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DIFFERENCES BETWEEN SINISTRALS' AND DEXTRALS' ABILITY TO INFER A WHOLE FROM ITS PARTS: A FAILURE TO REPLICATE

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Abstract—We attempted to replicate the study reported by NEBES [9] which suggested that sinistrals and dextrals differ in perceptual abilities. Three samples of university students totalling 102 subjects were administered Nebes' arc–circle test, in which subjects are asked to examine an arc with their fingers and identify to which of 3 circles the arc belongs. In all three studies we failed to find the differences, predicted by Nebes, between the ability of our sinistral and dextral subjects. Furthermore, the performance on the task did not depend on the mode of response (pointing to vs naming of the correct circle).

INTRODUCTION

SPERRY and his associates [1] have demonstrated a variety of functional differences between the two cortical hemispheres. They have achieved this in a series of ingenious studies of the symptoms attendant upon the disconnection of the cerebral hemispheres [2]. Many investigators have since reported data obtained from samples of intact subjects [see 3] in support of the hemispheric difference hypothesis. These studies usually involve the selective presentation of information to either of the hemispheres [4, 5]. It has, also, been shown that electrocortical activity over the two hemispheres reflects the proposed functional asymmetries [6]. It seems therefore well established that the two hemispheres are characterized by different processing modes and may indeed subserve different functions. Little or no information is available on the manner in which the two hemispheres interact to perform the information processing tasks. The behavioral output of the organism must be determined by a well regulated functional integration of the two hemispheres, which cannot be studied exclusively by directing specific inputs to either hemisphere or by focusing on manifestations of hemispheric activity such as the EEG. A possible approach to the problem might capitalize on differences in hemispheric utilization between sinistrals and dextrals [7, 8]. An interesting attempt has been made by NEBES [9].

Using commissurotomized patients, NEBES [10, 11] has been able to show that the right hemisphere is superior to the left in inferring a spatial configuration from its parts. Specifically subjects were better able to infer to which of 3 circles a given arc belonged when the information was delivered to the right, rather than to the left hemisphere. Nebes then predicted that this hemispheric difference would manifest itself as a difference between sinistrals and dextrals, the former committing more errors than the latter. NEBES [9] reported that when the test was administered to several groups of university students, sinistrals indeed committed more errors than dextrals. These data seem to demonstrate that hemispheric functional differences can translate into differences in the behavior of individuals with connected hemispheres. We report here a failure to replicate Nebes' findings.

Our replication of Nebes' study was motivated by a need for a test that would distinguish sinistrals from dextrals. This need arose in connection with our studies of the so-called Readiness Potential, a slow negative cortical potential which precedes voluntary, self-paced movement [12–15]. As we found [16, 17] that the degree of hemispheric asymmetry of the Readiness Potential depends on the hand used for movement and on the subject's handedness, we required a finely graded measure of handedness.

A search of the literature revealed no single, well established and commonly accepted measure of handedness. We proceeded therefore to administer a battery of tests to all subjects that were to be run in our motor-potential studies. The Nebes' test was included in that battery. While most measures of handedness turned out to be correlated with each other to some degree, the Nebes' test was poorly correlated with the other tests. As we felt that the implications of Nebes' reports go beyond the mere development of a handedness test we conducted two additional studies as a further test of Nebes' assertions. In no case were we able to replicate the differences reported by Nebes. Due to the theoretical significance of Nebes' report [8] and its potential as a handedness measure we report here on this failure to replicate.

EXPERIMENT I

Methods

Subjects. Thirty-five (18 reporting themselves as right-handed, 17 reporting to be left-handed) University of Illinois graduate and undergraduate students (mean age = 24) were paid for participating in this experiment. Three of the left-handed subjects were females. Three of the right-handers and 13 of the left-handers reported having sinistral relatives.

Procedure. Each subject was administered a series of tests in the following order: (a) The subject was asked to clasp his hands with fingers alternating. The dominant thumb was recorded [18]. (b) Subject responded to a questionnaire developed by LEVY [19] which determines the frequency of usage and skill of performance of each hand on 8 standard tasks. The style of writing (inverted vs normal) was also noted [8]. (c) A Steadiness Test using a Stoelting apparatus was administered [20, 21]. Subjects performed 5 times, for a 30 sec period, with each hand. (d) Subjects were interrogated about the incidence of left-handedness among relatives and history of changes in hand preferences if any. (e) The Edinburgh Inventory was completed [22]. (f) Subjects were asked to draw a human profile with each hand [23]. (g) The final task was a variant of the somesthetic visual form of the Arc–Circle Test [9, 10]. In this case, the subjects' task was to indicate from which of 3 circles of different sizes a particular arc had been taken. The 3 circles were in full view of the subject at all times. Examination of the arcs was limited to tactile sensations with the index finger of either hand. No limit was imposed on the time available for the examination of the arc. When the subject decided which circle corresponded to the arc he examined, he reported his choice verbally: "small", "medium", or "large". Table 1 describes the scoring scheme used.

The stimuli were made, according to the specifications given by NEBES [10], from plexiglass rings 3·81 cm (1·5 in.), 3·18 cm (1·25 in.), and 2·54 cm (1 in.) i.d. For each size there were 2 complete rings and 4 arcs: 280°, 180° 120°, and 80°. All had the same height (0·31 cm) and thickness (0·31 cm). The arcs were painted black and mounted singly on white index cards.

An experimental session consisted of presenting the 12 arcs and 3 full circles once to each of the subjects' hands in a random order, using the same physical arrangements and procedures described by NEBES [9]. In 9 of the dextral subjects and 9 of the sinistral subjects the right hand was tested first while the reverse sequence was used with the other subjects.

RESULTS

The correlation coefficients* between all pairs of scores on all tests were computed. An examination of the correlation matrix indicated that the various tests tend to fall into

*In all cases these were Pearson Product moment correlations. However, whenever one of the variables was dichotomous we obtained the equivalent point-biserial correlation. For the purposes of the present discussion the difference between these coefficients is immaterial.

Table 1. Determination of scores for variables included in handedness battery.

Self-Report	Score 1 for Dextral; 2 for Sinistral
Thumb on Top (Thumb)	Score 1 for Right Thumb; 2 for Left Thumb
Profile-Right Hand (Profile-R) Profile-Left Hand (Profile-L)	Score 1 for profile facing to the right Score 2 for profile facing to the left
Edinburgh-Unimanual (Edin-Uni)	Edinburgh score derived only from activities requiring one hand
Edinburgh-Bimanual (Edin-Bi)	Edinburgh score derived from activities requiring use of two hands
Edinburgh-Total (Edin-T)	Score derived from total question (+1.00 indicates extreme dextrality, -1.00 indicates extreme sinistrality
Dominant Eye (Eye) Dominant Foot (Foot)	Score 1 for Right; Score 2 for Left; Score 3 for no Preference
Sinistral Relatives (Relatives)	Score 1 for Yes; 2 for No
Arc-Circle-Right Hand (Arc-Circle-R)	Total correct (out of 15) using Right Hand
Arc-Circle-Left Hand (Arc-Circle-L)	Total correct (out of 15) using Left Hand
Arc-Circle-Total (Arc-Circle-T)	Combined Total correct (out of 30) for both hands
Strength-Right Hand (Strength-R) Strength-Left Hand (Strength-L)	Strength (in Kg.) determined for each hand when subjects were asked to squeeze a dynamometer with maximum, sustained grip
Levy Score (Levy)	Score determined on Levy questionnaire (0 indicates perfect dextral; 64 indicates perfect sinistral)
Writing Style (Style)	Score 1 for normal; 2 for inverted style
Steadiness-Total Hits (Hits)	Score indicates total number of contacts (stylus & side of hold) for right hand trials minus left hand trials
Steadiness-Elapsed Time (ET)	Score indicates total contact (stylus & side of hole) in msec for right hand trials minus left hand trials
Elapsed Time/Hit (ET/HIT)	Ratio for right hand trials minus left hand trials.

a small number of clusters. This could best be examined by extracting the principal components of the correlation matrix [24]. It turned out that 69 per cent of the variance could be accounted for by 5 factors. A Varimax rotation was then used on these 5 principal components (PC). The loading of each of the test scores on each of the five PCs is shown in Table 2. It is clear that all scores which are based primarily on self-report are all represented jointly by high loadings on PC I. The performance measures (the Stoelting Test) cluster on PC V. Loadings of the steadiness scores on PC I reflect a measure of correlation between self-report and performance measures, similar degrees of weak but positive correlation also appear on the other PCs. PC III, however, shows high loadings for all scores derived from the Nebes' test and for no other score. The isolation of the Nebes' test is also illustrated in Table 3 in which we list the actual correlations between the score on the

Table 2. Results of principal component analysis of test battery*

PC I		PC II		PC III		PC IV		PC V	
Edin-Uni	(-.96)	Strength-R	(.90)	Arc-Circle-T	(.93)	ET/HIT	(-.68)	Foot	(.77)
Edin-Total	(-.96)	Strength-L	(.88)	Arc-Circle-L	(.78)	Profile-R	(.66)	ET	(.54)
Self-Report	(.95)			Arc-Circle-R	(.57)	Profile-L	(.64)	Hits	(.53)
Levy	(.93)					Eye	(.59)	Arc-Circle-R	(-.50)
Edin-Bi	(-.77)								
Style	(.70)								
Relatives	(-.65)								
ET	(.58)								

*The numbers in parenthesis represent Principal Component loadings for each variable after Varimax rotation. Only variables with loadings greater than ± 0·50 are listed.

Table 3. Correlation matrix for Levy questionnaire, elapsed time on steadiness test and total arc–circle score.

	Levy	ET	Arc-Circle-T
Self Report	.94	.52	.08
Thumb	.29	.11	-.22
Profile-R	-.08	.11	.10
Profile-L	.02	-.03	.27
Edin-Uni	-.95	-.56	-.05
Edin-Bi	-.63	-.38	.11
Edin-T	-.94	-.56	-.01
Eye	.07	-.07	-.13
Foot	.29	.31	-.18
Relatives	-.59	-.32	.07
Arc-Circle-R	.07	-.08	.77
Arc-Circle-L	-.07	.12	.65
Arc-Circle-T	-.00	.01	--
Strength-R	.00	.05	-.19
Strength-L	.11	.19	-.19
Levy	--	.57	-.00
Style	.65	.41	.15
Hits	.51	.78	.06
ET	.57	--	.01
ET/HIT	.32	.50	.02

Levy questionnaire, the score on the Stoelting Steadiness Test as well as the Nebes' test with all the other scores.

Table 4a. Mean total correct responses and standard deviations for Experiment I by handedness and hand used. Subjects were presented with 15 stimuli per hand for a total of 30.

Hand Used	Right	Left	Total
Dextral	9.6	9.9	19.5
	(1.9)	(1.5)	(2.3)
Sinistral	9.9	10.1	20.2
	(1.9)	(1.6)	(2.8)

Table 4b. ANOVA summary table for Experiment I

Source	df	SS	MS	F	P
Handedness	1/33	.85084	.85084	.2760	.60283
Hand Used	1/33	.91428	.91428	.3046	.58471
Subjects (Handedness)	33	101.72059	3.08244		
Handedness x Hand Used	1/33	.04486	.04486	.0149	.90343
Hand Used x Subjects (Handedness)	33	99.04065	3.00123		

Table 5. ANOVA summary table for steadiness test*

Source	df	SS			
Handedness	1/33	23497434.0	23497434.0	.1125	.73939
Hand Used	1/33	127701930.0	127701930.0	2.2314	.14473
Subjects (Handedness)	33	6890122000.0	208791580.0		
Handedness x Hand Used	1/33	695531270.0	695531270.0	12.1533	.00141
Hand Used x Subjects (Handedness)	33	1888591100.0	57230033.0		

*Dependent variable, total elapsed time per hand used.

While this analysis suggested that the Nebes' test could not predict self proclaimed handedness there remained the possibility that there are group differences between the sinistrals and the dextrals in their performance in the arc circle task. Table 4a presents an analysis which corresponds to that applied by Nebes to his data. The mean number (and standard deviation) of correct responses made by each group of subjects when using either hand are tabulated. It is clear that the differences are small. An ANOVA presented in Table 4b fails to reveal any significant effect either of subject handedness or the examining hand on the number of correct responses. By way of comparison, we present in Table 5 an ANOVA of the steadiness test scores, which shows that performance varied as a function of subject handedness and the hand used. That is, dextrals perform better with their right hand and sinstrals better with their left. We present this last ANOVA as a demonstration that our failure to find differences on the Nebes' test cannot be attributed to a general lack of differences between our sinistral and dextral subjects.

DISCUSSION

Our data suggested that the differences between sinistrals and dextrals reported by Nebes are not universally present. The study, however, could not be considered a fair replication of Nebes' work because of 3 differences between our procedure and his. Our subject named the correct circle while Nebes' subjects *pointed* to the correct circle. As has been shown by LEVY [8] the different modes of response might call upon different processing capacities. Secondly, we included the 3 circles as test stimuli among the arcs which the subject examined. Nebes used only the arcs as stimuli. Thus our subject had somewhat more experience with the circles. Finally, we presented the arcs for examination in random order, which was determined anew for each subject and for each hand. Nebes presented the stimuli to all subjects in the same random sequence. As there may be sequential effects in task performance this difference in procedure might have been crucial.

We conducted a second study in which all 3 differences between Nebes' procedures and ours were eliminated.

EXPERIMENT II

Methods

Subjects. The subjects consisted of 39 (20 right-handed, 19 left-handed) University of Illinois graduate and undergraduate students (mean age = 21). Twelve of the right-handed and 9 of the left-handed subjects were female. None of these subjects participated in Study I.

Procedure. Again, each subject placed one hand behind a screen and blindly examined with his index finger an arc taken from one of the 3 full circles. For 2 series of arc presentations, subjects were asked to withdraw their hand from behind the screen and *point* to the correct circle. In 2 other series, subjects were required to *name* the circle to which the arc belonged.

The complete circles were not included in the stimulus series. The arcs were presented in the same random order to all subjects; the same sequence used for all series. In an experimental session the 12 arcs were presented twice to the subject for examination by each hand, once for each response mode. The naming and pointing tasks were presented in a counterbalanced order. Between the pointing and the naming conditions subjects were required to complete the Edinburgh Inventory.

RESULTS

Table 6a displays mean correct choices for task by order (i.e., naming preceding pointing or pointing preceding naming), by hand used, by subjects' handedness. An ANOVA (Table 6b) indicated that only the subjects' handedness had a statistically significant effect on the results. However, the direction of the difference was opposite to that found by Nebes. Task, order, and hand used did not have statistically significant effects, nor did any of the interactions. No differences were found between the naming and pointing response modes.

Table 6a. Mean total responses and standard deviations for Experiment II. Treatment conditions represent task (mode of response), order (pointing or verbal responses first), hand used and subject's handedness. Subjects were presented with 12 arcs per hand for a total of 24 per task

Task	POINTING						VERBAL					
Order	Pointing First			Verbal First			Pointing First			Verbal First		
Hand Used	R	L	T	R	L	T	R	L	T	R	L	T
Dextral	6.5 (2.2)	6.6 (1.6)	13.3 (2.7)	7.6 (0.9)	7.0 (1.0)	14.6 (1.5)	6.8 (1.5)	7.3 (1.8)	14.1 (2.4)	6.6 (1.5)	7.7 (1.2)	14.2 (2.2)
Sinistral	7.8 (1.2)	7.5 (2.5)	15.3 (3.3)	7.9 (0.7)	7.8 (1.3)	15.8 (1.0)	8.0 (1.5)	7.8 (2.1)	15.9 (3.1)	8.7 (1.9)	8.2 (1.6)	16.9 (2.1

Table 6b. ANOVA summary table for Experiment II

Source	df	SS	MS	F	P
Task	1/35	3.45337	3.45337	1.2459	0.27194
Order	1/35	5.63485	5.63485	1.8949	0.17739
Handedness	1/35	35.84078	35.84078	12.0527	0.00139
Hand Used	1/35	0.01125	0.01125	0.0041	0.94926
Subjects (Order, Handedness)	35	104.07054	2.97367		
Task x Order	1/35	0.22599	0.22599	0.0815	0.77692
Task x Handedness	1/35	0.67423	0.67423	0.2432	0.62495
Task x Hand Used	1/35	1.76133	1.76133	0.8530	0.36203
Task x Subjects (Order, Handedness)	35	97.01388	2.77182		
Order x Handedness	1/35	0.01192	0.01192	0.0040	0.94986
Order x Hand Used	1/35	0.01125	0.01125	0.0041	0.99060
Handedness x Hand Used	1/35	3.05662	3.05662	1.1159	0.29805
Hand Used x Subjects (Order, Handedness)	35	95.87247	2.73921		
Task x Order x Handedness	1/35	2.55687	2.55687	0.9225	0.34342
Task x Order x Hand Used	1/35	0.55839	0.55839	0.2704	0.60632
Task x Handedness x Hand Used	1/35	2.85668	2.85668	1.3835	0.24745
Task x Hand Used x Subjects (Order, Handedness)	35	72.27045	2.06487		
Order x Handedness x Hand Used	1/35	0.00038	0.00038	0.0001	0.99060
Task x Order x Handedness x Hand Used	1/35	2.02049	2.02049	0.9785	0.32936

The mean Edinburgh index score for dextral subjects was 0·72 while for sinistrals the mean was —0·26. The correlation between subjects' score on the Edinburgh index and number of correct responses in the pointing condition was —0·33.

DISCUSSION

Our second experiment also failed to replicate Nebes' results. In fact, the data pointed to a trend in the opposite direction, i.e., that left-handers as a group performed this perceptual task slightly better than right-handers. Yet, we felt another replication was in order. To provide for any specific sequential effects Nebes' original stimulus presentation sequence was used [25] also, in order to enhance possible differences in group performance subjects were preselected to the extent possible by the Edinburgh Inventory to be *strongly* right- or *strongly* left-handed. The Inventory was administered to 350 students in Psychology classes. All those with extreme scores who were willing to participate were used.

EXPERIMENT III

Methods

Subjects. Twenty-eight (14 left-handed, 14 right-handed) University of Illinois undergraduate students served as subjects (mean age = 20). The mean Edinburgh index score for the dextral group was 0·87 and for the sinistral group the mean was −0·62. Seventeen of the subjects (8 right-handed and 9 left-handed) were female. One of the right-handers and 8 of the left-handers reported sinistral relatives.

Procedure. As in Experiment II, subjects responded on some series by pointing to, and on some by naming, the circle of their choice. However, in this study, the 2 pointing tasks always preceded the 2 naming tasks. The arcs were presented in precisely the same order used by Nebes. Within any handedness group half the subjects started the task with their right hand while the other half started with the left hand. The Levy questionnaire was administered between the pointing and naming conditions. The Edinburgh scores for these subjects were available from the preselection tests.

RESULTS

Table 7a presents the mean correct responses for the different experimental groups in the manner used by Nebes. The lack of any systematic trends is obvious. Table 7b presents

Table 7a. Mean total correct responses and standard deviation for Experiment III. Treatment conditions represent task, hand used, and subject's handedness. Subjects were presented with 12 arcs per hand for a total of 24 per task

Task	Pointing			Verbal		
Hand Used	R	L	T	R	L	T
Dextral	7.0 (1.8)	6.9 (1.5)	13.9 (2.7)	6.8 (2.1)	7.1 (2.1)	13.8 (3.5)
Sinistral	6.4 (1.8)	6.4 (2.0)	12.7 (3.0)	6.4 (2.3)	7.4 (1.5)	13.7 (3.2)

an ANOVA of the data collected in this experiment. No statistically significant differences were found for any of the main effects (task, hand used, and handedness) or for any of the possible interactions. The correlation between subjects' score on the Edinburgh index and total correct responses in the pointing condition was 0·09.

DISCUSSION

Three samples of university students totalling 102 subjects were administered Nebes' arc–circle test. We failed in all three studies to replicate Nebes' findings of a significant superiority of dextrals to sinistrals in inferring a configuration from its parts. Subjects' performance was also independent of the response mode (naming vs pointing). Even when we selected groups at extreme ends on the handedness continuum we failed to replicate Nebes. The only significant difference we found was in a direction opposite to that reported by Nebes. Sampling error probably accounts for the small, but statistically significant, differences we found in Experiment II. Of course, it is possible that some systematic differ-

Table 7b. ANOVA summary table for Experiment III

Source	df	SS	MS	F	P
Task	1/26	1.75000	1.75000	0.5385	0.46964
Handedness	1/26	2.89285	2.89285	0.4371	0.51434
Hand Used	1/26	2.28571	2.28571	0.7123	0.40637
Subjects (Handedness)	26	172.07143	6.61813		
Task x Handedness	1/26	1.75000	1.75000	0.5385	0.46964
Task x Hand Used	1/26	3.57142	3.57142	2.0249	0.16663
Task x Subjects (Handedness)	26	84.50000	3.25000		
Handedness x Hand Used	1/26	1.28571	1.28571	0.4007	0.53226
Hand Used x Subjects (Handedness)	26	83.42857	3.20879		
Task x Handedness x Hand Used	1/26	0.57142	0.57142	0.3240	0.57411
Task x Hand Used x Subjects (Handedness)	26	45.85714	1.76373		

ence between University of Illinois and Cal Tech and Duke students account for the difference. Yet, on the basis of our findings, we must conclude that the arc–circle test is not a good discriminator between right- and left-handed samples. If there is any substance in Nebes' hypothesis it depends on some unexplained differences between subject populations. The fact that the magnitude of the differences reported by Nebes decreases in his own report from one replication to the other suggests that it is safest to attribute his findings to sampling fluctuations. In this context it might be noted that LEVY [8] cites a personal communication from Nebes to the effect that "no difference in performance of left- and right-handed high school students was observed unless left-handers were partitioned into familial and non-familial sinistrals". In our samples whether the sinistrals did or did not have any left-handed relatives did not seem to have any significant effect on the subjects' performance in the arc–circle test.

We wish to emphasize that our data do not bear upon the conclusions Nebes drew from his study of commissurotomized patients. It may indeed be the case that the right- and left-hemispheres differ in their ability to infer wholes from parts. The various assertions about functional hemispheric differences derived from studies of commissurotomized patients have received considerable support from assessments of hemispheric activity [11]. It is the extension of such results to the performance of the "whole" system that is fraught with danger. To assume, as Nebes did, that hemispheric differences will be manifested in complex perceptual performance differences between sinistrals and dextrals is to assume a very specific mode of operation of the integrated system. For this set of assumptions there is little empirical support. We need to know how hemispheric functions are differentially utilized by the intact subject. Only from such knowledge could one derive specific predictions about differences between sinistrals and dextrals.

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