Stimulus dimensionality and temporal repetition*

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Two experiments involving temporal repetition of tachistoscopically presented visual stimuli are reported. Experiment I employed an alphabet of four straight lines presented one, two, or four times. Experiment II employed three stimulus sets, such that the stimuli varied in size, brightness, or both, with the forms being presented either once or four times. The Ss made four-choice identification responses. Results indicate that multidimensionality is not a necessary condition for better identification performance with multiple observations, and that this differential in favor of multiple observations persists after many, many experimental sessions.

Many investigators have demonstrated that temporally repeated observations of a simple stimulus yield better performance on some perceptual index than do single observations. Doherty and Keeley (1972) review studies using a fairly wide variety of visual stimuli, all of which show this "temporal repetition effect." The present investigations are concerned with the effect of the physical characteristics of the stimuli on increases in hit rate (HR), specifically with whether the complexity of the stimuli plays a role in mediating the HR increments that obtain with temporal repetition.

Experiment I addresses the question of whether HR increases with repetitions of unidimensionally varying stimuli. Doherty and Keeley (1969) and Keeley and Doherty (1968; Experiment 1) found a repetition effect with Landolt rings, often considered unidimensional. It was thought, however, that these may represent a unique form of unidimensional stimuli, since the failure to perceive a part or parts of the tachistoscopically presented stimulus would create one or more additional "gaps" in the perceived ring. Thus, there remained some question whether the repetition effect held with unidimensionally varying stimuli, at least for those without the specific characteristic of Landolt rings noted above.

Experiment II is concerned with whether there is a greater increase in HR with repetitions of multidimensional stimuli than with repetitions of simpler stimuli, and also with the effects of extended practice.

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EXPERIMENT I

Method

Subjects

Two males with normal vision served as Ss.

Apparatus

A Scientific Prototype Model GB tachistoscope, with a handswitch permitting S to initiate stimulus onset, was the basic apparatus. A Hunter timer was wired into the circuit in order to keep presenting the stimuli at predetermined intervals as long as S held the switch depressed. An audible click accompanied each stimulus presentation. A response panel permitted S to respond nonverbally and to obtain immediate knowledge of results. A black line, subtending a visual angle of approximately .2 deg, on a white background served as a fixation point. The white background and fixation point were illuminated at all times. A stimulus form was a straight, horizontal line, photographed using Kodalith film. The transilluminated negative produced a white form against the white background provided by the fixation field. The stimulus alphabet consisted of four such forms, subtending visual angles of 1.8, 2.0, 2.3, and 2.5 deg and appearing directly above the fixation point.

Procedure

Viewing was monocular with S's preferred eye. Three experimental conditions were employed, one requiring a response after a single observation opportunity (1L), another requiring a response after two opportunities to observe (1L2), and the third requiring a response after four opportunities to observe (1L4). In all conditions, S responded by identifying the line and by making a confidence judgment indicating whether he "felt sure," "thought so," "was guessing," or "saw nothing." The response was in the form of a buttonpush. The S had a 4 x 4 array of buttons, with the columns corresponding to the identification responses and the rows to the confidence judgments. Thus, one button sufficed for both the identification and the confidence judgment. Immediate knowledge of results was given by having a light appear at the bottom of the column of buttons corresponding to the correct stimulus. The stimulus-response correspondence was such as to maximize S-R compatibility, with the shortest line being coded verbally by the number "1" and by the leftmost button, the next shortest by the number "2" and by the next button, etc. Stimulus presentation in the 1L condition was initiated by S after a ready signal, which was the sound of the stimulus tray being inserted into the tachistoscope. In the multiple observation conditions, the onset of the first presentation was controlled by S, but the subsequent observation opportunities were programmed by a

Table 1
HRs in Experiment I

S	Condition		
	1L	1L2	1L4
1	.36	.42	.46
2	.36	.50	.58

recycling timer to control the onset-onset interval within a trial. This interval was .65 sec. The sound of a relay informed S when the final observation opportunity of a trial had occurred. Pretraining of Ss was extensive, with E manipulating the exposure duration in 1L trials to obtain a stable HR which was better than chance but sufficiently less than perfect identification so as to allow improvement. For one S, this duration was 9 msec, for the other, 10 msec. These were maintained for the duration of the experiment.

The actual experimental sessions, each approximately 1 h in length, comprised three blocks of 25 experimental trials each, preceded by 5 practice trials. Trials from the 1L, 1L2, and 1L4 conditions were randomly intermixed, and the S did not know in advance from which condition a trial was to be selected. The sequence of stimuli was random, and was different for every session. One S ran 15, the other 20, experimental sessions. One block of 25 trials was lost for the former S, so that the data are based on 1,100 and 1,500 trials.

Results

Table 1 presents the overall HR for the two Ss. There is the typical repetition effect, with the larger increase being from one to two observations. Table 2 presents the confusion matrices separately for each S for each condition. Inspection of these confusion matrices reveals a very substantial response bias toward the response labeling the shorter lines. Looking at the matrices in terms of the proportions of responses that are correct is revealing. For the shorter stimuli (A and B), there was virtually no increase in the proportion of times a given stimulus was correctly identified, but there was a substantial increase in accuracy for the longer lines, C and D. S 1 decreased in accuracy from one to two to four observations on the shortest line, but doubled his

accuracy on the two longer ones. S 2 increased slightly on the two short lines, but more than doubled his accuracy on both longer ones. These changes are understandable if the extreme response biases of the Ss in the one observation condition are representative of the Ss' perceptual process. For both Ss, the frequency of one-observation responses decreased markedly from the response corresponding to the shortest stimulus (Response a) to the response corresponding to the longest stimulus (Response d). This bias may be partly due to the fact that to obtain the desired single observation HRs, exposure durations became so brief that the task may have assumed characteristics of a detection task, which was confounded with its identification component. This is also true of the earlier studies, but with the lines, certain line portions, if picked up by S, were very highly diagnostic of the stimulus, while others conveyed erroneous information, or actually no information at all. A small segment of the line perceived at the center of the field could be from any one of the four stimuli, accounting for the high frequency of a and b responses. This seems to be at least a partial explanation of the sharp increase in the C and D accuracy, since multiple looks would be expected to increase the probability of seeing the end of a long line.

The use of unidimensional stimuli in an effort to degrade repetition performance stemmed primarily from a rather obvious hunch that multiple observations led to an increase not because the observations were repeated, but because they were different. In other words, different observations permitted the sampling of different features of the stimulus configuration, providing an opportunity to obtain additional self-correcting information about the stimulus state (Keeley & Doherty, 1968).

This experiment actually turned out to be formally equivalent to the Keeley and Doherty (1971b) experiment in which the prior probabilities of the stimulus states were manipulated. The data matrices

Table 2
Confusion Matrices for the 1L, 1L2, and 1L4 Conditions Collapsed Over Sessions and Confidence Judgments

Condi- tion	Response	Stimulus State							
		S 1				S 2			
		A	B	C	D	A	B	C	D
1L	a	73	70	34	29	85	69	33	29
	b	21	27	18	20	31	40	31	36
	c	3	9	14	17	11	21	28	38
	d	2	1	12	18	0	1	22	25
1L2	a	60	39	10	15	71	50	8	6
	b	23	32	27	22	20	44	33	17
	c	8	10	27	30	7	23	65	42
	d	2	5	25	36	0	7	37	68
1L4	a	52	33	13	3	114	56	3	1
	b	17	22	23	11	24	42	22	15
	c	7	17	56	43	7	14	78	43
	d	6	5	18	36	0	2	27	57

show that Ss were responding with radically different proportions of the various responses, in effect converting the experiment into a subjectively unequal prior probability study. Deviations from optimal responding (as defined in Doherty & Keeley, 1969; Keeley & Doherty, 1971a) in the multiple observation conditions are not reported, but they were of precisely the same form as those in Keeley and Doherty (1971b).

Since Experiment I demonstrated that the repetition effect does occur with unidimensional visual stimuli, it alone does not yield information directly about the possible role of dimensionality. It is possible that more complex stimuli would result in relatively greater increases in HR, when contrasted with less complex stimuli. Thus, rather than run additional Ss in the above condition, the Es manipulated dimensionality, defined physicalistically, in Experiment II. Some information concerning the effect of extended practice was also obtained.

EXPERIMENT II

Method

Subjects

Six paid undergraduates, with normal or corrected-to-normal vision, served for from 31 to 35 h.

Apparatus

The same apparatus as in Experiment I was used, except that the automatic timing apparatus was taken out of the circuit. The S refixated and self-initiated on each observation with the handswitch. One field was used as the stimulus field, but both other fields were on at all times.

Stimuli

Three sets of stimuli were cut from Munsell paper and mounted on 5 x 7 pieces of white oak tag. The sets varied in size (SIZ), brightness (BRI), and size and brightness redundantly (RED). Table 3 specifies the stimulus characteristics.

Procedure

The procedure was the same as for Experiment I, with the

Table 3
Summary of Stimulus Characteristics for Experiment II*

Dimension	Stimulus Name				Value on Irrelevant Dimensions
	1	2	3	4	
SIZ	.156	.234	.352	.527	N3
BRI	N8	N7.5	N7	N6.5	1.0
RED	.156	.234	.352	.527	-
	N8	N7.5	N7	N6.5	-

*Values are in centimeters² and standard Munsell notation.

following changes. In the sessions of primary interest (experimental trials), blocks of 25 trials of a given stimulus set were run, with 1L and 1L4 trials completely randomized within blocks. Block order was randomized across days. Two different forms of pretraining were employed, each with three Ss. Both pretraining procedures involved first having S learn the names of the SIZ set given unlimited inspection time.

One procedure then manipulated the exposure duration for 1L SIZ stimuli only for about 2 h, until E was fairly confident that a .50 HR exposure duration had been established. In this procedure, E would change the exposure duration as soon as S's confidence judgments and HRs warranted, in order to get a stable .50 HR as quickly as possible. This was repeated with the BRI and the RED stimulus sets. After the three exposure durations had been settled upon, which took from 5 to 7 days, E switched S to the experimental trials. This technique yields a relatively large number of experimental trials.

The other technique permits more information about the earlier time course of the effects of practice. This involved placing S in pretraining sessions which were simply blocks of 1L trials immediately after the S's having learned the stimulus names. In this procedure, from 14 to 16 h of 1L observation trials were run before the 1L4 trials were even introduced. For these three Ss, the first hour's data were discarded. The signal-to-noise ratios were changed immediately after the first hour in order to get relatively low 1L HRs with relatively long exposure durations. This was done by reducing the brightness of the stimulus field.

In the experimental trials, E monitored both the HR and general level of confidence judgments, making slight adjustments in exposure durations in order to maintain the 1L HR around .50.

Results

Influence of Dimensionality on Repetitions

The individual S's HRs were recorded and inspected

Table 4
Confusion Matrices for 1L and 1L4 Conditions for S SG Collapsed Over Sessions and Confidence Judgments

Condition	Response	Stimulus State											
		SIZ				BRI				RED			
		A	B	C	D	A	B	C	D	A	B	C	D
1L	a	47	10	10	1	55	20	3	0	61	20	1	1
	b	12	53	4	5	21	36	11	0	17	34	11	0
	c	17	9	31	12	3	24	20	5	2	24	29	19
	d	2	2	26	61	0	3	33	72	0	6	28	55
1L4	a	46	3	3	1	57	11	1	0	66	18	2	1
	b	13	58	0	0	12	44	12	1	6	39	14	0
	c	10	16	58	18	2	14	50	14	1	20	53	17
	d	1	0	14	57	0	0	17	59	0	0	12	68

Table 5
Exposure Durations (ED) in Milliseconds, Overall HRs, and T(X:Y) Values at Asymptote for Each S

S	Stimulus Set	ED	HR		T(X:Y)	
			1L	1L4	1L	1L4
JS	SIZ	12.0	.54	.72	.6433	.8702
	BRI	25.0	.67	.80	.7506	1.2322
	RED	26.0	.67	.77	.8795	1.1071
DM	SIZ	9.5	.46	.70	.2639	.8285
	BRI	16.5	.48	.53	.4141	.7427
	RLD	19.0	.55	.62	.5803	.9026
KM	SIZ	12.0	.48	.67	.4724	.9146
	BRI	20.0	.58	.72	.7176	.9757
	RED	21.0	.51	.74	.5583	1.0052
SG	SIZ	9.0	.64	.74	.6383	.9395
	BRI	25.0	.60	.71	.7659	.9112
	RED	21.0	.56	.71	.6855	.9306
LK	SIZ	15.0	.49	.63	.3822	.7026
	BRI	24.0	.46	.63	.4223	.7825
	RED	24.5	.40	.49	.1459	.5263
JU	SIZ	10.5	.39	.48	.1041	.3772
	BRI	22.0	.47	.62	.3821	.7215
	RED	25.0	.57	.71	.5383	.9504
Average	SIZ	11.3	.50	.66	.4174	.7721
	BRI	22.1	.54	.67	.5754	.8943
	RED	22.8	.54	.67	.5646	.9037

for what seemed to be a reasonable estimate of asymptote. Since changes in the last 2 weeks of the experiment were rare, fairly large numbers of blocks of trials with the same exposure durations were available for each S. Even though the changes in exposure duration that were made were very slight, only data for a single exposure duration for a given S are presented. Asymptotic data for the S with the longest runs of change-free sessions are presented in Table 4, exemplifying the kind of confusion matrices obtained. Exposure durations, overall HRs, and transmitted information, T(X:Y), values for the asymptotic data are given in Table 5 for all six Ss.

Performance increased with additional opportunities to observe for all three stimulus sets for all Ss, as indexed by both HR and T(X:Y). The absolute magnitudes of the dependent variables are not of interest, since they are determined by the exposure duration, and are thus substantially under E's control. Similarly, differences between stimulus sets are not meaningful, since the exposure durations were adjusted for each stimulus set separately. Note further that the high exposure durations for the RED set are not interesting, since, as Table 3 shows, the values on the irrelevant dimensions of the other sets make comparisons between durations uninterpretable. What are of interest are the magnitudes of the differences between the 1L and 1L4 conditions, especially the comparison between the RED and the other two conditions. These differences, in both HR and T(X:Y), are virtually identical from stimulus set to stimulus set.

The Effect of Extended Practice

The data relevant to this question are the actual session-to-session HRs and confidence judgments, separately for each S, stimulus set, and repetition condition. Such a large amount of data cannot, of course, be presented. The SIZ data for S.D.M. are presented for illustration in Table 6. Considerable block-to-block variability is evidenced since the HR for a single block is based on 25 trials and, subsequent to the introduction of 1L4 trials, on only 12.5 (on the average) trials.

There was considerable regularity among Ss, however, and the authors believe that after about 15 sessions, the Ss had reached asymptotic performance. This could very likely have been accomplished more rapidly, but it is impossible to know just how much so. The methodology employed involved three separate stimulus sets, and required observation of a number of blocks of trials after an adjustment of the exposure duration before it could be determined whether it should be readjusted and, if so, which way to adjust it.

The essential point about practice to be made in this

Table 6
Exposure Durations (ED) in Milliseconds and HRs for S DM for Blocks of 25 Trials*

Block	ED	HR	Block	ED	HR
1	S/N ratio too high		17	14	.60
2	150	.80	18	12	.60
3	100	.88	19	11	.44
4	80	.72	20	11	.28
5	40	.64	21	11	.48
6	30	.72	22	11	.52
7	25	.60	23	11	.40
8	22	.60	24	11	.48
9	22	.60	25	11	.60
10	20	.56	26	10	.52
11	18	.76	27	10	.44
12	15	.48	28	10	.56
13	14	.40	29	10	.52
14	14	.48	30	10	.48
15	14	.44	31	10	.44
16	14	.48			

HR				HR			
Block	ED	1L	1L4	Block	ED	1L	1L4
32	10	.58	.38	45	9.5	.25	.62
33	10	.31	.58	46	9.5	.60	.67
34	10	.45	.71	47	9.5	.62	.92
35	10	.17	.68	48	9.5	.36	.86
36	10	.45	.79	49	9.5	.60	.73
37	10	.45	.57	50	9.5	.43	.73
38	10	.50	.53	51	9.5	.67	.69
39	10	.55	.86	52	9.5	.50	.69
40	10	.44	.50	53	9.5	.42	.69
41	10	.64	.64	54	9.5	.45	.57
42	10	.55	.57	55	9.5	.33	.54
43	10	.56	.69	56	9.5	.46	.75
44	10	.62	.58	57	9.5	.42	.85
				58	9.5	.36	.57

*The 1L4 trials were introduced for the first time in Block 32. Data are for SIZ only.

context is that the repetition effect is not an evanescent effect of early trials. It persisted in this experiment after more than 30 h of practice.

DISCUSSION

The data indicate that number of dimensions does not interact with number of repetitions in influencing HR. This result does not conflict with any published results of which the authors are aware, but was unexpected. The possibility that the lack of effect of multidimensionality might be due to confounding an identification paradigm by using detection-level stimuli is ruled out by the dispersions of the errors in the confusion matrices. None of the Ss' confusion matrices looked like those of Experiment I, the asymmetries of which were interpreted above as being due to just such confounding.

While Experiment II was not designed to test the model proposed in Doherty and Keeley (1969), two Ss were run in enough consecutive sessions without changes in exposure duration to provide a reasonable test. For S.G., the predicted frequencies of correct responses were too high in all three conditions. For J.V., there was an adequate amount of asymptotic data only for SIZ, in which condition the multiple observation performance was predicted almost perfectly.

Temporal repetition seems to have a quite reliable influence on overall recognition performance. Increases

are found with stimuli as complex as words (Haber, 1965) and as simple as angles (Ulehla, Halpern, & Cerf, 1968), patches of gray and straight lines. The difference between single and multiple observation performance persists even after thousands of observations.

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