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CONTROL-DISPLAY ASSOCIATION PREFERENCES FOR GANGED CONTROLS

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ABSTRACT

Seventy-five male college students and twenty-five human engineering psychologists were given a questionnaire presenting diagrams consisting of three concentrically ganged knobs and three dials which they were told the knobs operate. They were asked which dial they thought should be operated by each of the three knobs. Knob-dial associations were obtained with dials in horizontal and vertical arrays above, below, to the left of, and to the right of the knobs, and with dials differing in size, shape and distance from the knob axis. Knob-dial associations were found to be influenced by all of these factors except dial shape. Associations which were both strong and relatively unrivaled were found for dial position in a horizontal array (except when the array is to the left of the knobs), and for dial size. Subjects associated the spatial knob progression, front knob to back knob with the spatial dial progression, left dial to right dial and with the dial size progression, smallest dial to largest dial. Strong, but strongly rivaled, associations were found for dial position in a vertical array and for dial distance from the knob axis.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:



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CONTROL-DISPLAY ASSOCIATION PREFERENCES FOR GANGED CONTROLS

INTRODUCTION

The number of instruments required in military aircraft is increasing rapidly, and control panels, whose dimensions are limited by the confined areas available, are fast becoming overcrowded with controls. A possible solution to this problem is to "gang" or "stack" several control knobs on a single axis (by attaching them to concentric protruding shafts).

One phase of this larger problem is the determination of the factors influencing control-display associations. "Common sense" would suggest that when dials are ganged (i.e., when dial scales are concentric) a given dial should be associated with the knob in the same relative ganged position. However, when knobs are ganged but dials are not ganged, control-display associations are more difficult to predict. It is the purpose of this study to investigate whether or not, with unganged dials, relative dial position, size, shape or distance from knob axis is associated with relative knob position on a ganged control shaft.

PROCEDURE

The present investigation utilizes a printed test technique previously used and described by Warrick in Memorandum Report MCREXD-694-19A, "Direction of Motion Stereotypes in Positioning a Visual Indicator by Use of a Control Knob: II. Results from a Printed Test." Warrick found considerable agreement between results from a printed questionnaire and those obtained with actual apparatus.

Seventy-five male college students and twenty-five human engineering psychologists were given a printed test in which a number of diagrams were presented, each containing three concentric knobs and three dials. The subject was asked to label each dial with an F, an M, or a B, depending on whether he thought it should be operated by the Front knob (the knob protruding farthest from the control panel and, therefore, the knob nearest the operator), the Middle knob, or the Back knob (the knob nearest the control panel and, therefore, the knob farthest from the operator). A three dimensional picture of the knobs, with the front, middle and back knobs labeled, was provided on the front cover, along with the instructions, so that there might be no ambiguity as to terms. Also, the subject was told that each of the three knobs could operate only one of the three dials.

In all except one of the diagrams containing dials differing in position, size or distance from the knob axis, the dials used were semicircular. In order to gain insight as to whether or not the preferences expressed were unduly influenced by the particular dial shape used, one diagram was repeated, at the end of the test, with circular dials. Results were quite similar for both dial shapes. While such results do not permit definite conclusions, they suggest that knob-dial associations are probably not strongly influenced by dial shape so long as the same shape is used for all dials.

At the end of the test one diagram was presented which contained only the knobs. Here the subject was asked to label the knobs in the sequence in which he thought they should be operated (i.e., first, second, or third). Because it was thought that the sequence of knob operation preferred might influence the knob-dial associations preferred, all of the data were originally broken down into sequence-preferring groups (within the two subject groups) and analyzed as such. Although the group preferring the sequence F M B was more definite in its preferences than were the other groups, the direction of preference appeared to be the same for all groups. Therefore, the data to follow will be broken down only for the subject groups (i.e., psychologists and students) and not for sequence-preferring groups.

RESULTS*

Sequence of knob operation:

Subjects were nearly unanimous in feeling that the operator should start at one end of the knob shaft and operate the knobs in spatial succession, without reversing his direction of progress, until the other end of the shaft is reached. A significantly larger proportion of both groups chose the front knob to back knob direction of progress than chose the reverse.

Dials in a horizontal array:

Four diagrams presented dials arranged in a horizontal line: (1) above, (2) below, (3) to the left of, and (4) to the right of the knobs. Nearly all subjects selected the middle knob to operate the middle dial. The association, front knob - left dial, middle knob - middle dial, back knob - right dial, was an exceedingly strong one. A highly significant proportion of both groups chose this association in all four diagrams. Furthermore, this association invariably was clearly superior to its strongest rival (which was the association, front knob - right dial, middle knob - middle dial, back knob - left dial). This rival association was chosen with a significantly high frequency only for the case where the dials are to the left of the knobs, and then only by college students.

Dials in a vertical array:

Four diagrams presented dials arranged in a vertical line: (1) above, (2) below, (3) to the left of, and (4) to the right of the knobs. Again, nearly all subjects selected the middle knob to operate the middle dial. The general, although not universal, tendency was for both the front knob - upper dial, middle knob - middle dial, back knob - lower dial association and the reverse association (i.e., front knob - lower dial, middle knob - middle dial, back knob - upper dial) to be chosen by a significantly large proportion of subjects. Comparing these two associations with one another, a significantly larger proportion of college students chose the former association when the dials were below or to the right of the knobs; a significantly larger proportion of psychologists chose the latter association when the dials were above the knobs. Neither association was significantly preferred over the other, by either group, when the dials were to the left of the knobs.

* For a complete statistical breakdown of results, see Statistical Appendix.

Dials differing in size:

Three diagrams presented dials differing in size. Three dial sizes were used, each dial appearing at one of three dial positions ("northwest", "southwest" and "northeast" of the knobs). In order to take account of any possible positional preferences, each dial size appeared at a different one of the three dial positions in each of the three diagrams. One, and only one, association was chosen by a significantly large proportion of subjects: the association, front knob - smallest dial, middle knob - medium sized dial, back knob - largest dial was chosen by significantly large proportions of both psychologists and students in all three diagrams. Furthermore, this association was significantly preferred over its strongest rival in all three diagrams by both groups.

Dials differing in distance from the knob axis:

Three diagrams presented dials differing in distance from the knob axis. As with dials differing in size, each distance was used at each of three dial positions ("northwest", "southwest" and "east" of the knobs) in order to take account of possible positional preferences. In all three diagrams significantly large proportions of both groups chose the association, front knob - nearest dial, middle knob - medium distanced dial, back knob - farthest dial. This was the only association chosen by a significant proportion of psychologists, and in two of the diagrams they significantly preferred it over its strongest rival. However, in all three diagrams a rival association was chosen by a significantly large proportion of college students - that the front knob should operate the dial farthest to the left; the middle knob, the middle dial; and the back knob, the dial farthest to the right. It so strongly rivals the front to back knob - nearest to farthest dial association that neither association can be said to be significantly superior to the other on the basis of the data collected here.

Dials differing in shape:

Three diagrams presented dials differing in shape. Three dial positions were used, and each shape appeared at a different position in each of the three diagrams. The data for shape associations are somewhat ambiguous, and the reader is invited to consult the appendix for detailed information. There was a suggestion of two associations: a front knob - left dial, middle knob - middle dial, back knob - right dial association; and a front knob - round dial, middle knob - rectangular dial, back knob - arch shaped dial association. Because the dials occupy almost exactly the same positions in the three diagrams, the three frequencies can be averaged (thereby balancing out positional effects) and their significances tested. This was done for the hypothesized associations mentioned. The only significant association found in this manner was the front knob - left dial, middle knob - middle dial, back knob - right dial association, which was significant at the .01 level among college students but entirely absent among psychologists.

DISCUSSION

The front to back knob - left to right dial association is apparently very strong. It occurred with great strength and was nearly unrivaled when dials were in a horizontal array. Furthermore, with naive subjects this association

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TABLE I

The Most Favored Knob-Dial Association for Each Situation Tested.
Percentage of All Subjects (Both Groups Combined) Choosing the Most
Favored Association and Percentage Choosing Its Strongest Rival

Most Favored Knob-Dial Association	Percent of Subjects Choosing Association Shown	Percent of Subjects Choosing Strongest Rival	Most Favored Knob-Dial Association	Percent of Subjects Choosing Association Shown	Percent of Subjects Choosing Strongest Rival
	<u>83***</u>	14		<u>59***</u>	19
	<u>78***</u>	12		<u>58***</u>	37***
	<u>77***</u>	13		48***	44***
	<u>70***</u>	28**		44***	28**
	<u>67***</u>	30***		43***	27**
	<u>64***</u>	15		<u>42***</u>	23
	<u>62***</u>	30***		29**	29**
	<u>60***</u>	38***		27**	23
	<u>59***</u>	15		23	22

Asterisks indicate significance level for exceeding "chance" frequency; underline refers to significance level for exceeding frequency of strongest rival. One asterisk or underline = .05 level of significance; two = .01 level; three = .001 level. See paragraph on notation in Statistical Appendix.

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was powerful enough to encroach in the situation where it was intended to measure distance and shape associations only and where the dials were not arranged in a linear array but were widely scattered.

No such clear and simple rule appears when dials are arranged in a vertical array. Although certain associations were strong when the array was in certain positions with respect to the knobs, the nearest rival association was usually of such appreciable strength as to discourage the use of dials in a vertical array when some other arrangement is practicable.

The front knob is the smallest knob and the knob nearest to the operator. It is not surprising, then, that it should be associated with the smallest dial and with the dial nearest the knob axis (and that the back knob should be associated with the largest dial and with the dial farthest from the knob axis). The size association is a strong, and, under the conditions of this test, an unrivaled one. There is strong rivalry, however, between the dial distance and dial position associations. It is desirable, therefore, that dials be arranged so that these two associations do not conflict (i.e., so that the dial nearest the knobs is also the dial farthest to the left, etc.).

The data collected suggest that, had a larger sample been tested, dial shape might have proved a significant factor in knob-dial associations. However, while dial shape may be a real factor, it is almost certainly not an important one.

CONCLUSIONS

There is a significant tendency to associate the spatial progression - front knob to back knob, with the following dial progressions:

(1) Left dial to right dial. This association is very strong for dials in a horizontal array. However, with dials of equal size, the association is still fairly strong when the array is not a linear one (even though the dials may differ in shape or in distance from the knob axis).

(2) Smallest dial to largest dial. This association is a strong one, presumably because the knobs increase in size from front to back.

(3) Nearest dial to farthest dial from the knob axis. This association encounters strong competition from the left dial to right dial association and from the following associations.

(4) Top dial to bottom dial, and the reverse association, bottom dial to top dial, depending on the position of the array relative to the knobs.

Dial shape probably does not greatly influence knob-dial associations.

Where ganged knobs are to be operated in a temporal sequence, they should be operated in the sequence - front to back.

In deciding which ganged knob should operate which dial, the engineer should take account of all of the above tendencies, avoiding situations where they conflict. For instance, when a horizontal array of dials is placed to the left of the knobs, the left dial to right dial association is in conflict with the nearest

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dial to farthest dial association. In following this rule, all vertical arrays of dials will be avoided. Probably the optimum arrangement, for non-ganged dials, from the point of view of knob-dial association would be a horizontal array of dials increasing in size from left to right and placed to the right of the knobs (other consideration, however, will probably require that the dials be placed above the knobs even though associations for this orientation are slightly less strong) with the front knob operating the small dial on the left, the middle knob operating the medium sized dial in the center, and the back knob operating the large sized dial on the right. Table I should be consulted in all cases and those dial arrangements avoided where more than one association is significantly preferred.

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STATISTICAL APPENDIX

The statistical notation used will be as follows: When a cell frequency is given one asterisk, the cell frequency exceeds the expected "chance" frequency at the .05 level of significance. Two asterisks mean that the "chance" frequency has been exceeded at the .01 level of significance; three asterisks, the .001 level of significance. Since, in every case, we are dealing with the possible permutations of three things, the expected cell frequency will always be one-sixth the number of subjects. (However, the reader should be cautioned that not all permutation frequencies will be given, and the category "Other" is not a single cell frequency, but rather includes the combined frequencies of four cells).

When the largest cell frequency in a given subject group is underlined, it will mean that it is significantly greater than its nearest rival (underlined once = .05 level of significance, twice = .01 level of significance, three times = .001 level of significance). Here, of course, the "expected" frequency will be one-half the sum of the cell frequency and the frequency of its nearest rival.

When expected frequencies are greater than 5, the Chi Square statistic is used. When they are less than 5, probabilities and significance levels are calculated from the Poisson distribution.

TABLE II

Frequencies with Which Each Group Chose Certain Sequences of Knob Operation

Preferred Sequence of Knob Operation





Group	Front Knob First Middle Knob Second Back Knob Last	Back Knob First Middle Knob Second Front Knob Last	Other
Psychologists	<u>18***</u>	6	1
College Students	<u><u>48***</u></u>	21*	6
Total	<u><u><u>66***</u></u></u>	27**	7

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TABLE III

Frequencies with Which Each Group Chose Certain Knob-Dial Associations When Dials Were in a Horizontal Array

Position of Array with Respect to Knobs






Group	Knob-Dial Association				
Psychologists	Front Knob - Left Dial Middle Knob - Middle Dial Back Knob - Right Dial	<u>21***</u>	<u>21***</u>	<u>19***</u>	<u>22***</u>
	Front Knob - Right Dial Middle Knob - Middle Dial Back Knob - Left Dial	3	3	6	3
	Other	1	1	0	0
Students	Front Knob - Left Dial Middle Knob - Middle Dial Back Knob - Right Dial	<u>56***</u>	<u>57***</u>	<u>48***</u>	<u>61***</u>
	Front Knob - Right Dial Middle Knob - Middle Dial Back Knob - Left Dial	10	9	24***	11
	Other	9	9	3	3
Total	Front Knob - Left Dial Middle Knob - Middle Dial Back Knob - Right Dial	<u>77***</u>	<u>78***</u>	<u>67***</u>	<u>83***</u>
	Front Knob - Right Dial Middle Knob - Middle Dial Back Knob - Left Dial	13	12	30***	14
	Other	10	10	3	3

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TABLE IV

Frequencies with Which Each Group Chose Certain Knob-Dial Associations When Dials Were in a Vertical Array

Position of Array with Respect to Knobs

Group	Knob-Dial Association					
Psychologists	Front Knob - Upper Dial Middle Knob - Middle Dial Back Knob - Lower Dial	7	7	15***	8	11**
	Front Knob - Lower Dial Middle Knob - Middle Dial Back Knob - Upper Dial	<u>18***</u>	<u>18***</u>	10*	16***	13***
	Other	0	0	0	1	1
Students	Front Knob - Upper Dial Middle Knob - Middle Dial Back Knob - Lower Dial	30***	31***	<u><u>55***</u></u>	40***	<u><u>51***</u></u>
	Front Knob - Lower Dial Middle Knob - Middle Dial Back Knob - Upper Dial	40***	42***	18	28***	17
	Other	5	2	2	7	7
Total	Front Knob - Upper Dial Middle Knob - Middle Dial Back Knob - Lower Dial	37***	38***	<u><u>70***</u></u>	48***	<u><u>62***</u></u>
	Front Knob - Lower Dial Middle Knob - Middle Dial Back Knob - Upper Dial	<u>58***</u>	<u>60***</u>	28**	44***	30***
	Other	5	2	2	8	8



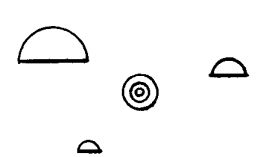
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In the tables giving data on dials differing in size, shape or distance from the knob axis, the six possible permutations of knob-dial association will be represented by placing an F, an M and a B, each at the relative position occupied by the dial with which the knob symbol is associated. For instance, B F will mean that the "northwest" dial is associated with the back knob; the M "southwest" dial, with the middle knob; and the "northeast" dial, with the front knob.

TABLE V

Frequencies with Which Each Group Chose Certain Knob-Dial Associations When Dials Differed in Size

Positions of Dials with Respect to Knobs


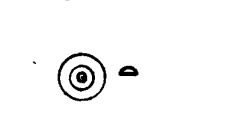

Knob-Dial Association									
	Psych.	Stud.	Total	Psych.	Stud.	Total	Psych.	Stud.	Total
F B M	<u>17***</u>	<u>47***</u>	<u>64***</u>	0	6	6	1	10	11
F M B	3	12	15	1	12	13	2	17	19
M B F	2	3	5	1	14	15	0	3	3
M F B	1	3	4	<u>18***</u>	<u>41***</u>	<u>59***</u>	1	0	1
B M F	1	0	1	3	1	4	<u>20***</u>	<u>39***</u>	<u>59***</u>
B F M	1	10	11	2	1	3	1	6	7

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TABLE VI

Frequencies with Which Each Group Chose Certain Knob-Dial Associations When Dials Differed in Distance from the Knob Axis

Positions of Dials with Respect to Knobs

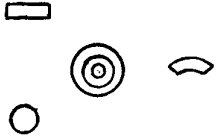

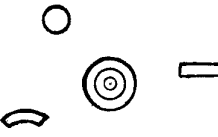
Knob-Dial Association										
		Psych.	Stud.	Total	Psych.	Stud.	Total	Psych.	Stud.	Total
F	B	13***	31***	44***	1	7	8	3	20*	23
M	M	2	10	12	2	11	13	2	10	12
M	B	5	23**	28**	3	24***	27**	2	9	11
M	F	1	4	5	<u>14***</u>	29***	43***	2	2	4
B	M	3	1	4	4	1	5	<u>15***</u>	27***	<u>42***</u>
B	F	1	6	7	1	3	4	1	7	8

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TABLE VII

Frequencies with Which Each Group Chose Certain Knob-Dial
Associations When Dials Differed in Shape

Positions of Dials with Respect to Knobs

Knob-Dial Association									
	Psych.	Stud.	Total	Psych.	Stud.	Total	Psych.	Stud.	Total
F B M	5	18	23	2	21*	23	4	25***	29**
F M B	3	19	22	7	15	22	9*	20*	29**
M B F	6	21*	27**	2	8	10	2	5	7
M F B	2	5	7	4	11	15	4	7	11
B M F	8	5	13	6	7	13	5	3	8
B F M	1	7	8	4	13	17	1	15	16