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ABSTRACT

The purposes of this investigation were to compare an individual's magnitude and direction of error in three tests of kinesthetic perception, and to determine whether individuals tend generally to reduce, augment, or moderate stimuli on all three tests. A single group design was employed, using a sample of 34 male students. The variables of joint angle reproduction (JAR), muscular tension reproduction, and limb load discrimination were measured in random order for each subject individually by the investigator and one assistant. It was found that the group as a whole was much more accurate at joint angle reproduction and weight discrimination than at muscle tension reproduction; between the two primarily proprioceptive tasks, JAR and muscular tension reproduction, no relationship was found. JAR and muscular tension reproduction appear to be highly specific abilities and depend largely on short-term memory traces. (JB)

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Patterns of Error in Kinesthetic Perception*

Skilled motor behavior is dependent upon efficient sensory-motor integration, entailing an accurate processing of sensory information followed by efficient neural discharges to appropriate muscle groups. The development of motor skill is accomplished by cortically selecting the correct behavioral components and modifying them by integrating somatosensory feedback information. It is well known that sensory information is critical to efficient motor learning. For example, Everts (3) has shown that the ability to detect joint displacement, force of muscle contraction, and rate of change of force is critical to motor control. Individual differences in sensory detection and processing are well known in terms of individuals' sensory accuracy. Less understood, however, is the individual's general approach to sensory discrimination. Petrie(16) has suggested that individuals generally tend to be subjective reducers or augmentors of sensory stimuli such as time estimation, detection of weight and size differences, and tolerance of pain. Little is known about individuals' subjective pattern of detection of their own body parts in relation to each other and in their own evaluation of the amount of muscular tension they are producing. Detection of sensory stimuli that are self generated, or internally initiated, is called kinesthetic sensitivity. If individuals are consistent in subjectively reducing all kinesthetic input, it would systematically affect their motor output. The discovery of such a pattern would enable the investigator or teacher to predict

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therefore, the direction of motor error. Not only will information of this type contribute substantially to the basic understanding of the way humans integrate and consequently improve motor performance, it will have implications for teaching motor skill tasks.

Purpose

The purpose of this investigation was to compare individuals' magnitude and direction of error in three tests of kinesthetic perception, and to determine whether individuals tend generally to reduce, augment, or moderate stimuli on all three tests.

Specific objectives of the study were to

1. determine individuals' absolute errors, direction of error, and variable errors on joint angle reproduction, muscular tension reproduction, and limb load discrimination,
2. classify individuals as reducers, augmentors, or moderators on each of the three kinesthetic tests,
3. determine whether an individual's classification on one test is related to his classification on another.

Experimental Design

The parameters of this study were investigated by the use of a single group design, in which 34 male students enrolled at The University of Texas at Austin comprised the sample. The variables of joint angle reproduction, muscular tension reproduction, and limb load discrimination were measured in random order for each subject individually by the investigator and one assistant.

Instrumentation

Joint angle reproduction was measured by the use of an electrogoniometer; muscular tension reproduction was assessed by the use of electromyography; limb load discrimination was determined by the difference limen (DL) technique. All tests were administered in the Motor Integration Research Laboratory at the University of Texas at Austin. The laboratory is temperature controlled and is equipped with a Faraday enclosure and other necessary accoutrements for this type of measurement.

Joint angle reproduction. The ability to reproduce angles of 30°, 40°, 50° and 60° of the forearm in relation to the upper arm were measured by the use of an electrogoniometer placed on the lateral aspect of the elbow joint of the dominant arm. The subject was tested in a specially designed chair, with the dominant arm resting supinely on a braced chair arm. The initial arm position was a 90° angle at the elbow joint, with the forearm horizontal to the floor and the upper arm vertical. Upon command, the subject slowly flexed the forearm upon the elbow joint until told that the test angle had been reached. After a two-second pause, the forearm was extended to the original position, followed by an immediate attempt to return to the test angle. Both the practice to the test angle with experimenter cues and the trial without experimenter or visual cues were recorded on a Honeywell Visicorder. Deviations, both positive or negative from the test angle were ascertained for analysis. Five trials (consisting of one practice with experimenter cues and one attempt with no experimenter cues) were given for each of the test angles. Subjects were blindfolded prior to the beginning of the tests.

Muscular tension reproduction. Subjects were seated in the test chair, with the forearm in a supine position on the chair arm which was bracketed so that subjects' dominant elbow joint was at a 45° angle. The motor point of the biceps brachii was determined by the use of a TECA Chronaxiemeter, and the silver disk recording surface electrode was placed directly on it with the reference electrode 5 mm adjacent to it. A ground electrode was placed equidistant from the two electrodes.

Muscular action potentials (MAPs) were recorded from the biceps brachii by a Honeywell Visicorder, and the magnitude of these potentials was integrated over a one-second period of time. The subject sat with the arm relaxed and eyes upon the voltmeter. He was allotted enough practice trials so that he was able to voluntarily contract the biceps until a 50% maximum level was reached at the end of the integrated time period. This was termed his reference MAP level. When the subject showed that he fully understood the task by controlling his muscular contraction so that it reached the reference MAP each time, the subject was provided one practice with visual cues, followed by one attempt to reproduce the tension without visual cues from the voltmeter. This was replicated four more times, so that five trials were provided for the MAP reproduction task. In these trials the subject used the verbal signal "now" to indicate that the correct muscular force was being applied, and this point was marked by the investigator on the records. After a two-minute rest period, subjects repeated the five practice and five reproduction trials. The score was determined from the visicorder records as the amplitude, in uv, above or below the reference voltage.

Limb load discrimination. The difference limen (DL) for lifted weights was determined in a modification by Fleishman and Rich (5) of that proposed by Woodworth and Schlosberg (24). Weights used were 96, 98, 100, 104, 106, 108, 110, 112, 114, and 116 grams. The standard weight used was 106 grams. The subject was seated, with the forearm resting supine on the chair desk. The reference weight was placed in the palm of the subject's hand, whereupon he flexed his forearm at the joint and lifted the weight through the entire 90° range of motion. The weight to be discriminated was then placed in the palm. The subject made all lifts of weights as identical as possible, and determined whether the latter weight was heavier or lighter than the reference weight. Notations of over or underestimating were made. Two ascending and two descending series of judgements were made. The procedure for calculating the DL for lifted weights was that suggested by Woodworth and Schlosberg.

Analysis

Statistical techniques were used as a basis for interpretation of results. Computation was accomplished by the use of The University of Texas Computation Center. Descriptive techniques, such as means, standard deviations, and standard errors, were obtained for all variables.

Group means and standard deviations for each reproduction angle, and split-half reliabilities (corrected with the Spearman Brown formula) were obtained. Intraindividual variability was calculated for each subject by computing the average error and the standard deviation for all trials of joint angle reproduction.

Muscular tension reproduction was evaluated in terms of absolute and variable errors. The first is an indication of the magnitude of error and is equal to the subject's mean MAP minus the reference potential. The variable error is equal to the standard deviation of the distribution of subjects' scores during attempts to produce the MAPs. The relationship of absolute errors to variable errors was determined by constructing a Pearson product-moment coefficient matrix. In addition, subjects were classified as either reducers, augmentors, or moderators on the basis of their deviation of errors on joint angle reproduction. Subjects were classified as augmentors or reducers on a ratio of 2:1, i.e., if they augmented twice as much as they reduced, they were classed as augmentors. Those subjects who never augmented or reduced on a 2:1 basis were classified as moderators. A multiple discriminant analysis was used to determine the extent and manner in which these three so defined groups could also be differentiated by the variables of muscular tension control and weight discrimination operating together.

Results

Means, standard deviations, and intercorrelations of all variables for all subjects are presented in Table I. It may be seen that, disregarding direction of error, the group as a whole was much more accurate at joint angle reproduction than at muscle tension reproduction or weight discrimination. They were also more homogeneous at joint angle reproduction and weight discrimination than at muscle tension reproduction. The muscle tension reproduction task proved to be very difficult for most subjects, and as can be seen from the mean muscle tension reproduction variable error of 105.38, most subjects were quite inconsistent in their attempts to reproduce the standard muscle action potential level. All distributions were normally distributed in terms of skewness and kurtosis.

Test reliabilities were determined by the split-half method and corrected by the Spearman-Brown formula. These reliabilities were: joint angle reproduction, .78 corrected to .86; muscle tension reproduction, .75 corrected to .83; and weight discrimination, .39 corrected to .56.

Relationships among variables may also be seen in Table I. The only high and significant correlations were those between the absolute and variable errors of joint angle reproduction and muscle tension reproduction.

It may be noted that the AE and VE in Table II are rather highly correlated. This is consistent with what might be expected. At the Perceptual Motor Symposium in Waterloo this fall Shutz and Roy showed that when CE $\simeq$ 0 then AE = $.8\sqrt{VE}$. In other words, AE is completely dependent on CE and VE. In this study, CE was near zero and thus AE is really a measure of variability about the target.

$$E(AE) = CE\ (2Ay) + .798\sqrt{VE}^{-1/2\frac{CE^2}{VE}}$$

All information in AE is in

CE when ratio $\frac{CE}{\sqrt{VE}} \gtrsim 2.0$

or in

VE (When CE $\simeq$ 0.0)

If CE = 0, AE & VE measure same thing

If CE is large, CE & AE measure same thing

Subjects who were least accurate were also most inconsistent. The only other significant correlation was a quite low r=.34 between joint angle reproduction variable error and weight discrimination. Although one might

TABLE I

INTERCORRELATIONS OF VARIABLES

Tests	Means (N=34) SDs	2	3	4	5
1. Joint angle reproduction - Absolute error	2.47[a] .63	.82*	.05	-.08	.14
2. Joint angle reproduction - Variable error	1.90[a] .39		.00	-.03	.34*
3. Muscle tension reproduction - Absolute error	147.29[b]			.75*	.22
4. Muscle tension reproduction - Variable error	105.38[b] 59.49				.19
5. Weight Discrimination	26.42[c] 5.48				

[a]Unit of Measure = degrees of error
[b]Unit of Measure = microvolts
[c]Unit of measure = frequency of errors out of a possible 66 errors

*$r_{df=32} > .33 = p < .05$

speculate that consistency in the detection of joint angle reproduction might be contributing to accuracy in discriminating between weights moved through the same range of motion, the correlation coefficient was so low that it's significance might also be explained as a significent r that occurred by chance in a matrix of 10 r coefficients.

The means and standard deviations of the sub-groups of augmentors, moderators, and reducers, divided on the basis of joint angle reproduction scores, are shown in Table II.

To determine whether an individual's perceptual classification on one task is related to his classification on another, a multiple discriminant analysis was used. Each of the JAR groups--Augmentors, Moderators, or Reducers,--was identified as a dependent variable, and group classifications on MAP reproduction and weight discrimination were represented as independent variables. Binary vectors were generated for each group.

This, of course, provided only one root which accounted for 100% of the variance and a chi square of 35.7--highly significant. The Wilks Lambda was .286, but the F value of 3.63 indicated that it was highly significant. In analyzing the univariate Fs, it was found that weight discrimination groups, operating together, could accurately predict JAR group membership.

TABLE II

MEANS AND STANDARD DEVIATIONS OF THREE GROUPS CLASSIFIED AS REDUCERS, MODERATORS, OR AUGMENTORS

	Tests	Reducers	Moderators	Augmentors
1.	Joint angle reproduction	2.47[a]	2.29	2.66
	Absolute error	.51	.62	.71
2.	Joint angle reproduction	1.95[a]	1.80	1.96
	Variable error	.35	.33	.45
3.	Muscle tension reproduction	138.46[b]	1[illegible]4.82	148.60
	Absolute error	72.00	79.25	99.52
4.	Muscle tension reproduction	105.21[b]	112.[illegible]	98.84
	Variable error	67.49	52.67	56.56
5.	Weight Discrimination	26.09[c]	[illegible]4.73	28.45
		6.10	[illegible].99	4.58

[a]Mean error per trial in degrees
[b]Mean error per trial in microvolts
[c]Mean errors in discrimination over all trials

Discussion

Petrie's findings that individuals could be classified as consistent augmentors, moderators, or reducers or stimuli was partially corroborated by the present study. Dinnerstein, et al (2), Sweeney (21), and Ryan and Foster (18) also found subjects to be consistent in their reduction or augmentation of stimuli. The stimuli, with one exception, used in these studies were received by the subjects' exteroceptors; i.e., pain, pressure, and tactile receptors. In the present study, as in Norrie's (15) study, proprioceptors were the primary sources of stimulus input. In the present study, no relationship was found between JAR and MAP, the two primarily proprioceptive tasks. The results of this study agree with those of Norrie's (15) both in terms of no relationship between tasks and also in the finding that intraindividual variability was greater than interindividual variability. It appears from the present findings that if the concept of subjects' subjectively and consistently reducing and augmenting stimuli exists, it exists only in the perception of stimuli by distance receptors and exteroceptors, but not by proprioceptors.

Joint angle reproduction and muscle tension reproduction appear to be highly specific abilities. All three tasks were designed so that the reproduction of the standard occurred within two seconds. This time lapse is short enough to allow the subject to utilize short term memory traces produced by the standard. Apparently motor output that is based upon short term memory is also specific in nature. The findings regarding weight discrimination should probably be considered with great caution. The reliability of this test, as was also detected by Norrie (15), was less than satisfactory.