The Effects of Individual Spatial Cognitive Styles and Spatial Stimulus-Response Pairing Patterns on Choice Reaction Time

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Abstract

The purpose of this study is to explore the effects of both individual spatial cognitive styles and spatial stimulus-response (S-R) patterns on average choice reaction time. The experiment employed a 2 (individual spatial cognitive styles) × 2 (spatial S-R pairing patterns) split-plot design. The individual spatial cognitive styles used field-dependent-independent (FDI) cognitive styles that were tested with Riding's computer-administered Cognitive Styles Analysis (CSA). The spatial S-R pairing patterns used correspondent spatial S-R pairing task and non-correspondent spatial S-R pairing task. Analysis of variance showed that both individual spatial cognitive styles and spatial S-R pairing patterns were significant. Further, it was found that the difference in the FD participants' performances between the two different spatial S-R pairing pattern tasks varied more significantly than the difference in the FI participants' performances (the FD participants performed significantly more slowly than the FI participants in the non-correspondent spatial S-R pairing task than in the correspondent spatial S-R pairing task). This indicates that spatial-cognitive individuals performed differently in different spatial S-R pairing pattern tasks, and demonstrates the important role of selecting operator for spatial S-R pairing tasks, especially in the advanced control room.

Keywords: Individual Spatial Cognitive Styles, Spatial Stimulus-Response Pairing

Introduction

Spatial stimulus-response (S-R) pairing refers to the spatial arrangement of controls and their associated displays [7]. Such control systems are commonly used at work and in daily life, for example the arrangement of burners and controls on a stove, and the arrangement of information on a monitor and the related keys on a keyboard [2, 3, 5]. In order to improve safety and efficiency, the most effective patterns of spatial S-R pairing have been widely discussed [1, 8]. One popular method employed in discussing these patterns is the concept of correspondent spatial S-R pairing and non-correspondent spatial S-R pairing[1]. For example, Chapnis and Lindenbaum [3] used this concept to investigate the optimal spatial S-R pairing patterns for a stove.

Correspondent spatial S-R pairing is the most popular spatial S-R pattern employed in designing a safe and efficient arrangement for operating a control-display device [4]. However, in some conditions, the spatial S-R pairing pattern used in a control-display device might not always be the correspondent spatial S-R pairing pattern, such as the conditions with unclear-cut stereotype and the limitation of controls in manufacturing. For example, even if the population stereotype is not clear (or when the relevant spatial S-R pairing principles are in conflict), the designer still needs to make a design decision. This can be seen in the inconsistent arrangement between the burners and controls in a typical four-burner stove. Regarding the limitations on controls in manufacturing, the various arrangements of a stimulus are paired with only one signal pattern of the arrangement of the controls, such as the various arrangements of function key labels in different software which are paired with the usual arrangement of function keys on a standard keyboard. In these conflicting conditions, the non-correspondent spatial S-R pairing pattern might occur to influence some individuals' performances. In order to improve safety and efficiency in such conditions, it becomes necessary to select suitable operators. Thus it is important to discuss the individual differences in the performances of spatial S-R pairing. Of special relevance is the way in which the individual performances of individual spatial cognitive styles vary in different spatial S-R pairing patterns. Therefore, the purpose of this study is to explore how the spatial cognitive individuals perform differently in different spatial S-R pattern tasks by elucidating the effects of individual spatial cognitive styles and spatial S-R pairing patterns on participants' performances in spatial S-R pairing.

The field-dependent-independent (FDI) cognitive styles[2] are described as the individual spatial cognitive difference regarding the individual's cognitive characteristic and consistent approach to process spatial information [9]. Two cognitive styles, field-dependent (FD) cognitive style and field-independent (FI) cognitive style, are combined into the FDI cognitive styles. It can be seen that in misleading condition, rather than un-misleading condition, the FD cognitive style's performance is influenced by the spatial information due to his/her wholist (global) manner relative to the FI cognitive style's analytic manner；but the FI cognitive style is not so influenced [6]. This indicates that FDI cognitive styles might perform differently in different spatial S-R pattern tasks that are also the misleading condition (non-correspondent spatial S-R pairing) and un-misleading condition (correspondent spatial S-R pairing) [4]. Thus this study uses FDI cognitive styles to explore the individual performances of individual spatial cognitive styles varied in different spatial S-R pairing patterns. It is assumed that the FD cognitive style's performances in two spatial S-R pairing patterns might vary more significantly than that of the FI cognitive style.

Methodology

2-1 Experimental Design

The experiment employed a 2 × 2 (individual spatial cognitive styles) × (spatial S-R pairing patterns) split-plot design. The individual spatial cognitive styles included the FD cognitive style and the FI cognitive style. The FDI cognitive styles can be measured with Riding's computer-administered Cognitive Styles Analysis (CSA)[3]. If the value of the CSA was over 1, the participant was classified as an FI participant. Conversely, if the value of the CSA was less than 1, the participant was classified as an FD participant. Additionally, the spatial S-R pairing patterns included a correspondent spatial S-R paring task and a non-correspondent spatial S-R paring task. Both spatial S-R pairing tasks were located on the right side and left side of the central red mark on the display (Fig. 1). The correspondent spatial S-R paring task included two conditions：the right response key to the right stimulus, and the left response key to the left stimulus. Conversely, the non-correspondent spatial S-R paring task included the other two conditions：the right response key to the left stimulus, and the left response key to the right target stimulus.

2-2 Participants

Twenty-four undergraduate and graduate students (12 participants per cognitive style were included, 6 male and 6 female) from National Yunlin University of Science and Technology University participated in the experiment. Their mean age was 22.5 years (SD=2.7). They were all healthy and right handed. Each participant’s cognitive style pattern was measured with CSA.

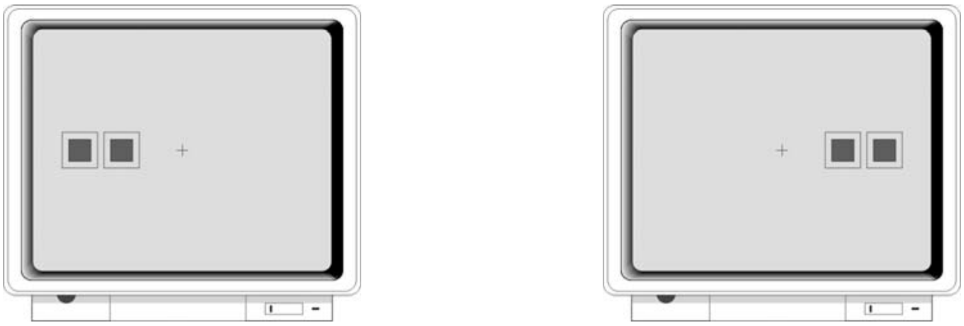
2-3 Materials and Equipment

The experimental tasks were performed on a personal computer. The participants used double keys control (Lumina LP-400) to respond to the stimulus on the display (Viewsonic 17-inch VA702). The distance between the display and a participant’s eye was 40 cm. The visual angle was 3.6 sec.

The experimental tasks were programmed with Visual Basic with a black background. The position of the stimulus was located within two 2.5 cm × 2.5 cm hollow, thin, white squares (the distance between the two squares was 0.5 cm)(Fig. 1). The stimulus was a 2.0 cm × 2.0 cm yellow square which randomly appeared three times in each of the two squares. One second after making a response by pressing a key, the next stimulus randomly appeared in either the left square or the right square.

2-4 Tasks and Procedure

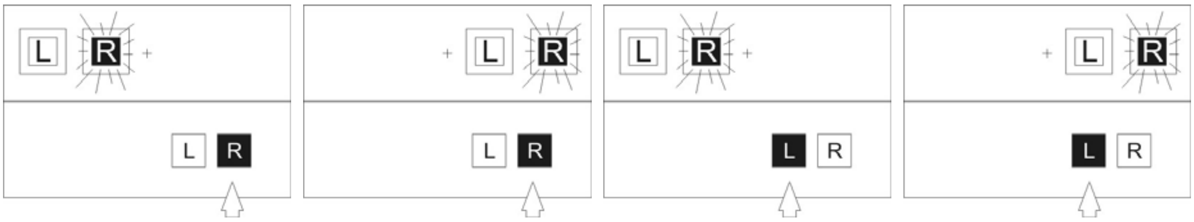
The four spatial S-R pairing tasks in each trial of the experiment were performed only with the finger of a participant’s two hands (Fig. 2). Before the formal test, each participant had to read the instructions out loud to ensure that he/she had understood the procedure of the experiment. After the four spatial S-R pairing tasks had been completely performed using both hands, one trial of the experiment was completed. Four experimental tasks were randomly assigned for every participant.



a. left side stimulus

b. right side stimulus

Fig. 1 The stimuli locations.

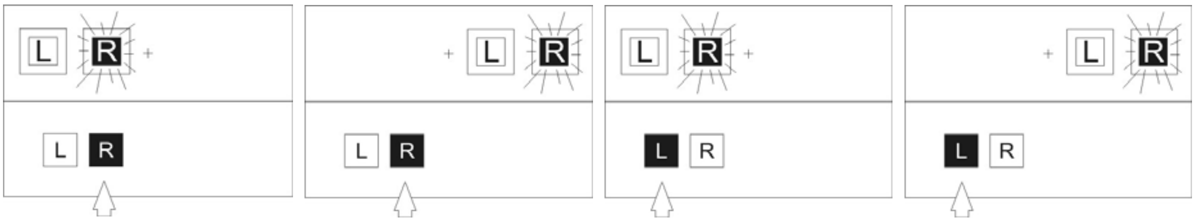


a. left side stimulus, correspondent pairing, and right hand manipulated

b. right side stimulus, correspondent pairing, and right hand manipulated

c. left side stimulus, non-correspondent pairing, and right hand manipulated

d. right side stimulus, non-correspondent pairing, and right hand manipulated



e. left side stimulus, correspondent pairing, and left hand manipulated

f. right side stimulus, correspondent pairing, and left hand manipulated

g. left side stimulus, non-correspondent pairing, and left hand manipulated

h. right side stimulus, non-correspondent pairing, and left hand manipulated

Fig. 2 The four tasks carried out with two hands.

2-5 Dependent Measures and Data Analysis

The participant's performance was defined as an average of the choice reaction time in each spatial S-R pairing task. For example, in either the right side or left side correspondent spatial S-R pairing task, the participant's performance means the average choice reaction time of correspondent spatial S-R pairing task in each side. The choice reaction time was defined as the time that elapsed between the appearance of the stimulus and the pressing of the response key. This study used the significant variance analysis of participant's performances between correspondent spatial S-R pairing task and non-correspondent spatial S-R pairing task in each side as the criteria to evaluate the assumption of this study. If a cognitive style's performances in correspondent and non-correspondent spatial S-R pairing tasks varied more significantly than the other cognitive style's performances in both spatial S-R pairing tasks, this can be taken as support for the hypothesis of this study.

Results and Discussion

3-1 Significant Analysis of the Two Independent Variables

This study was done to explore how spatial cognitive individuals perform differently in different spatial S-R pattern tasks by elucidating the effects of FDI cognitive styles and spatial S-R pairing patterns on participants' performances. Two independent variables, the individual spatial cognitive styles and spatial S-R pairing patterns, were investigated. The significant analysis of variance (Table 1) indicates that both the FDI cognitive styles and spatial S-R pairing patterns influenced the participants' performances for both hands. The interaction between the FDI cognitive styles and the spatial S-R pairing patterns also influenced participants' performances for both hands. This indicates the effects of individual spatial cognitive styles and spatial S-R pairing patterns on participant's performances.

Table 1：Significant Analysis of Two Independent Variables

Sources	Left hand				Right hand			
	Left side stimulus		Right side stimulus		Left side stimulus		Right side stimulus	
	F	Sig.	F	Sig.	F	Sig.	F	Sig.
Individual spatial cognitive styles (A)	94.15	0.000	80.40	0.000	130.79	0.000	55.127	0.000
Spatial S-R pairing patterns (B)	48.89	0.000	21.88	0.000	32.87	0.000	12.47	0.000
(A) x (B)	21.88	0.000	10.78	0.001	11.91	0.001	10.23	0.001

3-2 The Effect of Spatial S-R Pairing Patterns on Participants' Performances

Fig. 3 and Fig. 4 show that：1) For both hands, and for a stimulus on either side, both cognitive styles performed significantly faster in the correspondent S-R pairing task than in the non-correspondent S-R pairing task；2) For both hands, and for a stimulus on either side, the difference in the participants' performances between the two cognitive styles was larger in the non-correspondent spatial S-R pairing task than in the correspondent spatial S-R pairing task. These results agree with the results of similar studies, such as Bayerl, et al.'s [2] case study of the spatial arrangement of the function keys of a keyboard and the function key labels on a screen. This confirms the effect of spatial S-R pairing patterns on the participant's spatial S-R pairing performances.

3-3 The Effect of FDI Cognitive Styles on Participants' Performances

Fig. 3 and Fig. 4 also show that：1) For both hands, and for a stimulus on either side, the FI participants spent much less time than the FD participants in performing the two different spatial S-R pairing pattern tasks；2) The variance of the FD participants' performances in the two different spatial S-R pairing tasks varied more significantly than the variance of the FI participants' performances. This indicates that the FD cognitive style' performance was more influenced by the spatial S-R pairing patterns than those of FI cognitive style, and confirms the importance of selecting a suitable operator.

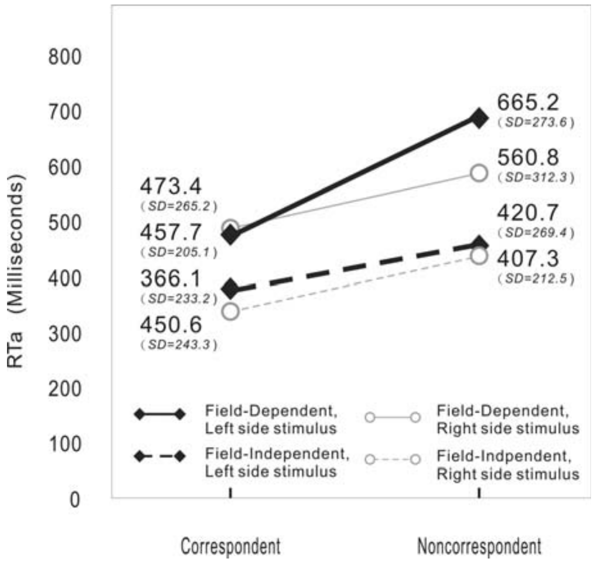


Fig. 3 Left hand performances.

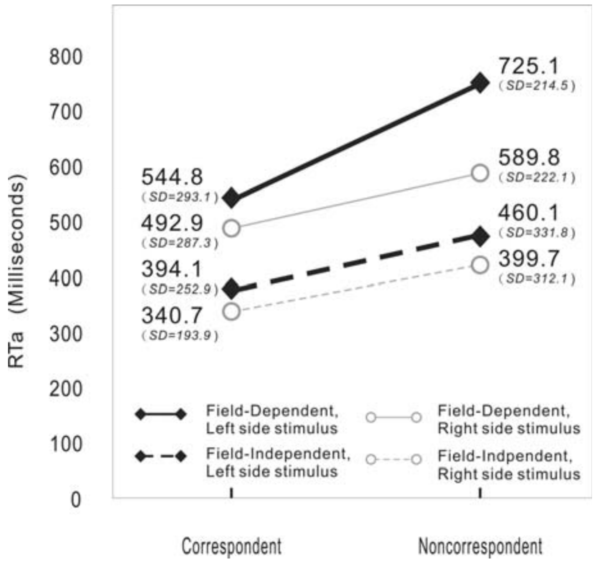


Fig. 4 Right hand performances.

It is wroth to point out that the findings and suggestions of this study were different with those findings and suggestions of current spatial S-R pairing studies, such as the case study of keys arrangement on keyboard and its related labels on display [2]. In these studies, the well correspondent S-R pairing pattern was usually found and suggested, rather than the suitable operators. However, in the conditions with unclear well correspondent S-R pairing pattern due to the indecision that a designer still cannot make whether or not the spatial S-R pairing was correspondent S-R pairing pattern (or when relevant spatial S-R pairing principles are in conflict), the non-correspondent S-R pairing might be employed, and some ones might be significantly influenced. Thus, it becomes important and necessary to suggest the suitable operators for keeping the safely and efficiently operating of spatial S-R pairing tasks in case of dangerous. For example, FI cognitive style, rather than FD cognitive style, was suggested to be more suitable for spatial S-R pairing task. Because the outcomes of this study showed that FI subjects' performances were not significantly influenced by spatial S-R pairing task with different spatial S-R pairing patterns. Thus the suitable operator rather than well correspondent S-R pairing pattern was suggested in this study.

Conclusion

Based on the above, it can be concluded that both of the spatial cognitive styles performed differently in different spatial S-R pairing pattern tasks. It was indicated that the FD participants' performances were more influenced than those of FI participants by the spatial S-R pairing patterns tasks (the FD participants performed significantly slower than the FI participants in the non-correspondent spatial S-R pairing tasks than in the correspondent spatial S-R pairing task). Thus the important role of selecting a suitable operator for spatial S-R pairing task, especially in advanced control room, was suggested. In the future, a suitable interface with regard to spatial S-R pairing for the spatial cognitive individuals will be explored.

End Notes

[1] Fitts et al. [4] defined spatial S-R pairing patterns as correspondent spatial S-R pairing and non-correspondent spatial S-R pairing. It was claimed that：1) If the spatial S-R pairing's reaction time is shorter, the efficient condition is termed "correspondent spatial S-R pairing"；2) Conversely, if the choice reaction time for spatial pairing is longer, this non-efficient condition is termed "non-correspondent spatial S-R pairing." They also state that：1) The efficient spatial S-R pairing which requires a shorter reaction time is termed "compatible" ; and 2) Conversely, the non-efficient spatial S-R pairing is termed "incompatible."

[2] FDI cognitive style is the individual difference with respect to cognitive processing as defined in [9] rod and frame test. It describes that：1) FDI cognitive style is a bipolar contrast in which individuals are positioned along a continuum dimension from extreme field-dependent （FD） cognitive style to extreme field-independent （FI） cognitive style；2) An individual located towards the FD end of the dimension has difficulty in separating incoming information from its contextual surroundings, is more likely to be influenced by external cues and to be non-sensitive to their information uptake；3) Conversely, FI individuals have no difficulty in separating the most essential information from its context, are more likely to be influenced by internal than external cues, and to be sensitive in their information uptakes. This indicated that FDI cognitive styles referred to the individual spatial difference that was described as："an individual's cognitive characteristic and consistent approach to processing information（stimulus）in the misleading condition."

[3] CSA（computer-administered Cognitive Styles Analysis）is a computer-aided test proposed by Riding [6] for measuring the pattern of cognitive style. This test classifies a person's cognitive style as either FD cognitive style or FI cognitive style participant.

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空間認知風格與空間刺激反應配對形式對選擇反應作業績效之影響

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摘要

本研究之目的，旨在探討空間認知個別化差異與空間刺激反應配對形式差異，對現代化控制室之空間刺激反應作業反應績效之影響。本研究之實驗採用 2 (空間認知風格) × 2 (空間刺激反應配對形式) 之 split-plot 設計。空間認知個別化差異，以 Riding 設計之電腦化 Cognitive Styles Analysis (CSA)測驗所判定之場地獨立 (field-independent) 與場地依賴 (field-dependent) 等兩空間認知風格定義之。而空間刺激反應配對形式，以一致性刺激反應配對作業與非一致性刺激反應配對作業定義之。實驗結果顯示，空間認知風格與空間刺激反應配對形式等兩實驗變數，對受測者之作業反應績效均產生影響。其中，場地依賴認知風格者，受空間反應刺激配對作業形式差異之影響，要比場地獨立認知風格者所受的影響來得大。此顯示，空間認知形式不同者，在空間刺激反應作業中會有不同的作業績效表現。因此，建議應審慎評估，挑選操作現代化控制室之空間刺激反應配對作業的操作人員。

關鍵字：個別化空間認知風格, 空間刺激反應配對