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FUNCTIONAL AGING IN PILOTS: AN EXAMINATION OF A MATHEMATICAL MODEL BASED ON MEDICAL DATA ON GENERAL AVIATION PILOTS

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16. Abstract

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FAA pilot medical records were employed in a series of two group discriminant function analyses. Group one consisted of records where no pathology was listed. Group two consisted of records where a cardiovascular, cerebrovascular, or diabetic pathology was listed.

The analyses presented some pertinent results. (i) Age is not as accurate in discriminating between the sudden incapacitating pathology and nonpathology groups as the linear discriminant composite. (ii) As age increases from post-50, to post-55, to post-60, classification accuracy using the discriminant index increases monotonically. (iii) Better measures that predict these pathologies with more accuracy would further separate the CPDF's of the pathology and nonpathology groups. Based on these results a possible strategy for future study on pilot certification is discussed.

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FUNCTIONAL AGING IN PILOTS: AN EXAMINATION OF A MATHEMATICAL MODEL BASED ON MEDICAL DATA ON GENERAL AVIATION PILOTS

Introduction.

In a recent series of papers Gerathewohl (1,2,3) cogently reviewed the literature on aging in relation to efforts to develop a precise indication of a person's ability to function. He also reviewed several efforts to develop a "functional age" index. The development of such an index has a very compelling intuitive basis. Everyone probably knows some chronologically younger persons who function less capably than others who are chronologically older.

The most significant criticism of efforts to develop a functional index has been aimed at the selection of the criterion. Most of the studies have involved a regression of some type using age as the criterion (1). This strategy, however, contains a serious flaw in that the linear composite (the functional index) is formed by maximizing the prediction of age which is the variable one is seeking to replace. Any study of a functional index must consider this criticism.

If a functional age index were to be developed it would have many applications. The application of interest in this study is pilot certification. In March 1960, Federal Aviation Administration (FAA) Civil Air Regulation 40-22 was implemented which stated that "no individual who has reached his 60th birthday shall be utilized or serve as a pilot on any aircraft engaged in air carrier operations." The ruling came under immediate fire from several groups, including the Air Line Pilots Association (ALPA). In 1960, the FAA then began what was planned to be a 20-year study on pilot aging at the Georgetown Clinical Research Institute (GCRI), designed to develop a physiological aging rating (PAR). Due partly to Federal budgetary cuts, the Georgetown facility was closed in 1966 and the aging project was abandoned far short of its goal (4). The recent work by Gerathewohl is the first major work in the FAA on functional aging since the Georgetown project.

Gerathewohl's approach to the development of a functional age index involves three interacting components: (i) physiological measurement, (ii) psychological measurement, and (iii) performance measurement. He reasoned that if an individual were physiologically and psychologically healthy and could demonstrate sufficient ability to perform well, then that person could safely be allowed to fly regardless of chronological age. Gerathewohl's writings reviewed several mathematical procedures employed in efforts to develop a functional age index. He regarded the FAA medical certification examination records as one possible source of data that could be used in developing an index. The purpose of the present study was to apply mathematical procedures to the FAA pilot medical data to examine the feasibility of devising a linear numbering system such that (i) the cumulative probability distribution functions (CPDF) for persons who are not diagnosed as having an acute pathology is lower on the scale than the CPDF's for those diagnosed as having an acute pathology, and (ii) the cumulative probability distribution functions for both groups overlap minimally.

Methods.

Medical Data. Medical data were drawn from 8,600 randomly selected pilot medical certification records taken from the current FAA pilot medical certification files stored on computer at the Mike Monroney Aeronautical Center in Oklahoma City. The records were transferred via magnetic tape and placed on a VAX 11/780 computer for analyses.

Measures. The FAA medical records contain the most recent physiological measures taken by aviation medical examiners across the country for pilot medical certification. The records also contain coded information on various pathologies and abnormalities. A full listing of the measures in each record can be obtained from the FAA Aeromedical Certification Branch in Oklahoma City.

Analyses. The first step in the analyses involved variable selection. In order to view the orthogonal variable structure related to aging, a factor analysis with a varimax rotation was performed on all the measures. Loadings on factors where age loaded more highly were examined, and selection of variables was made on the basis of the factor description. The selected variables were then employed in a series of two group discriminant function analyses. Group 1 consisted of records where no pathology was listed. Group 2 consisted of records where a cardiovascular, cerebrovascular, or diabetic pathology was listed. These pathologies were selected as having an important relationship to sudden incapacitation (4). This methodology eliminates the inappropriate use of age as a criterion, replacing it with the criterion of concern, known incapacitating pathology. As a baseline for comparison, the CPDF's for the two groups were separately computed and plotted as a function of age (i.e., the cumulative probability for being a certain age or less and being in either group); the optimum classification accuracy for the two groups was then calculated. A comparison with age data was performed by calculating discriminant functions, optimum classification accuracies, and CPDF's for the two groups. CPDF's were plotted as a function of discriminant scores for (i) all 8,600 records, (ii) records for those 50 years of age and older, (iii) records for those age 55 and older, and (iv) records for those age 60 and older. Since this was a feasibility study and since a large sample size was involved, no cross-validation was done.

Results and Discussion.

Table 1 shows the factors derived from the factor analysis and the loadings for each variable. Factors were derived until the eigenvalue fell below 1.0. Three distinct factors related to age were revealed by the analysis: (i) a sensory factor (ii) a cardiovascular factor, and (iii) a blood pressure factor. These factors were used to select variables listed in Table 2 for further analysis. While these factors are congruous with prior research on aging (1), there are many other variables in the literature not included in our data base that better discriminate aging, particularly more stringent cardiovascular measures and simple performance tasks such as grip strength.

Table 1. Factors Associated with Age, Based on Selected Pilot Medical Data

Measure	Loading	Measure	Loading
Factor 1 (Sensory)		Factor 2 (Arterial-Cardiovascular)	
Distant Vision		ECG	
Right Uncorrected	.58	Having 1 defect code	.36
Left Uncorrected	.32	Having 2 defect codes	.58
Right Corrected	.56	Having 3 defect codes	.61
Left Corrected	.36	Having 4 defect codes	.65
Near Vision		Having 5 defect codes	.49
Right Uncorrected	.79	Age	.23
Left Uncorrected	.41		
Right Corrected	.79	Factor 3 (Blood Presure)	
Left Corrected	.36	Systolic	.48
Hearing		Dystolic	.51
Right Ear	.78	Age	.24
Left Ear	.79		
Age	.45		

Table 2. Measures Selected for Analyses, Based on Factor Analysis

Height	Near Vision-Right Eye Uncorrected
Weight	Near Vision-Right Eye Corrected
Hearing - Left Ear	Near Vision-Left Eye Uncorrected
Hearing - Right Ear	Near Vision-Left Eye Corrected
Distant Vision-Right Eye Uncorrected	Urinalysis - Albumin
Distant Vision-Right Eye Corrected	Urinalysis - Sugar
Distant Vision-Left Eye Uncorrected	ECG Defect Code
Distant Vision-Left Eye Corrected	Blood Pressure - Systolic
	Blood Pressure - Dystolic

Figures 1 and 2 compare the accuracy of age and the discriminant index in correctly classifying all records as pathology or nonpathology. The calculated classification accuracy listed on the figures is reflected visually in the CPDF's. Optimizing the prediction of pathology and nonpathology groups results in an overall accuracy of 61%, using age, and an accuracy of 82%, using the discriminant index. Figures 3 through 5 compare classification accuracy by using the discriminant index for a more refined grouping based on age. Figure 3 is for those 50 years and older, Figure 4 is for those age 55 and older, and Figure 5 is for those age 60 and older. The classification accuracies for the age group analyses are 78%, 81%, and 89%, respectively.

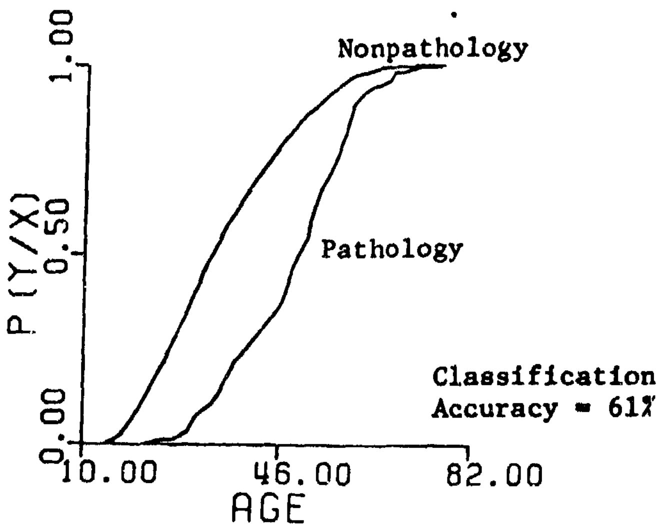

Figure 1. Cumulative probability functions for nonpathology and pathology across age.

The figures and classification accuracies present some pertinent results: (i) Age is not as accurate in discriminating between the selected sudden incapacitating pathology and nonpathology groups as is the optimized linear discriminant composite of the selected measures from medical certification records. (ii) As age increases from post-50, to post-55, to post-60, classification accuracy using the discriminant index increases monotonically. (iii) Better, perhaps more stringent, measures that predict these pathologies with more accuracy would further separate the CPDF's of the pathology and nonpathology groups, and the distance of separation would be greater as age is increased. This would result in far greater classification accuracy for all age groups, and particularly the older groups.

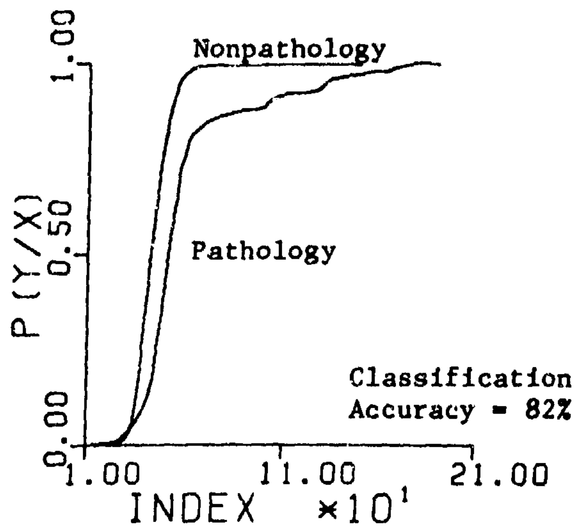

Figure 2. Cumulative probability functions for nonpathology and pathology across discriminant function score for all records.

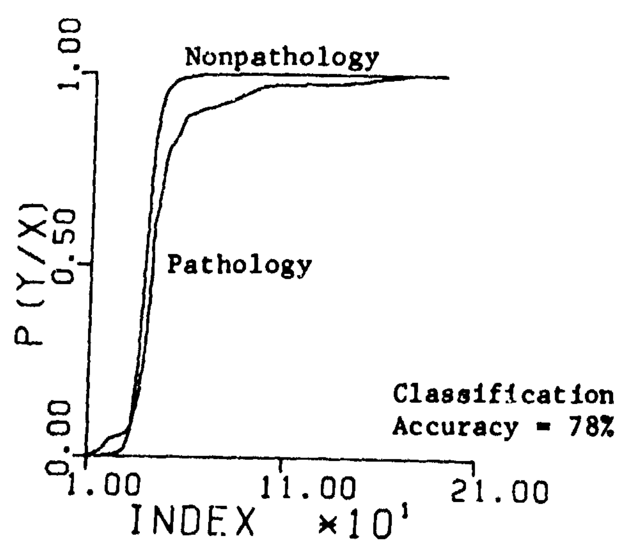

Figure 3. Cumulative probability functions for nonpathology and pathology across discriminant scores for those age 50 and older.

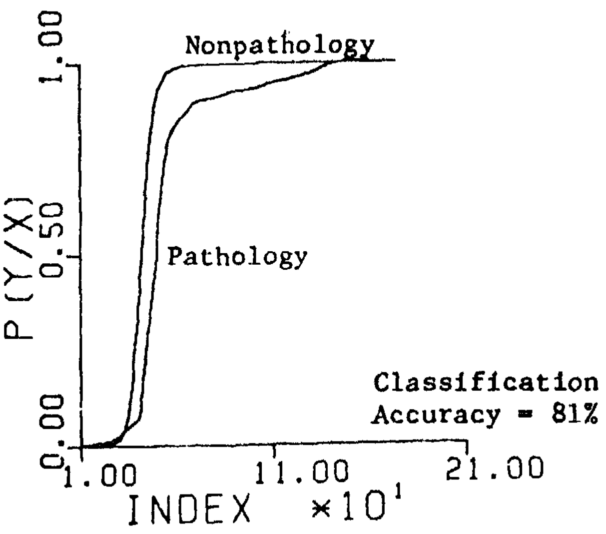

Figure 4. Cumulative probability function for nonpathology and pathology across discriminant scores for those age 55 and older.

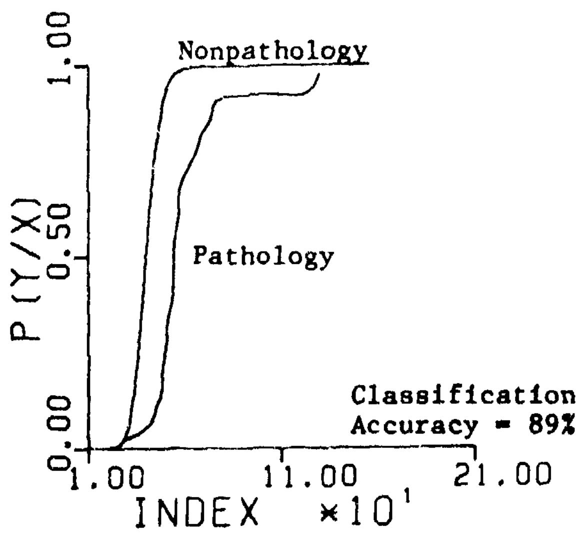

Figure 5. Cumulative probability functions for nonpathology and pathology across discriminant scores for those age 60 and older.

Based on these results, information from prior research where more stringent measures related to aging were employed, and prior research that shows a strong relationship between performance and aging, a possible strategy for future study emerges. Using the cumulative probability for pathology across age, an age where sufficient probability for acute pathology exists could be selected. For pilots above this age, more stringent physical measures, especially cardiovascular tests, could be made, and performance measures could be taken during simulator and/or actual flights. This data base could be utilized to more accurately establish pathology and to develop a refined, optimized discriminant index. After the development of the index, a sequential decision process could occur for pilot certification. Persons below the selected age could be certified through utilizing the usual process. Those above the selected age who desired to continue as pilots could be required to take a more stringent physical. Pilots with profiles with sufficiently high probability for pathology based on the more refined measures might not be medically certified. Pilots with profiles with sufficiently high probability for nonpathology could move to the next step, i.e., demonstration of pilot performance. A successful demonstration of performance could then lead to certification. This strategy could permit pilots above the selected age whose health profiles match those of healthy persons and who can demonstrate sufficient performance ability to be allowed to continue flying, while it could serve to identify those over the selected age whose health profiles match those of the pathological group and who, consequently, might not be certified.

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