for IBIs for each Hand-Phase combination, separately for each subject. As with the IBI data itself, no significant main effects or interactions were obtained.

### Experiment II

The data from this experiment were analyzed as in Experiment I, the only difference being that the Phase factor for this study had 4 levels.

Table 1 presents the means and standard deviations<sup>1</sup> of tap latency separately by Hand and Phase. An ANOVA revealed a highly significant main effect for Hand ( $F(1/18) = 14.24, p = .001$ ) indicating that across phase, the left hand tapped more closely to the last R-spike than did the right ( $\bar{X}$  for left hand = 368.0;  $\bar{X}$  for right hand = 399.7). A significant main effect for Phase was also obtained ( $F(3/54) = 5.95, p = .001$ ). As can be seen from Table 1, both hands tend to tap further away from the previous R-spike as the experiment proceeds from one phase to the next.

Although the interaction of Hand  $\times$  Phase was not significant, *t*-tests were performed comparing left versus right hand tap latency within each phase in order to provide tentative data on which phase produced the strongest hand effect. Since multiple *t*-tests were performed, we adopted the Bonferroni procedure (Hays, 1963; see also Friedman, Simson, Ritter, & Rapin, 1975) which takes this into account by dividing the desired overall alpha level by the total number of comparisons. For an overall confidence level of .05, if four comparisons are performed (one comparison for each phase), a level of .0125 was considered necessary for a given comparison to achieve significance. Using this criterion, a

<sup>1</sup>The standard deviations are computed by obtaining the means across subjects and should not be confused with the standard deviations of tap latency computed within subjects.

Hand effect was 3.29,  $p = .004$ ).

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TABLE 1  
Means and standard deviations of tap latency for Experiment II

Hand	Means (SDs in Parentheses) (msec)			
	Phase 0	Phase 1	Phase 2	Phase 3
Left	322.1 (75.28)	363.7 (89.46)	390.7 (97.54)	395.5 (63.23)
Right	352.8 (106.63)	410.3 (80.39)	416.3 (85.69)	419.4 (91.64)

Hand	F
Left	320.
Right	334.

Hand effect was obtained only in Phase I ( $t(19) = 3.29, p = .004$ ).

The variability of tap latency was examined as described for Experiment I. No significant main effects or interactions were obtained.

IBI and IBI variability data were also examined as described for Experiment I. Again, no significant main effects or interactions were obtained on either measure.

On-line computer processing of data in this experiment enabled us to compute within subject correlations between tap latency and concurrent IBI. Results of these within subject correlations showed that the majority of correlations were positive, indicating that longer tap latencies were associated with longer concurrent IBIs replicating an effect described by the Lacey's (Lacey & Lacey, 1978). Separate correlations were performed for each Hand-Phase combination separately for each subject, and out of a total of eight Hand-Phase combinations, six revealed significantly more positive correlations than would be expected by chance (by the binomial distribution, 14 or greater correlations out of 20 which are positive is significant at  $p < .05$ ).

### Experiment III

The data from this experiment were analyzed in the same manner as in the previous studies. Since this experiment involved the consecutive presentation of three Phase I periods, each period is referred to as Block, rather than as Phase.

As was found for Experiment II, an ANOVA on tap latency revealed a significant main effect for Hand ( $F(1/12) = 4.45, p = .057$ ). It can be seen from Table 2 that the left hand tapped more closely to the previous R-spike than the right hand ( $\bar{X}$  for the left hand = 312.07 msec; right hand = 323.29 msec).

A significant main effect for Block was also obtained on the tap latency data ( $F(2/24) = 5.32, p = .012$ ) and indicates that subjects tap more closely to the previous R-spike as the experiment proceeds ( $\bar{X}$  for Block 1 = 327.52; for Block 2 = 321.50; for Block 3 = 304.02). As the data in Table 2 indicate,

TABLE 2  
Means and standard deviations of tap latency for  
Experiment III  
Each block is equivalent to Phase I in the previous  
experiment  
 $N = 13$

Hand	Means (SDs in Parentheses) (msec)		
	Block 1	Block 2	Block 3
Left	320.64 (81.72)	318.9 (78.57)	296.8 (88.08)
Right	334.5 (87.68)	324.2 (88.78)	311.3 (84.10)

subjects show differences between the left and the right hands during all Blocks of the experiment and no significant Hand  $\times$  Block interaction was obtained.

The variability of tap latency was examined in the same manner as the previous experiments and the results revealed no significant main effects or interaction.

Similarly, the IBI and IBI variability data were examined and no significant main effects or interactions were obtained for either measure.

In this experiment we were able to obtain an additional measure not recorded in the previous two studies. This measure was the inter-tap interval (ITI)—the time in msec between each consecutive tap. For each subject, we computed the mean ITI for each Hand-Block combination as well as the standard deviation. ANOVAs were then performed on the ITI mean data and on the ITI standard deviation data. Importantly, no significant main effects or interactions were obtained for either measure.

### Discussion

The results from this series of studies indicate that when right-handed subjects are asked to tap separately with the forefinger of the right versus left hand, the left hand taps more closely to the immediately preceding R-spike than the right hand. This effect was obtained in Experiments II and III but not in Experiment I. Experiment I was the only study to reveal a significant main effect for Hand in variability of tapping with the left hand showing more within subject variability than the right. It is unclear why Experiment I was the only study to show this effect but it may be associated with the lack of a main effect for Hand in tap latency.

In order to more precisely specify the cause of any difference between Phases I and II, where subjects were tapping relatively regularly, and Phase III, where subjects were instructed to tap only when relatively certain that their heart had beat, we included in Experiment II a fourth phase (Phase 0) which preceded the other three, during which subjects were not given any instructions about their heart beat, but just told to tap aperiodically. A Hand  $\times$  Phase interaction for tap latency was not obtained. However, post-hoc analyses with the alpha level corrected by the Bonferroni procedure revealed that it was only in Phase I where significant Hand differences were obtained. This, coupled with the significant main effect for Hand obtained in Experiment III which consisted of three blocks of Phase I, tentatively suggests that the lateral difference which we have uncovered is most prominently observed when subjects are tapping regularly and

when they are not instructed to attend to their heart beats.

A second major finding emerged from the present series of studies that was not anticipated. In Experiment II a significant main effect for Phase was obtained and indicated that both hands tapped further away from the preceding R-spike as the experiment proceeded from one phase to the next. This effect may be a complex function of the changing instructional sets from one phase to the next and/or may be partially related to instructions to attend to their heart beat. This latter interpretation receives some support from Experiment III where a significant Block effect was obtained in a direction opposite to that found in Experiment II. In Experiment III, subjects were never provided with any instructions about their heart beat and were simply requested to tap at the rate of approximately once per second. As the experiment progressed from one block to the next, the latency between the subjects' tap and the immediately preceding R-spike decreased in both hands. It may be that instructions to attend to cardiac activity somehow increase processing time. Often when normally non-conscious automatic events are made more conscious, they take more time to perform. This interpretation must be tempered, however, by data obtained in Experiment II where the largest overall increase in tap latency from one phase to the next occurred from Phase 0 to Phase I (see Table 1). In neither phase were instructions to attend to cardiac activity given to subjects. Why the latency decrease across phase was found in Experiment III is unclear from the present set of findings.

The finding of major relevance to the hypothesis which this series of studies was originally designed to examine is the difference between the left versus right hands in the latency of a tap from the immediately preceding R-spike. These results are part of a growing series of findings implicating a differential contribution of left and right hemispheres to various aspects of cardio-behavioral processes. Our findings are consistent with the suggestion that the right hemisphere may be more sensitive or more efficient than the left in its response to cardiac afferent feedback (Walker & Sandman, 1979, 1980).

A number of authors have commented upon the role of the right hemisphere in the mediation of unconscious or non-conscious processes (e.g., Galin, 1974) while the left hemisphere may play a more prominent role in conscious and intentional activities (Luria & Simernitskaya, 1977; Dimond, in press). Given this suggestion, it may be more adaptive for visceral afferents to be represented in cortical regions to which we may have relatively less conscious access (see Davidson, 1980). For example, if we are consciously aware of modulation of perceptual activity with each cardiac cycle, it would likely be highly maladaptive for the maintenance of our ongoing stream of behavioral interaction with the environment.

A less tentative interpretation of these findings clearly awaits future research. In the meantime, investigators studying cardiac cycle effects and reaction time might fruitfully control or examine both the handedness of their subjects as well as the responding hand.

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## Announcements

### PREDOCTORAL AND POSTDOCTORAL FELLOWSHIPS (NIMH)

Predocctoral and postdoctoral fellowships (NIMH) are currently available in a research training program in Psychophysiology. The program stresses basic research techniques (with emphasis on measures of cortical event-related potentials and autonomic activity) as well as applications in the fields of developmental, cognitive, personality, and clinical psychology. Applicants should hold a B.S., Ph.D., or equivalent in an area relevant to the biological or behavioral sciences, and should be U. S. citizens, nationals, or permanent residents.

Send curriculum vitae or requests for further information to: Michael G. H. Coles, Ph.D., Department of Psychology, University of Illinois, Champaign, Illinois 61820. Affirmative Action/Equal Opportunity Employer.

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Immediate openings are available in an interdisciplinary program on cardiovascular control of hypertension. Participating departments include medical psychology, physiology, pharmacology, endocrinology, pediatrics, and biochemistry. Applicants can be Ph.D.'s or M.D.'s. To apply, send transcripts, three letters of recommendation, and a letter of interest to: Arthur R. Zeiner, Ph.D., Psychiatry and Behavioral Sciences, University of Oklahoma Health Sciences Center, P.O. Box 26901, Oklahoma City, OK 73190.

### POSTDOCTORAL FELLOWSHIP IN BIOLOGICAL PSYCHOLOGY

The University of Oklahoma Health Sciences Center has a postdoctoral fellowship in Biological Psychology, an appointment for approximately one year, to begin immediately. Candidates should have strong research backgrounds either in human cognitive processes or human performance, with interests in electrophysiology, psychophysiology, or neuropsychology. Interest in psychobiological applications to such health-related areas as alcohol or drugs is essential. Collaborative and independent studies in the above areas are expected. Opportunities exist for advanced training in biological and psychobiological areas related to behavior. Candidates are expected to assume light teaching loads in the Biological Psychology Ph.D. Program. Eleven-month salary range is \$10,000 to \$13,250 dependent upon qualifications. Submit a letter of application, vita, names and addresses of three references, and two recent preprints or reprints to: Professor Harold L. Williams, Department of Psychiatry and Behavioral Sciences, University of Oklahoma Health Sciences Center, PO Box 26901, Oklahoma City, OK 73190. The University of Oklahoma is an equal opportunity employer.