DOCUMENT RESUME

ED 047 800 PS 004 440

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TITLE	Non-Verbal Information Storage in Humans and Developmental Information Processing Channel Capacity.
INSTITUTION	Saskatchewan Univ., Saskatoon.
PUB DATE	7 Feb 71
NOTE	14p.; Paper presented at the Annual Meeting of the American Educational Research Association, New York, New York, February 7, 1971
EDRS PRICE	EDRS Price MF-$0.65 HC-$3.29
DESCRIPTORS	Cognitive Development, *Cognitive Processes, *Primary Grades, *Response Mode, Statistical Analysis, *Thought Processes, *Visual Stimuli

ABSTRACT

This study was designed to ascertain the nature of information storage in humans and to determine the channel capacity of Ss at various stages of development. A 3 x 2 x 2 multivariate complete factorial design was employed: the three levels of the first factor (Age) were 5, 8, and 12 years; the two levels of the second factor were Visual and Verbal inputs; and the two levels of the third factor were Reconstruction and Verbal Description. One hundred and twenty children, 40 at each age level, were randomly selected and assigned 10 each to each treatment. Ss were tested individually. The results indicated that information is stored in nonverbal form in such tasks. The nonverbal image storage is affected differently by the developmental level of the Ss. (Author)

NON-VERBAL INFORMATION STORAGE IN HUMANS AND DEVELOPMENTAL INFORMATION PROCESSING CHANNEL CAPACITY[1,2]

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This study was designed to ascertain the nature of information storage in human Ss and to determine the channel capacity of Ss at various stages of development.

There are two concurrent views as to the nature of information storage in information processing tasks. The first viewpoint is based on the experimental work by Glanzer and Clark (1963, 1964). Glanzer and Clark's position is popularly represented by the verbal-loop hypothesis, that is, Ss process information through the verbal storage and retrieval mode. The proponents of the second viewpoint, among others are Randhawa (1969, 1970) and Rosenfeld (1967); hold that it is the non-verbal referents, images, that are employed for the storage of information in information processing tasks particularly those involving matching. Hence the objective of the present study was to provide further evidence to help understand nature of information storage in the matching tasks. It was also intended to obtain asymptotic estimates of the apprehension spans (channel capacities) of Ss at three developmental levels. Channel capacity is defined here as the average upper limit to the amount of information output by the Ss during the given information processing of tasks of varied information content including the smallest possible value of one bit. Whereas the amount of information is a measure of how much the number of possible equiprobable outcomes is reduced, that is, a measure of the reduction of uncertainty. Every time the number of alternatives is reduced by one-half, one unit of information is gained. This unit is called one bit of information.

Method

Sample.--The Ss were 120 children, 40 from each of the 5, 8, and 12 year age levels. These children were selected randomly from the children in attendance at a sub-urban junior and senior elementary school. Ten children each from each age group were assigned randomly to each of the four treatments (2x2, input X output, conditions).

Materials.--A form-board varying on three binary dimensions and thirty-two plastic geometric shapes varying on five binary dimensions (2^5) designed and described by Randhawa (1969) were used as the basic test materials. The shapes were placed in a tray arranged in four adjacent sub-sets of eight each such that all of the five dimensions were equiprobable. Twelve color slides, to be used as visual stimulus and practice materials, were prepared. Five of the stimulus and two of the practice slides were prepared by placing the randomly selected shapes, from the randomly selected sub-set of shapes as a reference set for the information content varying from 1 bit to 5 bits, on a beige background. Three of the remaining stimulus and two of the remaining practice slides were prepared by placing the randomly selected shapes, from their respective reference sets, on the randomly selected form-board slots. The information content of these stimulus slides with regard to their respective reference set of shapes and the form-board ranged from 6 to 8 bits. Corresponding to these slides representing one to eight bits of stimulus information, which is based on the amount of reduction in uncertainty required for correct response--$\log_2 n$ where n is the number of possible outcomes, verbal messages were pre-recorded in the same random order as the order of visual stimuli for each S in either of the two visual input treatments. These messages were used as stimuli for the two verbal input treatments.

Tasks.--The stimulus and the response modes of the four information processing tasks for measuring the apprehension spans were: (1) Visual (V) input and Reconstruction (R) output, (2) V input and Verbal Description (VD) output, (3) Verbal (VL) input and R output, and (4) VL input and VD output.

For the V-R and VL-R treatments, the S was required to reproduce the design with the given materials after each presentation of the stimulus. But for the V-VD and VL-VD treatments, the S was required to give a verbal description of the design after each presentation of the stimulus in the context of the reference materials.

Design.--A 3 x 2 x 2 multivariate complete factorial design was employed: the three levels of the first factor (Age) were

5, 8, and 12 years; the two levels of the second factor (Stimulus Mode) were visual and verbal inputs; and the two levels of the third factor (Response Mode) were reconstruction and verbal description outputs. There were 10 Ss in each of the twelve groups and an S performed only one of the four tasks in one of the ten different orders selected so that the Ss in a group exhausted all of the orders.

Procedure.--In all treatments, the S was first acquainted with the shapes and the form-board as the E read the instructions.

After giving instructions, four practice trials were given in the four treatments in the same order to all the Ss. During these presentations, any questions or misunderstandings of the instructions were clarified and the practice trials were repeated if necessary.

In the first treatment (V-R), the S was shown a design, projected individually for five seconds on a white screen placed about ten feet in front of the S. Immediately after this presentation, the E uncovered the reference shapes and the assistant uncovered the form-board if necessary. The S was then required to reconstruct the design, i.e., to pick a shape from the shapes shown and to put it either in one of the form-board slots or on the beige cover of the form-board as the case may be. The response of the S in terms of codes was recorded after each trial.

In the second treatment (V-VD), the stimuli were presented exactly as in the first treatment. The S, at the instant the relevant materials were uncovered, began a verbal description of the design. The S was practiced to use the remote control switch on the microphone of the tape recorder and was led to believe that his messages were transmitted into another area where one of his schoolmates was to make an identical design, from identical materials, as that seen and described by the *S*. This prevented the *S* from simply pointing at the materials and saying "This one in this one", etc. Without such emphasis and instructions, responses of the above type were evidenced by the researcher in the previous work done. The assistant kept a record of the dimensions decoded by the *S*. These entries were checked against the tape recorded responses for accuracy.

The stimuli for the third and the fourth treatments were verbal messages tape recorded in advance, in ten different orders corresponding to the orders of presentation of the visual stimuli. The *S* in the third treatment (VL-R) was required to respond in the reconstruction mode in the same manner as to V-R treatment after the presentation of the stimulus. While in the fourth treatment (VL-VD) the *S* responded in the description mode in the same manner as to V-VD treatment after the stimulus was presented.

Analysis and Results

Ss' responses on each task were converted into scores in bits.

For the multivariate analysis of variance (MANOVA), the score matrix used was for those input stimuli only whose information content was 2 bits or greater because for 1 bit input stimuli the scores were perfect for all the *Ss* used in this study and hence the variance estimate corresponding to these perfect scores was zero.

Means for the main effects (Age, Input Mode, and Output Mode) are given in Table 1. The results of MANOVA on the channel capacity tasks data are provided in Table 2. In general, the

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Insert Table 1 about here
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results in Tables 1 and 2 show significant differences in channel

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capacities of children at the three age levels. Also a general significant difference in channel capacities of children under the visual and verbal input conditions is obtained. The channel capacities of children for the reconstruction output condition are significantly greater than the channel capacities for the verbal description output condition. There is a general significant interaction between age and output conditions. This suggests that there is generally a differential increase in the channel capacities with age under the two output conditions.

MANOVA tests for simple effects for channel capacity tasks are given in Table 3. Age effect for each treatment and each input and output condition separately is significant except for V-R. All the two-way interactions, reported in Table 3, except

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Insert Table 3 about here
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that between age and input (stimulus) conditions for VD partition are significant. The stimulus effects are significantly different under each of the two response conditions and also the response effects are significantly different under each of the two stimulus conditions.

From the data reported in this study, estimates of channel capacity for each age group and for each treatment were obtained.

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Insert Table 4 about here
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These estimates are given in Table 4.

Conclusions

Non-verbal image storage.--Other studies (Sperling, 1963) have used the term image to refer to an extremely brief and complete representation of a prior visual stimulus. However, in some other studies (Adams & Dykstra, 1966; Posner & Konick, 1966) the term image has been applied to the retention systems for motor movements. Posner (1967) used the term code for the storage system used in the visual and kinesthetic tasks. By this is meant only that the storage involves information which is not in the form of verbal labels. Visual and kinesthetic, Posner (1967) emphasized, refer to the types of information available in the task and not necessarily to the subjective experiences of Ss.

More recently Randhawa (1970) used the term image to refer to the storage in non-verbal form of information from visual and verbal tasks. In order to avoid confusion, the term non-verbal image has been applied to the storage system used in the present tasks. By this is meant that the storage of information involves representation which is not in the form of verbal labels.

On the basis of ordering in complexity of the tasks and the application of transformational analysis proposed by Randhawa (1970), it is easily seen that non-verbal images are employed for storage purposes and that these images are affected greatly by the constraints of different tasks. This constraint effect is further confirmed by the differential channel capacities of any age group for the different treatments.

Developmental channel capacity.--The most striking result of this study is that the non-verbal image storage is affected differently by the developmental level of the Ss. This confirms the predictions made from previous results (Randhawa, 1970). It can also be inferred that different task constraints have different developmental effects because of the differential storage capacities at different developmental levels.

It is possible, therefore, to consider the largest of the channel capacities, V-R, at any developmental level as the basic estimate of a single channel capacity (cognitive space) -- the other channel capacities could be considered as reflecting how much of the basic capacity (space) was taken up by operations such as decoding and encoding for representations in storage and retrieval depending on the task constraints.

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Footnotes

1. This paper is prepared for presentation at the Annual Meeting of the American Educational Research Association, New York, February 4-7, 1971.

2. I acknowledge with gratitude help and advice given by Dr. D. R. Olson. I am responsible for any inadequacies in this paper.

TABLE 1

Means (bits) for the Main Effects

Variable (bits)	Main Effects						
	Age (Years)			Input Mode		Output Mode	
	12	8	5	V	VL	R	VD
2	1.95	1.95	1.22	1.87	1.55	1.73	1.68
3	2.97	2.87	2.17	2.67	2.68	2.80	2.55
4	3.82	3.47	2.27	3.52	2.87	3.53	2.85
5	4.70	4.12	2.82	4.02	3.75	4.50	3.27
6	5.15	4.57	3.40	4.87	3.88	4.98	3.77
7	5.92	5.15	3.52	5.38	4.35	6.00	3.73
8	6.72	5.67	4.20	5.92	5.15	6.82	4.25

TABLE 2

MANOVA of the Measured Output in Bits for the Channel Capacity Data

Source of Variation	df	F - ratio	Probability (less than)
Age (A)	14/204	13.26	0.0001
Input (B)	7/102	9.86	0.0001
Output (C)	7/102	26.94	0.0001
A x B	14/204	1.61	0.0795
A x C	14/204	5.02	0.0001
B x C	7/102	1.08	0.3794
A x B x C	14/204	0.59	0.8706

TABLE 3

MANOVA Tests for Simple Effects

Source	df	F - ratio	Probability (less than)
Age for V-R	14/42	1.27	0.2686
Age for V-VD	14/42	3.42	0.0011
Age for VL-R	14/42	2.86	0.0043
Age for VL-VD	14/42	7.19	0.0001
Age for R	14/96	3.75	0.0001
Stimulus for R	7/48	11.95	0.0001
Age x Stimulus for R	14/96	1.83	0.0449
Age for VD	14/96	9.85	0.0001
Stimulus for VD	7/48	4.43	0.0008
Age x Stimulus for VD	14/96	0.84	0.6247
Age for V	14/96	4.49	0.0001
Response for V	7/48	15.02	0.0001
Age x Response for V	14/96	3.19	0.0004
Age for VL	14/96	9.08	0.0001
Response for VL	7/48	12.92	0.0001
Age x Response for VL	14/96	2.67	0.0025

TABLE 4

Channel Capacity Estimates of the Three Age Groups for the Four Treatments (bits)

Treatment	Age Group		
	5	8	12
V-R	6.1	7.2	7.5
VL-R	5.2	6.4	7.1
V-VD	2.3	4.4	6.1
VL-VD	1.7	4.2	5.4