COMPARISON OF SIMULTANEOUS TESTS OF RIGHT AND LEFT HAND GRIP WITH SEPERATE SUCCESIVE TESTS

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Two hands are better than one if they belong to the same head. They naturally supplement each other as cooperating allies for the exertion of force in a vast variety of behavior situations. The organism as a whole seems to gain in efficiency when both hands are active in the attainment of its goals. Hand dynamometry, however, has emphasized the measurement of grip force in each hand seperately and has drawn comparison between the two on the basis of succesive tests often repeated several times to find the maximum values. The hand dynamometers, as instruments, (1) (10) (12) have been designed appropriately for this type of program. But such use is only traditional, it is not obligatory (13). The program can be modified to one of simultaneous testing by making use of two identical dynamometers, one for each hand. It may be that this revised form of test can provide data more sensitive to introduced variables and perhaps somewhat more revealing of behavior changes than has been found for single-hand tests.

The problem in this study was of triple nature: (a) does the simultaneous testing of both hands give performance scores equal to those resulting from the routine of succesive tests, (b) do the two testing procedures give equal evidence of handedness as a functional psychomotor trait, and (c) with what preliminery success can subjects follow the instruction to make "half-force" grip efforts? Availability of subjects did not warrant an attempt to set up matched control and experimental groups. Two independant variables, "half-force" grip efforts, and single-hand full-force efforts, were introduced for comparison with simultaneous efforts as the dependent variable. The plan adopted for test sequence called for 7 efforts from each subject. All were simultaneous tests except nos. 6 and 7 which respectively, were on the left hand alone and right hand alone. Tests Nos. 3 and 4 were to be "half-force" efforts and served as a break in the series. This design was chosen with a view to securing an optimal sample of data from each volunteer subject without making the demand seem excessive or causing the later tests in the series to show marked decline due

to the loss of interest or to fatigue. The 7 grip tests provided 12 raw scores for comparison and correlation and gave the possibility of some tentative answers to our questions.

Method

The apparatus, instructions, and testing plan, were relatively uncomplicated. The complete program required about 10 min. service time from each subject examined. The apparatus consisted of two Smedly hand dynamometers fastened securely back to back with metal plates attached with screws thus providing a rugged double unit suitable for use with both hands at the same time. (8)[1] The weight of the unit was 1.53 Kg. For each hand there was, of course, a seperate registration dial 14.5 cm. in diameter calibrated in Kg. and with 0.5 Kg. markings. The adjustable handle of each unit was set so that the thumb and fingers in applying strength spanned a total distance of 6 cm. This was constant for both hands of all subjects. It is the same dimension as the widest part of the Collin instrument of oval shape.

The double instrument was held by the subject somewhat above his waist level and near the body. The arms were flexed at the elbows and turned inward with thumbs up. The action of the fingers of the subjects' hands were in opposite directions. One of the registration dials faced the subject parallel to his chest, the other faced away from him.

There were three parts to the instructions: (a) a short introductory demonstration of the double dynamometer, (b) an explanation of how to do the test, and (c) communication of results as the tests proceeded. The demonstration did not include a preliminary trial. It was to make clear the nature of the apparatus. The instructions were simple ones: "Don't push or pull, but when you are ready, make one squeeze as hard as you can with both hands at once, then pass the instrument back to me for reading the results". As the scores were entered on the record card the subject looked on and was aware of them but time was not used to make detailed comparisons. All the testing was individual and competition was not introduced as a factor in motivation. At the end subjects were thanked for their cooperation.[2]

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1) So far as the writer knows, this arrangement was first made by the psychologist, Dr. Franklin S. Fearing.

2) All the tests were administered by Miss Halide Yavuz, a graduate assistant whose competent service is gratefully acknowledged. The author also would express appreciation to the subjects who volunteered for the tests. Some men were tested but the group was too small to warrant reporting.

The subjects were 31 young Turkish women. They were university students, undergraduate, and a few graduate; most all of them were in the author's classes. The double dynamometer was shown to those classes when announcing the tests and requesting the service of volunteers. All the tests were made under what may be considered normal conditions, but at different hours of the day as convenience dictated. They were all made in cool stimulating weather in November and December during the Autumn semester 1954. All the subjects were judged to be in good health and cooperative. No lame hands were observed or reported. No subject professed to be left handed but one performed as if ambidexterous. The mean age for this group of 31 young women was 23.6 years, S.D. 3.6, range 19 to 32 years. Height and weight data were also supplied by the subjects and were not checked by the assistant. The range for height was 151 to 168 cm., Mean 159, S.D. 4.8 cm. The reported weights varied from 49 to 76 kg., Mean 56.1, S.D. 6.0. These subjects were not enrolled in physical training classes or much given to athletic sports. They were, when tested, not many weeks away from the long vacation and recreation period preceeding the start of the school year.

RESULTS

The test results seem to have given an answer to the first part of the problem and the answer is in the negative. Simultaneous and sucessive grip tests do not give the same results, the sucessive procedure shows higher scores as is seen in Table 1. The right hand tested alone, see R 7, gave a mean of 27.9, S.D. 4.6 Kg. This mean is larger than those for the right hand which appear in columns 5, 2, and 1 where the tests were simultaneous for both hands. Likewise the mean for the left hand, L 6, is above the comparable tests for this hand. The three means for L, 20.1, 19.8 and 18.7, result in an average of 19.4 which compared with L, 23.8 shows a difference of 4.3 kg. and amounts a drop of — 18.0 per cent. A similar treatment of the R scores shows a mean difference of of 2.6 kg. or — 9.4 per cent. The left appears to be almost twice as responsive as the right hand to this testing procedure variable.

Trials 1, 2, and 5 reveal a slight progressive decline in the mean scores for each hand. The drop from L 20.1 to L 18.7 amounts to 1.4 kg. and this difference proved stastically significant at the .02 per cent level of confidence. In contrast the shift from R 25.8 to R 24.8, a change of 1.0 kg., did not meet the criterions even at a .10 per cent level. This gives another indication that the left-hand score is more sensitive as a measure than the right.

Table 1. Comparison of simultaneous left and right hand grip scores under instructions to give full-force and half-force efforts. (Subjects, 31 young Turkish women. Scores in Kg.)

Trials	1 Full - Force		2 Full - Force		3 Half - Force		4 Half - Force		5 Full - Force		6 F - F	7 F - F
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Mean	20.1	25.8	19.8	25.3	13.1	16.2	12.1	14.8	18.7	24.8	23.8	27.9
S. D.	3.1	4.0	4.7	4.0	3.6	4.5	3.5	4.4	3.8	4.8	4.0	4.6
S. D^M	.57	.73	.86	.73	.66	.82	.64	.80	.69	.88	.73	.84
M_D *	—21.5		—21.6		—16.8		—15.9		—23.8		—14.3	
σ_D	10.4		14.3		18.1		17.6		11.6		7.7	
σ_{MD}	1.90		2.61		3.30		3.21		2.12		1.41	
t	11.3		8.28		5.09		4.95		11.3		10.1	
P	$<.001$		$<.001$		$<.001$		$<.001$		$<.001$		$<.001$	

* Determined individually for each S. on a percentage ratio basis L/R.

It seems quite probable that placement of the single-hand tests, L 6 and R 7, at the end of the series resulted in their showing somewhat lower means. This notwithstanding they are clearly representative of a different population of means than those resulting from simultaneous tests; this is indicated in Table 2. The series of mean differences between L 6 and L 5, L 2, and L 1 respectively are found to become progressively smaller and this is also true for the R 7 series. But in fact both series are large differences, five of them significant at better than the 1 in a 1000 probability level and the sixth having $P = < .01$. These results provide major support for the conclusion that the two hands tested one at a time may be expected to yield larger scores than when tested simultaneously, and that the score difference with the left hand will exceed that of the right in most cases.

Table 2. Differences between single - hand tests and three sets of two-hand tests (Subjects 31 young Turkish women, values in kg.)

Group	L6-L5	L6-L2	L6-L1	R7-R5	R7-R2	R7-R1
M_D	+5.09	+3.99	+3.78	+3.10	+2.66	+2.20
σ_D	2.83	3.10	3.19	3.97	3.53	4.10
σ_{M_D}	0.52	0.57	0.58	0.73	0.64	0.75
t	9.70	7.00	6.52	4.25	4.15	2.93
P	< .001	< .001	< .001	< .001	< .001	< .01
Minus Diff.	0/31	2/31	4/31	7/31	7/31	12/31

The second part of the generating problem in this study asked comparison of simultaneous and the successive type of testing as indicators of functional handedness. The mean differences in percentage appearing in the lower portion of Table 1 seem to favor the simultaneous test as revealing a significantly larger differention. The M_D for R 7 — L 6 — 14.3 per cent whereas Trials 1, 2 and 5 show, in the same order, M_{Ds} of — 21.5, — 21.6 and — 23.8 per cent, and in all these comparisons $P = < .001$. These data favor the simultaneous test as the stronger indicator of functional difference between the hands by a factor of about 0.5.

Subjective scaling of grip force implies making such efforts without visual or other sensory control except the naturally involved tactual-kinesthetic experience associated with squeezing the dynamometer handles.

The task for the subject is different from that of judging sensory magnitudes for loudness, brightness, lifted weights (11) and pressure on the finger. The sensory datum for judgment is pressure **by** the fingers. The process of estimation is complicated by the necessity for action as a means of presenting the stimuli which must be judged on the fly against a rather vague frame of reference. It seems likely that scaling in the sensory-motor area is possible with some measure of success but the data here represent only a very preliminary brush with the problem. The "half-force" efforts were made in Trials 3 and 4, see Table 1. In terms of the previous means both these efforts turned out too strong. The second was somewhat lower than the first. Calculations for L 3 - L 4 are presented in Table 3. There is a mean difference of — 4.9 per cent with P $\leqq$ .05. The parallel mean difference for R 3 - R 4 is - 5.3 but the variance is so large it has low statistical significance. The mean percentages by which the scaled efforts exceeded 50 per cent of the full-force trials are shown in Table 3. For both hands these differences are highly significant.

Table 3. Comparison of first and second trials in gripping with half-force by left and right hands simultaneously measured: (Subjects, 31 young Turkish women; values given in terms of percentage differences individually computed.)

Trials	3 Left	4 Left	L3-L4	3 Right	4 Right	R3-R4
M D	+16.0	+11.1	— 4.9	+13.0	+ 7.8	— 5.3
D	15.9	14.6	12.8	14.1	14.6	16.5
M D	2.90	2.67	2.34	2.58	2.67	3.02
t	5.52	4.16	2.09	5.04	2.92	1.74
P	<.001	<.001	$\leqq$ .05	<.001	<.01	<.10

The product-moment (Pearson r) correlation coefficients for right and left hand pairs of scores as recorded in Table 4 show a good degree of internal consistency in the series of seven tests. The six most naturally related pairs, including R 7 and L 6 among them, were found to have coefficients ranging from r .62 to .84 with critical ratios of 3.4 to 4.6. These coefficients appear in bold faced type in a diagonal line in Table 4. The 10 coefficients for R 7 with scores from the simultaneous tests appear in

the horizontal line at the bottom of the table. The lowest in the series is r .53, the highest is r .74, and the mean for the group of 10 is .61. Similarly for the 10 correlations of L 6, found represented in the second from the bottom of Table 4, the range is from r .50 to .76 and the mean is also .61.

Not counting correlations involving L 6 and R 7, discussed above, there are 45 other coefficients in Table 4. Forty of these represent measures not made at the same time, for example, L 1 and L 2, R 1 and R 2, and L 1 and R 2. These 40 coefficients were divided into three groups for comparison. There are 10 cases like the first example, 10 others for R and R, and 20 for combinations of L and R. The latter group gave a mean r of .48. Right hand correlated with other right hand scores gave a mean of .585, and the five left-hand groups when inter correlated showed .507 as an average.

Table 4. Product-moment correlation coefficients for right and left hand grip-test scores some recorded successively and others simultaneously. (Subjects, 31 young Turkish women; ungrouped data and rs not corrected for attenuation.)

Group	L 1	R 1	L 2	R 2	L 3h	R 3h	L 4h	R 4h	L 5	R 5	L 6	R 7
L 1		.62	.49	.66	.22	.37	.49	.49	.38	.36	.58	.55
R 1	**.62**											
L 2	.49	.53										
R 2	.66	.78	**.62**									
L 3h	.22	.37	.43	.38								
R 3h	.37	.61	.46	.59	**.83**							
L 4h	.49	.40	.50	.50	.72	.49						
R 4h	.49	.52	.63	.51	.57	.55	**.79**					
L 5	.38	.47	.60	.62	.64	.38	.60	.50				
R 5	.36	.66	.46	.71	.53	.48	.44	.44	**.78**			
L 6	.58	.57	.76	.66	.54	.50	.56	.54	.75	.67		
R 7	.55	.55	.60	.62	.69	.59	.66	.53	.74	.58	**.84**	

Discussions

No extensive comparison of the above results with the large amount of hand-grip data in earlier scientific literature seems necessary here. Variations in means from group to group are to be expected. The results of hand dynamometry are in accord in showing the right or dominant hand

stronger than its mate. This ratio is often stated as R/L. In this paper the reverse procedure has been adopted. The scores for the dominant hand appear to constitute the more stable body of data with greater internal consistency, therefore, R seems the preferable standard.[1] A few examples from the literature worked out on this basis may be cited. Downey (4) repeated single hand tests on a group of 94 college women. Two sets of means are given, one shows an L/R ratio difference of —14.2 per cent, the other —13.0. These values agree closely with the R 7 - L 6 difference of —14.3 shown in Table 1 above.

Data on men show a smaller L/R ratio difference than for women. Clarke (3) published single hand test scores of grip taken on 914 male students. The sub-group with high scores showed an L/R ratio difference of azout —6.4 per cent, the group with low scores gave —8.0, and the total average was —7.5 per cent. Wulfeck (15) secured grip measures of groups of men who were truck drivers representing three widely seperated locations in the United States. He used Smedley dynamometers, one in each hand, held down at the thigh level on each side. His subjects were told to "grip both together as hard as possible". At Baltimore 68 drivers showed a hand difference of —8.4 per cent; at Nashville 92 drivers gave a value of —8.2 per cent; and for the Chicago area 65 cases registered a percentage difference of —7.8. These results were secured from men who were off duty and had not been driving for several hours. Although two dynamometers were used the conditions were not directly comparable with those reported on the Turkish subjects. Wulfeck does not comment on how well his subjects carried out his instructions, which implied simultaneous grip action, and he does not use this phrase or discuss the L/R ratio in his report. It seems appropriate to compute the ratios from his data as evidence on the ratio difference between men and women.

The finding on the Turkish women that the two hands tested alone result in higher mean scores than when tested together at the same time may or may not be new. The literature on handedness and grip testing is large and very widely scattered. Years ago it was found that grip scores could be increased by means of a strong stimulus applied or given shortly before a subject squeezed a dynamometer. Reaction time was found to be quicker for a combination of stimuli than for one of these stimuli presented alone. When studies on summation and facilitation were being followed with keen interest related questions arose. One of these (2) was "with reference to the performance of two operations simultaneously, as for ex-

[1]) Another method of comparison, dividing the left-hand score by the sum of the scores for both hands, could have been used. This L-fraction for the six sets of means in Table 1 would range from .430 to .461.

ample, squeezing a dynamometer with the right and left hand simultaneously." The answer was, "evidence shows that the maximum squeeze of each hand is actually increased". Let us see how this answer fits with our data. In developing Table 2 the differences for each subject were computed between the single-hand efforts and the comparable two-handed efforts done in trials 1, 2, and 5. The total of such differences for the 31 subjects was 93 for each hand. As shown on the bottom line of Table 2,26 of the 93 differences for the right hand were of minus sign while for the left there were 6. There were 3 instances showing hoth L 6 and R 7 lower than L 1 and R 1 respectively, and one such instance in the comparison with L 2 and R 2. There were a total of 32 minus differences with a mean of 1.78 kg. as compared with a mean of 5.44 kg. for the 129 plus differences. About two-thirds of the minus deviations were accounted for by 6 of the 31 subjects. There was only one single-handed test available for comparison with three simultaneous tests and probably it had a less favorable position in terms of predictability for high score and this was by experimental design. The present study suggests the tentative conclusion that for some few subjects and very occasionally for others simultaneous grip efforts may register higher than single-handed tests but not on a general rule.

Simultaneous tests resulted in a wider seperation between the mean scores for the right and left hands than was found for the successive one-handed efforts and therefore may be described as a more positive measure of handedness. It seems unlikely that this is an undue exaggeration of handedness differences or a spurious measure of them. During the normal process of growth and development the hands receive intensive and varied training in working together. Testing the hands both at once can hardly be considered an artificial physiological or psychological situation, but rather the contrary. With the hands placed in readiness for action the effort of gripping requires neither visual guidance nor spatial precision. There is no tense period of readiness for an outer signal. One moment the subject is relaxed and the next he finds himself responding with all-out energy to an inner signal that has resulted in strong contractions in the flexor muscles of both upper limbs. The event is somewhat like diving or a standing broad jump except that it involves a more restricted group of muscles and seems to begin and end more quickly. Most other motor coordinations usable for securing measures of the relative efficiency of the two hands seem to require successive administration by reason of the complex of factors involved. The simple test of performing a rotary hand and fore arm movement at top speed for 10 sec. (5) (9) cannot well be done by both hands at once. Jerky movements and moments of blocking tend to occur. Tests requiring visual guidance in combination with factors of spatial precision and speed or tim-

ing are all the more limited to one hand. The organism as a whole is responding at one time with the right hand as its operational instrument but may at another time use the left for the same objective purpose. If the means for samples of responses under the two conditions show a reliable difference handedness as the independent variable gets the credit. For example a reaction - coordination test (7), that requires speed and a moderate degree of skill in placing movements, has been found (6) to register as large a percentage difference in L/R ratio as was found for the simultaneous grip tests. A group of 38 young women, with age range 20-29 years, measured for reaction-coordination time showed a mean for the right hand of 1.11 sec. and for the left a mean of 1.35 sec. The L/R ratio difference was +21.6 per cent. This is much larger than is usually found as a difference between the two hands (14) in simple reaction time tests and experiments. The reaction - coordination test as compared with simple reaction time thus appears to qualify as a more sensitive indicator of handedness organization, responsivenes and skill. Shifting the emphasis from the older objective of measuring the maximal exertable force of each hand when examined alone, simultaneous testing directs experimental attention to the functioning of the two hands together.

Summary

Two procedures for the study of functional handedness were examined by an experimental design using seven tests and 31 Turkish university women as subjects. The design included two trials of scaling grip to "half-force". The apparatus was a double hand dynamometer formed by securely fastening two Smedley instruments back to back. Simultaneous testing of both hands was found to give reliably lower mean scores than found with the common procedure of testing each hand alone. This difference was smaller for the right hand (2.6 Kg., —9.4 per cent) than for the left (4.3 Kg., —18.0 per cent). The simultaneous performances showed a significantly larger difference between the hands than was found when the hands were tested one at a time. Three tables of derived data in which the Ps are usually $< .001$ and a table of intercorrelation coefficients are interpreted as tending to support the conclusion that the simultaneous form of examination is a more sensitive psycho-motor test of behavior.

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