BARNSLEY   HANDEDNESS: PROFICIENCY VERSUS STATED PREFERENCE

Abstract

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Handedness: Proficiency versus stated preference

Department of Psychology

Master of Arts

Summary

An investigation into the performance factors of developed hand preference was undertaken. Measurements taken from both the preferred and non-preferred hands of 50 males and 50 females yielded scores on 61 dependent variables from 32 tests. Factor analyses of the scores produced nine interpretable factors of hand performance. Each of the nine factors were common to male-female; and preferred—non-preferred performance. However, preferred hand performance was superior on almost all tasks. It was suggested that preferred hand performance is characterized by "Automatization" of the skills involved in hand performance. The results cast serious doubt on the validity of using questionnaires of hand preferences to measure the degree of established handedness.

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HANDEDNESS: PROFICIENCY VERSUS STATED PREFERENCE

by

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Introduction

The impetus for this study lies in the conflicting results of investigations of the relationship between handedness and reading ability. A thorough examination of these discrepant reports suggested that an explanation lay in the procedures used for assessing handedness. It became clear that before a more definitive answer could be given concerning the relationship of handedness to reading ability, the approach to the assessment of handedness would have to be examined more closely. It was to this end that this investigation was directed.

The relationship of handedness to reading ability has been discussed by a number of authors. Coleman and Deutsch (1964, p.43) in their summary state, "The failure of children to establish complete unilateral preferential usage has been seen as an expression of incomplete cerebral dominance which itself causes reading disability (Orton, 1937), or—in a modification of this theory—as an expression or neural maturational lag underlying reading disability (De Hirsch, 1952). Others (Benton and Menefee, 1957) have considered the possible interference of incomplete lateral dominance with the development of right-left discrimination, which itself is considered essential to learning to read." Palmer (1964) suggests

that the proper assessment of handedness could act as an index of general development. For him the failure to establish handedness would indicate retarded development and hence, one would expect reading ability or more specifically, reading readiness to be associated with degree of handedness.

Studies investigating this proposition have produced conflicting results. The studies of Dearborn (1933), Harris (1957) and Vernon (1957) lend support to the relationship between reading ability and handedness. Balow (1963), Balow and Balow (1964), Capobianco (1966) and (1967), Chakrabarti and Barker (1966), Coleman and Deutsch (1964), and Silver and Hagin (1960) provide data which do not support this relationship.

Examination of the procedures used for assessing handedness suggests an explanation for the inconsistency. Some studies have determined handedness by asking the subject to state with which hand he writes and throws, (e.g. Chakrabarti and Barker, 1966). Other studies have asked several questions about hand preferences, such as, enquiring into the hand used for cutting with scissors and turning a door knob (e.g. Belmont and Birch, 1963). From such tests, conclusions are drawn about whether the subject is right-handed (if he says he uses the right hand for

all or most of the activities); left-handed (where
the left hand is used for all or most of the activ-
ities); or ambidextrous (if the subject responds
by saying he used the right hand for some activities
and the left hand for the other activities).

Clearly, in such studies the conclusions are
determined by procedures which rely completely on the
subject's report. In long questionnaires, such as
those used by Harris (1958) and Crovitz and Zener
(1962), and especially with young children, persever-
ation of responses may be involved. Further, im-
plicit in this procedure is the assumption that the
activities sampled are an unbiased selection of the
population of tasks performed with the hands. The
ramifications of this assumption are most evident
when one considers the case where a subject is labelled
ambidextrous because he states a mixed preference for
the tasks sampled. It would not be unreasonable to
suspect that the tasks (for example, those the subject
answered "left" to) may be the entire population of
tasks that he performs with that hand. In such a case,
the subject would be wrongly classified. It may also
be seen that questionnaires of hand preferences gen-
erally lack standardization; often necessitate quali-
tative assessment by the tester; and the resulting

classification is too rigid to adequately define
the range of handedness.

A further confusion is evident in these studies.
The use of the questionnaire or hand preference tech-
nique for measuring handedness does not allow the dis-
tinction to be made between whether a subject is ambi-
dextrous or whether he is ambilateral or ambisinistral.
Ambidextrous subjects are those who have not establish-
ed a dominant hand, but can use both hands with the
same facility as a unilateral person can use his dom-
inant hand. Whereas, ambilateral or ambisinistral
individuals are those who have not established a dom-
inant hand and can not use either hand as well as
the unilateral person can use his dominant hand.
Palmer (1964) suggests that the failure to make this
distinction may be part of the explanation for the
conflicting results among the studies cited above.

Of more importance, however, is the question of
whether such scales actually measure what is meant by
the concept of handedness. Harris has said that,
"Lateral dominance means the preferred use and better
performance of one side of the body as compared to the
other side." (Harris, 1958, p.3) Hildreth in her ex-
haustive review of the theory and research on hand-
edness states that, "Handedness is a matter of degree

determined by the difference in skill with which both hand are used." (Hildreth, 1949, p.201) Benton, Myers and Polder (1962, p.331) state that, "Handedness is far too complex to be defined adequately in simple typological terms." Indeed, it appears that the questionnaire approach, which has been used almost exclusively to the present time, is not only psychometrically inadequate, but it does not seem to measure what is in fact meant by handedness, namely, the degree of proficiency.

Thus, the need is to develop a scale of handedness by the use of performance measures rather than the usual hand preference questionnaire. Such a plan concurs with a statement by Hildreth (1949, p.205) that, "The essential problem in studying handedness is to determine the relative skill and dexterity of the two hands..." The same idea was again stated by Palmer (1964, p.261), "By measuring an individual's proficiency with each hand separately, and in different tasks, more complete information could be obtained than through exclusive reliance on a questionnaire." Hence, although others have recognized and pointed out the need for a handedness scale based on the relative performance of each hand, few appear to have attempted the task.

Benton, Myers and Polder (1962) investigated the relationship between hand preference (as measured by a self-rating scale and questionnaire of hand preferences) and relative manual dexterity (as measured by the Small Parts Dexterity Test and a scissor cutting task). The results suggested that the added use of manual dexterity tests in assessing handedness gave more information than a preference questionnaire alone. However, no statement could be made about the validity of the combined measurements. Simon (1964) measured the relationship of hand preference to a steadiness task, and he concluded that, "steadiness cannot be rearded as a reliable index of handedness, for while the right-handed group performed significantly better with the preferred hand, the left-handed group did not," (Simon, 1964, p.205). This conclusion loses its cogency when consideration is given to the questionable value of stated hand preference as a criterion variable for handedness.

Thus, a scale for an adequate assessment of handedness is still lacking. In accordance with Palmer (1964) it is here suggested that the development of a scale could best be accomplished by measuring the proficiency of each hand separately on a

wide variety of tasks. The tasks would be chosen
to measure many different facets of hand performance.
By factor analyzing such measurements, it would be
possible to isolate the factors involved in hand
differentiation. These factors would then form the
basis of a comprehensive scale of handedness. The
construction of such a scale has been the purpose of
the study.

Method

Subjects

The subjects were 50 females, 17.9 - 27.4
years of age ($\bar{X}$=20.6), who were employed by the
Montreal Children's Hospital; and 50 males, 17.3 -
34.1 years of age ($\bar{X}$=21.5), most of whom were un-
dergraduate Psychology students at either McGill
University or Loyola College. $\underline{S}$s were screened
for permanent injury or deformity to either of their
arms or hands. An assumption was made that these
subjects possessed established hand preferences and
that a factor analysis of their scores on the var-
ious tasks would yield factors associated with de-
veloped handedness.

Tasks

Fleishman and Hempel (1954, 1955 and 1958) and
Fleishman and Ellison (1962) have factor analyzed
the results of a large number of psychomotor tests
which are performed with the hands. As many of the
tasks were performed with either one hand only or bi-
manually, the results were used only as a guideline
for the selection of the tasks used in this study.
A number of the tests in the present investigation
were chosen with reference to their loading on the
relevant factors observed in the studies by Fleish-

man and his colleagues. Tests were also chosen with
a view to other relevant studies, while some tasks
were picked solely for intuitive reasons.

Abbreviations by which the dependent variables
will be referred to in the following sections precede
the definition of each variable.

Test-retest reliability coefficients corrected
by the Spearman-Brown formula (r) have been calculated
from the data and are included after the description
of each dependent variable, except for Left-right
discrimination; Hand preferences; and Handedness--
self-classification.

Factor: Finger or Fine Dexterity (Fleishman and
Hempel, 1954)

Test 1: Purdue Peg Board: A board containing two
columns of small holes (25 holes in each column) and
a container holding pegs, are used. The $\underline{S}$ is re-
quired to pick up pegs, one at a time, and place
them in the holes as quickly as possible.

Purdue PB=Time to fill one column. (r=.85)

Test 2: O'Connor Finger Dexterity Test: A board
containing 100 holes and a tray holding 300 pins is
used. The $\underline{S}$ picks up three pins at a time and places
them in each hole.

Connor FDT = Time to fill one row of 10

holes. (r=.73)

Test 3: Grooved Peg Board (Klöve Motor Steadiness

Battery): The S places grooved pegs into holes which

are arranged in differing positions on a board.

Grooved PB = Time to fill three rows of five

pegs each. (r=.78)

Factor: Manual Dexterity (Fleishman and Hempel, 1954)

Test 4: Minnesota Rate of Manipulation--Turning: A

large board containing 58 holes and 58 cylindrical

blocks is used. The S removes a block; turns it over;

replaces it; and so on.

Minn RM = Number of blocks turned in 30 seconds.

(r=.89)

Test 5: Marble Board (Hempel and Fleishman, 1955):

The S places marbles, one at a time, in a groove on

a board.

Marble Bd = Time to fill the groove (20 marbles).

(r=.81)

Factor: Wrist-Finger Speed (Fleishman and Hempel, 1954)

Test 6: Tapping--Large: With a pencil, the S places

three dots successively in each of a series of 7/16

inch circles.

Tap--Large = Time to complete one block of circles (40). (r=.96)

Test 7: Tapping--Small: With a pencil, the S places one dot in each of a series of 1/8 inch circles.

Tap Sm-Time = Time to complete one block of circles (40). (r=.97)

Tap Sm-Err = Number of dots not in the respective circles (errors). (r=.91)

Tap Sm-TxE = One plus number of errors multiplied by the time. (r=.91)

Factor: Aiming (Fleishman and Hempel, 1954)

Test 8: Square Marking: The S marks an "X" in each of a series of 1/8 inch squares.

Sq Mk-Time = Time to complete two rows (36 squares). (r=.99)

Sq Mk-Err = Number of "X's" protruding from the squares (errors). (r=.93)

Sq Mk-TxE = One plus number of errors multiplied by the time. (r=.95)

Test 9: Marking Accuracy: On an IBM answer sheet various slots are circled. The S is required to move from item to item filling in the circled slots as quickly as possible.

Mk Acc-Item = Number of items marked in 30 seconds. (r=.97)

Mk Acc-Err = Number of marks protruding outside the circle (error). (r=.88)

Mk Acc-I-E = Number of items correctly marked. (r=.96)

Factor: Arm-Hand Steadiness (Hempel and Fleishman, 1955)

Test 10: Hand Steadiness (Klöve Motor Steadiness Battery): The S rests his arm against a table and places a stylus in successively smaller round holes. The S holds the stylus in each hole for ten seconds while attempting not to touch the sides of the hole.

Hd St-Hole = Smallest hole (numbered ordinally) in which S first produced five touches. (r=.67)

Hd St-Touch = Cumulative number of touches for the nine holes. (r=.86)

Hd St-Dur = Cumulative duration of touches for the nine holes. (r=.58)

Test 11: Arm Steadiness (Klöve Motor Steadiness Battery; and Simon, 1964): This test is identical to Test 10, except that the S is not allowed to rest his arm against the table which holds the apparatus.

Arm St-Hole (r=.77); Arm St-Touch (r=.92);

Arm St-Dur (r=.78) = Same as for Test 10.

Factor: Response Orientation (Fleishman, 1958)

Test 12: Discrimination Reaction Time: Although
Fleishman (1958) used a four choice discrimination,
it was decided to use a two choice discrimination
at this time. To a red and green light, mounted
vertically, the S responds to either the left or
right reaction time key (colour-coded red and green)
depending on which light is activated.

Discrim RT = Median of five trials recognition
time (the length of time S takes to begin a response
after the stimulus has been presented). (r=.70)

Discrim MT = Median of five trials movement
time (the length of time that S takes to move from
the start button to the response button—does not
include recognition time). (r=.79)

Discrim TT = Reaction time (the sum of the med-
ian recognition time and the median movement time).
(r=.71)

Test 13: Printed Discrimination Reaction Time:
Going from item to item as rapidly as possible, the
S makes a check mark in one of four slots (arranged
in an up-down, left-right pattern) according to the
configuration of black and white dots.

Pr Disc Rt = Time to complete 32 items. (r=.88)

Factor: Fine Control Sensitivity (Fleishman, 1958)

Test 14: Rotary Pursuit: The S attempts to keep
a flexible stylus on a circle (one inch in diameter)
which is mounted on a turntable moving at 45 r.p.m.

Rot Purs = Amount of time that the stylus is in
contact with the target during a 20 second trial. (r=.92)

Factor: Reaction Time (Fleishman, 1958)

Test 15: Auditory Reaction Time: The S responds
to the onset of a tone by pressing, as quickly as
possible, a response key which is mounted one inch
away from a start key.

Aud RT (r=.85); Aud MT (r=.89); and Aud TT
(r=.86) = Same as for Test 12.

Test 16: Visual Reaction Time: This test is id-
entical to Test 15, except that the S responds to
the onset of a light, rather than a buzzer.

Vis RT (r=.77); Vis MT (r=.87); and Vis TT
(r=.85) = Same as for Test 12.

Factor: Speed of Arm Movement (Fleishman, 1958)

Test 17: Jump Visual Reaction Time: This test is
identical to Test 16, except that the S moves from
a start key mounted six inches from the response key.

J Vis RT (r=.85); J Vis MT (r=.90); and
J Vis TT (r=.89) = Same as for Test 12.

Test 18: Jump Auditory Reaction Time: This test
is identical to Test 17, except that the S responds
to the onset of a buzzer, rather than a light.

J Aud RT (r=.89); J Aud MT (r=.89); and
J Aud TT (r=.89) = Same as for Test 12.

Factor: Aiming (Fleishman and Ellison, 1962)

Test 19: Pursuit Aiming: The S is required to fol-
low a pattern of small circles (3/16 inches in dia-
meter) placing one dot in each circle around the pat-
tern.

P Aim-Time = Time to dot all 80 circles. (r=.97)

P Aim-Err = Number of dots not in their res-
pective circle (error). (r=.88)

P Aim-TxE = One plus number of errors multi-
plied by time. (r=.86)

Other Tests

Test 20: Hand Preferences (Harris, 1958): S is
asked with which hand he performs each of ten dif-
ferent activities.

Hand Pref = Number of activities performed by
each hand.

Test 21: Printing Name (Harris, 1958): Although Harris asks his $\underline{S}$s to write their name (first and last), it is felt that printing will circumvent the consideration of abbreviations that are frequently found in adults' signatures.

Print Name = Time taken to complete the response divided by the number of characters produced. (r=.98)

Test 22: Dynamometer (Harris, 1958): The $\underline{S}$ is asked to squeeze a dynamometer as hard as he can.

Dynamom = The strength of grip exhibited in kilograms. (r=.97)

Test 23: Dealing Cards (Harris, 1958): The $\underline{S}$ deals 26 cards alternately to the $\underline{E}$ and himself as fast as he can.

Deal Cards = Time time to complete the task. (r=.97)

Test 24: Dowel Balancing (Palmer, 1963): The $\underline{S}$ balances an 18 inch long by 5/16 inch diameter dowel on his forefinger.

Dowel Bal = The amount of time that the $\underline{S}$ is able to balance the dowel. (r=.80)

Test 25: Left-Right Discrimination (Benton, 1959): The $\underline{S}$ is tested concerning his knowledge of left-right awareness for both self and other person items.

L-R Dis = Number of correct items out of 32.

Test 26: Small Parts Dexterity Test (Crawford and Crawford, 1956; and Benton, Myers, and Polder, 1962): With tweezers, the $\underline{S}$ picks up small pins; places them in holes; then picks up a small metal collar and places it on the pin.

Sm Pt Dex = Time to assemble a row of six such units. (r=.77)

Test 27: Vertical Movement Steadiness (Klövé Motor Steadiness Battery): The $\underline{S}$ moves a stylus through a 16 inch long by 4.00 mm. wide, vertically mounted track while attempting not to touch the sides.

Ver St-Touch = Number of touches. (r=.75)

Ver St-Dur = Cumulative duration of the touches. (r=.79)

Ver St-Time = Time to complete the task. (r=.85)

Test 28: Horizontal Movement Steadiness (Klövé Motor Steadiness Battery): This test is the same as Test 27, except that the track is mounted horizontally.

Hor St-Touch (r=.74); Hor St-Dur (r=.65); and Hor St-Time (r=.72) = The same as for Test 27.

Test 29: Maze Movement Steadiness (Klövé Motor Steadiness Battery): The $\underline{S}$ traces a track through a maze with a stylus while attempting not to touch the walls of the track.

Maz St-Touch (r=.85); Maz St-Dur (r=.84); and

Maz St-Time (r=.90) = The same as for Test 27.

Test 30: Finger Tapping--Short (Reitan, 1955):
The S taps a mechanical tapper with his forefinger
as fast as he can for ten seconds.

F Tap-Short = Number of taps. (r=.88)

Test 31: Finger Tapping--Long: This test is the
same as Test 30, except that the S is required to tap
for one minute. This test is an attempt to assess
differences in fatigue between the hands.

Tap Long-TT = Total number of taps. (r=.90)

Tap Long-31 = Number of taps in the last 30 se-
conds of the trial. (r=.86)

Test 32: Handedness--Self-Classification (Adapted
from Benton, Myers and Polder, 1962): On a line seven
inches long, with the left-hand pole marked "Strong
Left"; the middle marked, "No Preference"; and the right
hand pole marked, "Strong Right", the S is asked to
rate himself as to how handed he thinks he is.

H Self Clas = Distance of rating from the center
or "No Preference" point.

Procedure

To facilitate the administration of the large
number of tests they were divided into five divis-
ions: 1. reaction time tests (includes tests 12, 15,
16, 17 and 18); 2. steadiness tests (tests 10, 11, 14,

27, 28, and 29); 3. pencil and paper tests (tests
6, 7, 8, 9, 13, and 19); 4. apparatus tests (tests
1, 2, 3, 4, 5, and 26); and 5. miscellaneous tests
(tests 20, 21, 22, 23, 24, 25, 30 and 31). By use
of random number tables, the tests were assigned to
an order within their respective classification. This
order may be found in Appendix A.

Reaction time tests, steadiness tests and tap-
ping—large, tapping—small, and marking accuracy
formed Battery A. Administration of Battery A al-
ways began with the pencil and paper tests (all pos-
sible combinations of order were used). The reaction
time and steadiness tests were given in a forward or-
der one-half of the time and in a backward order the
other half. Reaction time and steadiness tests each
followed immediately after presentation of the pen-
cil and paper tests an equal number of times. This
procedure resulted in 24 different orders of admin-
istration.

Battery B consisted of the apparatus tests, the
miscellaneous tests, and square marking, pursuit aim-
ing and printed discrimination reaction time tests.
All possible combinations of order of administration
were used between the classifications. The order of
presentation within the classifications was reversed

one half of the time. This procedure yielded twelve
different orders of administration.

All tests (except tests 20, 25, and 32) were
administered twice to each hand in a counter-bal-
anced order. Test 32 (which was always the first
test administered) was used to determine the prefer-
red hand which was then always used first in the coun-
ter-balanced order.

Testing was done in two sessions, each of approxi-
mately an hour and a quarter duration, on separate days.
Battery A was administered during one session, Bat-
tery B during the other. One-half of the subjects
performed Battery A first; one-half Battery B. The
order of administration in each battery was assigned
to each S at the time of testing.

A detailed account of the administration pro-
cedure for each test may be found in Appendix A.

All testing was performed by two Es. Each E
did approximately one half the testing of Battery A
and Battery B. All tests were individually adminis-
tered in appropriate rooms containing only the sub-
ject and the E.

Design

All tests (except Hand Pref, H Self Clas, and
L-R Dis) yielded four scores, two for preferred hand

performance and two for non-preferred hand perfor-
mance. In each case the two scores were summed.
This procedure produced a non-preferred hand perfor-
mance score (called "NP") and a preferred hand per-
formance score (called "P"). These scores were clas-
sified by sex and four groups resulted: 1) Male P
(called "M-P"); 2) Male NP (called "M-NP"); 3)
Female P (called "F-P"); and 4) Female NP (called
"F-NP").

The skewness and kurtosis of the distributions
of each variable was calculated and compared with that
of a normal distribution. Where the skewness or kur-
tosis of a variable differed significantly from
"normal", appropriate transformations were applied.
This procedure yielded all distributions essentially
"normal". From these calculations four inter-cor-
relation matrices were derived from the following
dependent variables: 1) M-P; 2) M-NP; 3) F-P; and
4) F-NP. Two remaining inter-correlation matrices,
one for males and one for females, were formed by
correlating ratios between P and NP (P/NP). This
procedure was used by Palmer (1967) as a method of
quantitatively describing factor differences between
preferred and non-preferred performance.

Factor analysis (principal component method) was

performed on each of the outlined inter-correlation matrices. A Varimax rotational solution was applied to all non-rotated factors possessing an Eigenvalue rating of greater than one.

A "t" test for independent samples was performed on each variable in the following comparisons: 1) M-P vs. F-P; and 2) M-NP vs. F-NP. Correlated "t" comparisons were made between: 1) M-P and M-NP; and 2) F-P and F-NP.

Results

Although no distribution is available by which
the significance of a factor loading may be assessed,
a cutoff score for significance at $p < .01$ was deter-
mined to be ± 0.3648 for $N=50$. This value was ob-
tained by assuming the S_e (Standard Error) of a fac-
tor loading to be equal to one divided by the root of
N $(1/\sqrt{N})$. A significant factor loading was thus
equal to $\pm 2.58 S_e$. Only those variables which loaded
significantly $(> \pm 0.36)$ on a factor are reported.

M-P; M-NP; F-P; and F-NP Factors

Factors from these four factor analyses have
been qualitatively assessed, and where intrepretable,
labels have been applied to the skill represented.
In order to present these data in a comprehensible
form, four factors (one from each of the four analyses)
have been grouped. Factors presented together in
such a manner are thought to be representative of
similar skills and are called factors of hand per-
formance. Included with the factor loadings are:
1) factor number ("Factor No."), which is the ordinal
position of that factor's extraction in its group's
Varimax solution; and 2) % Variance, which is the
percentage of the total variance accounted for by
the factor within its group. Factors of hand perfor-

mance are numbered by their rank order based upon

the mean of % Variances (ie., the percentage of vari-

ance accounted for across all four groupings).

FACTOR I

	M-P	M-NP	F-P	F-NP
Factor No.	3	3	1	1
% Variance	7.6	8.6	18.1	19.0
Variable	Loading	Loading	Loading	Loading
Aud RT	.75	.68	.88	.90
Vis RT	.84	.87	.84	.88
Aud TT	.58	.47	.69	.87
Vis TT	.60	.64	.68	.83
J Aud RT	.71	.86	.80	.82
J Vis RT	.86	.86	.84	.82
J Vis TT	.56	.60	.68	.81
J Aud TT	.53	.62	.56	.62
Vis MT				.53
Aud MT				.52
J Vis MT				.50
Discrim RT	.55	.51	.79	.50
Discrim TT			.60	.46
Grooved PB		.36		

Factor I is identified as a <u>Reaction</u> <u>Time</u> fac-

tor. The scores which load on this factor are basi-

cally all measures of the speed with which an <u>S</u> can

respond to the onset of a stimulus. These results

replicate the Reaction Time factor of Fleishman (1958),

however, the loadings found on these factors are sub-

stantially higher than those witnessed by Fleishman.

The data also support his findings that: 1) tasks of

more complexity do not load on this factor; and
2) the ability to respond to the onset of a light
or a buzzer is similar. Although this factor accounts
for a greater amount of variance in the female groups,
qualitatively there is no sex difference. Similarly,
there appears to be no difference between preferred
and non-preferred hand performance. The Grooved PB
seems out of place on the M-NP factor, but this may
be due to chance. The Reaction Time factor accounts
for a mean % variance across the four groups of 13.3%.

FACTOR II

	M-P	M-NP	F-P	F-NP
Factor No.	2	1	3	9
% Variance	9.6	24.5	8.5	3.3
Variable	Loading	Loading	Loading	Loading
J Vis MT	.91	.88	.80	.40
J Aud MT	.88	.88	.86	.92
Vis MT	.86	.82	.61	
Aud MT	.71	.80	.44	
Discrim MT	.76	.80		
J Aud TT	.68	.69	.70	.65
J Vis TT	.71	.67	.57	
Aud TT		.62		
Vis TT	.66	.60	.46	
Discrim TT	.48	.56		
Hor St-Dur		.44		
Hor St-Touch		.43		
Sq Mk-TxE		.38		
Arm St-Hole	-.36			
Minn RM			-.43	
Hd St-Dur			.38	
L-R Dis				-.37

Speed of Arm Movement appears to be the basic
characteristic of tests which load on Factor II. The
dependent variables which are found on this factor
measure the speed with which $\underline{S}$ moves from a start
button to a response button--a gross, but discreet
movement. Basically, these findings are the same as
those found by Fleishman (1958), however, the loadings
on these factors are once again substantially higher
than the loadings on Fleishman's Speed of Arm Move-
ment factor. This is probably due to the greater
control exerted in this study in separating the re-
action time from the movement time. Furthermore,
these data demonstrate that Speed of Arm Movement
is not specific to the direction or length of the
movement (e.g. compare J Vis MT, Vis MT and Discrim MT).
It is noted that F-NP is a weak factor, however, it
still appears as a stronger factor than that observed
by Fleishman. With this possible exception, there
seems to be no sex or preferred--non-preferred dif-
ferences with regard to speed of arm movement. This
factor accounts for a mean percent variance of 11.5.

Factor III is identified as a factor which mea-
sures Wrist-Finger Speed. This factor has previously
been identified by Fleishman and Hempel (1954), Hempel
and Fleishman (1955), and Fleishman and Ellison (1962).

FACTOR III

Variable	M-P	M-NP	F-P	F-NP
Factor No.	1	4	5	5
% Variance	22.4	6.4	6.1	5.4
	Loading	Loading	Loading	Loading
P Aim-Time	.85	.73	.68	.55
Sq Mk-Time	.83	.76	.79	.59
Tap Sm-Time	.79	.78	.65	.65
Mk Acc-I-E	-.78	-.62		-.79
Mk Acc-Item	-.75	-.54		-.84
Pr Disc RT	.70	.39		
Tap--Large	.67	.50		.43
Print Name	.55	.83		.50
P Aim-Err	-.50		-.46	
Minn RM	-.45			
Aud TT	.42			
Deal Cards	.40			.38
Hd St-Dur	.40			
Grooved PB	.37			
Dynamom			-.38	
Marble Bd			.38	

Basically, these data replicate all of the previous
findings. Fleishman and Ellison's (1962, p.101)
description of the performance involved in Wrist-
finger speed is appropriate here. "...Wrist-Finger
Speed is a narrow factor emphasizing rapid pendular
and/or rotary wrist movements, best measured by printed
tests involving rapid, repetitive jabbing movements
with a pencil, where accuracy is not critical." In
light of the finding that this factor is best meas-
ured by printed tests, it is intriguing that the
factor is produced in non-preferred hand performance.

Indeed, except for the large proportion of variance accounted for by the factor in the M-P group, there is essentially no difference between sex or preferred—non-preferred performance. This factor, _Wrist-Finger Speed_ accounts for an average of 10.1% of the variance of all four groups.

FACTOR IV

Variable	M-P	M-NP	F-P	F-NP
Factor No.	7	5	4	3
% Variance	4.2	5.6	8.0	9.5
Variable	Loading	Loading	Loading	Loading
Hd St-Hole	-.73	-.84	-.39	-.82
Hd St-Dur		.59	.44	.77
Dowel Bal				-.73
Hd St-Touch	.90	.83	.47	.72
Arm St-Hole	.70	.63	.87	.60
Arm St-Dur		.54	.88	.58
Arm St-Hole	-.51	-.49	-.91	-.56
Rot Purs				-.48
Tap--Large				.40
Sm Pt Dex				.38
Ver St-Touch	.42			
Mk Acc-I-E		-.39		

Factor IV has been identified as representing _Arm-Hand Steadiness_. This name has been borrowed from Fleishman (1958), but the data bear little relation to his so named factor. More closely resembling Fleishman's Arm-Hand Steadiness Factor is this study's Factor V which is discussed next. Factor IV, _Arm-Hand_

<u>Steadiness</u>, is represented mainly by loadings on the two tests: arm steadiness and hand steadiness. Both tests measure a static-type steadiness, that is, a tremor or a shake. From these data it may be concluded that arm steadiness is no different from hand steadiness in a static task. However, this may be because hand steadiness is really the crucial variable in the arm steadiness task. Once again, a qualitative analysis of the four factors in this factor of hand performance suggests no sex or hand preference difference. <u>Arm-Hand Steadiness</u> accounts for 6.8% of the average variance.

FACTOR V

Variable	<u>M-P</u> Loading	<u>M-NP</u> Loading	<u>F-P</u> Loading	<u>F-NP</u> Loading
Factor No.	6	8	6	2
% Variance	4.9	3.4	5.2	12.9
Maz St-Dur	.85	.39	.38	.85
Maz St-Touch	.85		.36	.85
Hor St-Touch		.38	.83	.74
Ver St-Dur		.84	.52	.72
Ver St-Touch		.85	.50	.72
Hor St-Dur		.40	.85	.70
Discrim RT				.42
Arm St-Hole				-.39
Arm St-Dur	.45			.37
Hd St-Dur	.51			
Sm Pt Dex	.39			
Deal Cards			.52	
Marble Bd			.41	

Factor V has been named and interpreted as an
Arm Movement Steadiness factor. All three tests,
Maze, Horizontal and Vertical Movement Steadiness,
require the S to move a stylus through an apparatus
without touching the sides. It was noted that nearly
all the Ss performed this task with a rigid wrist
and with the stylus held still in the hand. It is
for this reason that the factor appears to measure
only "arm" movement steadiness. It is suggested
that this factor may be the same factor identified
by Fleishman (1958) as Arm-Hand Steadiness. The
comparison is made because his highest loading test,
Track Tracing, is very similar to the Maze Movement
Steadiness Test of this study. With the possible ex-
ception of the M-P group, which is not as general a
factor as found in the remaining three groups, lack
of sex and preferred hand differences is again evi-
dent. This factor accounts for 6.6% of the average
variance across the four groups.

Although Factor VI appears similar to Factor III
regarding the tests that load on each, it should be
noted that the dependent variables in either case are
very different. Whereas the measurements in Factor III
were representative of fast movement only, the loadings
on Factor VI are basically error measurements.

FACTOR VI

Variable	M-P	M-NP	F-P	F-NP
Factor No.	4	2	7	7
% Variance	6.2	10.9	4.2	3.7
	Loading	Loading	Loading	Loading
Tap Sm-Err	.90	.88	.89	.89
Tap Sm-TxE	.90	.84	.86	.90
P Aim-Err	.66	.82	.51	
P Aim-TxE	.75	.80	.51	
Mk Acc-Err		.75	.46	.72
Sq Mk-Err		.74		
Sq Mk-TxE		.65		
Maz St-Dur		.43		
Pr Disc RT			-.38	
Sm Pt Dex				.36

Thus, Factor VI appears to be measuring the accuracy of wrist-finger speed. Because of its similarity to the factor found by Fleishman and Hempel (1954) and Fleishman and Ellison (1962), this factor has been named Aiming. This factor appears to be measured by printed tests which require strict visual-motor control of a pencil in keeping marks within a specified enclosure. As noted with regards to Factor III, it is extremely interesting that the abilities necessary to perform on printed tests is as evident in non-preferred as in preferred hand performances. Once again, no difference appears to exist between the groups. The Aiming factor accounts for an average of 6.3% of all groups' variance.

FACTOR VII

Variable	M-P	M-NP	F-P	F-NP
Factor No.	5	7	2	8
% Variance	5.4	3.6	10.0	3.5
	Loading	Loading	Loading	Loading
Ver St-Time	.91	.86	.88	.80
Maz St-Time	.69	.60	.86	.81
Hor St-Time	.86	.88	.83	.85
Ver St-Touch	-.55		-.71	
Ver St-Dur	-.49		-.70	
Maz St-Touch			-.36	
P Aim-Err			-.35	
Minn RM			.33	
P Aim-TxE			-.31	
Arm St-Hole	-.36	-.58		
Arm St-Touch		.47		
Arm St-Dur	.38	.37		

Factor VII, because of the diverse nature of its loadings, proves to be a very difficult factor to identify in terms of hand performance. However, the suggestion that the four groups belong together under a single factor is supported by the identical three highest loadings on each. These three tests (Ver St-Time, Maz St-Time, and Hor St-Time) do not appear to measuring steadiness or loadings on Factors IV and V would have been observed. Therefore, it seems appropriate to seek an explanation for this factor in terms other than hand performance. In the administration of all three tests the S was instructed to perform the task "as slowly as you need to not to make errors". The S's willingness to follow these

directions, therefore, would be measured by the three scores under consideration. It is suggested that the similar factor loadings found in the four groups are explained best by this reasoning. To conclude, Factor VII emerges as a motivational rather than a hand performance factor. 5.6% of the mean variance is accounted for by this factor.

FACTOR VIII

Factor No.	M-P 9	M-NP 6	F-P 8	F-NP 4
% Variance	3.3	4.1	4.1	8.1
Variable	Loading	Loading	Loading	Loading
Tap Long-TT	.95	-.83	.92	-.94
Tap Long-31	.95	-.86	.90	-.92
F Tap-Short	.53		.51	-.77
Connor FDT				.66
P Aim-Time				.56
Sq Mk-Time				.44
Grooved PB				.39
Mk Acc-Item		-.52		
Mk Acc-I-E		-.41		
Aud RT		.37		
L-R Dis			.48	

Factor VIII is a specific factor basically loading only on the Finger Tapping tests. For obvious reasons, this factor has been named Finger Tapping. The skill found in finger tapping is more generalized for the non-preferred groups as witnessed by the loadings of other tests on these factors.

However, that this is a similar factor across the four groups is demonstrated by the consistently high loadings of the finger tapping tests in each analysis. Except for the small difference already noted, sex and preferred—non-preferred factors appear similar. It is interesting to note that Tap Long-31, a measure of fatigue, loads on the same factor in each group as Tap Long-TT. This observation contradicts the finding by Palmer (1967) that a fatigue measure discriminates preferred from non-preferred hand performance. Finger Tapping accounts for 4.9% of the average variance.

FACTOR IX

	M-P	M-NP	F-P	F-NP
Factor No.	11	9	13	6
% Variance	2.6	3.1	2.6	4.8
Variable	Loading	Loading	Loading	Loading
Marble Bd		.51	.49	.79
Purdue PB	.57		.73	.70
Grooved PB	.51	.61	.63	.57
Minn RM		-.66	-.48	-.56
Discrim RT				.52
Discrim TT				.40
Hor St-Dur				.38
Deal Cards		.51		
Connor FDT	.55	.37		
Sm Pt Dex	.62			
Ver St-Dur	.44			

Factor IX has been interpreted as a <u>Dexterity</u> factor. In previous studies, Fleishman and his co-workers (1954, 1955, and 1962) found two dexterity factors—Fine or Finger Dexterity and Manual Dexterity. The four groups found in Factor IX present a pattern very similar to the combination of the two dexterity factors found by the above researchers. Therefore, these data do not support the distinction made by Fleishman of finger versus hand dexterity. It is most surprising to note that on the <u>Dexterity</u> factor of hand performance no preferred—non-preferred hand difference is in evidence. Similarly, no sex difference is found. This factor accounts for 3.3% of the average variance across the four groups.

FACTOR X

	M-P	M-NP	F-P	F-NP
Factor No.	14	13	14	11
% Variance	2.2	2.1	2.3	2.8
Variable	Loading	Loading	Loading	Loading
Hand Pref	-.85	.73	.67	-.78
H Self Clas		-.66		.73
Print Name			.80	.42
F Tap-Short		.51		
Mk Acc-Err	.41			
Tap—Large			.49	
L-R Dis			-.41	

Factor X, a very weak, but common factor, has been interpreted as a measure of <u>Stated</u> <u>Hand</u> <u>Preference</u>. With the possible exception of the Print Name task, this factor is limited to the <u>S</u>'s verbal statement about his preferred hand. Several other tests are found on these factors, but they possess very low loadings and are not consistently observed in the four groups. These results cast serious doubt on the validity of using a questionnaire of hand preference (Harris, 1958) or the self rating method (Benton, Myers and Polder, 1962) to assess preferred hand performance. These data do not support Palmer's (1967) finding that the "conventional questionnaire measure of handedness" is related to behavioral measures. This factor accounts for 2.4% of the average variance of the four groups.

In the M-P and F-P groups there are seven factors which have not been reported and in the M-NP and the F-NP there are six factors yet to be reported. These factors have not been placed in the text, but they may be found in Appendix B. They have been relegated to the Appendix section for either one of the two following reasons: 1) the factor is uninterpretable (most fall into this category); or 2) no meaningful pattern is observed between the four groups.

As even the largest of these factors accounts for
only 3.6% of its group's variance, only a small
oversight could be committed. These 26 factors pre-
sented in the Appendix accounted for a mean per-
centage of the variance across the four groups of
14.7, whereas the 40 factors which made up the 10
factors of hand performance accounted for 70.8%
of the four groups' average variance.

M-P/M-NP and F-P/F-NP Factors

In order to render the data of this study com-
parable to those of Palmer (1967) factor analysis on
ratio scores derived by dividing P by NP were per-
formed for both sexes. This method was devised to
quantitatively demonstrate factor differences bet-
ween preferred and non-preferred hand performance.
The two principle component solutions were rotated
for ten factors with a Varimax solution.

The resultant factors for each analysis are
presented in Appendix C. The factors are not reported
in this section because they are uninterpretable and
not at all qualitatively meaningful.

A possible explanation for this lack of mean-
ingful factors may lie in the procedure of forming
ratios between P and N-P. It is suggested that this
method effectively removed all of the common variance

from the test scores. The validity of this contention
is supported by two observations. First, the per-
centage of the variance accounted for by the factors
fails to show the characteristic large drop between
the first few factors extracted. In fact each of
the ten factors in both analyses account for approxi-
mately 5% of the variance. (for M-P/M-NP, Factor I =
6.5% and Factor X = 3.9%; for F-P/F-NP, Factor I = 7.3%
and Factor X = 3.7%). These low and consistent per-
centages of variance accounted for suggest that the
factor loadings are representing mainly specific and
error variance.

Secondly, the inter-correlation matrices upon
which the factor analyses were performed were examined
for the number of significant correlations. Applying
a Chi Square test of significance, it was found that
in the Male group the number of correlations signifi-
cant at $p < .05$ was no more than could be expected by
chance ($X^2 = 1.26$, df=1, $p < .30 > .20$). The results are
not as clear for the Female group ($X^2 = 8.07$, df=1,
$p < .01 > .001$), however, the absolute number of signifi-
cant correlations is not impressive (118 correlations
significant at $p < .05$; 91.5 correlations expected to be
significant by chance alone). Therefore, an explanation
for the lack of meaningful factors which is based upon

the premise that the formation of ratio scores re-
moved most of the common variance, seems very reasonable.

<u>"t" Comparisons</u>

Independent "t" comparisons performed between
M-P and F-P; and between M-NP and F-NP are reported
in Appendix D. Also included in Appendix D are the
means and standard deviations of each variable in the
four groups. A summary list of those comparisons
yielding significant "t's" (p<.05) are reported in
Table 1.

Table 1

M-P vs. F-P Comparisons

Female performance better	Male performance better
Arm St-Touch	J Aud MT
Arm St-Hole	Vis MT
Hd St-Touch	Vis TT
Hor St-Touch	J Vis MT
Ver St-Touch	J Vis TT
Maz St-Touch	Discrim MT
Marble Bd	Ver St-Time
P Aim-Err	Maz St-Time
P Aim-TxE	Rot Purs
Tap Sm-Err	Dynamom
Tap Sm-TxE	Dowel Bal
L-R Dis	Tap Long-TT
	Tap Long-31
	F Tap-Short

Table 1 (cont.)

M-NP vs. F-NP Comparisons

Female performance better	Male performance better
Discrim RT	J Aud MT
Arm St-Touch	J Aud TT
Hd St-Touch	J Vis MT
Hor St-Touch	J Vis TT
Ver St-Touch	Discrim MT
Maz St-Touch	Ver St-Time
Purdue PB	Rot Purs
Marble Bd	Dynamom
Sq Mk-Time	Dowel Bal
Sq Mk-Err	Tap Long-TT
Sq Mk-TxE	Tap Long-31
P Aim-Err	F Tap-Short
P Aim-TxE	
Tap Sm-Err	
Tap Sm-TxE	
Mk Acc-I-E	

The "t" tests for correlated samples that were performed on M-P vs. M-NP groups and F-P vs. F-NP groups are reported in Appendix E. Also included in Appendix E are the means of the differences ($\overline{D}$) and the standard deviations of the differences (S_D).

In the female group all reaction time dependent variables were not significant, except for J Aud MT, J Aud TT, Aud RT and Discrim RT. With the exceptions of Hd St-Touch and Hor St-Dur, all other measures of hand performance differed significantly (all but three at $p < .01$). All demonstrated superior preferred hand performance.

In the male group all reaction time dependent variables were not significant, except for J Aud MT, J Aud TT and J Vis RT. With the exceptions of Hor St-Dur, Hor St-Time and Ver St-Time, all other measures of hand performance differed significantly (all at $p<.01$). Each comparison demonstrated superior preferred hand performance.

Discussion

The results of the factor analyses performed on the four groups, M-P, M-NP, F-P, and F-NP demonstrate one major finding. There appears to be no factor or qualitative skill difference between preferred hand performance and non-preferred hand performance. Also, no qualitative sex difference was found. The identified factors of hand performance closely resemble the results found by Fleishman and his co-workers (1954, 1955, 1958 and 1962). However, these investigators did not consider the major question of this study—differences in preferred—non-preferred hand performance. The fact that the findings of this study can be considered to closely replicate the previous results of Fleishman and his colleagues, comments favourably on the reliability of these data. Therefore, it can be stated with confidence that the same skills are involved in non-preferred hand performance as in preferred hand performance.

The results of the factor analyses performed on the ratio scores (M-P/M-NP; and F-P/F-NP) are consistent with the conclusion already reached. As no psychologically meaningful factors emerged from these analyses, the only acceptable explanation available

is that the skills involved in non-preferred hand performance are essentially the same as the skills involved in preferred hand performance.

The results of "t" tests carried out on M-P vs. M-NP and F-P vs. F-NP data add another dimension to the findings of the factor analyses. With the exception of the reaction time tests, there is a consistent and reliable superiority on all behavioral tests of preferred hand performance. Therefore, although the same skills are to be found in either hand, the preferred hand is characterized by better performance in each skill.

The "t" comparisons for sex differences produced some interesting findings. Basically, female performance was better on tasks demanding finely controlled and accurate movements. To be specific, female performance exceeded that of the males on the following factors: 1) Arm-Hand Steadiness; 2) Arm Movement Steadiness; 3) Aiming; and 4) Dexterity. These results are consistent for preferred and non-preferred hands.

Male performance was superior on tasks involving quick, gross movements. The factors on which male performance exceeded that of the females were: 1) Speed of Arm Movement; and 2) Finger Tapping.

Males were obviously stronger, as measured on the dynamometer test and they also showed superior performance on Rotary Pursuit and Dowel Balancing.
To conclude, although no qualitative skill differences were observed as a function of sex, sex differences were noted relevant to the level of performance on various factors.

The results of this study strongly question the validity of using preference questionnaires for assessing the degree of established handedness (e.g. Belmont and Birch, 1963; Chakrabarti and Barker, 1966; and Harris, 1957). As handedness has been shown to be characterized by superior performance of the preferred hand on many independent skills, it is obvious that such performance differences cannot be measured by a questionnaire technique. The Stated Preference factor of hand performance provides direct quantitative support for this proposal. On this factor, the questionnaire of hand preferences (Hand Pref) and the self-rating scale (H Self Clas) were the only consistent loadings. As factor extractions were orthogonal, it may be stated that these measurements are not quantitatively related to the factors of hand performance.

The findings of this study do not support the conclusions reached by Palmer (1967)[1]. In a study (conducted only on males) similar in design to the present investigation, Palmer isolated two factors which differentiated preferred—non-preferred hand performance. He identified these factors as measuring: 1) strength-power; and 2) precision-control in fine hand movements. As already noted, no factor differences between preferred—non-preferred hand performance were observed in the present study. More specifically, Tap Long-31 (designed as a measure of fatigue) loads on the same factor as other tests of finger tapping which do not appear to measure fatigue. Further, Wrist-Finger Speed, which appears similar to Palmer's second factor, was found in both preferred and non-preferred hand performance.

The conclusion reached by Palmer (1967) that handedness is not a unitary phenomenon is not supported by this study. Indeed, handedness appears to be a single dimension characterized by the superior performance of the preferred hand. This

[1]This paper, as yet unpublished, was presented at the annual meeting of the Eastern Psychological Association while the present study was in progress. A detailed report of the investigation has not been made available to the author.

relationship holds for all of the factors of hand
performance isolated in this study except, <u>Reaction
Time</u> and <u>Speed of Arm Movement</u> which do not differ-
entiate preferred from non-preferred hand performance.

It is suggested that the single dimension which
defines hand performance is the production of highly
practised and over-learned skills in the preferred
hand. Broverman's (1960) concept of "Automatization"
may be applicable to this hypothesis. Broverman has
demonstrated that individuals differ in the degree
to which they perform simple repetitive tasks. Per-
formance on these tasks that demonstrates a greater
ability than would be predicted from an individual's
general level of performance is called "Strong Auto-
matization". "Weak Automatizers" are classified by
poorer performance than would be predicted from their
general ability level. Possibly, preferred hand
phenomena are understandable as stronger automati-
zation of the skills involved in hand performance.
It should be noted that Palmer (1967) found a posi-
tive relationship between hand differentiation and
Broverman's "Automatization" dimension. Possibly,
these considerations could lead to a fruitful area
of research.

Also of interest here, is the recent finding by Mathewson (1967) that oral reading ability in ten year old boys was positively related to strong automatization. In future investigations concerning the relation of handedness to reading ability, it may be wise to consider the ability to automatize as a common link.

Future research in the area of handednes should be immediately concerned with repeating the present study with young children. Factor analyses of the hand performance of children aged five or six would yield much information concerning the early development of preferred hand performance. The results of this type of study in conjunction with the data from the present investigation should yield sufficient information to assemble a valid handedness battery; a battery based on hand performance. Hopefully, such a battery would include only a small proportion of the original tests. An item selection procedure based on the results of an adult and child study should produce a scale for the measurement of handedness that would be applicable to a wide age range.

Further research might seek to standardize a scale of handedness on many different age levels.

This type of study would allow a developmental examination of the sex differences observed in the present investigation. Further, possible differential factor growth rates of the differences found between preferred and non-preferred hand performance could be explored. The age that handedness becomes completely developed could be ascertained. Finally, the normative data gained in a study of this type would be of clinical value in assessing one aspect of the degree of a child's motor development.

Summary

An investigation into the performance factors of developed hand preference was undertaken. Measurements taken from both the preferred and non-preferred hands of 50 males and 50 females yielded scores on 61 dpendent variables from 32 tests. Factor analyses of the scores produced nine interpretable factors of hand performance. Each of the nine factors were common to male-female; and preferred--non-preferred performance. However, preferred hand performance was superior on almost all tasks. It was suggested that preferred hand performance is characterized by "Automatization" of the skills involved in hand performance. The results cast serious doubt on the validity of using questionnaires of hand preferences to measure the degree of established handedness.

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Appendix A

Included in Appendix A are the standardized instructions used for the administration of all tests. The order of the tests within each classification is that order which was achieved by a random selection.

BATTERY A

REACTION TIME TESTS

Jump Auditory Reaction Time

Instructions: Each test will begin with your index finger depressing the yellow button closest to you. When the buzzer sounds, hit the blue button as quickly as possible and keep it depressed until the buzzer is turned off.

Practice: S practices movement three or four times with each hand.

Visual Reaction Time

Instructions: You will begin each test with your index finger on the yellow button farthest from you. When the white light goes on, hit the blue button as quickly as possible and keep it depressed until the light is turned off.

Practice: S practices movement three or four times with each hand.

Jump Visual Reaction Time

Instructions: You will begin each test with your index finger depressing the yellow button closest to you. When the white light goes on, hit the blue button as quickly as possible and keep it depressed until the light is turned off.

Practice: S practices movement three or four times with each hand.

Auditory Reaction Time

Instructions: You will begin each test with your
index finger on the yellow button farthest from you.
When the buzzer sounds, hit the blue button as quick-
ly as possible and keep it depressed until the buzzer
is turned off.

Practice: S practices movement three or four times
with each hand.

Discrimination Reaction Time

Instructions: You will begin each test with your in-
dex finger on the yellow button closest to you. If
the green light goes on, hit the green button to your
right. If the red light goes on, hit the red button
to your left. Keep the button depressed until the
light is turned off.

Practice: S practices movement three or four times
with each hand.

STEADINESS TESTS

Arm Steadiness

Instructions: Put the stylus inside the designated
hole and hold it as still as possible. You may not
rest your wrist or arm on the table or against your
body. You may find it easier if you hold your breath
during the tests.

Practice: None.

Administration: For each hole, one through nine, ad-
minister a trial of ten seconds duration. Require-
ment--beginning hole has no touches.[1]

Hand Steadiness

Instructions: Put the stylus inside the designated

hole and hold it as still as possible. You may rest
your wrist on the edge of the table. You may find it
easier if you hold your breath during the tests.
Practice: None
Administration: For each hole, five through nine, ad-
minister a trial of ten seconds duration. Requirement--
beginning hole has no touches.[1]

Horizontal Movement Steadiness
Instructions: Move the stylus back and forth through
this groove without touching the sides. No part of
your hand or arm may rest on the table or apparatus.
Go through the groove as slowly as you need to not to
make errors. With your right hand begin at the left
side OR With your left hand begin at the right side.
Practice: None.

Vertical Movement Steadiness
Instructions: Move the stylus up and down through
this groove without touching the sides. No part of
your hand or arm may rest on the table or apparatus.
Go through the groove as slowly as you need to not to
make errors. With each hand, start at the bottom;
go up; and then come down.
Practice: None.

Maze Movment Steadiness
Instructions: Take this stylus and put it in this
opening (start position) and move it all the way
through the maze (point to end). Try to go through

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[1]After one of these tests has been competed E may be-
gin the first series of the remaining test with the
hole of his discretion. Requirement of no touches on
the first hole must be met.

the maze without touching the sides. Go through the
maze as slowly as you need to in order not to make
errors. Make sure you do not rest your hand or arm
on your side; or on the stand; or brace it in any way.
Practice: None.

Rotary Pursuit

Instructions: As the turntable rotates try to keep the
stylus on the metal disc. Hold the stylus lightly.
Try to keep your body still.
Practice: one 20-second trial with each hand.
Administration: S standing.

PENCIL AND PAPER TESTS

Tapping-Large

Instructions: Put three dots in each circle. Work
horizontally across the page and as quickly as pos-
sible. With your right hand begin the block at the
top left-hand corner, OR, with your left hand begin
the block at the top right-hand corner and continue
alternating direction on each succeeding row until
you have completed the whole block of circles.
Practice: One line practice with each hand.
Administration: Demonstrate rhythm.

Tapping-Small

Instructions: Place one dot in each circle, working
as quickly as you can across the rows. With your right
hand begin a block at the top left-hand corner, OR,
with your left hand begin the block at the top right-
hand corner and continue alternating direction on each
succeeding row until you have completed the whole block

or circles. An error is counted if each dot is not completely in a circle. Work as quickly as you can without errors.
Practice: Two rows per hand.

Marking Accuracy

Instructions: Going from item to item mark each circled slot as quickly as possible. An error is counted if any part of the mark extends from the circle. Work as quickly as you can without making errors.
Practice: None.

BATTERY B

APPARATUS TESTS
Purdue Peg Board

Instructions: Picking up the pegs one at a time, fill one vertical column. If you happen to pick up two pegs, pretend it is only one and repeat the movement to the dish before using the second peg. Begin at the top of the column.
Practice: Ten pegs with each hand.

Minnesota Rate of Manipulation

Instructions: Turn over as many cylinders as you can in 30 seconds. Pick each cylinder up cleanly, before turning it over and replacing it. With your right hand begin the first row from the left side, OR, with your left hand from the right side. When you come to the end of the first row return in the opposite direction on the following row. Follow the same procedure for

succeeding rows.
Practice: Ten cylinders with each hand.

Crawford Small Parts Dexterity

Instructions: Use the tweezers to pick up one of
these pins, gripping the pin at right angles to the
tweezers. You will find it easier to pick up the
pin at the end that will be the top when you place
the pin in the hole. Place the pin in a small hole.
Next, pick up a collar and put it down over the pin
so that the flange is on the plate. You will find it
easier to choose collars that are already sitting on
the flange. Each hole must be filled with a pin and
collar before moving on to the next hole. Complete
one row working with right hand from left to right, OR,
Complete one row working with your left hand from right
to left. There are extra pins so don't stop to pick
up any you may have dropped.
Practice: Fill one row with each hand.

Grooved Peg Board

Instructions: Picking up the pegs one at a time,
place them in the holes as rapidly as possible.
Since each peg is "keyed", it will fit only one way
in the grooved hole. Fill three horizontal rows,
working from right to left with the left hand, OR,
from left to right with the right hand.
Practice: One row with each hand.

Marble Board

Instructions: Take the marbles one at a time from the
dish and fill one row as quickly as possible. With

your right hand work from left to right, OR, With
your left hand work from right to left.
Practice: Ten marbles with each hand.

O'Connor Finger Dexterity
Instructions: Pick up three pins at a time and fill
the holes as fast as you can. Be sure to fill each
hole completely before you start the next. There
are extra pins in this tray so that if you drop one
or two on the floor you still will have enough left,
so do not stop to pick them up. With your right hand
move horizontally from left to right, OR, with your
left hand move horizontally from right to left.
Practice: One row per hand.

PENCIL AND PAPER TESTS
Square Marking
Instructions: Mark "X's" in the small squares in
the corners of the large squares. Do two horizontal
rows beginning with your right hand on the left side
and then returning on the next row in the opposite
direction, OR, beginning with your left hand on the
right side and then returning on the next row in the
opposite direction.
Practice: None.

Pursuit Aiming
Instructions: Place one dot in each circle, starting
bere (E points) until you come to the end. An error
is counted if each dot is not completely in a circle.
Work as quickly as you can without errors.
Practice: None.

Printed Discrimination
Instructions: S reads from the direction sheet.
Practice: Last sheet. Half for each hand.
Administration: Check not necessary, just a line in the appropriate space. Sheets up-side-down for left hand.

MISCELLANEOUS TESTS
Left-Right Discrimination
Instructions: Respond as directed.
Administration: Ask questions.

Hand Preferences
Instructions: Respond by naming the hand you prefer for each of the following activities.
Administration: Ask questions. S may act-out.

Dynamometer
Instructions: This is a test of your hand strength. Hold your arm by your side. When I say BEGIN, squeeze as hard as you can.
Practice: None.
Administration: S standing. Adjust handle to comfort.

Dowel Balancing
Instructions: See how long you can balance this stick on your forefinger. Steady the dowel with your other hand and remove it when you are ready to start. You may move around as much as you wish.
Practice: Once with each hand.
Administrations: Standing in an open area.

Dealing Cards

Instructions: Deal the 26 cards alternately to the
two squares before you. Work as quickly as possible.
Practice: None.
Administration: Hand throwing card denotes trial.

Finger Tapping--Long

Instructions: Tap on this lever as quickly as you
can. This is to be a finger movement only, so rest
your wrist on the board and move only the index finger.
This test will last 60 seconds.
Practice: Sufficient for smooth operation.

Finger Tapping--Short

Instructions: Tap on this lever as quickly as you
can. This is to be a finger movement only, so rest
your wrist on the board and move only the index finger.
This test will last ten seconds.
Practice: Sufficient for smooth operation.

Printing Name

Instructions: Print your first and last name in capi-
tal letters of normal writing size. Work as quickly
as you can.
Practice: None.

Handedness--Self Classification

Instructions: Consider how much you prefer one hand
or the other for all manual tasks. Then place a mark
on the line between "Strong Left" and "Strong Right"
to describe how handed you think you are.

Appendix B

In Appendix B are the factors from the M-P; M-NP;
F-P; and F-NP factor analyses that were not reported
in the results section.

M-P FACTORS

Factor No.	8		Factor No.	10
% Variance	3.6		% Variance	3.0
Variable	Loading		Variable	Loading
Sq Mk-TxE	.87		Hor St-Touch	.87
Sq Mk-Err	.82		Hor St-Dur	.85
H Self Clas	.59		Mk Acc-Err	-.37

Factor No.	12		Factor No.	13
% Variance	2.5		% Variance	2.3
Variable	Loading		Variable	Loading
Marble Bd	.75		Dowel Bal	-.76
Deal Cards	.67		Discrim TT	.48
Connor FDT	.39		Discrim RT	.41

Factor No.	15		Factor No.	16
% Variance	2.1		% Variance	1.7
Variable	Loading		Variable	Loading
Dynamom	.76		L-R Dis	-.79
Minn RM	-.41			
Arm St-Touch	.38			

Factor No.	17
% Variance	1.6
Variable	Loading
Print Name	.45
Mk Acc-Err	.40

M-NP FACTORS

Factor No.	10		Factor No.	11
% Variance	2.7		% Variance	2.3
Variable	Loading		Variable	Loading
Maz St-Touch	.71		Hor St-Touch	.58
L-R Dis	-.66		Connor FDT	.54
Maz St-Dur	.62		Hor St-Dur	.53
			Pr Disc RT	.46
			Tap--Large	.40
			Dowel Bal	-.38

M—NP FACTORS (cont.)

Factor No.	12		Factor No.	14
% Variance	2.3		% Variance	2.0
Variable	Loading		Variable	Loading
Discrim TT	.62		Sm Pt Dex	.70
Discrim RT	.60		Dynamom	−.63
F Tap——Short	−.57			
Marble Bd	.37			

Factor No.	15		Factor No.	16
% Variance	1.8		% Variance	1.6
Variable	Loading		Variable	Loading
Rot Purs	.79		Maz St—Time	.44
			Dowel Bal	−.42

F—P FACTORS

Factor No.	9		Factor No.	10
% Variance	3.2		% Variance	3.0
Variable	Loading		Variable	Loading
Mk Acc—Item	.85		H Self Clas	−.72
Mk Acc—I—E	.84		Discrim MT	.70
Tap——Large	−.37		Discrim TT	.57
			Aud MT	.47
			Vis MT	.40

Factor No.	11		Factor No.	12
% Variance	2.8		% Variance	2.7
Variable	Loading		Variable	Loading
Sq Mk—Err	.95		Connor FDT	.70
Sq Mk—TxE	.93		Mk Acc—Err	−.50
P Aim—TxE	.33		Pr Disc RT	.49
P Aim—Err	.33		Maz St—Dur	.48
			Deal Cards	.37
			Maz St—Touch	.36

F-P FACTORS (cont.)

Factor No.	15	Factor No.	16
% Variance	1.9	% Variance	1.7
Variable	Loading	Variable	Loading
Rot Purs	-.78	Hd St-Hole	-.65
F Tap-Short	-.55	Hd St-Touch	.63
Discrim MT	.38	Hd St-Dur	.49
Tap-Large	.36	Dowel Bal	-.47

Factor No.	17
% Variance	1.6
Variable	Loading
Sm Pt Dex	.83
Dowel Bal	-.37

F-NP FACTORS

Factor No.	10	Factor No.	12
% Variance	2.9	% Variance	2.3
Variable	Loading	Variable	Loading
P Aim-Err	.83	Sq Mk-Err	.90
P Aim-TxE	.80	Sq Mk-TxE	.89
Discrim MT	.36		

Factor No.	13	Factor No.	14
% Variance	2.0	% Variance	1.9
Variable	Loading	Variable	Loading
Dynamom	-.79	J Vis MT	.36
Arm St-Touch	.36	Sq Mk-Time	.40

Factor No.	15	Factor No.	16
% Variance	1.7	% Variance	1.5
Variable	Loading	Variable	Loading
Pr Dis RT	.61	Deal Cards	.58
Minn RM	-.47	Discrim MT	.50
		Sm Pt Dex	-.38

Appendix C

In this appendix are the factors extracted in the factor analyses performed on the ratio scores (M-P/M-NP and F-P/F-NP).

M-P/M-NP FACTORS

Factor No.	1	Factor No.	2
% Variance	6.5	% Variance	5.8
Variable	**Loading**	**Variable**	**Loading**
P Aim-Time	.90	J Vis RT	.79
Connor FDT	-.90	Ver St Dur	.73
Arm St-Touch	.86	Maz St-Time	.71
J Vis MT	.69	Vis TT	.56
Aud RT	-.49	Sm Pt Dex	.53
		Hand Pref	-.52

Factor No.	3	Factor No.	4
% Variance	5.4	% Variance	5.2
Variable	**Loading**	**Variable**	**Loading**
Hor St-Touch	-.73	J Vis TT	.62
J Aud RT	.69	Marble Bd	.58
Aud TT	.61	Ver St-Touch	.48
J Aud TT	-.57	Mk Acc-Err	-.46
Aud RT	.56	Sm Pt Dex	.40
Discrim RT	.41	J Aud MT	.37

Factor No.	5	Factor No.	6
% Variance	4.9	% Variance	4.7
Variable	**Loading**	**Variable**	**Loading**
Sq Mk-Time	.77	P Aim-Err	.87
Hd St-Dur	.70	Sq Mk-TxE	.84
Arm St-Hole	-.54	Vis MT	.79
Hd St-Hole	-.49	P Aim-TxE	.41
Mk Acc-Err	.46		
H Self Clas	.43		

M-P/M-NP FACTORS (cont.)

Factor No.	7	Factor No.	8
% Variance	4.6	% Variance	4.3
Variable	**Loading**	**Variable**	**Loading**
Aud MT	-.72	Rot Purs	.71
Tap Sm-Time	.65	Arm St-Dur	-.66
Tap Long-31	-.49	Maz St-Dur	.65
L-R Dis	.44	Ver St-Touch	.41
Sq Mk-Err	.40	Arm St-Hole	.41
P Aim-TxE	.39		
Tap--Large	-.38		
J Aud TT	.36		

Factor No.	9	Factor No.	10
% Variance	4.1	% Variance	3.9
Variable	**Loading**	**Variable**	**Loading**
Tap Sm-Err	-.89	Ver St-Time	.80
Purdue PB	-.63	Vis RT	-.76
Maz St-Touch	.60	Mk Acc-I-E	.43
Mk Acc-Item	.53	Tap--Large	.39
Discrim RT	.41	Hor St-Dur	.38
Print Name	.37	Minn RM	.36

F-P/F-NP FACTORS

Factor No.	1	Factor No.	2
% Variance	7.3	% Variance	6.8
Variable	**Loading**	**Variable**	**Loading**
Aud RT	.88	Print Name	.86
P Aim-TxE	-.86	Discrim TT	-.84
P Aim-Err	-.80	Mk Acc-I-E	.67
Discrim RT	.72	Rot Purs	-.56
Ver St-Touch	.42	Marble Bd	-.55
Hd St-Touch	-.42	Arm St-Dur	-.49
Hd St-Hole	.41	Tap Sm-Time	.37
Pr Disc RT	-.37		

F-P/F-NP FACTORS (cont.)

Factor No.	3	Factor No.	4
% Variance	5.4	% Variance	5.3
Variable	Loading	Variable	Loading
Arm St-Hole	.81	Discrim MT	.74
Tap Sm-TxE	-.71	Mk Acc-Item	-.69
Dynamom	-.68	Sq Mk-Time	.61
Hd St-Touch	.68	Rot Purs	-.55
Tap Sm-Err	.45	Tap--Large	.42
Hd St-Hole	.39	Hor St-Dur	.41
Sq Mk-TxE	.36	Mk Acc-I-E	.40

Factor No.	5	Factor No.	6
% Variance	5.1	% Variance	4.7
Variable	Loading	Variable	Loading
Sq Mk-Err	.66	J Vis TT	-.76
Sq Mk-TxE	.55	Tap Sm-Err	.74
H Self Clas	.53	Deal Cards	-.73
Purdue PB	-.38	Maz St-Time	.53
Dynamom	-.37	Grooved PB	.44
Pr Disc RT	-.37	L-R Dis	.41
Sm Pt Dex	.37	Purdue PB	-.37
Ver St-Time	-.37		

Factor No.	7	Factor No.	8
% Variance	4.4	% Variance	4.2
Variable	Loading	Variable	Loading
Hd St-Dur	-.84	Vis RT	.63
Mk Acc-Err	.78	F Tap-Short	.50
Tap Long-TT	.75	Tap Long-31	-.48
		Arm St-Dur	.43
		J Aud RT	.43
		Hor St-Touch	.41
		Tap Sm-Time	.38

Factor No.	9	Factor No.	10
% Variance	3.8	% Variance	3.7
Variable	Loading	Variable	Loading
Minn RM	-.84	Maz St-Touch	-.66
J Vis MT	.68	Vis TT	.60
Hor St-Dur	-.37	Maz St-Dur	-.58
		Hand Pref	.44
		Vis MT	.42

Appendix D

The results of independent "t" comparisons performed between M-P and F-P (numerator = (F-P)-(M-P)) and between M-NP and F-NP (numerator = (F-NP)-(M-NP)) are reported here. Also included in this appendix are the means and standard deviations (S.D.) of each variable in the four groups. Reaction time tests are recorded in milliseconds.

Variable	Female P Mean	Female P S.D.	Male P Mean	Male P S.D.	"t"
J Aud RT	401.4	65.5	397.7	75.3	0.26
J Aud MT	342.7	74.9	299.1	69.7	3.02
J Aud TT	741.8	111.7	696.8	117.0	1.97
Vis RT	405.7	61.8	386.1	57.9	1.64
Vis MT	289.0	56.7	261.3	65.4	2.27
Vis TT	694.0	92.3	647.4	102.4	2.39
J Vis RT	464.4	71.4	458.1	81.6	0.41
J Vis MT	370.8	73.2	305.7	78.7	4.29
J Vis TT	835.2	109.2	763.8	120.8	3.10
Aud RT	337.3	44.8	335.8	61.2	0.15
Aud MT	268.2	48.6	258.9	56.6	0.88
Aud TT	599.5	68.3	594.7	94.6	0.29
Discrim RT	682.5	130.9	710.7	96.3	-1.23
Discrim MT	430.4	100.8	371.6	100.8	2.92
Discrim TT	1111.0	145.4	1082.3	134.9	1.02
Arm St-Touch	119.4	51.3	166.6	63.1	-4.10
Arm St-Dur	27.1	8.0	24.1	9.0	1.76
Arm St-Hole	13.6	1.8	12.5	2.0	2.68
Hd St-Touch	46.7	33.4	60.4	33.3	-2.04
Hd St-Dur	11.0	5.1	9.2	5.1	1.85
Hd St-Hole	17.2	1.0	17.1	1.1	0.66
Hor St-Touch	5.3	3.8	8.1	4.6	-3.32
Hor St-Dur	.9	.9	1.1	.9	-0.89
Hor St-Time	47.4	23.8	39.4	27.2	1.55
Ver St-Touch	4.6	3.7	7.4	5.2	-3.07
Ver St-Dur	.6	.6	.6	.5	-0.14
Ver St-Time	53.4	24.0	42.2	20.2	2.52
Maz St-Touch	12.9	7.4	18.0	9.7	-2.92
Maz St-Dur	2.0	1.2	2.0	1.4	-0.10
Maz St-Time	116.3	47.7	98.8	37.9	2.03
Purdue PB	89.2	8.1	91.7	6.9	-1.66
Minn RM	61.7	6.3	59.9	6.1	1.45
Sm Pt Dex	67.4	15.5	72.8	16.1	-1.69
Grooved PB	60.0	5.7	60.5	5.8	-0.43
Marble Bd	35.6	3.1	37.2	3.1	-2.67
Rot Purs	14.9	6.8	21.3	8.8	-4.12
Connor FDT	79.5	12.4	84.0	11.4	-1.89

| | Female P | | Male P | | |
Variable	Mean	S.D.	Mean	S.D.	"t"
Sq Mk-Time	48.9	6.2	50.9	9.5	-1.27
Sq Mk-Err	3.0	4.8	4.2	5.1	-1.25
Sq Mk-TxE	121.6	111.4	148.9	115.2	-1.20
P Aim-Time	72.1	8.3	72.5	12.5	-0.23
P Aim-Err	2.0	2.5	3.9	5.7	-2.10
P Aim-TxE	141.4	80.5	198.8	179.3	-2.06
Pr Disc RT	74.4	13.1	71.6	17.2	0.92
Tap--Large	53.3	6.5	52.2	9.4	0.63
Tap Sm-Time	35.4	6.2	36.7	6.7	-1.00
Tap Sm-Err	.9	1.4	2.2	3.5	-2.50
Tap Sm-TxE	49.5	23.1	73.9	58.4	-2.75
Mk Acc-Item	124.4	24.0	122.8	32.6	0.27
Mk Acc-Err	4.8	10.2	6.8	11.3	-0.95
Mk Acc-I-E	119.5	24.0	116.0	31.0	0.64
L-R Dis	63.1	1.6	61.4	5.5	2.12
Hand Pref	18.6	3.0	19.3	1.8	-1.30
Dynamom	54.7	10.0	86.0	12.4	-13.90
Dowel Bal	6.4	4.4	16.1	14.0	-4.68
Deal Cards	24.7	5.3	22.7	6.0	1.88
Tap Long-TT	459.0	56.5	515.3	61.8	-4.75
Tap Long-31	209.0	35.8	233.7	37.0	-3.40
FTap-Short	100.6	11.8	111.3	12.4	-4.43
Print Name	9.7	2.0	10.2	2.1	-1.24
H Self Clas	44.6	14.5	50.3	15.9	-1.87

| | Female NP | | Male NP | | |
Variable	Mean	S.D.	Mean	S.D.	"t"
J Aud RT	406.5	69.5	395.7	77.8	0.73
J Aud MT	358.3	67.5	318.8	81.2	2.64
J Aud TT	762.7	103.2	714.5	124.5	2.11
Vis RT	409.6	75.2	386.8	66.1	1.62
Vis MT	290.9	66.1	267.3	77.8	1.63
Vis TT	700.5	118.2	656.0	115.8	1.90
J Vis RT	557.5	63.0	440.0	68.8	1.33
J Vis MT	380.4	76.1	313.5	76.6	4.38
J Vis TT	837.9	109.0	753.4	108.9	3.88
Aud RT	348.1	64.4	332.6	53.7	1.31
Aud MT	269.4	61.4	259.6	71.2	0.74
Aud TT	617.5	100.3	594.4	105.7	1.12
Discrim RT	651.2	106.0	698.0	106.4	-2.20
Discrim MT	444.3	92.3	380.4	100.7	3.30
Discrim TT	1095.5	118.5	1069.0	170.1	0.90

Variable	Female NP		Male NP		"t"
	Mean	S.D.	Mean	S.D.	
Arm St-Touch	134.6	67.7	181.2	78.3	-3.18
Arm St-Dur	31.6	13.5	28.6	11.3	1.19
Arm St-Hole	12.7	2.4	11.8	2.0	1.90
Hd St-Touch	51.8	34.8	79.9	46.8	-3.41
Hd St-Dur	13.5	6.4	11.4	6.0	1.69
Hd St-Hole	16.6	1.4	16.2	1.6	1.24
Hor St-Touch	6.7	4.0	11.2	7.5	-3.77
Hor St-Dur	1.0	.7	1.2	.8	-1.39
Hor St-Time	50.6	24.6	46.5	45.1	0.57
Ver St-Touch	8.0	8.0	11.8	6.9	-2.51
Ver St-Dur	1.1	1.4	1.2	1.0	-0.47
Ver St-Time	61.6	33.7	44.1	20.5	3.14
Maz St-Touch	19.8	16.0	26.0	12.5	-2.15
Maz St-Dur	2.8	2.2	3.1	1.9	-0.61
Maz St-Time	131.3	55.5	113.6	53.5	1.63
Purdue PB	94.3	8.9	98.8	9.0	-2.52
Minn RM	58.4	6.3	57.9	6.4	0.38
Sm Pt Dex	88.8	24.4	86.6	15.5	0.52
Grooved PB	66.7	6.5	65.4	7.8	0.89
Marble Bd	37.8	3.5	39.5	3.8	-2.37
Rot Purs	11.3	6.0	17.8	7.6	-4.75
Connor FDT	87.2	14.5	89.6	11.5	-0.93
Sq Mk-Time	83.6	17.8	92.6	22.4	-2.23
Sq Mk-Err	12.6	12.3	19.5	14.6	-2.54
Sq Mk-TxE	597.2	460.0	964.5	646.5	-3.27
P Aim-Time	105.7	16.5	105.5	23.0	0.04
P Aim-Err	6.5	6.1	14.1	14.3	-3.45
P Aim-TxE	436.3	290.5	800.8	677.6	-3.50
Pr Disc RT	81.2	16.6	81.1	18.4	0.03
Tap--Large	61.3	11.7	58.7	10.8	1.17
Tap Sm-Time	52.5	11.1	54.6	12.3	-0.90
Tap Sm-Err	4.8	6.1	8.8	8.1	-2.81
Tap Sm-TxE	169.3	133.0	285.8	219.6	-3.21
Mk Acc-Item	81.3	19.4	78.3	25.0	0.66
Mk Acc-Err	11.3	11.9	16.4	16.9	-1.76
Mk Acc-I-E	69.9	19.1	62.3	17.7	2.07
L-R Dis	63.1	1.6	61.4	5.5	2.12
Hand Pref	2.7	3.9	1.9	2.9	1.09
Dynamom	49.5	8.3	80.8	14.9	-12.97
Dowel Bal	4.6	3.1	8.3	8.3	-2.97
Deal Cards	32.0	8.6	31.6	8.5	0.21
Tap Long-TT	404.2	46.1	463.7	54.8	-5.88
Tap Long-31	183.3	25.6	211.6	30.7	-5.01
FTap-Short	86.1	11.3	95.4	9.3	-4.52
Print Name	19.6	6.3	22.0	5.4	-2.02
H Self Clas	44.6	14.5	50.3	15.9	-1.87

Appendix E

The "t" tests for correlated samples that were performed on M-P vs. M-NP groups (numerator = (M-P)-(M-NP)) and F-P vs. F-NP groups (numerator = (F-P)-(F-NP)) are reported here. Also included in this appendix are the means of the differences (Mean) and the standard deviations of the differences (S.D.). Reaction time tests are recorded in milliseconds.

Female Comparisons

Variable	Mean	S.D.	"t"
J Aud RT	-5.1	36.6	-0.99
J Aud MT	-15.5	46.5	-2.36
J Aud TT	-21.0	59.5	-2.49
Vis RT	-3.9	48.7	-0.56
Vis MT	-1.8	37.5	-0.35
Vis TT	-6.5	63.3	-0.73
J Vis RT	6.9	53.4	0.92
J Vis MT	-9.6	42.8	-1.59
J Vis TT	-2.7	65.7	-0.29
Aud RT	-10.8	35.0	-2.18
Aud MT	-1.2	36.9	-0.22
Aud TT	-18.0	63.5	-2.00
Discrim RT	31.3	81.7	2.71
Discrim MT	-13.9	69.8	-1.41
Discrim TT	15.4	96.5	1.13
Arm St-Touch	-15.2	37.7	-2.84
Arm St-Dur	-4.5	9.5	-3.34
Arm St-Hole	.9	1.5	4.32
Hd St-Touch	-5.1	19.9	-1.80
Hd St-Dur	-2.4	5.7	-3.00
Hd St-Hole	.6	1.2	3.45
Hor St-Touch	-1.4	4.3	-2.28
Hor St-Dur	-0.1	1.0	-0.44
Hor St-Time	-3.2	9.9	-2.31
Ver St-Touch	-3.4	6.7	-3.63
Ver St-Dur	-0.5	1.0	-3.63
Ver St-Time	-8.2	22.3	-2.61
Maz St-Touch	-6.9	12.7	-3.83
Maz St-Dur	-0.8	1.7	-3.38
Maz St-Time	-15.0	18.2	-5.83
Purdue PB	-5.1	7.7	-4.71
Minn RM	3.3	5.3	4.39
Sm Pt Dex	-21.3	19.8	-7.60
Grooved PB	-6.7	5.6	-8.42
Marble Bd	-2.2	3.6	-4.26
Rot Purs	-3.6	5.1	4.98
Connor FDT	-7.7	15.8	-3.43

Female Comparisons

Variable	Mean	S.D.	"t"
Sq Mk-Time	-34.7	16.5	-14.88
Sq Mk-Err	-9.6	9.6	-7.11
Sq Mk-TxE	-475.7	413.7	-8.13
P Aim-Time	-33.6	14.4	-16.49
P Aim-Err	-4.4	5.1	-6.18
P Aim-TxE	-294.9	264.6	-7.88
Pr Disc RT	-6.8	8.5	-5.66
Tap--Large	-8.1	7.3	-7.82
Tap Sm-Time	-17.1	8.6	-14.09
Tap Sm-Err	-3.9	5.3	-5.28
Tap Sm-TxE	-119.8	124.6	-6.80
Mk Acc-Item	43.1	16.1	18.89
Mk Acc-Err	-6.5	8.3	-5.55
Mk Acc-I-E	49.6	19.8	17.70
Hand Pref	16.0	6.6	17.17
Dynamom	5.2	6.1	6.03
Dowel Bal	1.9	2.9	4.57
Deal Cards	-7.3	11.2	-4.57
Tap Long-TT	54.9	51.4	7.54
Tap Long-31	25.7	30.1	6.04
FTap-Short	14.5	12.1	8.51
Print Name	-9.9	5.3	-13.28

Male Comparisons

Variable	Mean	S.D.	"t"
J Aud RT	2.0	45.9	0.31
J Aud MT	-19.7	39.8	-3.50
J Aud TT	-17.6	59.5	-2.10
Vis RT	-0.7	42.4	-0.11
Vis MT	-6.0	38.8	-1.10
Vis TT	-8.7	52.8	-1.16
J Vis RT	18.1	58.6	2.19
J Vis MT	-7.8	47.7	-1.16
J Vis TT	10.4	77.0	0.95
Aud RT	3.2	45.2	0.49
Aud MT	-0.7	42.3	-0.11
Aud TT	0.3	61.4	0.03
Discrim RT	12.8	78.1	1.16
Discrim MT	-9.0	70.9	-0.90
Discrim TT	13.3	122.9	0.77

Male Comparisons

Variable	Mean	S.D.	"t"
Arm St-Touch	-14.5	37.4	-2.75
Arm St-Dur	-4.5	6.4	-4.97
Arm St-Hole	0.7	1.4	3.53
Hd St-Touch	-19.6	34.6	-4.00
Hd St-Dur	-2.2	5.0	-3.15
Hd St-Hole	0.8	1.5	3.99
Hor St-Touch	-3.1	7.0	-3.15
Hor St-Dur	-0.1	.7	-1.14
Hor St-Time	-7.0	37.8	-1.32
Ver St-Touch	-4.4	7.0	-4.46
Ver St-Dur	-0.6	1.0	-4.36
Ver St-Time	-1.9	8.8	-1.53
Maz St-Touch	-8.0	9.3	-6.10
Maz St-Dur	-1.0	1.2	-6.05
Maz St-Time	-14.8	26.6	-3.93
Purdue PB	-7.2	6.3	-8.09
Minn RM	2.0	4.6	3.03
Sm Pt Dex	-13.8	9.9	-9.88
Grooved PB	-4.9	6.6	-5.25
Marble Bd	-2.2	2.9	-5.38
Rot Purs	3.5	5.3	4.76
Connor FDT	-5.6	11.2	-3.53
Sq Mk-Time	-41.7	16.7	-17.63
Sq Mk-Err	-15.2	11.6	-9.28
Sq Mk-TxE	-815.7	579.9	-9.95
P Aim-Time	-32.9	15.5	-15.00
P Aim-Err	-10.2	11.0	-6.54
P Aim-TxE	-602.1	587.8	-7.24
Pr Disc RT	-9.5	8.5	-7.86
Tap--Large	-6.4	4.5	-10.03
Tap Sm-Time	-17.9	8.0	-15.80
Tap Sm-Err	-6.7	5.9	-7.98
Tap Sm-TxE	-211.9	188.9	-7.93
Mk Acc-Item	44.5	16.9	18.61
Mk Acc-Err	-9.6	13.2	-5.14
Mk Acc-I-E	53.7	20.0	18.99
Hand Pref	17.4	4.5	27.34
Dynamom	5.2	9.1	4.08
Dowel Bal	7.8	10.8	5.11
Deal Cards	-9.0	10.9	-5.81
Tap Long-TT	51.6	54.8	6.66
Tap Long-31	22.2	33.6	4.66
FTap-Short	15.9	13.9	8.09
Print Name	-11.8	4.8	-17.46