The Relationship Between Age and Information Processing Capacity of Adults

William L. Carpenter[1]
Florida State University

Research has proven that older people can learn, although there is a decline in certain kinds of learning abilities and performance with age. With increasing emphasis on programs for middle-age and older adults, there is need for new approaches to the study of the human organism to determine its various capacities for learning and performances.

A mathematical model developed from information theory has provided a tool useful in measuring certain human characteristics, specifically the information processing capacity of the human organism when it is considered as a communication system.

Although this methodology has been used considerably by psychologists, the effects of aging or the relationship between age and information processing capacity has not been fully assessed. In this study the use of absolute judgments to measure information processing capacity was extended to measure subjects over a 45-year age range and under simulated classroom conditions. Using visual stimuli, 74 subjects judged size of dark squares on a light background in three tests and the location of the placement of a dot in a grid pattern in two tests. Information theory statistics were used for individual test data analysis, and conventional statistics were used to determine levels of significance of the data collected.

The purpose of this study was to determine (a) if there is a change in information processing and channel capacity as the human organism grows older; and (b) if the relationship found in (a) is altered with a change in stimulus complexity.

Theoretical Framework

The aging process can be divided into two stages: growth or evolution; and atrophy, shrinkage or involution.

[1]Now at North Carolina State University. The research reported here was carried out as a doctoral dissertation by the author at Florida State University.

It is generally conceded that both stages are at work throughout the life span, although growth is predominant until maturity. In the later years atrophy exceeds growth, but certain things continue to grow in the healthy organism until the end--the mind, for example.

Hand (1965) lists several major biological changes in the human organism correlated with aging that have relevance to education: (a) decline in visual acuity; (b) loss of hearing, (c) diminishing motor abilities; (d) decreased speed, strength, and endurance of skeletal neuromuscular reactions; (e) degeneration of the nervous system with impaired attention, memory and mental endurance; and (f) gradual aging of tissue, cells, and other organs of the body.

Of particular concern in this study are certain physiological changes attributed to aging. It has been well documented that there is an increase in simple reaction time with advancing age, and the effects of age are greater in complex choice reaction times than in simple responses (Birren, 1964).

The similarity between an electronic transmission system and the human organism has led to the treatment of the latter as a communication or information processing system.

Like an electronic communication system, the human system has limitations. It is subjected to interferences within and without the system. There are limitations on the sensitivity and ability to discriminate among stimuli, and the organism is restricted in the number of discrete responses that it can emit.

When the human is considered as a communication system, certain concepts from information theory can be used to measure information processing capacity of the system--the ratio between the information received by or fed into the communication system (input) and the information that is transmitted through the system (output), measured in bits per stimulus or given time period.

The objective is to determine how much information the observer obtains about a particular stimulus. There may be one (unidimensional) or more than one (multidimensional) stimulus dimensions to the objects being judged.

The absolute judgment method of stimulus response--defined as a type of judgment in which an observer is required to identify by a name, number, or value each member of a set of individually presented stimuli--is an effective measurement technique.

Psychologists have carried out considerable research using information theory and absolute judgment to measure information capacity of the human organism. Stimuli used have been auditory, taste, touch, and visual, presented as single and multidimensional stimuli. However, most such studies have used college undergraduates as subjects, in specially-equipped experimental laboratories.

All studies have demonstrated that when exposed to a multidimensional stimulus, the information output is greater than it is with a single stimulus. Where a single stimulus was used, information output averaged around 2.5 bits of information per stimulus; where more than one stimulus dimension was used, information output ranged as high as 4.0 bits per stimulus. Articles by Miller (1956), Alluisi (1957), and Garner (1962) give good summaries of the studies using this technique.

To guide the research activities, the following four directional hypotheses were deduced and tested:

1. As age increases, information processing capacity of the human organism will decrease when measured by a single or unidimensional visual stimulus.

2. As age increases, information processing capacity of the human organism will decrease when measured by a multidimensional visual stimulus.

3. At all ages, information processing capacity of the human organism will be greater when exposed to a multidimensional visual stimulus than when exposed to a unidimensional visual stimulus.

4. The decrease or loss of information processing capacity as related to age (Hypotheses 1 and 2) will be greater in more complex stimulus situations where finer discriminations are called for (Series A: Test 1 compared with Test 2, Test 2 compared with Test 3; Series B: Test 4 compared with Test 5).

Methodology and Procedures

Participants of the Southeast Regional Teacher Training Institute, held on the Florida State University campus in July, 1967, served as subjects in the study. Four test groups, ranging from 17 to 20, and five sets of stimuli were used. The following block design was selected:

Group 1: Tests 1, 2, 4

Group 2: Tests 1, 2, 5

Group 3: Tests 1, 3, 4

Group 4: Tests 1, 3, 5

The following sets or tests were selected: 1, 2, and 3 (Series A) with size of squares as the stimulus; 4 and 5 (Series B) with the dot and grid pattern.

Series A

Test 1: Size range of 8, maximum information in test, 3.0 bits.

Test 2: Size range of 13, maximum information in test, 3.70 bits.

Test 3: Size range of 20, maximum information in test, 4.32 bits.

Series B

Test 4: 4 x 4 matrix, maximum information in test, 4.0 bits.

Test 5: 6 x 6 matrix, maximum information in test, 5.17 bits.

Two requirements were established for the selection of amount of stimulus uncertainty in the tests: (1) The first test in each series (Tests 1 and 4) should be at a fairly simple level at which all respondents could be expected to make near-perfect discriminations, including those at the older end of the age range should it develop that subjects in the older age groups had real difficulty in making judgments of the kind called for in this experiment; (2) The remaining test(s) in each series (Tests 2, 3, and 5) should be at a level difficult enough to approach the point at which such judgments of this type could not be made with any degree of accuracy.

In Test Series A, the squares were cut from black posterboard. The largest size in each set was approximately 5 inches, and the smallest was the size of the largest divided by the number of stimuli in the set. In Test 1 the squares ranged from 5/8 inch to 5 inches on a side, varying in 5/8-inch steps; in Test 2 squares ranged from 3/8 inch to 4 7/8 inches on a side, varying in 3/8-inch steps; in Test 3 the squares ranged from 1/4 inch to 5 inches on a side, varying in 1/4-inch steps. In Tests 4 and 5 the grid pattern of the matrix was made up of 1-inch squares, with the dot approximately 3/8 inch in diameter.

The squares and patterns were photographed and made into 2 x 2 slides. The presentation was made in a semi-darkened room. A timer on the slide projector controlled the time between stimulus presentation (8 seconds) and a tachistoscope mounted on the projector lens controlled the duration or stimulus exposure time (1/10th second).

The experimenter gave a warning signal or cue approximately 2 seconds before each image was flashed on the screen. In Test Series A response was made on preprinted forms by numbers with the smallest square in each test as Number 1. In Test Series B the subjects responded by indicating location of the dot on preprinted response forms.

All groups were first exposed to Test 1, then the other Series A test, followed by the Series B test. There were five trials or replications on each test.

Findings

The basic analysis of the experiment was performed by using a standard computer program to determine the significance of the relationship between age and information processing capacity.

As shown in Table 1 and Figures 1 and 2, and as predicted, there was some decline in information processing capacity as age of the subjects increased. In Tests 1, 2, and 4 this decline was statistically significant; in Tests 3 and 5 it was not.

Table 1 and Figures 1 and 2 provided the information used in testing Hypotheses 1 and 2. Both were concerned with information processing capacity, and the following statistical hypotheses were established:

$$H_0: r = 0; \quad H_1: r < 0; \quad H_2: r > 0.$$

Hypothesis 1 stated that as age increased information processing capacity of the human organism would decrease when measured by a single or unidimensional visual stimulus. Stimulus Series A, containing Tests 1, 2, and 3, provided data for the testing of this hypothesis. As shown in Table 1, in Test 1 the correlation of -.35 was significant

TABLE 1

Statistical Analysis of Five Tests Used in the Experiment to Determine Significance of Relationship Between Age and Information Processing Capacity

Test	Sample Size	Test Mean	Correlation Coefficient[a]	F-value	df	Level of Sig.
1	71	1.88	-.35	9.73	70	.01
2	37	2.24	-.42	7.40	36	.025
3	37	2.50	-.10	0.35	36	NS[b]
4	36	3.77	-.46	9.17	35	.01
5	38	4.33	-.17	1.06	37	NS[b]

[a]The linear correlation between age and test scores, with the negative sign indicating a decline in performance as age increases.

[b]At .05 level.

at the .01 level. In Test 2 the correlation of -.42 was significant at the .025 level. The result of Test 3, with a correlation of -.10, although not significant at the .05 level, was in the predicted direction. Therefore, the null hypothesis of $r = 0$ was rejected, and alternate hypothesis 1 ($r < 0$) was sustained. The directional hypothesis, which stated that as age increased information processing capacity would decrease, was therefore accepted.

Hypothesis 2 stated that as age increased information processing capacity would decrease when measured by a multi-dimensional visual stimulus. Stimulus Series B, containing Tests 4 and 5, provided data for the testing of this hypothesis. As shown in Table 1, in Test 4 the correlation of -.46 was significant at the .01 level. The result of Test 5, with a correlation of 0.17, although not significant at the .05 level, was in the predicted direction. Therefore, the null hypothesis of $r = 0$ was rejected, and alternate hypothesis 1 ($r < 0$) was sustained. The directional hypothesis, which stated that as age increased information processing capacity would decrease, was therefore accepted.

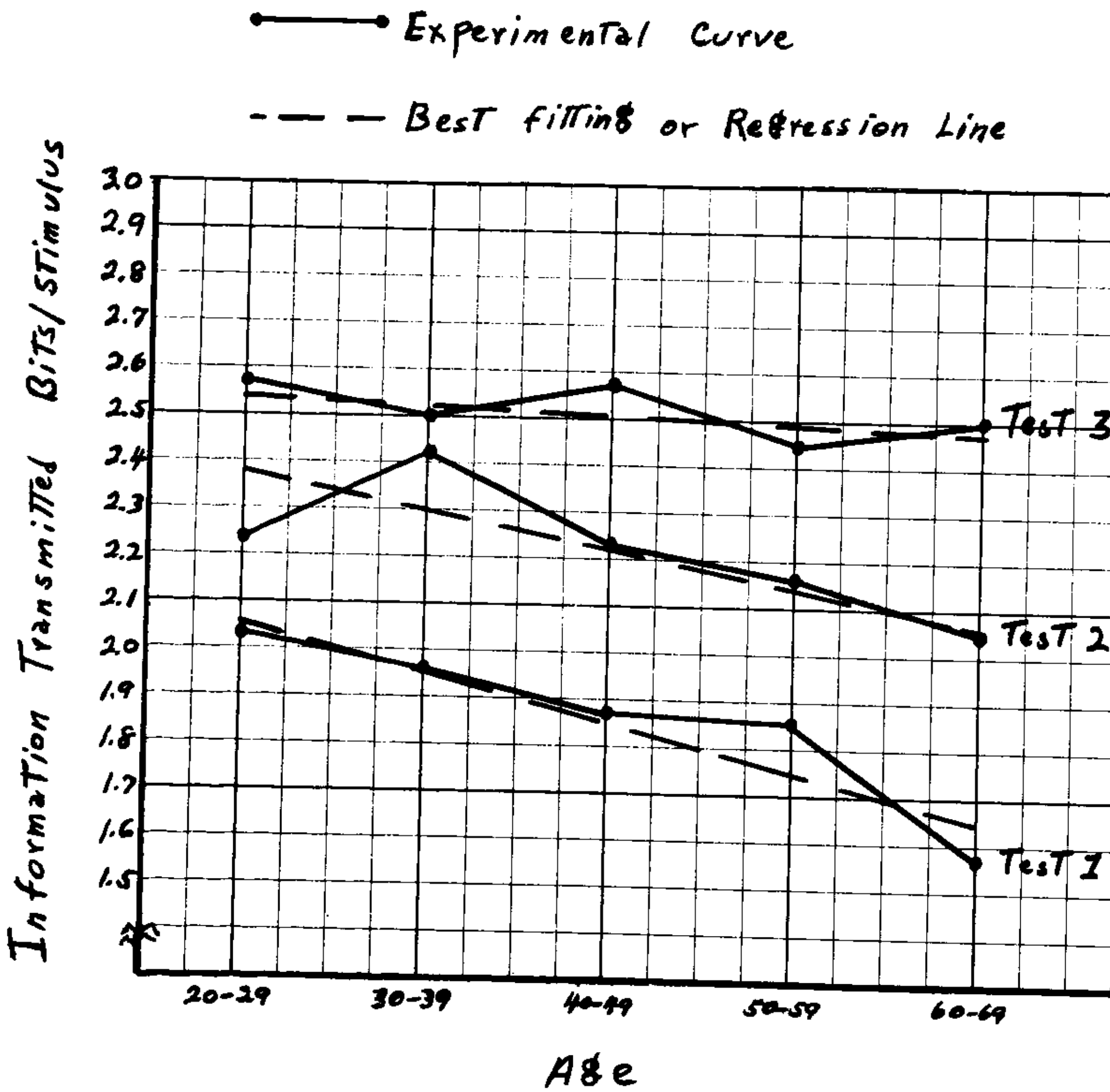

Fig. 1. Information transmitted scores by 10-year age grouping for the Series A tests using unidimensional stimuli.

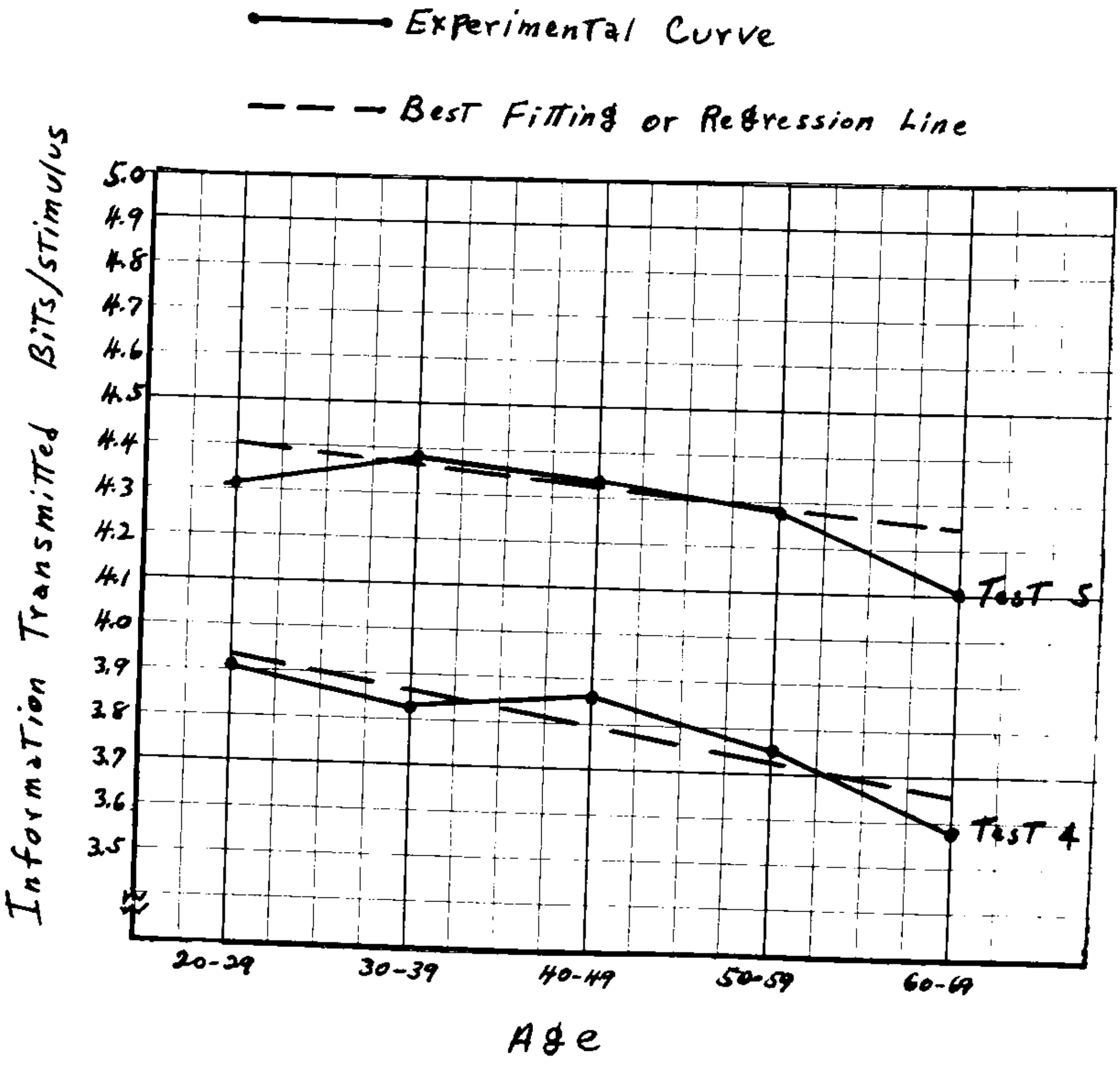

Fig. 2. Information transmitted scores by 10-year age grouping for the Series B tests using multidimensional stimuli.

A number of tests, where comparisons between unidimensional and multidimensional stimuli had been made, showed conclusively that the human organism acting as a communication system could process more information if the judgments could be based on more than one dimension. However, all subjects had been college age. Hypothesis 3 in this experiment stated that the ability to transmit information would be greater in the multidimensional stimulus situation at all age levels. The data in Table 2 and Figure 3 show that indeed it is. As shown in Figure 3, not only did the line for the multidimensional stimulus (Test 4) lie above the unidimensional stimulus (Test 3) at all age levels, but it was far above the lower line.

TABLE 2

A Comparison of Scores and Percentage of Uncertainty Reduced in a Unidimensional Stimulus Test and a Multidimensional Stimulus Test With About Equal Stimulus Uncertainty

		Age Groups				
Test	Item	20-29	30-39	40-49	50-59	60-69
3	Mean Score	2.58	2.50	2.57	2.44	2.50
	Percentage	59.7	57.9	59.5	56.7	57.9
4	Mean Score	3.91	3.82	3.84	3.75	3.59
	Percentage	97.8	95.5	96.0	93.8	89.8

Table 2 shows the mean scores for each age group on each test, and also the percentage of the maximum scores possible that was obtained for each age group, based on these means. For example, Test 3 contained an input of 4.32 bits of information. The 20-29 age group had a mean score of 2.58 on this test, which was 59.7 per cent of the maximum score that could have been made on the test. In comparison, the same age group had a mean score of 3.91 on Test 4, or 97.8 per cent of the maximum score of 4.0 that could have been made on this test. At all age levels there was a higher mean score and a higher percentage score. Therefore, the directional Hypothesis 3 was accepted.

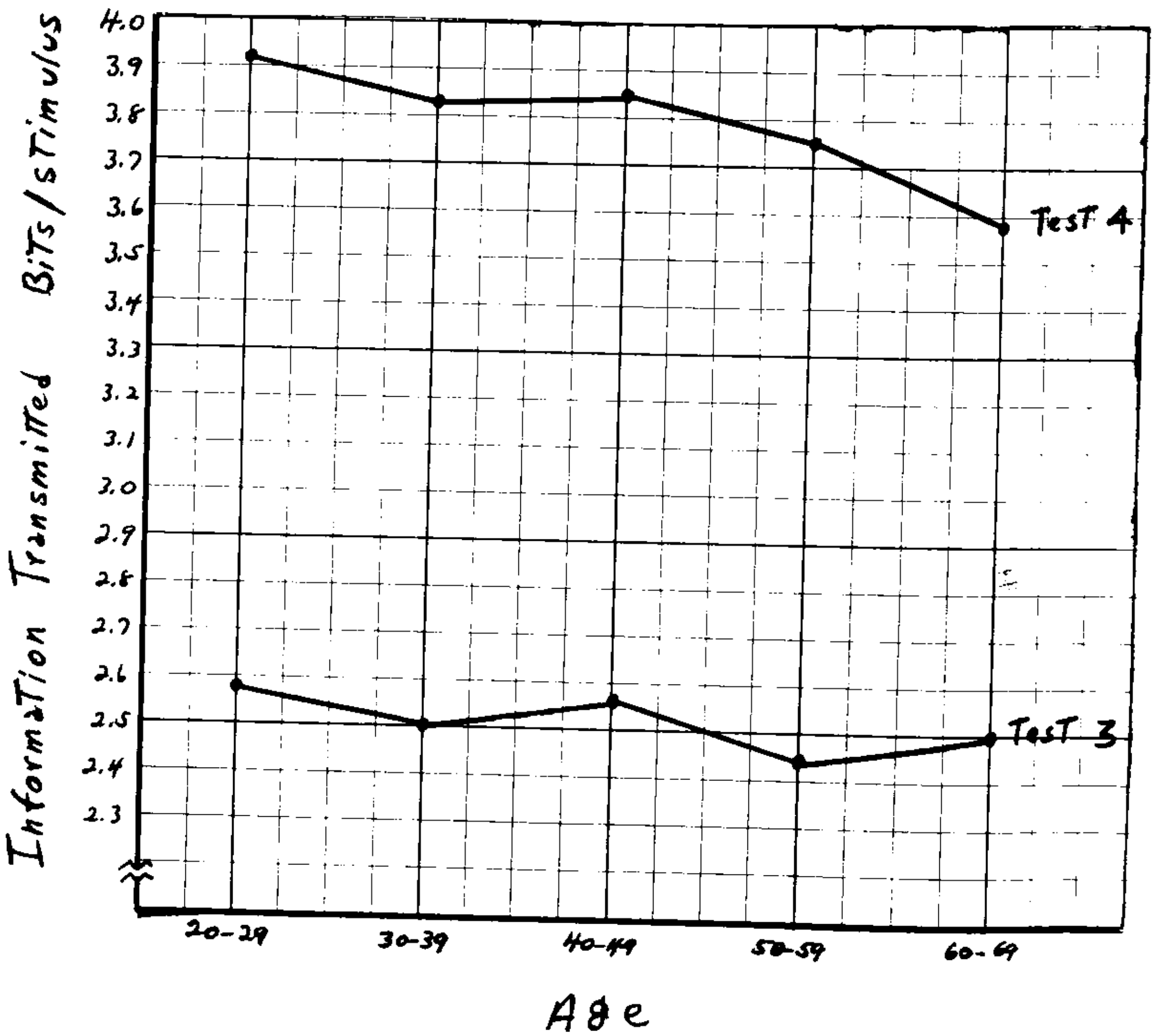

Fig. 3 . A graphic comparison between a unidimensional stimulus test and a multidimensional stimulus test with about equal stimulus uncertainty.

Hypothesis 4 was concerned with the difference in slope of the lines representing the different tests. The directional hypothesis stated that the decrease or loss of information processing capacity as related to age would be greater in more complex stimulus situations where finer discriminations were called for (Test 1 compared with Test 2; Test 2 compared with Test 3; Test 4 compared with Test 5). Statistically the null hypothesis $B_1 - B_2 = 0$ was tested using a special t-test. The results of this analysis are shown in Table 3.

TABLE 3

Scores From t-test Used to Test the Difference in Slope of Regression Lines Representing Several Tests

Tests Compared	t Score	Level of Significance
1 and 2	.0014	NS*
2 and 3	.0041	NS*
4 and 5	.0030	NS*

*At .05 level.

The regression lines tested have been drawn in on Figures 1 and 2. Although the scale is too small in these figures to portray the picture accurately, it can be seen that slopes of the lines representing Tests 1 and 2 are very much parallel. The lines representing Tests 2 and 3 and Tests 4 and 5 are less parallel, but as shown in Table 3, the t-values are very low and do not come close to the t-value of approximately 1.68 that would be needed for significance at the .05 level. Therefore, the null hypothesis that $B_1 - B_2 = 0$ was sustained, and the directional hypothesis was rejected.

Interpretations and Conclusions

There was concern as to whether or not this stimulus pattern would work satisfactorily in a simulated classroom situation and if subjects throughout the age range would be able to perform satisfactorily under the experimental conditions imposed. All subjects were able to perform the experimental task and there was no evidence of practice, fatigue effects, eye condition or other intervening variables.

It is believed the data provided reasonably good measure of information processing capacity (Hypotheses 1 and 2). As shown in Figures 1 and 2, there was a decline with age in all tests, as predicted, with a statistically-significant decline in three of the five tests.

The most interesting phenomena in the study was the Test 3 results, when analyzed in terms of the independent variable. It was predicted (Hypothesis 1) that as age increased performance would decrease. This did not happen ($p > .05$, Table 1). Also, it was predicted that in this more complex discrimination situation older subjects would have more difficulty, relatively, making the judgments called for than they would where coarser discriminations were called for (Tests 1 and 2) in the unidimensional stimulus situation. In fact, it would not have been surprising if the line representing Test 3 scores at the older age end of the range in Figure 1 would have dropped below the line representing Test 2 scores. In other words, the distance between lines representing Tests 2 and 3 were expected to be less at the right side of the graph (if they did not cross and intermingle) than they would at the left side (Hypothesis 4). There was no significant difference ($t = .0041$) in these distances.

These results lend themselves to considerable speculation. It is possible, although considered unlikely, that there is some element from, or net result of, long-term experience that would enable the older subject to perform at a higher level as the complexity of the stimulus condition increases. Also, it is possible that older subjects might have applied themselves more strenuously, or were more concerned with a high level of performance, although the subjects were not aware that age was one of the variables being studied.

There is a strong possibility that the older subjects entered the test situation at a higher stress or anxiety level than did the younger subjects. Researchers at the Duke University Center for the Study of Aging discovered that older subjects entered a short learning-testing situation (40 minutes) at a higher anxiety level than did younger subjects, and with the older subjects the anxiety level continued to increase through the test period, while for the younger subjects there was an anxiety leveling off or reduction starting about 10-12 minutes into the test situation. Then, for the older subjects the anxiety level started to go down some 10-15 minutes after the test was completed (Powell, 1964). It is possible that the older subjects in this study reached the point of anxiety reduction during the second test.

A follow-up study is being carried out, designed to examine this stress and anxiety hypothesis. In this test some 70 subjects over approximately the same age range as used in this study are being exposed to the three size-of-squares tests, but in an order so that some subjects will be exposed to the more complex tests (tests 2 and 3) first. The results from this study, titled "The influence of stress and anxiety on adult performance as related to time and varying levels of stimulus complexity," should be available early in 1969.

References

Alluisi, E. A. "Conditions affecting the amount of information in absolute judgments," Psychological Review, 1957, 64, 97-103.

Birren, J. E. The Psychology of Aging. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964.

Garner, W. R. Uncertainty and Structure as Psychological Concepts. New York: John Wiley and Sons, Inc., 1962.

Hand, S. E. A Review of Physiological and Psychological Change in Aging and Their Implications for Teachers of Adults. Tallahassee, Florida: The State Department of Education, Bulletin 71G-1, 1965. (Pamphlet).

Miller, G. A. "The magical number seven, plus or minus two: some limits on our capacity for processing information," Psychological Review, 1956, 63, 81-97.

Powell, A. H., Jr. "Physiologic response patterns observed in a learning task," Archives of General Psychiatry, 1964, 10, 120-124.