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Effect of visual dimensions on discriminative learning and contingency analysis by children

Efecto de las dimensiones visuales sobre el aprendizaje discriminativo y el análisis de las contingencias infantiles

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RESUMEN

En un estudio previo (Hernández-Pozo, 1988) se detectó el papel diferencial que juegan tres aspectos dimensionales de los estímulos visuales en tareas de tipo conceptual infantil: color, forma y número. Este estudio se diseñó con el fin de explorar mediante un diseño intrasujeto, la influencia que ejercen cinco propiedades dimensionales de los estímulos sobre el aprendizaje conceptual infantil, cuando se las define como dimensiones críticas. Cinco niños de primaria fueron entrenados en un procedimiento discriminativo computarizado; se emplearon cinco programas en los que sucesivamente una propiedad particular de un estímulo visual complejo se definía como estímulo discriminativo durante una sesión. El estímulo complejo tenía propiedades de color, forma, número, posición y tamaño, cada una con dos valores. El orden de administración de los programas de computadora a los que fueron expuestos los sujetos, siguió un diseño de cuadrado latino. Los niños recibieron entre 10 y 200 ensayos bajo cada programa dependiendo de su ejecución; el criterio de aprendizaje fue dar diez respuestas correctas consecutivas. Se dio retroalimentación al final de cada ensayo. Independientemente de su ejecución, al fin de cada sesión, se le pidió a los sujetos que describieran la forma en que creían que ganaban puntos. Los resultados demostraron diferencias en la ejecución asociadas a dimensiones particulares: los niños calificaron mejor con número y posición independientemente del orden de exposición. Los sujetos necesitaron el mayor número de ensayos cuando el estímulo discriminativo fue forma. La ejecución en general mejoró en el quinto programa. En cuanto a las latencias no se encontraron diferencias significativas asociadas a dimensiones particulares: las latencias decrementaron conforme aumentó el número de ensayos. Los resultados diferenciales en los aciertos sugieren la existencia de niveles de abstracción dimensionalmente dependientes en los niños. La presencia de cambios súbitos en las latencias previos a los trenes de respuestas correctas se asoció con la conducta gobernada por reglas.

Palabras clave: color, conducta gobernada por reglas, discriminación, forma, niños, número, posición, tamaño.

Abstract

In a previous study (Hernández-Pozo, 1988) differential roles played by three dimensional aspects of visual stimuli were detected in the context of children's conceptual learning using color, shape and number. The aim of this study was to explore the influence that five dimensional properties of stimuli exert over children's conceptual behavior, when they are defined as critical for a task, by means of an within subject design. Five fifth grade elementary school children, with similar scores in a paper and pencil relational test, were trained in a computerized discrimination procedure. Five succesive programs were used in which a given property of a complex stimulus was defined as the discriminative stimulus within a given session. The complex stimulus had color, shape, number, position and size properties, each one with two values. The order of administration of the computer programs subjects received, followed a latin square design. Children received from 10 to 200 trials under each program according to performance; the criterion for learning were ten consecutive correct responses. Feedback was scheduled after each trial. Regardless of their performance at the end of each session subjects were asked to describe what they thought was the way to gain points. Results showed differences of performance related to particular dimensions: children scored higher with number and position regardless of the sequence of exposure. Subjects required the highest number of trials when shape was the discriminative stimulus. Performance in general improved by the fifth program. In regard to latencies, no significant differences were found in association to particular dimensions; latencies decreased as number of trials increased. Differential results in correct responses suggest the existence of dimensional dependent levels of abstraction among children. The presence of sudden changes in the latencies, previous to trains of correct responses was associated to rule-governed behavior.

Keywords: children, color, discrimination, number, position, rule-governed behavior, shape, size.

The study of dimensionally dependent learning in humans is not well documented in the field of behavior analysis, even though there is a good deal of literature concerning the way specific aspects of visual stimuli exert control over non human behavior (Biederman, McDonald, Heighington & Vanayan, 1988; Zentall & Edwards, 1984). Studies in conditional discrimination with primates (McClure & Helland, 1979) and parrots (Pepperberg, 1987a, Pepperberg, 1987b) have addressed the problem of teaching dimensional classes of stimuli to non humans, suggesting the existence of ecological factors responsible for the development of differential levels of abstraction related to particular dimensions, common to the species.

Inquiries about the relationship between complex human behavior and stimulus control are documented to have occupied a place in the agenda of scholars since IV a. d. (Aristotle, 1975) up to this century (Wittgestein, 1963). Questions related to this area were addressed early in the beginning of scientific psychology; however nowadays, perhaps due to the way this question is phrased, it seems more appealing to philosophers (Turbayne, 1974) and anthropologists (Lucy, 1981) than to specialists coming from a behavioral analytic background.

Classical research in human development has documented the emergence and status of some of the behaviors under dimensional control of the environment, such is the case of chromatic preferences (Banks, Aslin & Letson, 1975; Bank & Salapatek, 1983), distance perception (Gibson & Walk, 1960), and preferences for specific visual patterns (Cohen, Deloache & Strauss, 1979; Fantz, 1961; Fantz, 1963; Fantz & Miranda, 1975). However as far as we know, no study has taken up the project of studying age-bound or culturally-bound dimensional control of high discriminative behavior.

A previous study employing first and second order conditional discrimination of color, shape and number among maya and spanish speaking children (Hernández-Pozo, 1988) reported dimensional control both at baseline and after training. In that study, shape seemed to exert a significatively stronger control over matching behavior than any of the other dimensions, regardless of the cultural background of the subjects. This kind of findings provide isolated hints into a larger framework dealing with the social nature of human biases towards specific dimensions.

In order to understand and to be able to predict differential probabilities of stimulus control associated to specific dimensions, one first step could deal with the measurement of the children's capacities to learn tasks involving several dimensions as critical elements of a conceptual task.

The purpose of this study was to explore by means of an intrasubject design, the way children learn to perform in a conceptual task, using a discrimination procedure, when the discriminative aspects of a stimulus complex vary among dimensions of color, shape, number, position and size.

METHOD

The basic procedure consisted of exposure to a YES/NO discrimination task, with five succesive discriminative dimensions involving color, shape, number, position and size.

SUBJECTS

Five fifth grade clementary students from a public school in the Mexico City area, two male and three female with ages from 10 to 13 years old, participated in the study on a voluntary basis. These children were selected because they scored 2 standard desviations higher than correct responses by chance, on a paper and pencil test of relations previously administered to a larger population. Subjects were trained individually and attended the laboratory for approximately a 30 minutes period each time, during three to five days, according to their performance.

APPARATUS AND MATERIALS

Stimuli were presented to the subjects by means of a commodore 64 K computer, with an 11 inches chromatic monitor. Thirty two different drawings were used as stimuli, resulting from the combination of 2 shapes, 2 sizes, 2 color, 2 positions and 2 numbers. The shapes used were square and asterisk, the colors were green and red, positions were right and left, numbers were one or two and sizes large and small. Stimuli were presented in a medium resolution mode, which implies for commodore computers, a screen resolution of 160 pixels horizontally by 200 pixels vertically. Large figures occupied an area of 30 by 30 pixels, while small ones were drawn in a space of 10 by 10 pixels.

Responses consisted of pressing the "s" key for "yes" (S is a mnemonic for "yes" in spanish) or the "n" key for "no". After the stimulus appeared on the screen, there were 10 seconds to respond, if no response occurred within that period, it was scored as an omission and the following trial started. If the subject pressed the correct response, that is an "s" for the discriminative stimulus, or a "n" for the delta, a "correct" message appeared on the screen, accompanied by a five notes sound. In case of an incorrect response, the next trial started with no message nor sound; errors caused the cummulative counter of correct responses to reset to zero.

PROCEDURE

Experimental Design. Five programs were administered in a latin square design. Each subject received all five programs in a different sequence, the sequence for each subject is shown in Table 1. This type of design was chosen because it allows intrasubject comparisons, minimizing other sources of variability; it also provides a way to assess sequential effects of exposure to different conditions. At the same time, it allows the study of regularities of performances among subjects associated with specific conditions.

Training. Subjects received training in the computerized discrimination tasks, according to a particular sequence (see Table 1). Each task consisted of a maximum of 100 trials, divided in two consecutive sessions of 50 trials each. A session ended whenever a subject had ten consecutive correct responses, or after 50 trials had passed. Ten consecutive responses under these circumstances, meant a probability of .001 of getting them right by chance, given that there were 50% discriminative and 50% delta stimulus in a session.

Table 1

	Phases				
Code	First	Second	Third	Fourth	Fifth
N1	color	shape	position	size	number
N2	shape	number	color	position	size
N3	number	color	size	shape	position
N4	size	position	shape	number	color
N5	position	size	number	color	shape

Tabla 1. Sequence of discrimination traininf for each subject.

After a discrimination task was over, either because the subject fulfilled the criterion or after 100 trials, the following task was presented until a subject had completed all five tasks.

RESULTS

Performance was assessed in terms of four indexes: 1) Total number of trials undertook either to reach the performance criterion or the maximal amount allowed; 2) Number of incorrect responses; 3) Number of subjects who attained the performance criterion and 4) Response latencies.

TOTAL OF TRIALS

Given that subjects received as many trials as they needed in order to make ten consecutive correct responses, up to a maximum of 100 trials, number of trials was considered a measure of performance. Table 2 presents number of trials per individual according to dimension and phases of exposure for each discrimination task; subjects who had 100 trials did not meet the criterion. Children manifested a tendency to need a higher number of trials for shape, and lower for number and position. In terms of order of exposure or phases, a slight tendency of having lower number of trials for both the first and last discrimination tasks was observed for most of the subjects.

Table 2

Code	Color	Shape	Number	Position	Size	Total
N1	31	100	10	44	100	285
N2	100	60	14	10	11	195
N3	100	100	60	100	100	460
N4	11	100	47	29	70	257
N5	100	92	27	16	100	335
Total	342	452	158	199	381	1532

Code	First	Second	Third	Fourth	Fifth	Total
N1	31	100	44	100	10	285
N2	60	14	100	10	11	195
N3	60	100	100	100	100	460
N4	70	29	100	47	11	257
N5	16	100	27	100	92	335
Total	237	343	371	357	224	1532

Table 2. Numbre of trials per subjects during each discrimination task, and according to order of exposure.

Statistical analysis of number of trials per individual revealed that dimensions rather than individual sequences, or phases, were responsible for differential performances (comparisons for individual sequences F=2.37, d.f.=4/24, p.05; for phases F=1.17, d.f.=4/24, p.05; and for dimensions F=3.67, d.f.=4/24, p.05). Since different dimensions were associated to changes in performance, mean number of trials was compared among dimensions (for color = 68.4, shape = 90.4, number = 31.6, position = 39.8, and size = 76.2) with the Student "t" ratio, which threw significant differences between 2 groups of dimensions: number and position in one side, with color, shape and size in another group; this means that subjects required significantly less number of trials for both number and position, while they needed larger number of trials for color, size and shape.

INCORRECT RESPONSES

The rationale for using number of incorrect instead of the correct responses was that because correct responses depended on the number of trials, and trials depended of performance, if the comparison was made solely on the basis of number of correct responses, a subject with 10 correct responses in 10 trials, would had the same score than another with 10 correct responses in 100 trials. Using the same example however, it makes sense to compare 0 errors of the first subject, with 90 errors of the second, in this manner, number of incorrect responses reflects performance of these individuals in a more accurate way than number of correct responses does.

The total of incorrect responses during each discrimination task is presented in Table 3 both according to dimensions and to phases of exposure. Since there was always a 50% chance for correct responses at random, given the proportion of discriminative stimulus to delta stimulus, scores around 50's reflect random performance. As it can be appreciated from examination of this Table, children did not make as many errors under number and position (with the exception of subject N3) as they did with shape; no regular pattern of errors was recorded associated to the order of training.

Table 3

Code	Color	Shape	Number	Position	Size	Total
N1	8	40	0	10	42	100
N2	51	21	3	0	1	76
N3	48	41	26	52	42	209
N4	1	50	12	10	33	106
N5	48	45	7	2	45	147
Total	156	197	48	74	163	638
Code	**First**	**Second**	**Third**	**Fourth**	**Fifth**	**Total**
N1	8	40	10	42	0	100
N2	21	3	51	0	1	76
N3	26	48	42	41	52	209
N4	33	10	50	12	1	106
N5	2	45	7	48	45	147
Total	90	146	160	143	99	638

Tabla 3. Number of incorrect responses per subject during each disrminitation task and according to order of exposure.

Number of incorrect responses was analyzed in terms of particular sequences, dimensions, and phases; although dimension was very close to be statistically significant, none of these conditions was found responsible for differences in children's performances (comparison for particular sequences F=1.866, d.f.=4/24, p.05; for dimensions F=2.756, d.f.=4/24, p.05; and for phase F=.66, d.f.=4/24, p.05).

SUBJECTS ATTAINING THE PERFORMANCE CRITERION

An account of results concerning subjects' performance along different discrimination tasks suggests a tendency for fulfilling the criterion for both number discrimination, and the first task presented. Individuals meeting criteria throughout the experiment are shown in Table 4, for both dimensions and phases. Statistical analysis did not show significant differences either among dimensions or phases (x^2=2.65, D.F.=4, P.05).

Table 4

Code	Color	Shape	Number	Position	Size
N1	1	0	1	1	0
N2	0	1	1	1	1
N3	0	0	1	0	0
N4	1	0	1	1	1
N5	0	1	1	1	0
Total	2	2	5	4	2
Code	Firts	Second	Third	Fourth	Fifth
N1	1	0	1	0	1
N2	1	1	0	1	1
N3	1	0	0	0	0
N4	1	1	0	1	1
N5	1	0	1	0	1
Total	5	2	2	2	4

Table 4. Number of sujects who met the performance criterion.

RESPONSE LATENCIES

Latencies of responses during each discrimination task were recorded. Table 5 presents the mean of latencies per individual according to dimensions and phases. This table shows that subject N3, who by the way responded randomly to all dimensions but number, presented very regular latencies along different dimensions; latencies for the rest of the children showed a wide range of variability. No significant differences where found in terms or dimensions or phases of training. A moderate decremental tendency of reaction times could be appreciated when latencies are viewed by phases of exposure.

In summary a quantitative analysis of the data suggests that conceptual behavior of children differs depending from the critical dimension playing the role of discriminative stimulus. In that fashion, the dimensions of number and position were more readily learned when playing a discriminative function than the dimension of shape. Color and size were located at an intermediate level. Other indexes support as well the results previously described, even though they did not reached statistical significance, but nevertheless provided information about incipient relationships.

Table 5

Code	Color	Shape	Number	Position	Size
N1	31	-	10	44	-
N2	-	60	14	10	11
N3	-	-	60	-	-
N4	11	-	47	29	70
N5	-	92	27	16	-
Mean	21.0	76.0	31.0	24.8	40.5

Table 5. Number of trials per individual to met criterion of perfomance for different dimensions.

Table 6

Code	Color	Shape	Number	Position	Size
N1	4.2	0.9	0.7	0.6	0.6
N2	2.4	5.0	4.8	1.4	1.6
N3	1.8	2.0	2.0	1.5	2.0
N4	0.5	0.7	0.8	1.8	2.4
N5	1.0	1.4	1.2	5.0	1.6
Mean	2.0	2.0	1.9	2.1	1.6
Code	First	Second	Third	Fourth	Fifth
N1	4.2	0.9	0.6	0.6	0.7
N2	5.0	4.8	2.4	1.4	1.6
N3	2.0	1.8	2.0	2.0	1.5
N4	2.4	1.8	0.7	0.8	0.5
N5	5.0	1.6	1.2	1.0	1.4
Mean	3.7	2.2	1.4	1.2	1.0

Table 6. Mean latencies of response 2.4s during different discrimination tasks and according to order of exposure.

DISCUSSION

This study was designed to foster understanding of the differential probabilities of stimulus control among children, associated to specific dimensional properties of color, shape, number, position and size. Five children were trained successively with a YES/NO procedure, following different orders of exposure. Results from this study showed that the dimensions of number and position, when playing a critical role in the task, produced faster acquisition and less number of errors, than other aspects of the stimuli such as color, size and shape, in similar contingential arrangements. These results suggest an advantage for using number and position of visual stimuli in learning, among elementary school children, over properties such as color, size and shape. Particularly shape was the dimension which children had more problems with, both in terms of the number of trials they required, and in terms of the number of errors made during the training process.

Conclusions from philosophical discussions about the nature of different dimensions of the environment have settled in saying that color is the most basic property of stimuli (Turbayne 1974), and that is somehow less dependent of social learning than any other aspect of the environment (Lucy 1988). Other properties of the environment such as position, size and shape, all of them space properties, material properties such as texture, and conceptual properties such as number, develop later on in comparison with color. It is said (Turbayne 1974) also that shape, being a rather complex dimension, is the result of a long process of social education. If the above arguments were correct, one could expect that children would learn to discriminate fast and with no mistakes, when color is the key dimension to be learned, and that it would take longer and also that more mistakes would be involved when subjects are required to learn discriminations based on shape. Results of this experiment seem to partially support this argument, in relation to performance under shape discrimination, however, color does not seem to be associated with faster learning or less mistakes. Position, an space dimension, as well as number, a conceptual property, are associated to fast learning and low number of mistakes, even though number might be as dependent of social learning as shape is said to be.

From a different perspective, in simplistic terms, perhaps too naive, one could classify dimensional properties of visual stimuli as internal or external. An internal dimension being understood as a property enclosed within the spatial limits of the stimulus such as its color, shape, texture, temperature or its being a unit. External dimensions on the other hand would be those characteristics of the complex which literally go outside the stimulus, in a spatial sense, such as its number (if it is larger than the unit), its position, its size or its plasticity. By this token it might be reasonable enough to go on and assume that internal properties of a stimulus being less conspicuous than the external ones, at least spatially, might be less discriminable. The previous argument might work to give an account of the findings in the present study, that is, number and position when being the discriminative dimensions of a complex, are easily learned in comparison with shape. However, assuming this reasoning is correct, how could one explain the differences within the same type of dimensions, that is internal or external? Learning based on size as the discriminative dimension, threw different results than those obtained with number or position, so this explanation is not good enough. Also considering data reported in a previous study (Hernández-Pozo 1988), in equal conditions, children exhibit significant preferences for shape over color when both are available to be selected as discriminative properties. These preferences can not be explained by recourse to the simplistic internal-external account. Shape and color both being internal dimensions should not yield behavioral differences, which they do. The internal-external dimension argument, as incomplete as it looks, and with all its shortcomings, might serve as a working hyphotesis for the elucidation of why children and for that sake adults (Hernández-Pozo 1988) engage in significatively different behavioral relations towards specific dimensional properties of the stimuli. Results of this study emphazise the need to conduct thorough research in dimensional learning with children and adults, in order to explore in more detail dimensionally dependent learning and to try to elucidate the role upbringing plays in the process.

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