Control/Display Relationship of the Four-Burner Stove: A Reexamination

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SHORT NOTE

Control/Display Relationship of the Four-Burner Stove: A Reexamination

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Several previous studies concerning the arrangement of the control/burner relationship of a four-burner stove showed discrepancy in their results. For this reason, a further analysis of this arrangement is necessary and worthwhile. Two research methods were adopted to duplicate earlier studies. One was the paper-pencil test in which subjects took three different questionnaire forms that used alphabetical, sign, and numerical code systems. The other method was computer simulation in which subjects took part in a performance test of four arrangements of control/burner designs, and reaction time and error rate were measured. The results indicated the existence of a suggestive effect, which is a tendency by some stimuli-cues to induce a specific response unawares in subjects. This confounding variable must be controlled in the test tool design. Results also revealed a population stereotype in the control/burner linkage relationship that was different for Chinese subjects and for American subjects. The equivalence of research methods between the paper-pencil test and computer simulation was not completely assured.

INTRODUCTION

Compatibility refers to the agreement between the stimuli/response relationship and human expectations and as such is a central human factors issue. In this regard, a system that is ergonomically designed should be compatible with population stereotypes. We postulate that a greater degree of compatibility will result in faster learning, shorter response time, fewer errors, greater safety, and reduced mental workload.

After reviewing the literature of four-burner stove studies, we found that the classic example of control/response compatibility was worth reexamining. Chapanis and Lindenbaum (1959) and Ray and Ray (1979) presented several arrangements of controls and burners (as shown in Figure 1) to subjects and asked them to turn off or on specific burners. The stove model was simulated using colored perspex disks to represent the burners, each of which could be illuminated by bulbs. The results from both studies showed that Type II appeared to be superior.

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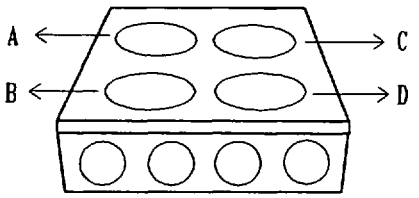

Type	Assigned Control Order				Burner Sequence
II	A	B	D	C	⊔
III	A	B	C	D	⊓
IV	B	A	D	C	⊔
V	B	A	C	D	⊓

Figure 1. *Control-burner arrangement relationship used in previous studies.*

Shinar and Acton (1978) presented to subjects a questionnaire containing a drawing and asked them to point out which of the unmarked controls they thought controlled each of the burners. As in Figure 2, the burners were labeled "A," "B," "C," and "D," and the controls were unlabeled. Shinar and Acton found that the most frequently chosen arrangement (see Figure 1) was Type III (31%). Arrangement Type II, which induced fewer errors than did Type III in previous studies, was chosen by only 25% of the subjects. Nevertheless, a chi-square analysis showed that Type V was chosen significantly less often than were Types II, III, and IV, which did not differ significantly from each other. This means that no particular stereotype emerged as predominant.

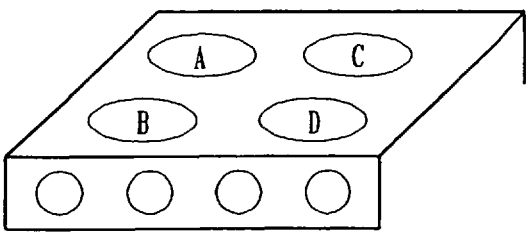

Figure 2. *Drawing from the questionnaire used in Shinar and Acton (1978).*

After considering the cause of those inconsistent and indefinite findings, we supposed they might have resulted from the code system used in Shinar and Acton's study (see Figure 2). Because the alphabetic codes A, B, C, and D are essentially sequential, some subjects might have been influenced unknowingly by this. Consequently, they filled in the four controls with those letters consecutively from left to right, thus facilitating a quasi-predominance of the Type III choice. Therefore, we were encouraged to conduct a study to test whether a suggestive effect on the subject's judgment actually existed with a code system of a sequential nature. *Suggestive effect* is defined here as the tendency to induce unawares a specific response in a receptive person by some kind of cue or stimuli.

We were also interested to know whether or not a difference in the population stereotype existed between Chinese and American subjects regarding the control/burner relationship. This aspect of the control/burner relationship had not been studied before.

Finally, we wanted to study the equivalence of two methods: the paper-pencil test to study choice and computer simulation to study reaction times and errors.

METHODS

Paper-Pencil Test

There were 423 college students—291 males and 132 females—who volunteered to serve as subjects in this study. In order to evaluate the possible suggestive effect of sequential codes, three different forms of questionnaires were developed. The code systems employed in each of these three questionnaires were as follows (see Figure 3):

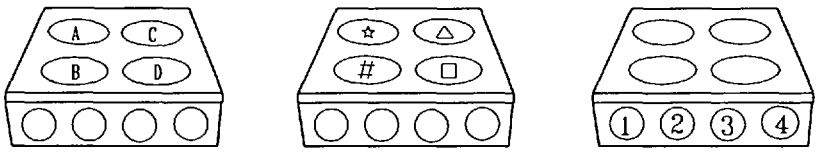

Figure 3. *The three forms of questionnaires used in this study.*

1. Alphabetical Questionnaire (Qa): The alphabetic codes A, B, C, and D were labeled over the four burners, as in Shinar and Acton's study (1978).
2. Sign Questionnaire (Qs): A set of sign codes, ☆, ≠, △, and □, devoid of sequentiality, were assigned arbitrarily to each burner.
3. Numerical Questionnaire (Qn): A string of numerical codes, 1, 2, 3, and 4, were allocated not to each burner but to each control from left to right.

The subject's task was to fill in each control blank with its corresponding burner's code (for Qa and Qs), according to his or her stereotyped judgment, and conversely to fill in each burner blank with its corresponding control's code (for Qn).

The three types of questionnaires were randomly distributed to the 423 subjects: Qa went to 153 subjects, Qs to 143, and Qn to 127.

Computer Simulation

A computer simulation was developed to model the four aforementioned types (II, III, IV, and V) of control/burner linkage. The experimental procedure was similar to that of Chapanis and Lindenbaum (1959). Fifteen male college students aged 18 to 20 years volunteered to participate in this simulation study.

At the beginning of each test session, the experimenter told subjects the purpose of the experiment and mentioned the type of control/burner linkage that would be used. The four keys (E, T, U, and O) on the keyboard were set up to act as stove controls. Subjects were asked to place their index fingers on (or return to) a predetermined point, designated as the ready position, on the table with the keyboard.

When subjects were ready, the computer displayed a graphic stove on the screen; then a light spot would appear on one of the stove's four burners simultaneously with an acoustic signal. The subjects' task was to turn off the light spot by pressing the "correct" key control as quickly as possible. If subjects made an error, they had to immediately try another key until the right one was found. Before the test began, subjects were allowed practice to make sure that they were familiar with the experimental task and control-burner configuration.

The testing order for the graphic burner light and the linkage type was randomized. Because linkage type was varied within subjects, a two-day break was instituted between testing sessions on the different types. Each light burner was turned on and off 20 times, so each type of linkage was tested a total of 80 times. The intertrial interval between light off and on was fixed at about 1 s.

The performance measures collected in this experiment consisted of reaction times and number of errors, which were automatically recorded by the computer.

RESULTS AND DISCUSSION

Paper-Pencil Test

Table 1 summarizes the numbers of intuitive choices (and the percentage these represent) of each possible control/burner linkage arrangement made by subjects in the three forms of questionnaires.

TABLE 1

Results of the Pencil-Paper Test

Type	Linkage Relationship	Qa (N = 153)			Qs (N = 143)			Qn (N = 127)		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
II	ABDC	15 (16%)	10 (17%)	25 (16%)	19 (19%)	9 (20%)	28 (20%)	14 (14%)	3 (11%)	17 (13%)
III	ABCD	46 (49%)	29 (49%)	75 (49%)	35 (36%)	19 (42%)	54 (38%)	35 (35%)	11 (40%)	46 (36%)
IV	BADC	11 (12%)	10 (17%)	21 (14%)	19 (19%)	8 (18%)	27 (19%)	24 (24%)	6 (22%)	30 (24%)
V	BACD	9 (10%)	5 (8%)	14 (9%)	9 (9%)	4 (9%)	13 (9%)	10 (10%)	5 (17%)	15 (12%)
VI	BDAC	7 (7%)	—	7 (5%)	7 (7%)	—	7 (4%)	—	—	—
VII	ACBD	—	4 (7%)	—	6 (6%)	4 (9%)	10 (7%)	9 (9%)	2 (7%)	11 (9%)
VIII	ADBC	—	—	—	1 (1%)	—	1 (1%)	1 (1%)	—	—
IX	BDCA	—	—	—	—	—	—	—	—	—
Others		6 (6%)	1 (2%)	11 (7%)	2 (3%)	1 (2%)	3 (2%)	6 (7%)	1 (3%)	8 (6%)
Total		94	59	153	98	45	143	99	28	127

Note. "ABCD" represents "☆#△□" in Qs and "1234" in Qn, respectively.

Table 1 shows that the most frequently chosen arrangement was Type III in all three questionnaires. Type III was chosen by 49%, 38%, and 36% of the subjects in the Qa, Qs, and Qn questionnaires, respectively. A chi-square test showed that Type III was chosen significantly more often than Type II, Type IV, and Type V, $\chi^2_{Qa}(3) = 69.06$, $\chi^2_{Qs}(3) = 28.75$, and $\chi^2_{Qn}(3) = 22.76$; all values of $p < 0.001$. No significant differences were found between male and female subjects, $\chi^2(3) = 2.778$, $p > 0.05$.

Type III was chosen by a dramatically high percentage of subjects in the case of Qa (49%) and a somewhat smaller percentage in the case of Qs (38%) and Qn (36%). Qa differed significantly from Qs ($p < 0.027$) and Qn ($p < 0.014$), but there was no difference between Qs and Qn.

These results suggest that the large number of Type III choices in Qa could be attributed to a kind of suggestive effect caused by the sequential nature of its alphabetical code. Moreover, Type III represented the population stereotype of control/burner arrangements for Chinese subjects because Qs and Qn were immune to this suggestive effect.

If the suggestive effect is eliminated from the Shinar and Acton data, then Type II would surpass Type III. This might be in complete agreement with earlier studies, although the difference probably would not have been significant. Consequently, Type II would have been confirmed as the American stereotype.

The difference in the stereotypes might arise from the reading/scanning habits of the two cultures. The Chinese ideogram is written and read vertically and from right to left, as with an "N" sequence, in contrast to the English language's "Z" sequence, which is read horizontally and from left to right. After the left-lower burner, the Chinese subjects had a tendency to shift to the right-upper burner instead of the Americans' right-lower burner.

Computer Simulation

The performance measures in reaction time and error rate with the computer simulation are shown in Table 2.

An analysis of variance showed that there were significant differences in the mean reaction time among the questionnaire types, $F(3,42) = 3.12$, $p < 0.05$, and among the subjects, $F(14,42) = 5.23$, $p < 0.01$. A further test using Duncan's techniques for comparing individual means with the data for all 80 trials showed that the mean for Type III was signif-

TABLE 2

Results of the Computer Simulation

Type	Linkage Relationship	Average Reaction Time (s)	Number of Errors (%)
II	ABDC	0.6650	126 (10.50%)
III	ABCD	0.6313	52 (4.33%)
IV	BADC	0.7158	124 (10.33%)
V	BACD	0.7202	135 (11.25%)

icantly lower than the mean for Types IV and V, but it did not differ significantly from that of Type II.

Therefore, the predominance of Type III was only partially supported by the quasi-objective performance measures of the computer simulation. Under these conditions the computer simulation should not be replaced, methodologically, by the paper-pencil test with the subjective judgment.

In addition, the error rates of the present study, compared with those of Chapanis and Lindenbaum (1959) and those of Ray and Ray (1979), are summarized in Table 3. As can be seen, the stereotype difference between cultures emerges again. Type III was the preferred arrangement for the Chinese subjects, and Type II was the preferred arrangement for the American subjects. Also, the results in Table 2 show that there was a significant difference for the number of errors among the types, $\chi^2(3) = 40.6$, $p < 0.001$.

TABLE 3

Comparison of Error Rates (%) with Previous Studies

Type	Linkage Relationship	This Study	Chapanis and Lindenbaum (1959)	Ray and Ray (1979)
II	ABDC	10	6[a]	9[a]
III	ABCD	4[a]	10	16
IV	BADC	10	11	19
V	BACD	11	—	12

[a] The preferred arrangement for the study.

CONCLUSIONS

Previous results and conclusions have been attributable in part to a suggestive effect that existed insidiously in some designs. For the sake of methodological soundness, an experimenter should always take care to exclude extraneous factors or confounding variables, such as was found in the codes with sequence implication in this four-burner stove study.

The population stereotypes regarding the control/burner linkage relationship have been shown to be culturally different: Type III or "I/I" (inverted N) sequence for Chinese subjects versus Type II or "U" sequence for American subjects. The cultural differences probably result from differences in reading or scanning habits.

In this research, the results of the paper-pencil test are not in complete agreement with those of computer simulation. Although the paper-pencil test may be a time-saving and low-cost method, it may not always yield ecologically valid results.

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