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A CLARIFICATION OF CONTINUOUS REPERTOIRE DEVELOPMENT

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The key-peck response of five pigeons was reinforced on a schedule whenever the interval between pecks at two response keys was between 1.0 and 2.33 seconds in the presence of a 2,500-Hertz tone or between 4.66 and 6.0 seconds in the presence of a 1250-Hertz tone. There was no tendency for responses of intermediate duration to occur when test tones of intermediate frequency were presented. This result clarifies a previous finding using a similar procedure but with a visual intensity stimulus dimension.

Key words: continuous repertoire, stimulus generalization, successive discrimination, key peck, pigeons

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Many contingencies require that, for each point along a stimulus dimension, a unique corresponding response be made along some response dimension. Skinner (1953) gave the example of reaching toward and touching a point in a visual field. Specific points on the response dimension (the spatial orientation of the finger) are under control of specific points on the stimulus dimension (the visual field). Response mapping to a stimulus dimension is termed a continuous repertoire (Holland and Skinner, 1961). Singing on key, drawing from copy, and a wide variety of other motor skills are commonly cited as examples.

A clear picture of how continuous repertoires develop has not yet emerged. Although it seems possible that training a few points along a stimulus dimension to corresponding responses along a response dimension may create a continuous repertoire, in which untrained but corresponding responses would be emitted in the presence of novel stimuli, experimental evidence for this has been sparse. Cross and Lane (1962), Migler (1964), and Cumming and Eckerman (1965) trained two different responses to two points on an intensity dimension. When intermediate stimulus intensities were presented, no intermediate response tendencies were observed. Wildemann and Holland (1972) trained pigeons with either two or three points of correspondence between stimulus and response dimensions. However, in neither case was there any evidence for intermediate responding when intermediate values along the stimulus dimension were presented.

Herrnstein and Van Sommers (1962) trained five interresponse times to five stimulus values. They obtained intermediate response rates in the presence of intermediate stimulus values. However, the results were inconclusive with respect to the present question, since only averaged data were reported. It may have been that the intermediate response rates reported were actually an average of the longer and shorter interresponse times that were trained. On the other hand, Boakes (1969) claimed evidence for response mapping after training responses to only two points on an intensity stimulus dimension. Pigeons were trained to peck two response keys in succession. The time between pecking the first and second key is referred to as the response-response time (RRT). Two points of correspondence between a stimulus intensity dimension and the RRT dimension were trained. Testing with intermediate stimuli, Boakes found that intermediate RRTs were obtained when the brighter stimulus was paired with the shorter RRT, but were not obtained if the dimmer stimulus was paired with the shorter RRT. However, this result is unconvincing with respect to whether response mapping can occur when only a few points are trained along a stimulus dimension, since it may be that stimulus intensity affects response latency.

To determine if response mapping does occur in the absence of intensity effects, an ex-

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periment similar to Boake's was conducted, but using a tone frequency stimulus continuum rather than the intensity dimension.

METHOD

Subjects

Five experimentally naive Silver King pigeons were maintained at 80% of base weight for the duration of the experiment. Two birds ceased responding before training was completed and were dropped from the study.

Apparatus

A 300-mm by 300-mm aluminum panel served as one wall of a partially soundproofed experimental chamber. Frosted response keys were mounted behind two 25.4-mm diameter circular holes in the panel. Each hole was located 240 mm from the floor grating and 90 mm from the right or left edge of the panel, respectively. The left response key was backlighted by a 7.5-W green Christmas tree bulb and the right key by a similar orange bulb. Access to the grain hopper was through a square hole in the panel, 100 mm below the level of the response keys.

A 38.1-mm permanent magnet speaker was mounted behind a hole in the panel, midway between the response keys and was covered with a mesh screen to prevent damage. The speaker, driven by a tone generator and amplifier, transmitted stimulus tones of 1250 Hz, 1470 Hz, 1668 Hz, 2222 Hz, or 2500 Hz at 90 dB relative to 0.0002 dynes $(10^{-5}\text{N})/\text{cm}^2$. The experimental chamber was in an air-conditioned room masked by white noise. Electromechanical equipment stationed about 3 m from the chamber controlled changes in stimuli. For each trial, the type of tone and the RRT in 0.33-sec intervals were recorded on paper tape with a Friden binary tape puncher. Tapes were later decoded by computer.

Procedure

A two-stimulus, successive discrimination was developed during the training phase of the experiment. Table 1 presents a summary of the procedure. The birds were trained to peck the green key and orange key successively. When the green key was illuminated, a response on it illuminated the orange key, which (if pecked) produced 4 sec access to mixed grain. A 5-sec intertrial interval occurred (a) if no response to the green key occurred within 8 sec of its illumination; (b) if no response to the orange key occurred within 6.66 sec of its illumination; (c) following reinforcement. All sessions were terminated after 50 reinforcements.

Table 1

Training Procedures

	Session		
	Bird		
Procedure	*304*	*305*	*306*
Shaping	1	1	1
1250-Hz tone only; all RRTs between 4 and 6 sec reinforced	2-12	2-12	2-12
1250-Hz tone only; all RRTs between 4.66 and 6 sec reinforced	13-33	13-36	13-42
2500-Hz tone only; all RRTs between 1 and 2.33 sec reinforced	34-36	37-39	43-45
Both tones presented randomly; all appropriate RRTs reinforced	37-54	40-61	46-66
Both tones presented randomly; 0.5 probability of reinforcement	55-57	62-73	67-79
Both tones presented randomly; 0.3 probability of reinforcement	58-100	74-83	84-93
Test	101-110	84-93	105-114

Following the initial shaping session, a 1250-Hz tone was presented simultaneously with illumination of the green keylight and remained on until the intertrial interval began. Reinforcement occurred whenever the RRT was between 4 and 6 sec. Otherwise, responses on the orange key produced the intertrial interval. After 10 sessions, only RRTs between 4.66 and 6 sec produced reinforcement. Training continued until no significant changes in the RRT distribution of each bird were observed.

Subjects were then given two sessions in which the stimulus was a 2500-Hz tone and reinforcement was produced by RRTs between 1 and 2.33 sec. The two types of trials were then intermingled in a Gellerman series. In order to maintain responding, a correction procedure was used, such that the next trial in the series was presented only after a reinforced trial. If the subject did not respond during a trial, that trial was repeated until a response occurred. This procedure continued until responses clustered near the appropriate response times and response distributions stabilized.

The probability of reinforcement was then reduced to 0.50 in a Gellerman series. Advancement to the next trial in the tone series occurred only after a reinforced trial, although several appropriate responses may have been made. When subjects stabilized on this schedule, the probability of reinforcement was further reduced to 0.30. When responding again stabilized, testing began.

Each subject had 10 test sessions. The procedure during testing was identical to training, except that nonreinforced test trials were randomly inserted between training trials. Since 40% of all trials were test trials, the probability of reinforcement during the two original training tones was increased to 0.50 to maintain the overall density of reinforcement at 0.30. Test trials were presented as if they were training trials, except that one of the test tones (1470 Hz, 1668 Hz, or 2222 Hz) was presented and test trials were never reinforced. There was an equal probability of each test tone occurring on any given test trial. If the subject did not respond during a test trial, that trial was repeated until a response was made. However, for the test tones, advancement to the next trial required responding only to the green key within 8 sec of its illumination and then to the orange key within 6.66 sec of its illumination. For the two training tones, advancement to the next trial occurred only after reinforcement.

RESULTS

During each test session, the ratio of RRTs occurring in each 0.33-sec interval to the total number of RRTs in all intervals resulted in an RRT distribution for each tone. The five distributions for each bird (two training tones and three test tones) were averaged across the 10 test sessions and are presented in Tables 2, 3, and 4. In addition, the standard deviation of the ratios across the 10 test sessions is included for each mean ratio value. Figures 1, 2, and 3 graphically present the five distributions for each bird.

Comparisons of the distributions for the 1250-Hz and the 2500-Hz training tones reveal the extent to which each bird discriminated the two training tones. The distributions for the 2500-Hz tone is well-defined: the RRTs cluster in or near those intervals in which responses could produce reinforcement (see

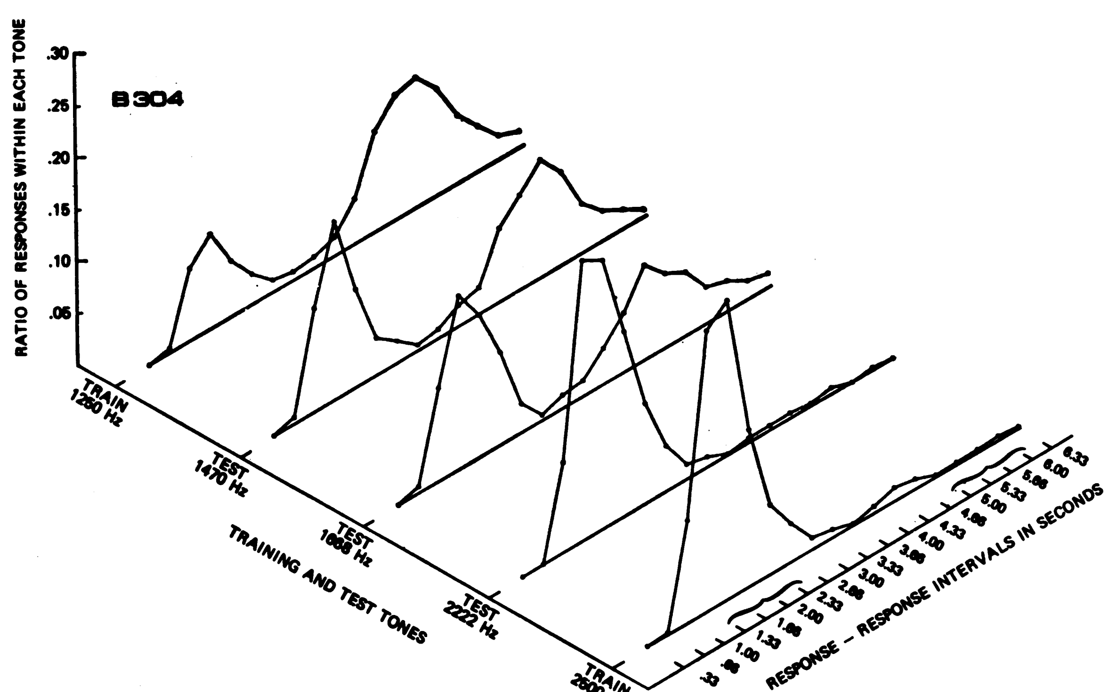

Fig. 1. Frequency distribution of response-response times (in 0.33-sec intervals) for each training and test tone for Subject B304, averaged across 10 test sessions.

Table 2

Subject B304's mean response-response time ratios and standard deviations for each 0.33-sec interval.

	Tone									
	1250 Hz Train		*1470 Hz Test*		*1668 Hz Test*		*2222 Hz Test*		*2500 Hz Train*	
Interval	*Ratio*	σ	*Ratio*	σ	*Ratio*	σ	*Ratio*	σ	*Ratio*	σ
0.33	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.66	0.004	0.004	0.004	0.011	0.005	0.010	0.000	0.000	0.003	0.006
1.00	0.067	0.033	0.097	0.055	0.085	0.054	0.106	0.082	0.090	0.060
1.33	0.097	0.039	0.164	0.068	0.170	0.063	0.237	0.098	0.270	0.073
1.66	0.060	0.022	0.109	0.056	0.147	0.068	0.258	0.050	0.305	0.125
2.00	0.033	0.016	0.040	0.030	0.096	0.062	0.190	0.080	0.159	0.070
2.33	0.014	0.010	0.024	0.019	0.033	0.028	0.102	0.075	0.072	0.065
2.66	0.009	0.013	0.005	0.011	0.008	0.014	0.046	0.051	0.040	0.038
3.00	0.011	0.013	0.009	0.012	0.017	0.014	0.017	0.021	0.011	0.013
3.33	0.017	0.012	0.022	0.032	0.014	0.016	0.012	0.020	0.008	0.010
3.66	0.043	0.022	0.024	0.023	0.036	0.021	0.002	0.005	0.003	0.008
4.00	0.101	0.024	0.072	0.037	0.051	0.042	0.006	0.008	0.005	0.012
4.33	0.124	0.023	0.097	0.038	0.089	0.044	0.007	0.011	0.011	0.014
4.66	0.133	0.036	0.115	0.051	0.070	0.023	0.006	0.008	0.007	0.016
5.00	0.112	0.025	0.090	0.058	0.065	0.026	0.004	0.007	0.004	0.008
5.33	0.076	0.025	0.058	0.029	0.037	0.042	0.005	0.010	0.003	0.005
5.66	0.050	0.019	0.037	0.032	0.035	0.031	0.001	0.003	0.003	0.005
6.00	0.028	0.015	0.023	0.016	0.022	0.016	0.003	0.006	0.004	0.012
6.33	0.021	0.016	0.010	0.013	0.018	0.020	0.000	0.000	0.003	0.008

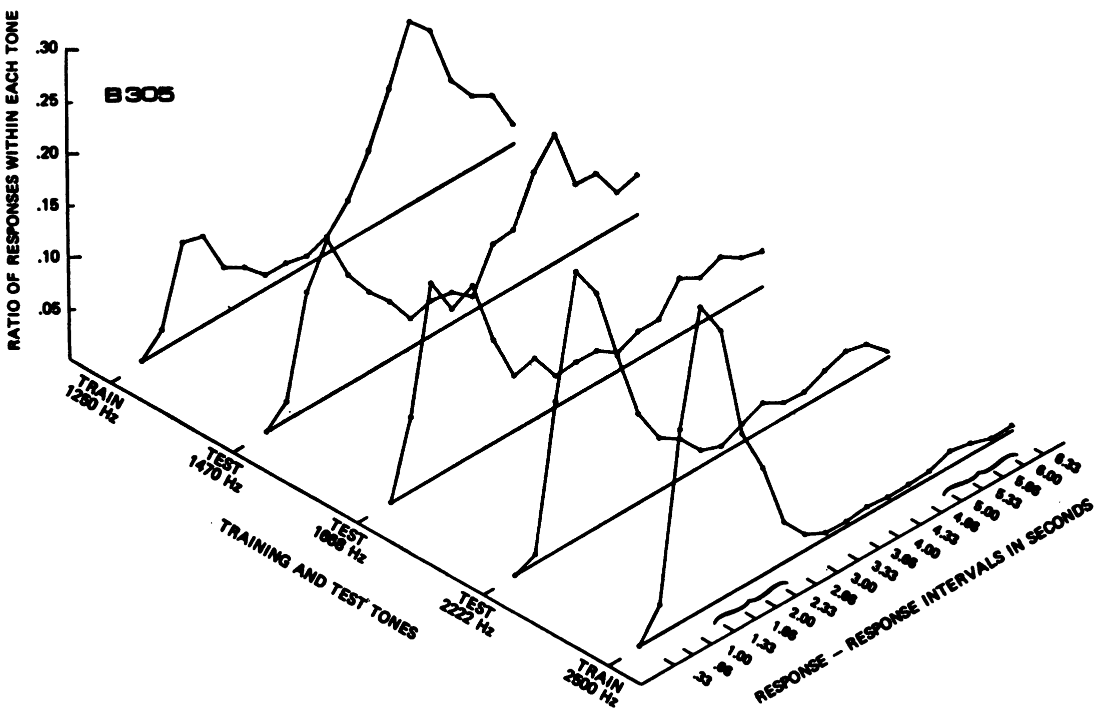

Fig. 2. Frequency distribution of response-response times (in 0.33-sec intervals) for each training and test tone for Subject B305, averaged across 10 test sessions.

Table 3

Subject B305's mean response-response time ratios and standard deviations for each 0.33-sec interval.

	Tone									
	1250 Hz Train		*1470 Hz Test*		*1668 Hz Test*		*2222 Hz Test*		*2500 Hz Train*	
Interval	*Ratio*	*σ*	*Ratio*	*σ*	*Ratio*	*σ*	*Ratio*	*σ*	*Ratio*	*σ*
0.33	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.66	0.012	0.012	0.020	0.020	0.060	0.088	0.008	0.013	0.026	0.018
1.00	0.062	0.042	0.090	0.046	0.160	0.055	0.124	0.072	0.153	0.076
1.33	0.066	0.028	0.129	0.058	0.128	0.045	0.234	0.062	0.257	0.065
1.66	0.034	0.017	0.090	0.039	0.145	0.057	0.203	0.104	0.229	0.063
2.00	0.026	0.017	0.061	0.047	0.085	0.042	0.134	0.038	0.132	0.054
2.33	0.013	0.009	0.045	0.032	0.037	0.033	0.070	0.055	0.089	0.036
2.66	0.009	0.009	0.024	0.021	0.056	0.036	0.049	0.036	0.040	0.027
3.00	0.006	0.007	0.026	0.022	0.028	0.029	0.031	0.025	0.015	0.017
3.33	0.016	0.008	0.023	0.025	0.026	0.025	0.016	0.025	0.007	0.009
3.66	0.026	0.019	0.011	0.016	0.025	0.019	0.010	0.012	0.007	0.012
4.00	0.054	0.030	0.044	0.023	0.021	0.022	0.012	0.017	0.006	0.009
4.33	0.102	0.029	0.048	0.054	0.020	0.019	0.017	0.021	0.003	0.010
4.66	0.151	0.050	0.082	0.038	0.021	0.012	0.011	0.014	0.006	0.012
5.00	0.136	0.031	0.106	0.044	0.041	0.033	0.011	0.014	0.005	0.011
5.33	0.122	0.066	0.060	0.038	0.035	0.026	0.018	0.021	0.008	0.024
5.66	0.074	0.046	0.070	0.070	0.044	0.025	0.025	0.025	0.007	0.021
6.00	0.064	0.041	0.035	0.024	0.031	0.030	0.020	0.030	0.003	0.007
6.33	0.026	0.026	0.038	0.030	0.038	0.036	0.009	0.016	0.006	0.011

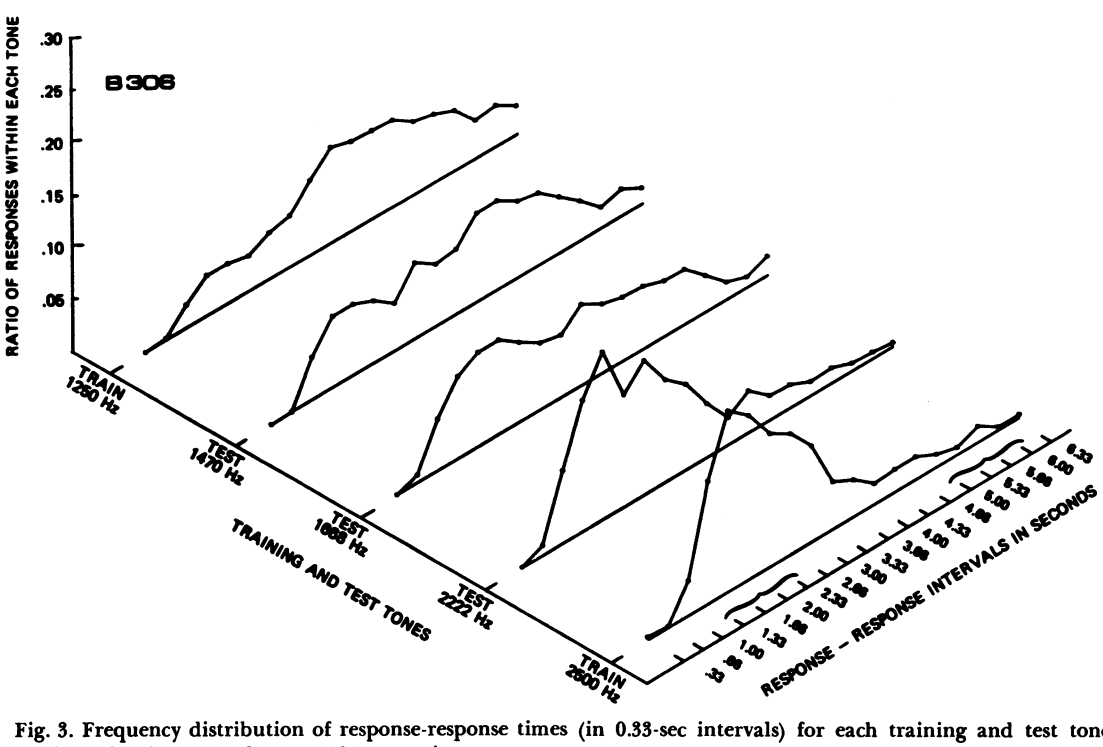

Fig. 3. Frequency distribution of response-response times (in 0.33-sec intervals) for each training and test tone for Subject B306, averaged across 10 test sessions.

Table 4

Subject B306's mean response-response time ratios and standard deviations for each 0.33-sec interval.

	Tone									
	1250 Hz Train		*1470 Hz Test*		*1668 Hz Test*		*2222 Hz Test*		*2500 Hz Train*	
Interval	*Ratio*	*σ*	*Ratio*	*σ*	*Ratio*	*σ*	*Ratio*	*σ*	*Ratio*	*σ*
0.33	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.66	0.001	0.002	0.000	0.000	0.009	0.013	0.010	0.022	0.000	0.000
1.00	0.025	0.012	0.045	0.023	0.053	0.030	0.066	0.022	0.031	0.015
1.33	0.042	0.025	0.070	0.031	0.089	0.034	0.106	0.038	0.130	0.053
1.66	0.037	0.022	0.075	0.047	0.104	0.059	0.166	0.047	0.197	0.094
2.00	0.033	0.023	0.061	0.048	0.098	0.056	0.104	0.044	0.167	0.076
2.33	0.043	0.014	0.040	0.028	0.072	0.032	0.131	0.054	0.133	0.040
2.66	0.040	0.025	0.068	0.035	0.052	0.036	0.102	0.036	0.123	0.038
3.00	0.064	0.025	0.054	0.032	0.054	0.032	0.084	0.027	0.081	0.032
3.33	0.091	0.030	0.058	0.022	0.077	0.032	0.055	0.020	0.037	0.022
3.66	0.084	0.026	0.081	0.037	0.064	0.035	0.028	0.025	0.032	0.021
4.00	0.086	0.024	0.101	0.042	0.056	0.030	0.043	0.028	0.015	0.016
4.33	0.089	0.021	0.082	0.030	0.070	0.030	0.026	0.030	0.014	0.026
4.66	0.074	0.032	0.080	0.045	0.052	0.025	0.027	0.027	0.015	0.021
5.00	0.078	0.031	0.063	0.031	0.055	0.038	0.016	0.019	0.008	0.014
5.33	0.070	0.024	0.046	0.040	0.042	0.026	0.015	0.012	0.004	0.010
5.66	0.052	0.023	0.024	0.025	0.020	0.019	0.011	0.017	0.009	0.019
6.00	0.052	0.030	0.035	0.019	0.012	0.014	0.007	0.008	0.002	0.005
6.33	0.039	0.025	0.017	0.017	0.022	0.018	0.003	0.006	0.002	0.005

brackets along the response-response interval axes of Figures 1, 2, and 3). However, the distributions produced in the presence of the 1250-Hz training tone are bimodal. This is perhaps due to the choice of training-tone frequencies one octave apart. It is, however, noteworthy that the bimodal effect occurs only in the presence of the tone requiring longer RRTs.

The test-tone distributions do not support the hypothesis that spontaneous response mapping occurs in the presence of novel stimuli. The intermediate test frequencies evoked responses that are like those observed during training trials. The RRTs clustered in or near those intervals where responses produced reinforcement during training trials.

However, the proportion of test-tone responses that fell in or near a particular set of reinforced intervals clearly depended on the frequency of the test tone. Most of the RRTs produced in the presence of the 2222-Hz tone tended to cluster in the same areas as those produced in the presence of the 2500-Hz training tone, while most of the responses produced in the presence of the 1470-Hz test tone clustered in the same areas as those produced in the presence of the 1250-Hz training tone. RRTs produced in the presence of the 1668-Hz test tone clustered in and near those intervals reinforced in the presence of both training tones.

DISCUSSION

This experiment was designed to determine whether the intermediate responding observed by Boakes (1969) was the result of stimulus-intensity effects, or whether spontaneous response mapping can occur when two RRTs are trained to two points on a stimulus dimension. The present results agree with the findings of most previous work in this area: when only a few points of correspondence between the stimulus and response dimensions are trained there is no tendency for untrained stimulus points to evoke corresponding responses. Responses produced in the presence of intermediate test stimuli are like those produced in the presence of the training stimuli.

The accumulating evidence therefore suggests that a continuous repertoire is no more than the individual points of correspondence between the stimulus and response dimensions that have been individually trained. The degree of control by the stimulus dimension over the response dimension is a direct function of the number of training points.

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