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The Most Influential Sensory Modality to Use as a Substitute for Testing Stereognosis

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ABSTRACT

This study identified the most influential modality to use as a substitute for stereognosis considering five discriminative sensations : kinesthesia, static and moving tactile localization, stationary and moving two-point discrimination.

Subjects of the study were thirty-three hemiplegic patients (27 males and 6 females), with a mean age of 65±7.5 (ranging 55 to 75), which suffered either right (16 patients) or left (17 patients) hemiplegia after cerebrovascular accidents. Detailed sensory data were compared using factor analysis, discriminant analysis, Spearman correlation coefficients, and Kendall's Tau-b.

Data analysis revealed a significant relationship between stereognosis and static tactile localization (classified 100% in stereognosis intact and 91.7% in absent), moving two point discrimination (95.2% in intact and 91.7% in absent), stationary two-point discrimination (90.5% in intact and 91.7% in absent), kinesthesia (90.5% in intact and 91.7% in absent), moving tactile localization (95.2% in intact and 75.0% in absent). Therefore each can be chosen as a representation of discriminative sensation. It was found that moving two-point discrimination and/or kinesthesia provided the most objective measurement. Further testing on the radial fingers of the hand (thumb, index, and middle) showed a high correlation between these fingers using the same modality. As background information, correlations between Brunnstrom recovery stage, hand use, time interval from onset to test date, and stereognosis were compared with each other. Limitations of the study, and recommendations for future research are discussed.

KEY WORDS

Hemiplegia, discriminative sensation, stereognosis, two-point discrimination

INTRODUCTION

Although a sensory deficit in hemiplegic hands affects the recovery of motor function, little is known about the mechanism of recovery and hence selection of appropriate treatment strategies. It is suspected that patients with sensory deficits are not expected to make as much recovery as those with motor loss, but it is nevertheless important for the occupational therapist to thoroughly evaluate the status of the hemiplegic hand. If the most influential modalities of sensation for purposeful activities in the hemiplegic hands are specified, the occupational therapist will be able to simplify the evaluation process and eliminate fatigue associated with complicated testing. In addition to sensory testing, it is also important to have a measure of functional skills as related to sensation.

Smith[1] stated that a patient or client with neurological disease or damage should always be tested for

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Table 1. Characteristics of subjects

Sex	male 27(81.8%)	female 6(18.2%)	total 33(100%)
Age	mean 65±7.5 (range 55-75 years)		
Affected side	right 16(48.5%)	left 17(51.5%)	
Brunnstrom recovery stage	severe 7(21.2%)	moderate 5(15.2%)	fine 21(63.6%)
Hand use	non-useful 9(27.3%)	assistant 13(39.4%)	useful 11(33.3%)
Time interval (onset-tast date)	mean 10.6±1.4m, under 6m 22(66.7%)	6m-1yr 4(12.1%)	over 1yr 7(21.2%)
Stereognosis intact gorup	number 21(63.6%)	age(mean) 66	
Stereognosis absent gorup	number12(36.4%)	age(mean) 63	

sensory loss in the following areas : tactile sense, temperature, proprioception (position sense), and stereognosis. Concerning functional restoration in cerebrovascular accidents, Spencer[2] stated that sensory impairment is manifested in reduced peripheral reception of stimuli, tactile function in the affected hand, and general sensory awareness. In all sensorimotor activities, it is therefore important to evaluate the status of sensation and sensory function in the extremities.

In the field of neurophysiology, a similar concept of sensorimotor function has been described as "active touch". The concept of active touch is defined as the exploratory function of the hand (Gibson)[3] and its neurological mechanism has been studied in a monkey and human. Gibson said "What happens at his fingers depends on the movements that he makes", that is, "variations in skin stimulation are caused by variation in motor activity". In other words, "active touch" can be termed "tactile scanning".

In occupational therapy evaluation, stereognosis is often the assessment used to determine functional use on the hand in the presence of sensory loss. However, some hemiplegic patients who have a motor loss can not manipulate objects in the hands. For these patients, Trombly & Scott[4] suggests passive manipulation of the hand by the therapist, but passive stereognosis testing is not always an accurate evaluation of the hemiplegic hand. If it can be demonstrated that there is a correlation between stereognosis and kinesthesia, tactile localization, and two-point discrimination, then these separate tests could be used to simplify methods of testing discriminative sensation in the hemiplegic hand. But little is known about the correlation between the sensations that give information regarding the functional value of the sensibility in cerebrovascular accident patients.

This study will seek to find a relationship between the discriminative sensations that could be presumed to contribute to the functional use of the hemiplegic hand, and to identify the most influentioal sensory modality to use as a substitute for stereognosis. Stereognosis was chosen as the independent variable, dependent variables included kinesthesia, tactile localization, and two-point discrimination in males and females between the age of 55 to 75 who suffered either right or left hemiplegia after cerebrovascular accidents.

METHODS

Subjects

Thirty three hemiplegic patients were chosen as subjects. Characteristics of subjects are shown in Table 1. Prior to participation, verbal consent to participate was obtained from the patients, the patients' family and the patients' physician. Testing procedures were explained and demonstrated to each patient to ensure each understood expectations of the sensory testing.

There were 27 males and 6 females with a mean age of 65±7.5 (ranging in age from 55 to 77).

Table 2. Variables in five modalities

	Numbers of variables	Name of variables
Kinesthesia(K)	4	thumb, wrist, elbow shoulder
Static Tactile Localization(sTL)	9	5 fingers, palm, wrist forearm, elbow
Moving Tactile Localization(mTL)	9	5 fingers, palm, wrist forearm, elbow
Stationary Two-Point Discrimination(s2PD)	6	5 fingers, palm
Moving Two-Point Discrimination(m2PD)	6	5 fingers, palm
Total	34	

Table 3. Categorical variables

Brunnstrom recovery stage	3	stage 1-3 severe stage 4 moderate stage 5~6 fine
Usefulness of the hand(hand use) *a	3	non-useful assistant useful
Time interval (between onset and test date)	2	under 6 month 6 month to 1 year
Group	2	stereognosis intact group stereognosis absent group
Total	10	

*a : Grading follows Fukui's upper extremity ADL test[5].

Sixteen subjects (48.5%) suffered right hemiplegia, and seventeen subjects (51.1%) were left hemiplegia. The six grade of the Brunnstrom recovery stage of the hand were narrowed down to three grades : severe, moderate, and fine in order to compare them with Fukui's Three Grades of Usefulness of the Hand : non-useful, assistant, and useful[5]. It was noted the number of subjects in each grades differed between Brunnstrom stage (severe 21.2%, moderate 15.2%, fine 63.6%) and hand use (non-useful 27.3%, assistant 39.4%, useful 33.3%). The time interval between onset and test date ranged from one month to six years (mean = 10.6 months), 66.7% of them were under six months. Subjects were divided into two groups : 21 subjects (63.6%) fell into the stereognosis intact group and 12 subjects into stereognosis absent group (36.4%).

Variables

For the purposes of this study, it was necessary to reduce the number of variables under consideration in

Table 4. Classification of the presence or absence of stereognosis

Modalities	Stereognosis % classified correct: Intact	Stereognosis % classified correct: Absent	Extracted factors used
Static Tactile Localization(sTL)	100	91.7	all
Moving Two-Point Discrimination(m2PD)	95.2	91.7	all
Stationary Two-Point Discrimination(s2PD)	90.5	91.7	one factor for ulna side fingers
Kinesthesia(K)	90.5	91.7	one factor for thumb
Moving Tactile Localization(mTL)	95.2	75	one factor for hand

order to determine if relationships were present between the main variables of stereognosis and five modalities ; kinesthesia, static tactile localization (sTL), moving tactile localization (mTL), stationary two-point discrimination (s2PD), moving two-point discrimination (m2PD). Thirty four discriminate measures in the five modalities were used to determine the relationship between stereognosis and those five modalities, and also between the five modalities (Table 2).

Furthermore 10 categorical variables included three ranges of Brunnstrom recovery stage, three ranges of usefulness of the hand, two ranges of time interval between onset and test data and two stereognosis group of stereognosis intact or absent. These variables were compared to get the background information on the subjects (Table 3).

Statistical analysis

Initially, means, standard deviations and a 34x34 matrix of intercorrelation of dependent variables in the five modalities were completed. Then a 3x6 and 6x2 matrix of categorical variables were completed. Next, a maximum likelihood factor analysis was performed on three matrixes and collapsed data. Finally, discriminant analysis was completed to determine relationships between stereognosis and five modalities. Categorical variables were compared to each other using a Kendall's tau-b analysis.

RESULTS

Relationship between five modalities and stereognosis

To determine the relationship between each modality and the presence or absence of stereognosis, a discriminant analysis was conducted using the extracted factors for each modality. This analysis was done using the BMDP program 7M "Stepwise Discriminant Analysis". The results of the classification are presented Table 4.

In discriminant analysis a score of 90% or higher was used to indicate a relationship between variables. In comparing findings between variables there was no difference between s2PD and m2PD in the absence of stereognosis (91.7%). However, when stereognosis was intact, m2PD had a higher predictability (95.2%) than s2PD (90.5%). The greatest difference were found with tactile localization. If the stimulus was sTL, it was 100% predictable in hands with stereognosis intact, 91.7% predictable if stereognosis was absent. If the stimulus was mTL, it was 95.2% predictable relationship in hands where stereognosis was intact : however, there was no predictable relationship if stereognosis was absent (75.0%). Predictability of kinesthesia was similar to s2PD in that a relationship was slightly predictable with stereognosis intact (90.5%), and slightly more predictable with

Table 5. Correlation between s2PD and m2PD in fingers

s2PD	m2PD				
	Thumb	Index	Middle	Ring	Little
Thumb	0.77	0.78	0.66	0.74	0.68
Index	0.74	0.86	0.75	0.82	0.76
Middle	0.69	0.76	0.72	0.75	0.66
Ring	0.73	0.84	0.82	0.81	0.79
Little	0.78	0.88	0.86	0.82	0.9

Spearman Correlation Coefficients p<.01 level.

Table 6. Correlation between fingers in same modality

		Thumb(1)	Index(2)	Middle(3)	Ring(4)	Little(5)
K	1					
sTL	1		0.97	0.98	0.98	0.98
	2			0.96	0.96	0.96
	3				1	1
	4					1
	5					
mTL	1		0.99	0.99	0.99	0.99
	2			0.99	0.99	0.99
	3				0.99	0.99
	4					1
	5					
s2PD	1		0.9	0.91	0.86	0.76
	2			0.89	0.86	0.78
	3				0.92	0.72
	4					0.88
	5					
m2PD	1		0.89	0.86	0.85	0.89
	2			0.92	0.92	0.93
	3				0.91	0.91
	4					0.93
	5					

Spearman Correlation Coefficients p<.01 level.
Note : Kinesthesia in fingers was measured only thumb.

stereognosis absent (91.7%)

Relationship between variables in five modalities

To determine which finger should be used in the discriminative sensory test, the relationship between modalities were compared using Spearman Correlation Coefficients.

Correlation between s2PD and m2PD is shown in Table 5. The values had a wide range of Correlation Coefficients from r = .66 to r = .90. S2PD in the little finger had a strong relationship with m2PD in each finger, especially in the little (r = .90), index = .88), and middle (r = .86) fingers. Even in tl same finger, correlation between s2PD and m2PD w not necessarily higher than the correlation betwe other fingers except the little finger. In radial si fingers (thumb, index and middle) which contribute the identification of objects, the index finger had t highest correlation between s2PD and m2PD.

The relationship between the fingers in the sai modality was strongly positive at the p< .01 level

Table 7. Correlation between variables of proximal to the hand

	Kinesthesia			sTL				mTL				s2PD
	W	E	S	P	W	F	E	P	W	F	E	P
K Wrist		.91	.68									
Elbow	.91		.72									
Shoulder	.68	.72										
sTL Palm	.82	.84	.54		.96	.96	.93					
Wrist	.86	.88	.61	.97		.98	.96					
Forearm	.85	.85	.56	.96	.98		.97					
Elbow	.88	.87	.57	.93	.96	.97						
mTL Palm	.84	.85	.57	.90	.95	.94	.97		.95	.94	.94	
Wrist	.81	.81	.53	.87	.91	.91	.94	.95		.99	.99	
Forearm	.80	.81	.52	.86	.90	.90	.93	.94	.99		.99	
Elbow	.80	.80	.50	.86	.90	.90	.94	.94	.99	.99		
s2PD Palm	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
m2PD Palm	-.38*	-.33*	NS*	-.38*	-.40*	-.40*	-.38*	-.38*	-.36*	-.36*	-.36*	NS*

Spearman Correlation Coefficients $p<.01$ level.
*$p<.05$ level.
Note K : kinesthesia
sTL : static tactile localization
mTL : moving tactile localization
s2PD : stationary two-point discrimination
m2PD : moving two-point discrimination
W : wrist
F : forearm
E : elbow
S : shoulder
NS : non-significant
-(minus value) : the better the sensory function, the smaller the distance of m2PD

shown on Table 6. Tactile localization had higher correlation than two-point discrimination, especially in mTL, each finger was almost equal in value from r = .99 to 1.00. The index and little fingers in sTL and the little finger in mTL were equal (r = 1.00). In s2PD and m2PD, values in each finger ranged from .72 to .93, and there was no specific relationship between the fingers as was found with tactile localization.

Correlations between other arm variables (palm, wrist, forearm, elbow, and shoulder) are shown in Table 7. There was a strong relationship between variables in kinesthesia, sTL and mTL which ranged from r = .72 to r = .99 significant at the p< .01 level except for the shoulder. Measurements for the shoulder included kinesthesia, and its values ranged from r = .50 to r = .72, thus there was a lower relationship than with the other variables. In s2PD and m2PD only the palm was measured, and there was no significant relationship between the palm in s2PD and the other variables. Also in m2PD, the palm did not show a strong relationship with the wrist, forearm, or elbow at the p< .05 level.

To determine the relationship between discriminative sensation and hand function, correlations between the five modalities of the thumb/index fingers and hand use/Brunnstrom recovery stage were compared using the Spearman Correlation Coefficient. As shown on Table 8, hand use showed relationship with five modalities ranging from r = .69 to r = -.35 with positive relationships noted in kinesthesia, sTL and mTL. Brunnstrom recovery stage did not show a strong relationships (NS to -.37). Non-significant relationships were observed between s2PD and recovery stage.

Relationship between categorical variables

To determine the correlation between categorical variables, a Kendall's Tau-b was conducted with significant set at the p< .10 level. A 10% error rate was chosen due to a small sample size. In this paper it would be mentioned about only the correlation

Table 8. Correlation between five modalities and hand use/recovery stage

Variables		Spearman Correlation Coefficients	
		Hand use	Recovery stage
K	1	.69	.49
	2	-	-
sTL	1	.62	.41
	2	.58	.38
mTL	1	.63	.43
	2	.63	.45
s2PD	1	-.35	NS
	2	-.44	NS
m2PD	1	-.53	-.45
	2	-.55	-.37

Spearman Correlation Coefficients $p<.05$ level.
Note 1) 1 thumb, 2 index finger.
2) Minus value present the less distance in s2PD/m2PD, the more useful of hand use or the higher stage of recovery.

between stereognosis and other categorical variables.

In the two groups of stereognosis intact and absent, 53.9% of subjects were in the fine recovery stage and they were included in stereognosis intact group. In the stereognosis absent group the same percent (15.4%) fell into the recovery stage of "severe" and "fine". There was no significant relationship between recovery stage and stereognosis.

In the relationship between stereognosis and hand use, the subjects with stereognosis absence of 23.1% had a non-useful hands, 15.4% had an assistive hand, and none of them had a useful hand. In the stereognosis intact group, subjects of 3.9% had an non-useful hand, 26.9% had an assistive hand, and 30.8% of them had a useful hand. Hand use had a correlation between stereognosis (tau-b= .67). These data suggest that when a subject demonstrates astereognosis he/she can not use the affected hand, but the better the recovery of stereognosis, the better the use of the hand.

There was no statistically significant relationship between the time interval and stereognosis.

DISCUSSION

This study demonstrated a significant relationship between intact/absent stereognosis and four modalities : sTL, s2PD, m2PD and kinesthesia, except mTL in the case of stereognosis absent. As Dellon[6] stated in his study of peripheral nerve injury, m2PD is more sensitive than s2PD in predicting the functional use of the hand. This study supports this findings even in the hemiplegic hand. The significant relationship between kinesthesia and stereognosis in this study implies that active touch is the very sensation used to identify objects as Gibson[3], Gordon[7] and Iwamura[8, 9, 10] stated. Active touch could be called active stereognosis, because it integrates sensation of touch, pressure, position, motion and temperature. These four modalities represent discriminative sensation and can predict the presence or absence of stereognosis. Therefore, the occupational therapist can choose any of these four modalities as an evaluation of discriminative sensation instead of testing for stereognosis. Although static tactile localization is the best predictor, other modalities for sensory evaluation should be chosen to get an accurate response of a patient and gain other objective measurements. Based on result of this study, recommended tests for discriminative sensation in hemiplegic hands include kinesthesia and/or m2PD. Although mTL has a strong relationship when stereognosis is intact, it can not predict the absence of stereognosis. mTL should be tested independently.

The reason why mTL differs from sTL not clear based on this study. Although tactile localization as well as stereognosis is considered prerequisite to

functional hand use (Trombly & Scott)[4], and used in sensory re-training (Wynn-Parry)[8] for median nerve injury patients, it also required good sensory motor functions in order to point out the stimulated part. Moreover, in central nervous system dysfunction, it would be different to plan a coordinated movement and trace the moving track accurately in the test of mTL.

To determine which finger should be selected for discriminative sensory testing, this study demonstrated a correlation between s2PD and m2PD and between fingers in the same modality. If m2PD is selected (for the reason mentioned above), any finger could be tested. Further, the radial side of the hand (especially index fingers) are recommended test site because of contribution to functional use of the hand.

Concerning the relationship between other parts of upper extremity (palm, wrist, forearm, elbow and shoulder), s2PD and m2PD in the palm showed no relationship with any of the four modalities. The correlation between the shoulder in kinesthesia and the other five modalities was the lowest. Therefore, based on this study, the therapist can choose one from three parts : wrist, forearm and elbow, and should test it including the palm and shoulder.

This study showed wider information for discriminative sensations in predicting the functional use of the hand than Moberg[12]. He stated that the Weber Stationary Two-Point Discrimination Test was used to give accurate information on the functional value of the sensibility in the hand. Moreover, his findings focused on peripheral nervous system dysfunction, while this study considered central nervous system dysfunction.

In this study of central nervous system dysfunction, subjects were divided into one of two groups according to their ability to identify objects using stereognosis. However, there is likely a wide range of variety of stereognosis ranging from the severely impaired to the minimally impaired. Because of this further study seems needed in this area.

Concerning the relationship between stereognosis and two measurements of hand function (Brunnstrom recovery stage and hand use measured with ADL inventory), the study showed interesting difference. Hand use had a positive relationship with stereognosis. This implied the better the recovery of stereognosis, the more useful the hand. However, no significant relationship was found between recovery stage and stereognosis. It could be that Brunnstrom stage is only the measurement of motor function of the hand, not the indicator of functional use of the hand represented by stereognosis.

CONCLUSION

As a discriminative sensation, stereognosis is one of the main modalities used to evaluate, plan for treatment and predict functional use of the hemiplegic hand in occupational therapy. However, many sensory modalities are induced for this purpose without certain ground of priority. The problem with stereognosis testing exists in the difficulty of testing a patient who can not identify objects by manipulation with his own hand. Recent studies for discriminating objects named "active touch" have demonstrated the importance of manipulating of objects. Therefore, the purpose of this study was to specify the most influential modalities for discriminative sensation related to stereognosis, to simplify the evaluation process, and to eliminate fatigue associated with complicated testing.

Stereognosis was chosen as the independent variable, dependent variable include 34 measures in five modalities of discriminative sensation (kinesthesia, static and moving tactile localization, and stationary and moving two-point discrimination). To analyze the data, a factor analysis was conducted for each of the five modalities to reduce the total number of variables. The BMDP 7M program-Stepwise Discriminant Analysis was used to determine how well measurement of each modality was able to classify the presence or absence of stereognosis. The Spearman Correlation Coefficients was used to determine the relationship between the five modalities. As background information, 10 categorical variables in four areas (Brunnstrom recovery stage, hand use, time interval between onset and test data, and stereognosis) are also compared using the Kendall's Tau-b.

The main question whether or not there was a relationship between stereognosis and five discriminative sensory modalities was answered by existence of a positive relationship in four modalities except mTL. Therefore, the occupational therapist can choose any

of those modalities, the recommended modalities were kinesthesia and/or m2PD because of their objectivity and accuracy.

There was a high correlation between fingers. To simplify the test procedure of m2PD, index finger can be chosen for testing, because of contribution to functional use of the hand. If testing for other parts of upper extremity are needed, the palm, one of three parts (wrist, forearm, and elbow) and shoulder should be tested independently because these parts had a lower relationship each other.

As background information for evaluation of discriminative sensation, four research questions addressed the relationships between Brunnstrom recovery stage, hand use, time interval, and stereognosis. Findings demonstrated s high correlation between recovery stage and hand use, and hand use and stereognosis. Time interval had no relationship with any other variables in spite of the belief of therapists as to the importance of time for recovery of sensory and motor function.

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立体覚テストの代替として最も相応しい知覚様式

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要　旨

手の操作能力を必要とする立体覚検査の代替として，片麻痺患者の麻痺手にも容易に実施できる客観性の高い知覚検査は何かを検討した。独立変数を立体覚，従属変数を運動覚，静的局在覚，動的局在覚，静的２点識別覚，動的２点識別覚の５種類の識別性知覚とし，上肢各部分での相関を統計的に検証した。

対象は脳卒中後片麻痺患者34名(男27，女６)で右麻痺16名，左麻痺17名，年齢65±7.5（55－75）歳であった。立体覚との相関を立体覚正常群と脱失群の２グループで比較すると，最も強い相関があったのは静的局在覚で正常群100%（脱失群91.7%），次ぎに動的２点識別覚95.2%（同91.7%），静的２点識別覚90.5%（同91.7%），運動覚90.5%（同91.7%）と続く。動的局在覚は立体覚正常群で95.2%と高いものの脱失群では75.0%で相関なしとみなされる。この理由は明確ではないものの局在覚を立体覚の代替として使うことに疑念を残す。静的・動的２点識別覚，運動覚共代替可能であるが，この中で感度の良さ，検査の容易さ，患者への負担の少なさを勘案すると動的２点識別覚が最も推奨出来る立体覚の代替検査であり，検査部位は操作機能における重要性からみて示指を選択することが勧められる。