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ABSTRACT

Witkin's Embedded Figures Test (EFT) was used to measure the changes with age in field dependence and problem-solving ability. Qualitative data concerning problem-solving strategies and quantitative data were collected. EFT was administered to 12 females in each of the following decades: 20s, 30s, 40s, 50s, 60s, 70s. All subjects were moderately to well-educated, healthy, and relatively active members of the community. All had at least 20/33 corrected or uncorrected vision. An interview was held with each participant after completion of the EFT. ANOVA of time scores indicated that significantly more time is needed to solve the items with an increase in age; a Tukey (a) test revealed a significant increase between the 40s and 60s age groups. With an increase in age a significant decline in the number of items solved was found. Partial correlations revealed that age is the most important factor relative to general intelligence, visual acuity, and the personality factors measured by the Eysenck Personality Inventory. The relative stability of performance up through age 49 and after 50 implies a decline in field independence rather than in higher-order cognitive processes. (Author)

The Effects of Age on Perceptual Problem-Solving Strategies*

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Running Head: Perceptual Problem Solving

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Abstract

Lee, J. A., & Pollack, R. H. The effects of age on perceptual problem solving strategies.

Witkin's Embedded Figures Test (EFT) was used to measure the changes with age in field dependence and problem-solving ability. Qualitative data concerning problem-solving strategies and quantitative data were collected. EFT was administered to 12 females in each of the following decades: 20s, 30s, 40s, 50s, 60s, 70s. All subjects were moderately to well educated, healthy, and relatively active members of the community. All had at least 20/33 corrected or uncorrected vision. An interview was held with each participant after completion of the EFT. ANOVA of time scores indicated that significantly ($p < .01$) more time is needed to solve the items with an increase in age; a Tukey (a) test revealed a significant ($p < .05$) increase between the 40s and 60s age groups. With an increase in age a significant ($p < .01$) decline in the number of items solved was found. Partial correlations revealed that age is the most important factor, vis-á-vis general intelligence, visual acutiy, and the personality factors measured by the Eysenck Personality Inventory. The relative stability of performance up through 49 and after 50 implies a decline in field independence rather than in higher-order cognitive processes.

The Effects of Age on Perceptual Problem-Solving Strategies

Although there is a large body of research relating to a deficit in problem-solving ability during senescence (Arenberg, 1973; Axelrod & Cohen, 1961; Baltes & Labouvie, 1973; Basowitz & Korchin, 1957; Clay, 1954; Friend & Zubeck, 1958; Jerome, 1962; Welford, 1958, 1969; Wiersma & Klausmeier, 1965; Young, 1966, 1971), there remains a lack of qualitative data suggesting to what this deficit can be attributed. The work of Witkin and his associates (Witkin, Dyk, Faterson, Goodenough, & Karp, 1962; Witkin, Lewis, Hertzman, Machover, Meissner, & Wapner, 1954) has suggested a means by which to implement a qualitative analysis of problem-solving ability. In their work with field dependence, they saw a strong correlation between perceptual functioning and problem solving: both processes often require that "parts" be disembedded from their context and "brought into new relationships" (Witkin et al., 1954, p. 477). The perceptual ability to overcome embeddedness has been consistently delineated by various factor analyses (Balinsky, 1941; Birren, 1952; Cohen, 1952, 1957, 1959; Goodenough & Karp, 1961; Hammer, 1950; Karp, 1963; Podell & Phillips, 1959; Witkin et al., 1962) as a manifestation of intellectual functioning.

In an attempt to carry out a qualitative analysis, this study employed Witkin's (Witkin, Oltman, Raskin, & Karp, 1971)

standard 12-item Embedded Figures Test (EFT) as a means of measuring and investigating the changes with age in perceptual problem-solving ability as well as the changes with age in field dependence. The EFT has proven to be a valid measure of both the perceptual and intellectual ability to overcome an embedding context (Witkin, 1960a; Witkin, 1960b; Witkin et al., 1962; Witkin et al., 1971). Relative to intellectual abilities, the weight of the evidence indicates that the EFT, like other related perceptual tests, specifically taps the analytic field approach factor of general intelligence and not verbal ability (Elkind, Koegler, & Go, 1963; Goodenough & Karp, 1961; Woerner & Levine, cited in Witkin et al., 1962) nor the factor pertaining to the ability to resist distraction (Karp, 1963).

Based on these foregoing data which appear to support the hypothesis that the ability to overcome embeddedness perceptually is a manifestation of intellectual functioning, the EFT was employed as a means for conducting a qualitative analysis of changes with age in problem-solving strategies. Based on the apparent decline during senescence, this study tested two hypotheses: (1) with an increase in age from the 20s more time would be needed to solve the EFT items, and (2) there would exists a significant difference between the strategies of older and younger persons in solving the problems. Past studies (Basowitz &

Korchin, 1957; Karp, 1967, Schwartz & Karp, 1967) which have employed an embedded figures test to investigate the cognitive and perceptual changes with age seem to favor these hypotheses.

Method

Subjects

The sample consisted of 12 white middle-class females from each of the following six decade age groups: 20s, 30s, 40s, 50s, 60s, and 70s. This resulted in a total of 72 subjects, all of whom were volunteers from Athens, Georgia and surrounding communities. All of the subjects had at least 20/33 corrected or uncorrected near vision as determined by the Master Ortho-Rater. All subjects were moderately to well educated, healthy, and relatively active members of the community. It has been manifested quite adequately that verbal comprehension is the factor of intelligence which is the slowest to decline with and least affected by middle and old age (Baltes & Labouvie, 1973; Botwinick, 1967, 1973; Eisdorfer, Busse, & Cohen, 1959; Jones & Conrad, 1933; Wechsler, 1958); hence, performance on a test of such an index, e.g., the Shipley-Hartford Verbal Test (SHV; Shipley, 1940) should reflect relatively closely the optimal level of general intelligence for the individual. Significantly high correlations between the Shipley-Hartford total scores and the WAIS full scale IQ have been consistently reported (Paulson & Lin, 1970; Prado & Taub, 1966; Sines & Simmons, 1959). Paulson and Lin (1970) have

found a correlation of .74 between the SHV vocabulary raw score and WAIS full scale IQ as well. On a 40-point scale, all participants scored better than 27 on the SHV. The mean SHV scores for the 20s, 30s, 40s, 50s, 60s, and 70s were 32.62, 35.94, 37.06, 35.27, 33.38, and 35.10, respectively. The vocabulary-age equivalent for a raw score of 32 is 17.8 years.

Procedure

All of the subjects completed the following tests without time limits.

The Embedded Figures Test (EFT). This test was administered to each subject individually in a small testing room. However, two of the participants in the 70s age group were tested in their respective homes. This concession was made at the participants' requests. The location of the testing did not seem to be a crucial factor since this was not a speed test nor a test of vigilance which required constant attention and strict control for distraction. At all locations only the subject and the experimenter were present. The amount of ambient light in both situations was constant and comfortable.

Witkin's (Witkin et al., 1971) 12-item EFT (Form B) requires the subject to locate a simple geometric figure (SF) which has been embedded in a more complex geometric figure (CF). This embedding is achieved by the creation of several subpatterns within the latter. In addition, the CF is colored in such a way

so as to reinforce these subpatterns, thereby increasing the difficulty of the test. The subject is presented a single CF for 15 seconds; then he/she is presented the SF that has been embedded in that particular CF for 10 seconds; finally, he/she is again presented the same CF with the instructions to locate and trace with a blunt stylus the SF. The subject is allowed to see the SF repeatedly upon request, but the SF and CF are never presented simultaneously. The sujects in this study were permitted to hold the cards bearing the figures in order to facilitate optimal viewing of their contents.

Any study of aging which reveals a decrement in performance during the later years of life must always deal with the question as to whether the obtained results were due to a speed factor rather than a true decline in ability (Canestrari, 1963; Friend & Zubeck, 1958). To investigate the possible artifactual effects caused by the standard 3-minute time of the EFT, the following procedure was adopted: the subjects' performances within 3 minutes were recorded; however, all subjects were allowed to continue with each specific item beyond 3 minutes. All performances beyond 3 minutes were also recorded. Although all subjects were encouraged to solve each item as quickly as possible, all were allowed to work at their own pace and to "give up" on each item whenever they chose. Progression to the next item occurred only

if the subject found the SF or if she requested it. The score for the test was the mean number of seconds per item.

Immediately following the EFT, an interview was held with each subject. These interviews were tape recorded with the subjects' full knowledge. The primary questions of the interview were:

1. "What steps did you take in trying to find the simple figures in the complex figures?"
2. "Is this the same procedure you used with all of the complex figures?"
3. Each subject was asked to relate how she proceeded to find the SF in at least one specific CF. A CF that she did not solve too readily and yet eventually solved served as the example. It is held that this procedure facilitated greater and more accurate expression of the strategies utilized by the subject.

The Eysenck Personality Inventory (EPI). This is a 57-item pencil and paper test which measures extraversion and neuroticism and includes a lie scale. The subject is instructed to answer "yes" or "no" to questions regarding her/his feelings, behavior, and actions. The EFT and EPI were administered during different sessions separated by at least 24 hours. The EPI was administered during the screening session along with the SHV and

the vision test. Half of the time the EPI was administered first followed by the SHV, and half of the time the reverse order occurred. These tests were administered in small groups in a testing room. No group was larger than eight. The vision test was always given last and individually. The EPI was not used as a criterion by which to select subjects, rather it was used as a measure to investigate possible personality factors and personality changes with age affecting performance on the EFT and problem solving in general. The EPI scores were not computed until all of the subjects had completed the EFT.

Results

The data analysis included a quantitative part and a qualitative part. The former indicated that with an increase in age from the 20s more time is needed to solve the EFT items. The latter, however, showed no significant difference between the strategies of older and younger persons in solving the items.

Quantitative Analysis

In the quantitative analysis the two measures of performance were the time scores and the number of items solved. Analyses of variance were followed by a Tukey (a) paired comparison analysis. First, an ANOVA of the time scores for each age group without a time limit indicates that significantly more time was needed to solve the items with an increase in age ($F = 6.11$,

$df = 5/66$, $p < .01$). Second, an ANOVA of the time scores based on performance within 3 minutes also indicates a significant increase with age ($F = 7.79$, $df = 5/66$, $p < .01$). In computing this second set of scores, all times beyond 3 minutes were scored as 3 minutes. Henceforth, these different sets of scores will be referred to as the modified time scores and the standard time scores, respectively.

A Tukey (a) paired comparison analysis was performed on each of the two sets of data just described. Both analyses indicate that a significant ($p < .05$) increase in the time which is needed to solve the items occurred between the 40-year-old age group and each of the 60- and 70-year-old age groups. No significant differences were found, though, among the 50s, 60s, and 70s in either analysis. None of the comparisons between adjacent age groups (i.e., 20s vs. 30s, 30s vs. 40s, etc.) showed a statistically significant difference. However, as shown in Figure 1,

Insert Figure 1 about Here

the major increase in time to solution between adjacent age groups occurred between the 40s and the 50s. The sequence of differences (in seconds) between the means of the standard time scores of the indicated adjacent age groups were as follows (proceeding from the 20s to the 70s): 30s -- 20s = 2.86; 40s - 30s = -.84; 50s - 40s = 40.09; 60s - 50s = -14.62; 70s - 60s = -1.82. The

negative signs indicate a decrease in time with an increase in age. The sequence of differences between the means of the modified time scores of the indicated age groups were as follows (proceeding from the 20s to the 70s): 30s - 20s = -4.11; 40s - 30s = -3.35; 50s - 40s = 43.12; 60s - 50s = 10.49; 70s - 60s = 5.74. The negative signs, again, indicate a decrease in time with an increase in age

Since the ANOVAs of both the modified time scores and standard time scores revealed almost identical patterns of changes across age groups, only the latter were used for further analysis. This procedure was adopted to facilitate comparison with past studies based on performance within 3 minutes.

Results also reveal that with an increase in age there is a significant decline in the number of items solved ($F = 4.82$, $df = 5/66$, $p < .01$). The graph of this function (see Figure 2) seems to reflect the reciprocal of the relationship expressed in

Insert Figure 2 about here

Figure 1. A Tukey (a) test indicates a significant ($p < .05$) decline between the 40s and the 60s; but, again, the major decline in performance was found to have occurred between the 40s and the 50s. The sequence of differences between the means of the "number solved" scores of the indicated adjacent age groups were as follows (proceeding from the 20s to the 70s): 20s - 30s = .59; 30s - 40s = -.34; 40s - 50s = 2.17; 50s - 60s = 1.25; 60s -

70s = -.75. A negative sign indicates an increase in the number solved with an increase in age. The shapes of both Figures 1 and 2 manifest a relative flatness from 20 to 49 and again after 50, with substantial declines in performances from the 40s to the 50s.

The Pearson product-moment correlation coefficients (see Table 1) reveal that chronological age is the most important

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Insert Table 1 about here

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factor contributing to group differences in performance. The partial correlations between each of the two measures of performance (i.e., the time scores and the number of items solved) and age with visual acuity (VA) and IQ separately held constant do not reduce significantly the correlations with age. (The SHV scores were converted to IQ scores for the purpose of data analysis.) However, correlations between each of the two performance measures and VA are reduced to a level of insignificance when age is partialled out. The correlations between each of the two performance measures and IQ are not altered greatly when age is partialled out, but the change is in the expected direction: IQ becomes more important when age is held constant.

Analysis of the data regarding personality reveals that the personality factors of extraversion and neuroticism as measured by the EPI are not significant factors. ANOVAs on both the extraversion and neuroticism scales reveal nonsignificant differ-

ences across the age groups. A significant difference ($p < .01$) was found on the lie scale. A Tukey (a) analysis on the lie scores indicates significant differences existed between the 70-year-old age group and each of the 20s, 30s, and 50s. No significant differences were found among the 70s, 60s, and 40s. The partial correlations between each of the two performance measures and age with the personality factors separately held constant do not reduce significantly the correlations with age. In sum, the data show a marked drop in field independence within middle age.

Qualitative Analysis

The qualitative analysis was based on Wernerian theory (1957) and Witkin's theory (1962). From these, three main cognitive styles were delineated from the protocols: Global, Analytical, and Flexible. These, in turn, were found to consist of different levels. The following criteria defining these styles, with specific reference to the EFT, were used by two independent, unbiased judges who rated the protocols.

1. "Global Cognitive Style" involves the tendency to deal with the Complex Figure (CF) as a whole. The parts of the CF are experienced as fused.

a. "Passive-Global Approach" (PG, the lower level of the Global Style)--The individual accepts the CF passively.

Any scanning utilized is done randomly.

b. "Active-Global Approach" (AG, the more advanced, higher level of the Global Style)--Active and more purposeful scanning techniques are employed. The subject maintains a mental template and searches systematically.

2. "Analytical Cognitive Style" involves the tendency to break down the stimulus into parts.

a. "Fragmented Analytical Approach" (FA, the lowest level of the Analytical Style)--The subject does not work with a plan; the parts are not readily related to other parts, but are dealt with individually. The individual lines and parts dominate the figure as a whole.

b. "Chaining Analytical Approach" (CA, the mid-level of the Analytical Style)--The individual breaks down the CF and forms relationships among the different parts, but this is done by chaining together adjacent parts.

c. "Synthetic Analytical Approach" (SA, the highest level of the Analytical Approach)--The subject brings all the parts of the SF together simultaneously from the various parts of the CF.

3. "Flexible Cognitive Style" entails the ability to intentionally switch from higher-order processes to lower-order processes, and vice versa, as necessary. Often performance is facilitated by utilizing lower-order processes and suspending

higher-order processes (Werner, 1937), i.e., perceptual vs. higher cognitive processes and a global approach vs. an analytical approach.

The two judges who were recruited for this study were chosen because of their related work and experience in this area of research. One was a graduate student and the other was a faculty member, both in the Department of Psychology at the University of Georgia. A third judge, who was a faculty member in the Department of Psychology, was employed to resolve discrepancies between these two. He, too, functioned independently of the others. His intervention was necessary for only 18 out of 144 classifications.

The ratings of the two primary judges were tabulated two ways: (1) according to the frequencies within each age group of the different levels of the cognitive styles, i.e., low, medium, and high levels of problem-solving strategies and (2) according to the frequencies within each age group of the different main cognitive styles, i.e., Global, Analytical, and Flexible. The levels in the first tabulation consisted of the appropriate levels from the three main cognitive styles. Inter-rater reliabilities of the two primary judges for the two tabulations were 84% and 90%, respectively. Each judge had a self-consistency rate of 80%.

Since the quantitative data reflected a major break between the 40s and the 50s, the subjects were grouped as "young" (20-49) and "old" (50-79) to ascertain whether this break would be replicated in the qualitative analysis. All further analyses were performed using this dichotomy. In the first analysis, the cases of high level functioning were merged with the "Medium Level" since there were so few (n = 7) of the former; and, a 2 x 2 chi-square (Age group x Level) was performed. The cell frequencies were as follows: Low Level Young, 10; Low Level Old,9; Medium/High Level Young, 26; Medium/High Level Old, 27. No significant difference was found.

A 2 x 2 and a 2 x 3 chi-square were performed on the data from the second tabulation, and both revealed no significant differences. The cell frequencies in the 2 x 3 were: Global Young, 19; Global Old, 20; Analytical Young, 8; Analytical Old, 10; Flexible Young, 9; Flexible Old, 6. In the 2 x 2, the two "single mode" cognitive styles, i.e., Global and Analytical, were merged and compared with the Flexible Cognitive Style. The cell frequencies were: Single Mode Young, 27; Single Mode Old, 30; Flexible Young, 9; Flexible Old, 6.

Discussion

Hypothesis (1) that with an increase in age from the 20s more time is needed to solve the EFT items was supported by the quantitative data. The qualitative data, however, failed to

confirm hypothesis (2) that there exists a significant difference between the strategies of older and younger persons in solving the problems.

The large discrepancy found between the quantitative performance scores of the 40s age group and those of the 50s shows that a marked decline occurs during middle age, vis-á-vis old age. This has important implications as far as what type of performance should be expected of those in their 50s. Furthermore, it could be suggestive of what factors might be causing the decline, e.g., hormonal changes within the individual.

It appears that the standard 3 minutes is an appropriate allotment of time in administering the EFT to an older population: optimal performance can be achieved by older persons within 3 minutes. Since all subjects of this study were explicitly informed that no time limit would be imposed, however, the pressure of the situation was alleviated. If a time limit is considered as producing a stressful situation, there is the possibility that the older persons would have performed considerably worse under the pressure of an announced time limit. Ross (1968), inducing a stressful situation with challenging instructions, found that older persons' performance deteriorates under stressful conditions.

The qualitative data are the more interesting part of this study and allow some speculation. Contrary to the quantitative

data, all the subjects, regardless of age, seem to have utilized predominantly the same style of problem solving: an Active Global Approach.

The discrepancy between these two sets of data seem to imply that the decline with age in problem-solving ability as measured by the EFT is not due to a deficit in higher-order cognitive processes but instead should be attributed to a decline in perceptual field independence. Corroborative evidence manifesting a decline in perceptual field independence with age is provided by other past studies (Comalli, Wapner, & Werner, 1959; Eisner, 1972; Markus, 1971; Markus & Nielsen, 1973). The older subjects were possibly hindered in their performance by some lower-order perceptual process. The shapes of Figures 1 and 2 support the contention of a perceptual problem. If the changes in performance were due to a decline in higher-order processes--and this is speculative, the graphs of these two functions would be relatively smoother, more gradual, with the greatest decline in performance occurring later than evidenced here and accelerating after 50. In contrast, Figures 1 and 2 manifest sharp changes between the 40s and 50s. The decline does not accelerate significantly after 50, but levels. The Tukey (a) analyses showed no significant differences between the 50s and 60s, 60s and 70s, nor 50s and 70s on either of the two performance measures.

This surmise of a perceptual impediment becomes more plausible when put into Werner's (1957) framework of an hierarchy of functions constituting mental functioning. He emphasized a distinction between performance and competence. According to him, "there is no strict relation between greater achievement and more mature processes" (Werner, 1937, p. 365).

The personality factors as measured by the EPI were not found to have been primary determinants of performance. Neither extraversion nor neuroticism correlated significantly with either of the two performance measures. The correlation ($r = .45$, $p < .001$) found between age and the lie scale could be cause for skepticism in the validity of the older subjects' scores on the EPI. However, the location of the significant differences found with the Tukey (a) test among the different age groups on the lie scale does not coincide with the location of the sharp decline on the performance measures. No significant difference was found between the 40s and the 60s on the lie scale. The correlation between age and the lie scale only seems to imply that those in the 70s were not as consistent as the younger subjects in answering the questions on the EPI. This inconsistency could be due to the possible inappropriateness of the EPI for a population of this age group. Some of the questions may be age related.

The nonsignificant correlation (r = -.019) found in this study between age and extraversion and the extremely small, yet significant, correlation coefficients found by others (Gutman, 1966; Heron & Chown, 1967) between these two indicate that factors other than age must be considered when looking at changes in extraversion (Botwinick, 1973). Evidence of an increase in introversion with age (Calden & Hokanson, 1959; Sealy & Cattell, cited in Botwinick, 1973; Slater & Scarr, 1964) gives rise to a curious paradox. This evidence together with the definitions (Eysenck & Eysenck, 1968; Witkin et al., 1971) of an introvert and an extravert imply that older persons should outperform younger persons on the EFT. The converse, which has been consistently found, seems to argue that there are other factors, e.g., perceptual ones, which could be causing the results.

The importance of perceptual factors can best be investigated by further research using other perceptual tests which do not involve the operation of higher-order processes but require the perceptual ability to manipulate figure and ground, e.g., the rod-and-frame test, tests with ambiguous figures, and masking tests. If these consistently replicate the pattern of decline in performance found in this study, then they will corroborate the hypothesis of a perceptual rather cognitive problem in certain

problem-solving situations. If this is confirmed, broad implications could be drawn. Although some decline can be expected (Miles & Miles, 1932), it will suggest that older persons are not as intellectually incapable as has been hitherto held.

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Table 1

Correlations Between Factors Related to Performance on the Embedded Figures Test

Variables	Correct[a]	IQ	VA[b]	Age	E[c]	N[d]	L[e]
Time scores	-.842***	-.264*	-.318**	.503***	.149	.000	.202
Correct		.346**	.286*	-.431***	-.105	-.029	-.172
IQ			.011	.053	-.200	-.132	.040
VA				-.582***	.046	.228	-.296*
Age					-.019	-.360**	.450***
E						-.112	-.108
N							-.319**

[a]Number of items solved.

[b]Visual acuity.

[c]Extraversion.

[d]Neuroticism.

[e]Lie scale.

*$p < .05$

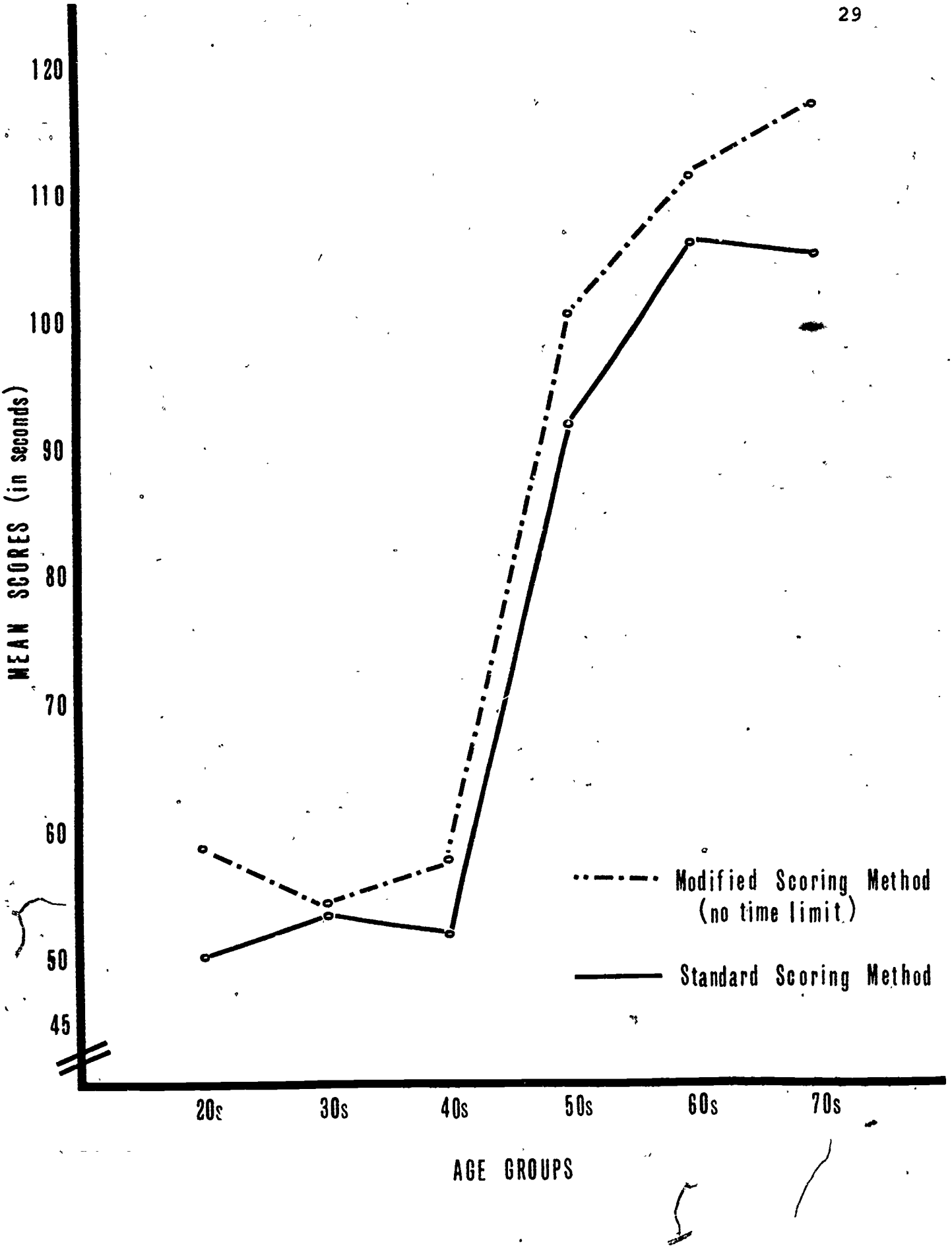
**$p < .01$

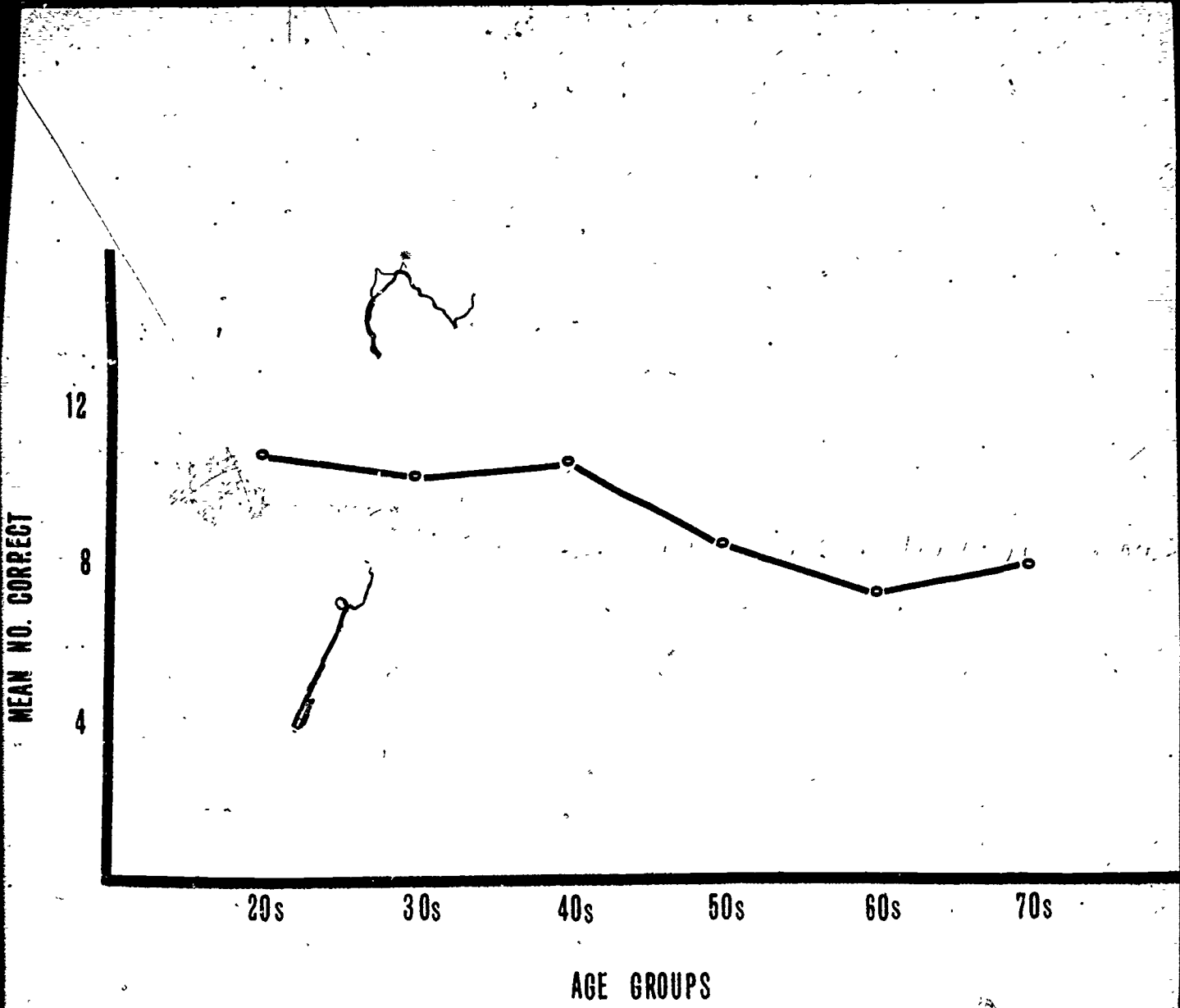
***$p < .001$

Figure Captions

Figure 1. Mean time scores on the Embedded Figures Test as a function of age.

Figure 2. Mean number of items correct on the Embedded Figures Test as a function of age.


120
110
100
90
80
70
60
50
45
MEAN SCORES (in seconds)
20s
30s
40s
50s
60s
70s
AGE GROUPS
Modified Scoring Method
(no time limit)
Standard Scoring Method


MEAN NO. CORRECT
12
8
4
20s
30s
40s
50s
60s
70s
AGE GROUPS