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IDENTIFYING THE RECOGNITION PROCESSING WITHIN THE EFFECT OF INDIVIDUAL DISCRIMINABILITY ON SPATIAL S-R COMPATIBILITY : A P300 STUDY OF REFERENCE CUE TASK

Chun-Wei Chen*, Chang-Franw Lee* and Chih-Chun Chen**

*Graduate school of Design
National Yunlin University of Science and Technology
Yunlin, Taiwan 64002, R. O. C.

**Department of Physical Medicine and Rehabilitation
Taipei Veterans General Hospital
Taiwan 11217, R. O. C.

ABSTRACT

The purpose of this study is to determine whether positional recognition is processed in the influences of individual discriminability on human performance in spatial stimulus-response (S-R) compatibility. An event-related potential (ERP) experiment with reference cue (as control group) /without reference cue (as experimental group) was carried out. A Group Embedded-Fig Test (GEFT) was employed to separate the participants into two categories: field-dependent (FD) and field-independent (FI) . The significant variance of the behavioral data as well as the ERP data of P300 between FD participants and FI participants in both the reference cue task (control group) and no reference cue task (experiment group) revealed that the individual discriminability effects respectively occurred in the no reference cue task. Thus positional recognition processing was confirmed in the influence of individual discriminability on human performance in spatial S-R compatibility.

Keywords：spatial stimulus-response compatibility, recognition, P300.

Ⅰ. INTRODUCTION

1.1 Motivation

Designing the human-machine interface (HMI) while taking into account such individual factors as learning strategies, individual cognitive abilities, and aging, is an important issue for the research field of HMI design. (Benyon, et al., 2001) Designing the HMI in accordance with individual factors has been discussed with regard to the individual differences in the human performances in different HMI patterns. For example, Nilsson, et al. (Nilsson and Mayer, 2002) demonstrated the suitable website patterns for spatial individuals by discussing the variation of spatial skills in the performance of different search tasks of aquatic animals' websites. Ford (Ford, 1995) demonstrated the need for suitable computerized learning materials by discussing the different learning styles using Pask and Scott's teaching materials. These studies demonstrated both the important role of individual difference in HMI and how to better design HMI with respect to individual differences. However, these studies only discussed how to improve the HMI design of the machine, but not the human factors. Yet the human being is the key factor in the effect of individual differences on human performance in HMI. Thus, it is important to explore how individual differences influence the performance in HMI.

In order to elucidate how individual differences influence the performance in HMI, Chen, et al. (Chen, et al.,

2006) used the reference cue/no-reference cue concept to identify the spatial recognition processing in the effect of individual spatial discriminability on participants' performances in spatial stumulus-response (S-R) compatibility. It was found that spatial recognition did being processed in the effect of individual spatial discriminability on participants' performance in spatial S-R compatibility. This effect, however, was not supported by direct evidence, such as event-related potential (ERP) . Thus, this study provides such evidence in the form of the ERP measure of P300.

P300 is a component of the ERP waveform, which is elicited positively at the latency from 240 to 700ms. It was found to be sensitive to the cognitive stage within the information processing (Donchin, et al., 1986; Donchin and Mccarthy, 1980; Kok, 2001; Polich and Kok, 1995). Moreover, it was found that the P300 at the Fz, Cz and Pz sites was elicited in recognition tasks (Fize, et al., 2005; Miyakoshi, et al., 2006). These studies revealed that the P300 at the Fz, Cz and Pz sites are related to the of recognition processing. Thus, this study used the P300 at the Fz, Cz and Pz electrode sites to confirm the spatial recognition processing in the individual spatial discriminability effect on participants' performances in spatial S-R compatibility.

1.2 Conceptual Background

The design of this experiment is based on the reference cue/no-reference cue concept. A reference cue task (Fig. 1a) was carried out as a control group, and a no-reference cue task (Fig. 1b) was carried out as an experimental group. In the control group, the positional information was directly supplied by the square mark on the side of the stimulus presented as the reference cue. In the experimental group, the positional information had to be recognized without the square reference cue. It was supposed that if the spatial recognition was processed within the effect of individual spatial discriminability on participants' performances in spatial S-R compatibility, the positional information would be recognized to respectively produce the individual discriminability effect in the no-reference cue task (experimental group) . Thus, the repeated individual spatial discriminability effect in even the no-reference cue task (the experiment group) would confirm the spatial recognition processing within the individual spatial discriminability effect in spatial S-R compatibilits. Hence, the concept of reference cue/no-reference cue was used to design the experimental task, and it is assumed that the individual spatial discriminability effect would be repeated in the no-reference cue task.

Moreover, since the P300 at the Fz, Cz and Pz electrode sites was used to confirm the spatial recognition processing within the individual spatial discriminability effect, it was necessary assumed that the P300 waveform which occurred in the individual spatial discriminability effect in the reference cue task would repeatedly occur in the no-reference cue task.

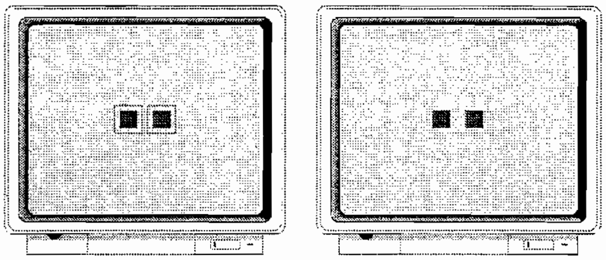
Ⅱ. METHODOLOGY

2.1 Participants

Witkin's Group Embedded-Fig Test (GEFT) was employed in this study to identify the individual spatial discriminability as either the field-dependent (FD) cognitive style or the field-independent (FI) cognitive style. A GEFT score above 10 indicates an FI cognitive style, while a score below 10 indicates an FD cognitive style. Six participants per cognitive style were selected (FD subject: mean score = 14.76, SD = 3.3 ; FI subject: mean score = 7.34, SD = 3.7) . The experiment had a total of twelve participants (seven males, five females) , with a mean age of 24.5 years (SD = 2.6) ; all were right handed.

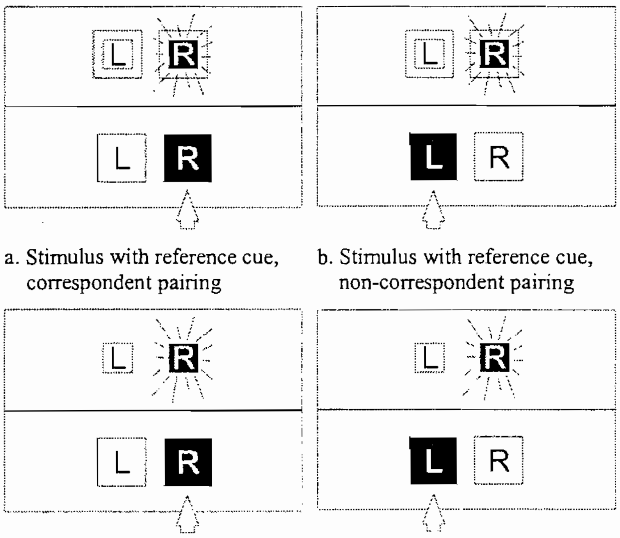
2.2 Experimental Tasks

In this study, two different reference cue tasks were designed : the reference cue task and the no-reference cue task (Fig.1) . Moreover, each reference cue task consisted of two assignments : a correspondent spatial S-R pairing task, and a non-correspondent spatial S-R pairing task. Thus, there were four assignments in total for each participant to carry out (Fig.2) . In the correspondent spatial S-R pairing, the participants were instructed to respond to the stimulus with the correspondent response key. For example, the left key was to be pressed in response to the left target stimulus. For the non-correspondent spatial S-R pairing, the participants were instructed to respond to the stimulus with the non-correspondent response key. For example, the right key was to be pressed in response to the left target stimulus. For each assignment, there were six left stimuli and six right stimuli. One second after making a response by pressing a key, the next stimulus randomly appeared in either the left position or the right position, and the participants had to respond while the stimulus was visible. Only after a response was made would the next stimulus appear. The computer automatically recorded the reaction time. During the entire experiment, the participants carried out these four assignments with the right hand only.



a. Stimulus with reference cue b. Stimulus without reference cute

Fig. 1 Two types of tasks in the experiment



a. Stimulus with reference cue, correspondent pairing

b. Stimulus with reference cue, non-correspondent pairing

c. Stimulus with no-reference cue, correspondent pairing

d. Stimulus with no-reference cue, non-correspondent pairing

Fig. 2 Four S-R compatibility conditions

2.3 Procedure

The control group tasks (reference cue tasks, Fig 2a, 2b) , were first executed by the subject's right hand. Then the same hand carried out the experimental group task (no-reference cue tasks, Fig 2c, 2d) . After carrying out the two tasks, one test was entirely completed.

2.4 EEG recordings

The electroencephalogram (EEG) was recorded (band pass DC-40Hz, sampling frequency 1000Hz) using a Neuroscan Nuamps EEG system (Compumedics Neuroscan, USA) with twelve electrodes at the Fz, Cz, Pz, Oz, F3, C3, P3, O1, F4, C4, P4, and O2 sites, according to the 10/20 system referenced to the linked earlobes. Two channels, HEOG and VEOG, were recorded to monitor the eye movement. These electrodes were grounded with an impedance from 5Ω to 10Ω. The EEG was off-line epoched and averaged using a 800ms analysis period following the stimulus. A baseline of −100 to 0ms was employed before the stimulus. The EEG was corrected using an ocular reduction technique developed by NeuroScan, and results exceeding $\pm 100\ \mu V$ at any electrode were omitted from the ERP averaging. The derived component of P300 was defined as the measuring from the deviants as the most positive in the range 250-550ms.

2.5 Statistical analysis

In this study, MANOVA is used to analyze the behavioral data (choice reaction time) and ERP data (the latency and the amplitude) relating to the influence of FDI cognitive styles on participants' performances in spatial S-R compatibility, either in the reference cue task (control group) or in the no-reference cue task (experiment group) .

Ⅲ. RESULTS

3.1 Behavioral data

An significant analysis of the behavioral data (Table 1) reveals that only the FDI cognitive style affected the participants' performances ($F_{FDI}(1, 274) = 79.993$, $p < 0.05$; $F_{reference\ cue\ task\ patterns}(1, 274) = 0.792$, $p > 0.05$) . A relationship between the FDI cognitive style and the reference cue task patterns was not found ($F_{FDI \times reference\ cue\ task\ patterns}(1, 274) = 0.207$, $p > 0.05$) .

Moreover, as shown in Fig. 3, the behavioral data of the individual cognitive styles shows that : 1. a significant

Table 1 Variance analysis of behavior data and ERP data

Variables for significant analysis	Behavior data		ERP data (F (1, 274))					
			Latency			Amplitude		
	F (1, 274)	P	Fz	Cz	Pz	Fz	Cz	Pz
FDI cognitive styles	79.993	0.000 *	0.987	1.132	0.204	3.612	10.753 *	8.973 *
reference cue task patterns	0.792	0.315	0.978	0.016	3.970	1.571	2.465	0.003
FDI cognitive styles × reference cue task patterns	0.207	0.649	0.654	1.254	3.044	0.781	0.469	0.524

* : significant variance, $p<0.05$

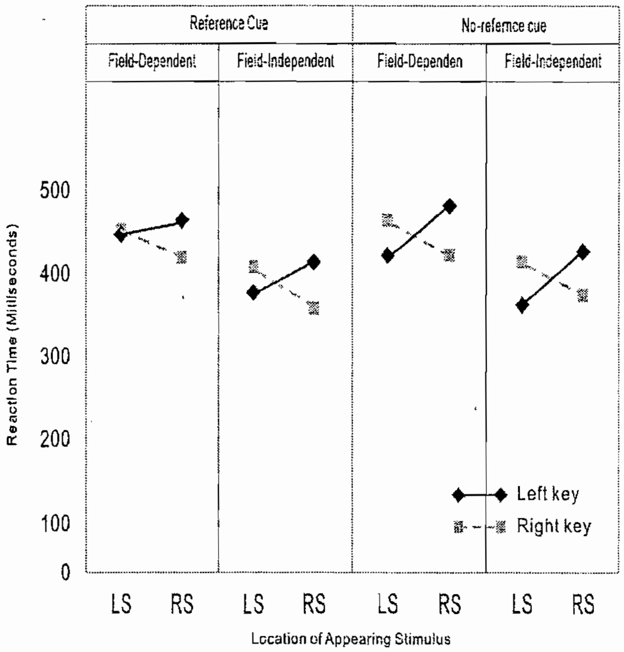


Fig. 3 Spatial S-R compatibility performances of FDI cognitive styles in the reference cue task and the no-reference cue task.

variance between FD participants' performances and FI participants' performances was found for most spatial S-R pairing pattern tasks in both the reference cue task and the no-reference cue task ; 2. FI participants performed significantly faster than FD participants in all spatial S-R pairing pattern tasks. Additionally, Fig. 3 also shows that : 1. there was no significant variance of either participants' performances within the two different reference cue tasks ; and 2. either FD participants or FI participants performed equally in both reference cue tasks.

3.2 ERP data

Analysis of the ERP data (Table 1) reveals that : 1. only the FDI cognitive style affected the P300 latencies and amplitudes of the three electrodes ; the reference cue task patterns had no effect ; and 2. an interaction effect between the FDI cognitive styles and reference cue task patterns on the P300 latencies and amplitudes in three electrodes was not found.

Moreover, for the FDI cognitive styles in ERP, Table 2 shows that : 1. for the latencies, FD participants' P300 elicited time was shorter than the FI participants' P300 elicited time for all the spatial S-R pairing patterns in both reference cue tasks (Fig. 4) ; 2. for the amplitudes, the FI participants' P300 waved more heavily than that of the FD participants' P300 for all pairing patterns in both reference cue tasks (Fig. 4) ; and 3. a significant variance of both individual cognitive styles' amplitudes was found for non-correspondent spatial S-R pairing at the Fz and Cz electrode sites in both the reference cue tasks.

For the reference cue task patterns in ERP, Table 3 shows that: 1. there was no significant variance of either reference cue tasks' latencies for both individual cognitive styles at all the three electrode sites, and 2. there was no significant variance of either of the reference cue tasks' amplitudes for both the two individual cognitive styles at all three electrode sites.

Ⅳ. DISCUSSION

Based on the behavioral data in section 3.1, it can be seen that : 1. the FDI cognitive styles did influence the participants' performances in spatial S-R compatibility, and 2. the effect of the FDI cognitive styles on participants' performances in spatial S-R compatibility was not influenced by the reference cue task patterns. These results indicate that the individual spatial discriminability effect repeatedly occurred in both reference cue tasks, thus confirming the hypothesis that positional recognition was processed in individual spatial discriminability effect in spatial S-R compatibility. This agrees with the findings of Chen, et al.'s (2006) study of positional

Table 2 FDI cognitive styles' ERP results in two different reference cue tasks

Component		Sites	Reference cue task							No-reference cue task						
			correspondent			non-correspondent				correspondent			non-correspondent			
			FD		FI	FD		FI		FD		FI	FD		FI	
P300	Latency (ms)	Fz	285.8	<	299.3	333.3	<	352.5		314.6	<	354.5	323.6	<	340.3	
		Cz	280.3	<	302.5	332.0	<	352.7	*	335.1	<	350.0	346.8	<	392.7	
		Pz	294.7	<	305.2	321.7	<	350.3		317.0	<	347.0	346.0	<	382.5	
	Amplitude (μA)	Fz	4.739	<	5.488	4.412	<	6.504		2.763	<	3.025	2.914	<	3.025	
		Cz	4.572	<	6.883	4.616	<	7.850	*	3.817	<	5.764	4.849	<	5.764	*
		Pz	4.909	<	5.448	4.452	<	7.030	*	4.762	<	6.950	5.517	<	6.950	*

*：significant variance, $p<0.05$

Table 3 The ERP results of the difference between the two reference cue tasks for each cognitive style

Component		Sites	FD						FI					
			correspondent			non-correspondent			correspondent			non-correspondent		
			reference cue		no-reference cue	reference cue		no-reference cue	reference cue		no-reference cue	reference cue		no-reference cue
P300	Latency (ms)	Fz	285.8	<	314.6	333.3	>	323.6	299.3	<	354.5	352.5	>	340.3
		Cz	280.3	<	335.1	332.0	<	346.8	302.5	<	350.0	352.7	<	392.7
		Pz	294.7	<	317.0	321.7	<	346.0	305.2	<	347.0	350.3	<	382.5
	Amplitude (μA)	Fz	4.739	>	2.763	4.412	>	2.914	6.488	>	3.025	6.504	>	3.025
		Cz	4.572	>	3.817	4.616	<	4.849	7.883	>	5.764	7.850	>	5.764
		Pz	4.909	>	4.762	4.452	<	5.517	7.448	>	6.950	7.030	>	6.950

*：significant variance, $p<0.05$

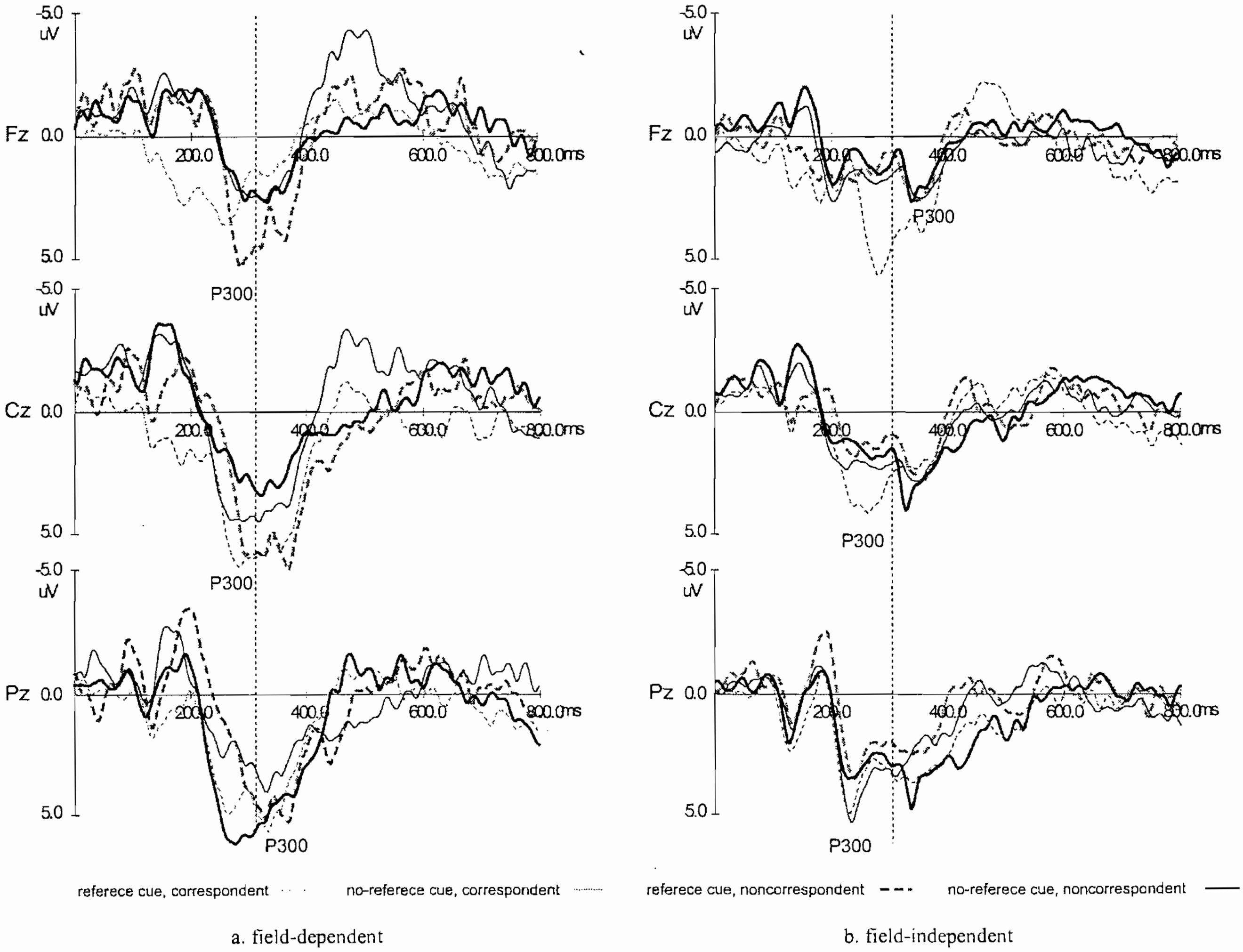


Fig. 4 FDI cognitive styles' Grand average P300 waveforms at Fz, Cz and Pz. Dash line indicates the 300ms point.

recognition in the individual spatial discriminability effect.

Moreover, the physiological evidence provided by the ERP data lends further support to this finding. For the individual cognitive styles, it can be seen that : 1. the significant variance of P300 amplitudes in both individual cognitive styles appeared in both the reference cue task and no-reference cue task confirms the repeated individual spatial discriminability effect in both reference cue tasks ; and 2. the absence of a significant variance of the P300 latencies and amplitudes in these two reference cue tasks for both FD participants and FI participants further confirms the equality of individual spatial discriminability effect in both reference cue tasks. These physiological evidences support the behavioral findings of this study. Thus, the study's assumption that positional recognition was processed in the individual spatial discriminability effect in spatial S-R compatibility was confirmed.

How to improve HMI designs by taking into account individual cognitive factors such as the pathway of recognition should be a subject of future research.

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以P300檢証區辨力對S-R相容行為影響中的識認處理

陳俊瑋[*]　李傳房[*]　陳至淳[**]

[*]國立雲林科技大學設計學研究所
[**]台北榮民總醫院復健醫學部

摘　要

以 P300 檢証識認行為是否存在在區辨力對 S-R 相容行為影響中，乃是本研究的目的。本研究以區辨力對 S-R 相容性影響行為中出現的 P300 波形 (代表識認行為)，是否重複出現在控制組 (方位訊息未被隱藏) 與實驗組 (方位訊息被隱藏) 等兩實驗狀況中，作為檢証識認行為是否存在在區辨力對 S-R 相容行為影響中之實驗假設的依據。實驗以有方位參考座標的 S-R 配對任務為控制組，以無伴隨方位參考座標的 S-R 配對任務為實驗組。在控制組中，方位訊息是直接被呈現的。在實驗組中，方位訊息是被隱藏的。由於方位識認是區辨力對 S-R 相容行為影響得以運作之基石，因此，若代表識認行之 P300 變化波形，在方位訊息被隱藏與否的兩實驗狀況 (控制組與實驗組) 之區辨力對 S-R 相容行為影響中重複出現，則方位識認行為之存在，便可獲得檢証。P300 之結果顯示，相同之 ERP 變化波形重複出現在兩實驗狀況中的區辨力對 S-R 相容行為之影響中。因此，本研究以為識認行為是存在在區辨力對 S-R 相容行為影響中的。

關鍵詞：刺激反應相容性、區辨力、識認、P300