OPTIMAL HUMAN OPERATION AND TARGET SIZE

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An experiment to find out the optimal human performance in target shooting was carried out on 25 university students. The accuracy in target shooting was found to be a function of the size of the target. A comparative study of the effects of configurational determinants in the light of previous experiments revealed that there was a decrease in error score on a target of 4 cm dia. as compared to targets of 3 and 5 cm dia.

It has been observed in the previous studies of aiming by Day[1], Mace[2], Lewin and Voigt[3], and Moffett[4] that an alteration in the size of a target, either by changing the actual physical dimensions or by changing the relative distance of the target from the subject, results in a corresponding variation in the accuracy of aim. Further, it has been shown by Lewin and Voigt[3] that within limits the accuracy increases with the increase in distance of the target from the subject and that to some extent, it is a function of the structure of the target.

Mace[2] has argued on the most obvious factor influencing efficiency in almost any operation is the worker's conception of what constitutes a 'good' or 'reasonably good' performance. He introduces the concept of implicit standard. In his view an implicit standard becomes operative whenever the individual has to reach a level of attainment such that performance below this level is followed by continued 'trial and error' variation, and also such that the attainment of this level is followed by stabilisation (provided stabilisation is not accounted for by any physiological limit). Mace has emphasized that the implicit standard, the central point in the neutral zone between the limen of disappointment and the limen of satisfaction or the point of transition from variability to stabilisation (presuming that these descriptions apply to the same phenomenon), is influenced by a number of distinct external conditions and is, in consequence, subject to experimental control.

The dart board test and the Musico's aiming test were used by Mace to verify the hypothesis that efficiency does, in fact, depend upon implicit standards set by the individual for a particular target and to determine more precisely the extent to which a modification of standard would influence the efficiency of performance. The results of his experiments show that a 'good', 'fair' or 'poor' shot was defined by the subject not in terms of its absolute distance from the bull's eye but in a way which was relative to the form of the target employed. Thus, according to Mace, a satisfactory shot would be defined in terms of the units provided by the concentric rings of the targets without precise regard to their size. It would be clear then that a modification in the design of the target entails a corresponding modification in the efficiency of performance through the operation of an implicit standard set up by the particular target design. As a general rule, the greater the size of the target, the smaller is the relative subjectively assessed error irrespective of the absolute distance from the bull's eye.

The present experiment was aimed to find out whether there exists a limiting value beyond which the functional dependence of accuracy of aim on target size failed to apply or reversed and to examine the results in the light of the experiments carried out by Day[1].

EXPERIMENTAL PROCEDURE

Twentyfive university students having normal eye-sight were selected for the present investigation. Five sizes of targets, as shown in Fig. 1, were used.

The design of the experiment was more or less the same as used by Day[1]. The targets were drawn on a white sheet and placed on a wooden board at a convenient height. The subjects were asked to aim at the target with the help of a stylus. A metronome, placed at the back of the subject and set at 180 beats per minute, controlled the rate of aiming by the subjects. The error score was taken to be the distance from the centre of the target to the point at which the stylus struck the paper.

A preliminary experiment was also carried out to divide the subjects randomly into five groups which matched in their initial ability to spear at targets. They were then asked to aim at the centres of crosses drawn on a white sheet put on a wooden board. This preliminary trial also served to familiarize the subjects with the general nature of the task and provided practice in aiming at the targets with the beating of the metronome. The subjects were divided into five groups on the basis of their ability. A final grouping was made in order to form five groups which will approximately match for initial aiming ability. This was done by randomly selecting one member from each of the above ability groups.

After the preliminary task, every group was assigned the task of aiming at the five sets (each having 12 shots). A rest interval of 5 minutes was given after the completion of every set.

RESULTS AND DISCUSSION

The error score throughout the experiment was the distance (in mm) from the centre of the target to the point at which the stylus struck the paper. Table 1 gives the mean error scores for each set of twelve shots for each subject, as well as the means and standard deviations of these scores for the five target sizes.

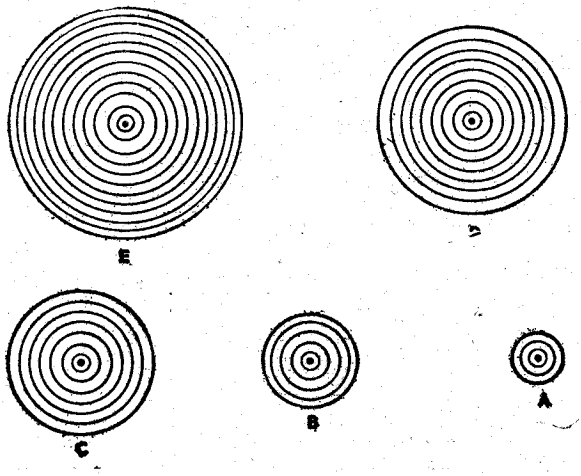

FIG. 1—The five targets (each consisting of a bull's-eye 1 mm. in dia. and equi-distant concentric rings. Target A, 3 rings; Target B, 5 rings; Target C, 7 rings; Target D, 9 rings; and Target E, 12 rings).

TABLE 1

MEAN ERROR SCORE

Target Size	Subject No.	Set Number & Mean Score					Mean Error Score	Standard Deviation
		1st	2nd	3rd	4th	5th		
A	1	3·69	8·65	4·75	5·12	5·75		
	2	6·00	5·27	5·62	7·24	6·92		
	3	5·81	5·21	6·29	4·85	3·25		
	4	5·97	6·92	7·25	5·00	5·57		
	5	9·25	3·25	3·00	3·16	4·55		
	Mean	6·145	5·860	5·382	5·075	5·208	5·51	0·60
B	1	3·65	5·55	5·24	6·62	6·16		
	2	3·95	5·02	8·46	3·65	3·85		
	3	3·00	9·00	4·21	3·57	5·45		
	4	6·21	5·00	4·81	4·23	5·68		
	5	8·00	4·10	3·85	4·00	6·80		
	Mean	4·962	5·735	5·315	4·415	5·588	5·19	0·55
C	1	9·95	9·00	10·25	8·85	5·50		
	2	6·00	7·75	7·45	7·76	9·15		
	3	7·92	7·65	7·75	7·75	7·25		
	4	9·95	7·25	4·68	10·25	7·85		
	5	8·75	6·21	6·21	3·25	3·54		
	Mean	8·515	7·572	7·208	7·552	6·658	7·50	0·59
D	1	8·65	6·45	7·85	6·35	7·35		
	2	7·45	8·35	5·66	5·75	5·54		
	3	5·05	7·32	4·82	4·65	4·63		
	4	4·20	5·65	3·15	3·96	3·35		
	5	6·02	4·02	6·65	5·45	3·57		
	Mean	6·275	6·358	5·625	5·232	4·885	5·67	1·14
E	1	8·35	9·25	6·54	7·50	7·75		
	2	11·65	6·42	7·75	6·85	8·95		
	3	9·25	5·45	4·05	9·92	5·85		
	4	9·24	8·45	8·96	4·44	6·65		
	5	3·15	7·00	6·12	5·35	5·49		
	Mean	8·328	7·255	6·685	6·812	6·938	7·29	1·00
	Mean (for the five targets)	6·845	6·556	6·055	5·817	5·856		

In Fig. 2, the error scores have been plotted against the target sizes and it can be clearly observed that there is a marked variation in the mean error score. The mean error score increases noticeably on target 'C' as compared to targets 'A' and 'B' between which there is hardly any difference. There is marked tendency on target 'D' for the error to decrease which is followed by an appreciable increase on target 'E' which is the biggest target in size.

From the analysis of variance given in Table 2 we find that 'F' attributable to target sizes is 9·12 which is significant at ·01 level. This means that the null hypothesis with regard to the difference between targets is untenable. As to the differences among subjects, we find that 'F' for them is 3·86 which is significant at ·05 level. This finding leads us to the conclusion that subjects differed among themselves with regard to accuracy in spear throwing at the targets.

A closer examination of the general trend of performance over the five sets of twelve shots for each target size reveals that there is a marked consistency for each set for the five target sizes. It may also be noted that there is a very small improvement in the mean error score of successive sets of twelve shots when we do not take into account the target size. This insignificant decrease is perhaps due to the practice effect.

Finally, the bare fact which seems to be adequately established by the experiment is that efficiency in this aiming operation varies with the size of the targets and that the mean error score decreases on target 'D' as compared to target 'C', and it increases again on target 'E'. That this may be due to the influence of objective conditions upon subjective standards is one explanation. In terms of the Mace's conception of the implicit standard, it may be argued that apparently the upper limit of the range over which the implicit standard operates has been reached with target 'C', and as Day points out, another factor viz. the ocular-motor has operated to produce the decrease. From this it can easily be deduced that the trend in accuracy of aim for the three bigger targets could be accounted for in terms of ocular-motor function rather than in terms of changes in the implicit standards as a function of the target size. But till date there is hardly an evidence to support this ocular-motor explanation in such types of experiments.

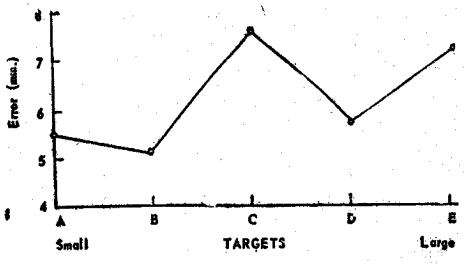

FIG. 2—Relationship between target and error.

Again it can be said that purely sensory factors are relevant to efficiency in aiming generally, but at present there is no evidence that purely sensory factors are alone sufficient to explain the superiority of smaller targets. From the point of Gestalt Psychologists, according as the bull's-eye is surrounded by nine or twelve or four equidistant rings, the same point will fall within the target or be referred to the background. But the difference is significant only in so far as it provides a perceptual content in terms of which an intention

is defined. If the intention is to strike 'at least within the target' the perceptual difference is also a difference in the object of conation. From the foregoing discussion it will be clear that an explanation based on Macé's work, which emphasizes the part played by implicit standard, would appear to be a more plausible explanation.

Finally Day has applied the Helsonian concept to explain these differences. Helson[5] has drawn a number of conclusions regarding sensory motor performance which appear to have more general validity. Briefly summarized his hypothesis of par or tolerance that operators seem to have a standard or par of excellence representing the maximum error they will tolerate under a given set of conditions. When the performance falls or appears to the operator to fall below this standard, he exerts greater effort to bring the error within his standard. This standard is the resultant of all factors in the working situation, including the operator's own set and motivation.

Applying this Helsonian concept of "the hypothesis of par of tolerance", it is said that the variation in error between targets 'B' and 'C' represents changes in the par of tolerance brought about by a modification in the subjective assessment of error resulting from target size. But it is equally probable that the differences in performance between the three bigger size targets could be due to variation in the par of tolerance springing more from ocular-motor phenomenon.

CONCLUSION

The results of the present investigation more or less agree in their general trend with those of Day. The differences could rather be explained in terms of the configurational determinants of the targets. While Day had kept the same configuration and structure of the targets, in the present investigation the five targets differ in the configuration. That configurational determinants of the targets can also produce some differences in the accuracy of aim, needs further research.

TABLE 2

ANALYSIS OF VARIANCE*

Source of Variation	Sum of Squares	d.	Mean Square	F.	Level of Significance
Between subjects	9·427	4	2·356	3·86	·05
Between Targets	22·242	4	5·560	9·12	·01
Interaction	9·750	16	0·609		
	Total	24			

*Analysed from data contained in Table 1.

The clear indication that a decrease in the size of the target is accompanied by an increase in accuracy (Target 'D') suggests the operation of an optimum objective. From the present investigation it can be safely concluded that the experimental condition of target 'D' favours optimal performance.

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