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An Investigation of the Relationship Between Chronological Age and Indicators of Job Performance for Incumbent Air Traffic Control Specialists

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16. Abstract

Over the last few decades, researchers have consistently found a negative relationship between the age of Air Traffic Control Specialists (ATCSs) and both training success and ratings of job performance (Trites, 1961; Trites & Cobb, 1962; Cobb, 1967; VanDeventer & Baxter, 1984). As more ATCSs reach retirement age and the FAA prepares for renewed hiring efforts, there is a need to once again explore this issue. According to Schroeder, Broach, and Farmer (1997), the potential effects of aging on cognitive functioning, and the consequences of these changes on job performance and future training requirements, are important considerations associated with the aging of the ATCS workforce. The present study revisited the issue of ATCS age and performance using incumbent controllers and newly developed measures of job performance. A recent Air Traffic-Selection and Training (AT-SAT) concurrent validation study afforded an opportunity to investigate the relationship between age and performance using criterion measures that did not exist for previous studies. One of these measures, a computer based performance measure (CBPM), served as a measure of the technical skills necessary to effectively and efficiently separate traffic on the job. Assessment ratings of job performance by peers and supervisors also served as a criterion measure for the current study. Results of ANOVA and regression analysis revealed that, on average, older ATCSs received lower scores on measures of job performance.

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An Investigation of the Relationship Between Chronological Age And Indicators of Job Performance for Incumbent Air Traffic Control Specialists

The relationship between age and job performance for Air Traffic Control Specialists (ATCSs) is an issue that has been revisited many times over the past few decades (Trites, 1961; Trites & Cobb, 1962; Cobb, 1968; VanDeventer & Baxter, 1984). Researchers have consistently found a negative relationship between controller age and performance across studies that have used different ATCS options (enroute, terminal), career stages (age at entry into training, current age on the job), and criterion measures (on-the-job ratings, academy performance) (Trites, 1961; Trites & Cobb, 1962; Cobb, 1968; VanDeventer & Baxter, 1984). That research provided support for congressional action that mandated both hiring age limits and retirement age requirements for the ATCS job. As more ATCSs reach retirement age and the FAA prepares for renewed hiring efforts, there is a need once again to explore this issue. According to Schroeder, Broach, and Farmer (1997), the potential effects of aging on cognitive functioning, and the consequences of these changes on job performance and future training requirements, are important considerations associated with the aging of the ATCS workforce. The purpose of this paper is to use a sample of incumbent ATCSs to explore the relationship between entry-on-duty age, current age, and indicators of job performance.

In 1972, in an effort to address safety issues related to the age-performance relationship, Congress began requiring that applicants for the ATCS job not reach their thirty-first birthday prior to initial appointment (VanDenventer & Baxter, 1984). Congress also set a mandatory retirement age of 56, at which time ATCSs are removed from positions requiring the direct separation and control of air traffic (Aul, 1991). These age restrictions are not without controversy, as there has been much criticism of these policies by those people who are excluded from employment (Aul, 1991). Despite the criticism, it is hard to ignore the consistent results found by researchers who have explored the relationship between age and performance.

In his study of air traffic control trainees, Trites (1961) found a negative relationship between age and supervisor rating, which led to his conclusion that older trainees were less likely to be viewed as the best controllers. Using criterion measures that assessed both FAA Academy training and job performance, Trites and Cobb (1962) found a negative relationship between age at entry into ATC training and subsequent Academy and job performance. These results led to the recommendation that there be a maximum entry age for air traffic controllers. The underlying causes of this negative relationship were not explored by those researchers.

Cobb (1968) used a sample of journeymen radar enroute ATCSs to provide further evidence of the negative relationship between age and performance, using job performance rating as the criterion measure. Potential reasons for the lower ratings obtained by older controllers were physiological aging, lower-level aptitudes and abilities, and/or lower motivation levels (Cobb, 1968). Cobb also suggested that the lower ratings for older controllers could have been due to biased attitudes toward older people.

Cobb and Mathews (1974) explored the relationship between age, air traffic experience, and experimental ratings of job performance for terminal ATCSs at high-density airports. As found in previous studies, the results revealed a negative relationship between age and the experimental job performance evaluations. The results also demonstrated that controllers over age 40 were rated as less proficient in their jobs than younger controllers. Cobb and Mathews were reluctant to attribute these differences to physiological aging alone. They speculated that the older controllers may not have been as highly motivated as younger controllers, that the older controllers may not have been among the top controllers at any point in their career, and that the low ratings may also have been due to age bias.

VanDeventer and Baxter (1984), administered a biographical questionnaire to trainees at the FAA Academy. The results revealed a negative linear relationship between age at entry and pass/fail status after initial ATCS screening. These results supported the findings of research from nearly two decades earlier. VanDeventer and Baxter speculated that this negative relationship might have a cognitive basis.

The present study revisited the issue of ATCS age and performance using incumbent controllers and newly developed measures of job performance. It is important to note that ATCSs were not tested on their own sectors, so their actual level of performance on the job remains unknown. A recent Air Traffic-Selection and Training (AT-SAT) concurrent validation study afforded an opportunity to investigate the relationship between age and performance using criterion measures that did not exist for previous studies. One of these measures, a computer based performance measure (CBPM), served as a measure of the technical skills necessary to effectively and efficiently separate traffic on the job. Assessment ratings of job performance by peers and supervisors also served as a criterion measure for the current study. Based on previous research, both current and entry-on-duty age were hypothesized to be negatively correlated with ATCS job performance.

METHOD

Participants

A total of 1083 Full-Performance Level (FPL) enroute ATCSs, supervisors, and staff participated in the AT-SAT concurrent validation study. A minimum of 75 ATCSs from each of 12 enroute air traffic control centers (ARTCCs) volunteered to participate. Personnel employed in supervisory or staff positions were excluded from the present study, leaving 828 FPL enroute ATCSs. All participants identified themselves as being FPL ATCSs at the time of the concurrent validation; 141 had previously held a staff position and 30 had previously been supervisors. Demographic information is presented in Table 1. Almost half of the controllers were between the ages of 32 and 37 ($\underline{M}$=36.4, $\underline{SD}$=5.7), and the majority of participants were Caucasian males. The average number of years in current position was 8.3, the average entry-on-duty age was 25.0, and the average number of years as an FPL ATCS was 7.2. Current age was positively correlated with many work-related variables, such as number of years as an FPL ATCS and number of years in current position. A positive correlation was found between current age and years in

Table 1. Demographics

Variable	Number	Percent
Current Age		
31 or Younger	144	17.5
32-37	391	47.6
38-43	197	24.0
44-49	59	7.2
50 or greater	30	3.7
Entry-on-Duty Age		
23 or Younger	252	33.6
24-25	208	27.9
26-27	127	16.9
28-29	107	14.3
30-31	52	6.9
Gender		
Male	690	83.3
Female	138	16.6
Race		
American Indian	17	2.1
Asian/ Pacific Islander	5	0.6
African American	36	4.3
Hispanic	33	4.0
White	731	88.1
Other	6	0.7
Education		
H.S. or GED	68	9.1
Attended Trade School	3	0.4
Completed Trade School	15	2.0
Attended College less than 2	165	22.1
Attended College 2 or more yrs.	179	23.9
Completed College, 2 yr. Degree	55	7.4
Completed College, 4 yr. Degree	225	30.1
Attended Graduate School	38	5.1

a staff or supervisory position. The duration of these assignments was quite short, as the average amount of time spent in these positions was less than 6 months. As shown in Table 1, only 10.9% of the participants were above the age of 43. Although this number is not proportional to the other age groups, it is consistent with skewed age distributions reported by previous researchers (Cobb, 1968; Cobb & Mathews, 1974). The age of the workforce is most likely skewed due to the firing of 11,000 controllers during the 1981 Professional Air Traffic Controllers Association (PATCO) strike.

Procedure

Data collection teams were assembled and trained to conduct testing at each of the 12 ARTCCs included in the study. Each team was comprised of a test site manager and two to four team members who were responsible for administration of the predictor battery and criterion measures. All participants were volunteers in the AT-SAT concurrent validation study who were recruited through on-site briefings and an informational memo. Volunteers were tested over a two-day period in a room provided by their facility. One day of computer-based testing was devoted to the predictor test, and one day was devoted to administration of the CBPM. Due to scheduling constraints, some volunteers took all parts of the test over two consecutive days while others spread testing out over the course of the on-site data collection period.

Each volunteer also identified two peers and two supervisors to complete experimental job performance assessment ratings. The supervisor and peer raters participated in an orientation and training program to ensure valid and accurate scaling. These raters were then asked to complete the forms and submit them to the researchers.

Measures

The criterion measures used in the AT-SAT concurrent validation study also served as the controller performance measures in the current study. Both the CBPM and peer and supervisor rating scales served as measures of job performance that were compared with both entry-on-duty age and current age.

Computer Based Performance Measure. The CBPM served as a measure of the technical skills necessary to effectively and efficiently separate traffic on the job (Hanson, Borman, Mogilka, & Manning, 1998). It is a 38-item, 2-hour test where controllers are presented a series of realistic air traffic scenarios and 2 to 5 multiple choice questions pertaining to each scenario. Each question has 3 to 5 response options representing different ways in which the air traffic problems might be addressed. During administration of the CBPM, controllers were presented with scenarios and given up to 60 seconds to review each one before it was presented for scoring purposes. Each scenario lasted no more than 5 minutes. Respondents were then given 25 seconds to answer each question. Once a response was chosen, controllers were unable to return to previous items or scenarios to review information or change answers (Hanson et al., 1998). Hanson et al. (1998) reported a coefficient alpha of .59 for the CBPM, which was validated against hi-fidelity air traffic simulations.

Peer and Supervisor Rating Scales. The peer and supervisor ratings are behavior-based scales with 10 dimensions and one overall effectiveness scale (see Appendix A). Rating standards, which describe controller proficiency at different effectiveness levels in an effort to make ratings more objective, are provided below each of the 10 dimensions. These rating standards were developed as part of the AT-SAT concurrent validation study (Borman, Hedge, Hanson, Bruskiewicz, Mogilka, Manning, Bunch, & Hogen, 1999). Raters were asked to read each category definition and rating standard, then compare the current effectiveness of the controller being rated with that standard. Ratings were made on a seven-point scale and were later combined to produce an overall criterion rating score. As shown in Table 2, the rating score was moderately but significantly correlated with the CBPM score. It should be noted that these ratings were completed independently of CBPM administration.

Analyses

The linear relationship between age and job performance was analyzed using Pearson's product-moment correlation. Analysis of variance (ANOVA) and post-hoc multiple comparison procedures were used to identify significantly different group means.

Although previous research has found a linear negative relationship between age and performance, an examination of bivariate scatterplots raised the possibility of a curvilinear relationship. Therefore, hierarchical polynomial regression analysis was used to assess the form of the relationship between age and performance. For each measure of job performance, age was entered into the equation first, followed by the age-squared (quadratic) term. If the relationship between age and job performance is primarily linear, then age alone should explain a significant proportion of the criterion variance, and the quadratic term that is subsequently added should not account for a significant change in R^2. If the quadratic term explains a significant proportion of the variance beyond the age term, then there is evidence of a curvilinear relationship between age and job performance.

RESULTS

Results are divided into two main sections based on age classification. The first section contains results of analyses using entry-on-duty age, whereas current age was used in analyses described in the second section.

Entry-on-Duty Age

Correlations. As shown in Table 2, there was little support for the hypothesized relationship between entry-on-duty age and performance. Entry-on-duty age was negatively correlated with peer and supervisor rating score ($\underline{r}$= -.07, $\underline{p}$<.01); however, this correlation is very small. The statistical significance of the relationship is likely due to the power of the test as influenced by the large sample size. Entry-on-duty age was not significantly correlated with CBPM score. Table 2 also shows a correlation between the CBPM and peer and supervisor rating score. Table 3 contains the results of Pearson product-moment correlations between age and variables related to work history. Entry-on-duty age was not significantly correlated with any of the work-related variables included in this table.

Prediction of Performance. The relationship between entry-on-duty age and criterion measure scores was explored further using hierarchical polynomial regression to predict performance. Two separate regression analyses were performed with entry-on-duty age as the predictor and CBPM and rating scores serving as dependent variables. Results revealed that entry-on-duty age did not significantly predict either CBPM or the experimental rating scores. Entering the quadratic term into the equation did not result in a significant change in R^2, providing no evidence of a curvilinear relationship between entry-on-duty age and the criterion measures.

Group Comparisons. Mean criterion scores for different age groups were compared using one-way ANOVA. Separate ANOVAs were performed for the CBPM and rating score, the results of which are presented in Table 4. No significant differences were found between entry-on-duty age groups for either the CBPM score or rating score.

Current Age

The results of analyses using current age as the independent variable provide partial support for the hypothesized relationship between age and performance. The results demonstrate that the relationship is curvilinear rather than linear.

Correlations. The results of Pearson product-moment correlations between current age and criterion measures are presented in Table 2. These correlations do not support the hypothesized negative linear relationship between current age and job performance. Although the very low correlation between current age and rating score was statistically significant (r=.08, p<.01), this is likely due to the power of the analyses as influenced by sample size. As shown in Table 3, current age was significantly correlated with entry-on-duty age (r=.47, p<.01), years as an FPL ATCS (r=.78, p<.01), years in current position (r=.72, p<.01), years in previous job (r=.16, p<.01), years in staff position (r=.40, p<.01), and years as supervisor (r=.27, p<.01).

Prediction of Performance. The relationship between current age and performance on the criterion measures was explored further using hierarchical polynomial regression. Two regression analyses were performed with current age as the predictor, and CBPM and rating score serving as dependent variables.

As shown in Table 5, age did not significantly contribute to the prediction of the CBPM score when entered into the regression equation. However, the quadratic term, or age-squared, did contribute significantly when added (R^2=.04), providing evidence of a curvilinear relationship. This relationship is depicted in Figure 1, which reveals that the predicted CBPM score increases gradually until approximately age 35, before declining after age 42.

Hierarchical polynomial regression also revealed a quadratic relationship between current age and peer and supervisor rating score. As shown in Table 6, only the quadratic model produced a significant R^2 change in predicting the overall rating score ($\underline{R}^2$=.02).

Table 2. Correlation of Age and Criterion Measures

Variable	Mean	S.D.	1	2	3
1. Current Age	36.4	5.7	1.0		
2. Entry-on-Duty Age	25.0	3.2	.47*	1.0	
3. CBPM	191.2	14.3	-.04	.02	1.0
4. Peer and Supervisor Rating	5.1	.97	-.08*	-.07*	.25*

* p<.01

Table 3. Correlates of age

	Mean	S.D.	1	2	3	4	5	6	7
1. Current Age	36.4	5.7	1.0						
2. Entry-on-Duty Age	25.0	3.2	.47**	1.0					
3. Years FPL ATCS	7.2	5.4	.78**	-.01	1.0				
4. Years in Current Position	8.3	5.9	.72**	.00	.81**	1.0			
5. Years in Previous Job	3.2	2.7	.16**	.05	.18**	.06	1.0		
6. Years Staff Position	.45	1.1	.40**	.04	.36**	.15**	.06	1.0	
7. Years Supervisor	.13	.69	.27**	.04	.21**	.05	.07	.35**	1.0

* p<.05
** p<.01

Table 4. Group Means and Results of One-way ANOVA of Criterion Measures by Entry-on-Duty Age Group

Entry-on-Duty Age

Job Performance Measure	23 and younger	24-25	26-27	28-29	30-31	F
CBPM	191.72	191.12	190.47	192.53	193.90	.72
Peer and Supervisor Rating Score	5.19	5.14	5.01	5.04	5.13	1.83

* p<.05

Table 5. Regression of Current Age on CBPM Score

Variable	B	B	ΔR^2
Current Age	4.68	1.82	.00
Current Age^2	-.06	-1.88	.04**
			R^2=.04
			Adj. R^2=.04
			R=.21**

**p<.01

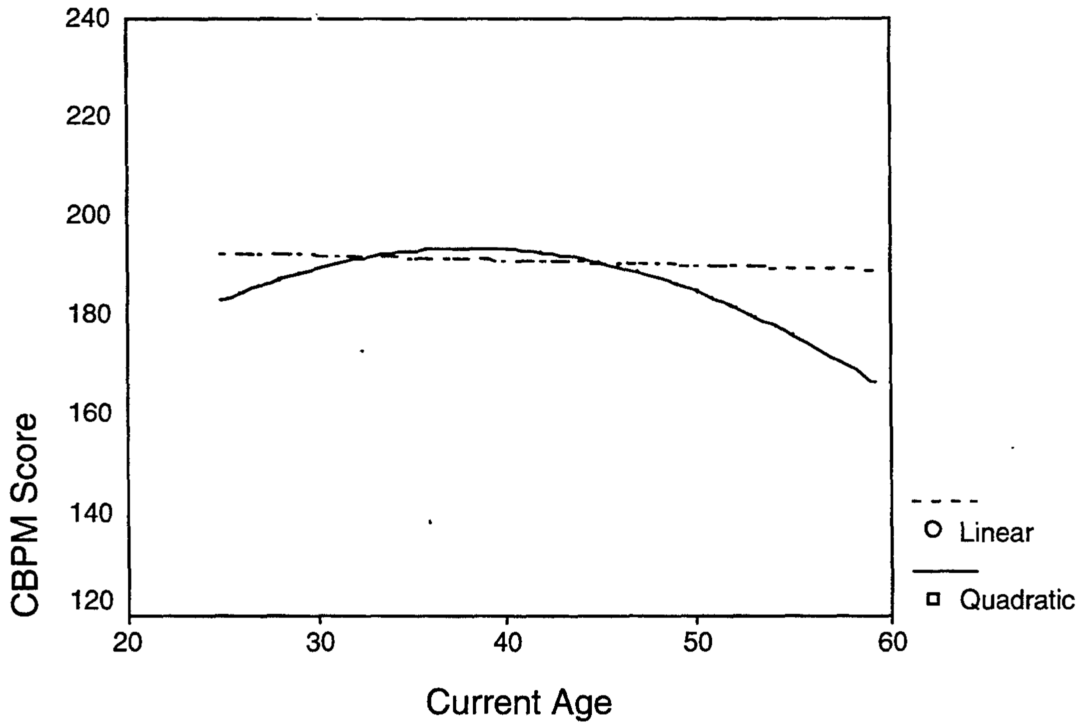

Figure 1. Regression of Current Age on CBPM

Table 6. Regression of Current Age on Peer and Supervisor Rating Score

Variable	B	β	ΔR^2
Current Age	.160	1.26	.00
Current Age^2	-.002	-1.19	.02**
			R^2=.02
			Adj. R^2=.02
			R=.15**

**p<.01

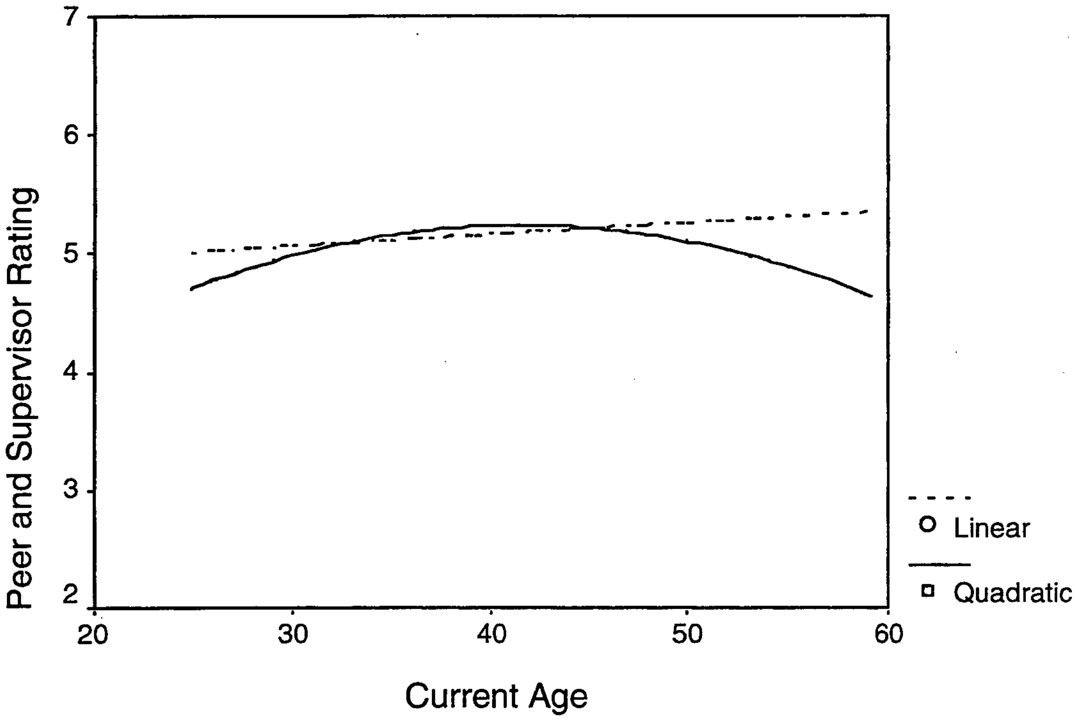

Figure 2. Regression of Current Age on Peer and Supervisor Ratings

Table 7. Group Means and Results of One-way ANOVA of Criterion Measures by Current Age Group.

Job Performance Measure	Current Age: 31 and younger	32-37	38-43	44-49	50 or Older	F
CBPM	189.10	192.51	193.36	190.54	178.54	7.33**
Peer and Supervisor Rating Score	4.98	5.10	5.22	5.44	4.75	6.89**

** $p<.01$

This relationship, plotted in Figure 2, suggests that peer and supervisor rating scores begin to decrease at approximately age 45.

Group Comparisons. A one-way ANOVA was performed for each criterion measure to determine differences in mean scores based on current age. The results of these analyses, which are summarized in Table 7, show significant age differences for each measure of controller performance. Tukey post-hoc comparisons were performed to determine which of the age groups differed significantly in terms of scores and ratings.

Results revealed that the mean CBPM score of 178.54 for controllers who were 50 or older was significantly lower than CBPM scores for controllers of the other age groups ($p<.01$). Figure 3 shows that

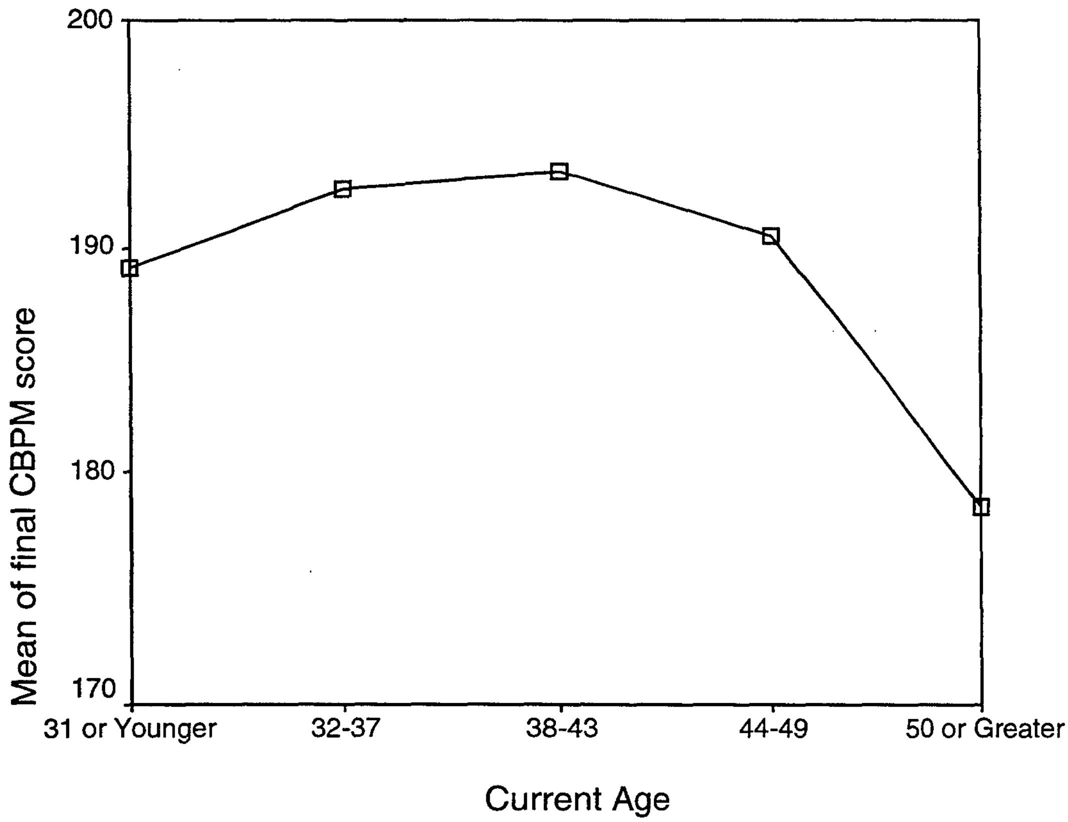

Figure 3. Mean CBPM Score for Current Age Group

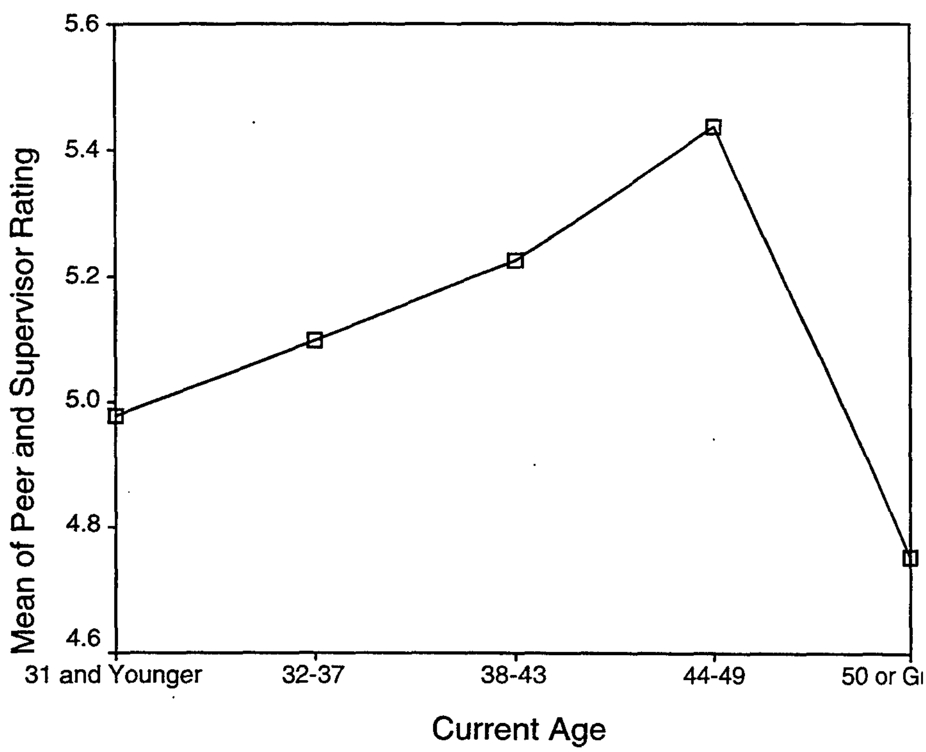

Figure 4. Mean Peer and Supervisor Ratings for Current Age Group

mean CBPM scores gradually increased with age until peaking for ATCSs in the 38-43 age range. Mean CBPM was lower for controllers age 44-49, then dropped significantly for ATCSs age 50 or older.

As shown in Table 7, significant age differences also existed for peer and supervisor ratings (F=6.72 (4, 744), p<.01). Tukey Post-hoc comparisons revealed that the mean rating score of 5.44 (SD=.65) for controllers age 44-49 was significantly higher than the ratings of controllers ages 31 and younger (M=4.98, SD=.60), 32-37 (M=5.10, SD=.72), and 50 and older (M=4.75, SD=.87). Furthermore, mean peer and supervisor ratings for controllers age 38-43 (M=5.22, SD=.68) was significantly higher than the ratings given to controllers age 31 and younger (M=4.98, SD=.60) and 50 and older (M=4.75, SD=.87).

The mean peer and supervisor criterion ratings for each age group are plotted in Figure 4. Mean peer and supervisor rating increased for each age group before peaking for ATCSs between the ages of 44-49. As discussed above, the decrease in mean rating for ATCSs ages 50 and older is statistically significant.

DISCUSSION

The results of statistical analyses, particularly hierarchical polynomial regression, provide evidence of a curvilinear relationship between age and ATCS performance. An examination of the linear relationship between age and job performance generally yielded non-significant results. However, the results of linear analyses do not provide a complete understanding of the relationship that exists between age and performance.

Entry-on-Duty Age

Inclusion of entry-on-duty age in this study provided an opportunity to investigate the existence of differences in performance that are based on the age at which current FPL ATCSs entered duty. Results of the analyses described above demonstrate no relationship between entry-on-duty age and performance on the CBPM. A small, but statistically significant, negative correlation was found between entry-on-duty age and peer and supervisor ratings. The ANOVA yielded non-significant results; there were no significant differences in CBPM score and rating score for people who entered duty at different ages. The results of regression analyses failed to demonstrate a relationship between entry-on-duty age and CBPM and rating scores. Since the sample of ATCSs used in this study was restricted by the hiring-age limit, no assumptions can be made regarding the potential performance levels of people hired over the age of 31. However, it should be noted that earlier research found differences in ratings when the age range went to 39 years (Cobb, 1968). The current sample is also restricted in terms of ATCS performance level, since it is comprised of only those people who succeeded through training; people who failed training are not currently employed as controllers.

Current Age

There is strong evidence to suggest that the relationship between current age and job performance is not linear. Although previous research revealed a negative linear relationship (Trites, 1961; Trites & Cobb, 1962; Cobb, 1968), such results were not found in the current study. Analyses reveal that the relationship between current age and performance is, in fact, curvilinear; performance scores increased with age until ATCSs reached their mid 30s. Performance then leveled off until ATCSs reached their mid 40s, when scores dropped.

Evidence of a curvilinear relationship between current age and performance was provided by the results of hierarchical polynomial regression, as well as analysis of variance. The patterns of relationship that were found between current age and the two criterion measures are similar, which is important given that the CBPM represents an objective measure of performance on air traffic-related tasks and was administered independently of the more subjective peer and supervisor ratings. The reported R-squares of .04 and .02 indicate that current age does not explain a large percentage of the variance in controller performance. These results, however, do reveal the trend of the relationship between these variables. Predicted CBPM score increased with age before peaking for ATCSs in their mid-30s through mid 40s. At approximately 45 years of age, predicted CBPM score begins to decrease and drop to a level below that predicted for the youngest and newest controllers. A similar pattern was found when using current age to predict peer and supervisor rating.

Plotting the mean CBPM and rating scores for controllers of different age groups provides another illustration of the relationship between current age and performance. Mean CBPM scores increased with age until reaching their highest point for controllers in the 38-43 year age range. The mean score then decreased for those age 44-49 before dropping significantly for those 50 or older. The mean CBPM score for controllers 50 and older was significantly lower than that of controllers from all of the other age groups. Peer and supervisor ratings are highest for the ATCSs between the ages of 44 and 49, before dropping significantly for ATCSs age 50 and greater.

The results of the comparisons of current age and measures of ATCS performance provide evidence of a general decline in performance for controllers once they reach their late 40s. The regression lines described above indicate that the drop in performance level begins to occur around age 45. The comparisons of group means clearly demonstrate that the level of performance, as measured by the CBPM and experimental rating score, is significantly lower for those controllers age 50 and older. Since the upper age range is restricted due to mandatory retirement, the extent to which this downward trend would continue for older controllers is unknown. One caveat with these findings is that the number of people included in this study who were 50 or over is much smaller than the number of people from other age groups, suggesting that the mean criterion scores for the older ATCSs may not be as robust.

The finding that, as a group, older controllers have lower ratings of job performance is consistent with findings of previous researchers who have explored this issue. However, previous studies have found this to be a negative linear relationship, whereas the current study provides evidence of a curvilinear relationship. Scores on the current measures of job performance actually increased with age until ATCSs entered their late 30s, indicating that job performance increases with air traffic experience. The strong positive correlation between current age and work experience indicates that younger controllers had less experience than older controllers. Given that more experience on the job should result in increased skill and learning, it is not surprising that people with more experience would have higher performance scores and ratings. As reported earlier, however, there is a point at which scores on these job performance measures no longer increase, and actually decrease, with age and despite experience. In the current study, performance scores decreased to the point that people over the age of 50 performed at a level that was lower than that of younger controllers who had much less job experience.

Limitations of the Study

There are limitations to this study that must be considered when reviewing the results and conclusions that are presented. All of the ATCSs who participated in this study were volunteers. It is therefore likely that controllers uncomfortable with their level of performance chose not to participate. This may be particularly likely for older controllers, since their average level of performance was found to be lower than that of younger controllers. Consequently, the older ATCSs included in this study may represent the better performers from that particular age group, resulting in an under-estimation of the age-related decline in job performance.

Although the CBPM used in this study provided valuable information about ATCS's ability to perform simulated tasks, it does not provide evidence of actual job performance since the ATCSs were not performing tasks using the airspace they work with on a daily basis. The experimental peer and supervisor ratings, however, did relate to actual performance on the job. The cross-sectional approach of this study also creates limitations. Conclusions regarding changes in ability are based on the assumption that ATCSs possess skill and ability levels that are relatively equal following training. Consequently, lower performance levels among older ATCSs would be attributed to decline in ability rather than to a lower level of ability throughout their career. One mitigating factor that must be considered is that the best performers are often promoted into supervisory positions. This means that the average performance level of older controllers may be lower because the "best" ATCSs of this age group are no longer actively controlling traffic. A longitudinal study of age, so that individuals are tracked throughout the course of their career, is the only way to determine the extent to which performance levels change over time, as well as the manner in which this change occurs.

CONCLUSION

Over the years, researchers have speculated about the possible causes of the decline in training and job performance scores with age (Trites, 1961; Trites & Cobb, 1962; Cobb, 1968). The most likely cause of the decline in job performance measures is an age-related decline in cognitive ability. Such a decline has been found in other studies, including those that have focused on cognitive decline in older pilots (Hardy & Parasuraman, 1997). Cobb (1968) speculated that lower performance ratings could have been the result of, among other interpretations, age bias on the part of the rater. The current study does not support that option: Controller's scores on the CBPM, which is an objective criterion measure, were positively correlated with peer and supervisor criterion assessment ratings. The pattern of relationship between current age and performance was relatively consistent across all criterion measures. Such a consistent pattern would not be expected if either the CBPM or the ratings were inaccurate or biased.

As the ATCS workforce ages and reaches retirement age, the actual job performance of older controllers becomes a more important issue. The present study provides experimental evidence that controllers over the age of 50 perform, on average, at a level that is lower than that of young controllers with little experience. They also perform, on average, at a level that is significantly lower than ATCSs who are just a few years younger. Although only a small percentage of the controllers in this study were age 44 or older, it is only a matter of time before the bulk of controllers reach this age. Almost one-half of the ATCSs included in this study were between the ages of 32-37. In 10 years time, the majority of these controllers will begin entering the age range at which predicted job performance level begins to decline.

Since work experience and current age are highly correlated (as shown in Table 3), it is not possible to disconnect the effects of these two variables. The curvilinear nature of the relationship between ATCS age and performance scores suggests that the youngest controllers are not necessarily the best. The regression lines shown in Figures 1 and 2 suggest that there is a ten-year span of time, between the ages of approximately 35 and 45, in which ATCSs are at their peak level of performance. It seems that ATCSs need to have a certain amount of work experience, or "seasoning," before they reach this peak performance level. The extent to which older controller's performance would have declined had they not had at least 10 years work experience, is unknown. It is likely, however, that they would not have peaked at a level as high as other controllers before experiencing age-related decline.

The mandatory ATCS retirement age means that the FAA loses its most experienced controllers when they may no longer be the best performers. However, this does not necessarily mean that they are no longer capable controllers. This raises questions about the level of ATCS performance considered "good enough" to continue separating traffic. Thus far, there is no apparent answer to this question. ATCSs work in an environment where there are sector differences and workload variability. Since changes in sector or workload may affect controller performance level, additional information is needed to better understand how they operate in sectors with different workload demands and conditions. It is important to understand whether or not expertise helps older controllers cope with novel or demanding situations as they control traffic. Another question that arises when considering the mandatory retirement age is whether or not modifications to the ATC work environment would compensate for possible age-related declines in performance. It should also be noted that not all older ATCSs exhibit a lower performance level; in fact many over the age of 45 achieved performance scores higher than those attained by younger controllers. When viewed as a group, older ATCSs are found to have lower levels of performance.

Since ATCS work in a safety-related occupation, the importance of understanding the relationship between current age and job performance cannot be over-emphasized. As has been the case with earlier studies, the current study cannot provide definitive reasons for the decline in performance scores that occurs for older controllers. To have a better understanding of this dynamic, it is important that this issue be studied in a more comprehensive manner, where age and performance are the specific research issues under investigation. An opportunity to conduct a longitudinal study of age and performance exists now that the FAA plans to increase its hiring efforts over the next several years. It is recommended that new ATCSs be tracked throughout their careers, with job performance being measured periodically to study the manner in which performance changes with age.

REFERENCES

Aul, J.C., (1991). Employing air traffic controllers. In H. Wing & C.A. Manning (Eds.). *Selection of air traffic controllers: Complexity, requirements, and public interest* (pp. 7-12). (DOT/FAA/AM-91/9). Washington, D.C. Federal Aviation Administration Office of Aviation Medicine. Available from: National Technical Information Service, Springfield, VA 22161; order # ADA238267.

Borman, W.C., Hedge, J.W., Hanson, M.A., Bruskiewicz, Mogilka, H., Manning, C., Bunch, L.B., & Horgen, K.E. (1999). *Development of Criterion Measures of Air Traffic Controller Performance.* (DOT/FAA/OAM Technical Report). Manuscript under review.

Cobb, B.B. (1968). Relationships among chronological age, length of experience, and job performance ratings of air route traffic control specialists. *Aerospace Medicine, 39,* 119-24.

Cobb, B.B., & Mathews, J.J. (1974). The relationships between age, ATC experience, and job ratings of terminal area traffic controllers. *Aerospace Medicine, 45,* 56-60.

Hardy, D.J., & Parasuraman, R. (1997). Cognition and flight performance in older pilots. *Journal of Experimental Psychology: Applied, 3(4),* 313-48.

Hanson, M.A., Borman, W.C., Mogilka, H.J., & Manning, C. (1998). *Computerized assessment of skill for a highly technical job.* Unpublished manuscript.

Schroeder, D.J., Broach, D., & Farmer, W.L. (1997). *Current FAA Controller Workforce Demographics, Future Requirements, and Research Questions.* In R.S. Jensen & L.A. Rakovan (Eds.) Proceedings of The Ninth Annual International Aviation Psychology Symposium, (pp. 135-41). Columbus, Ohio: The Ohio State University.

Trites, D.K. (1961). *Problems in air traffic management: I. Longitudinal prediction of effectiveness of air traffic controllers.* (DOT/FAA/AM-61/1). Oklahoma City, OK: FAA Civil Aeromedical Research Institute. Available from: National Technical Information Service, Springfield, VA 22161; order # AD268954.

Trites, D.K. & Cobb, B.B. (1962). *Problems in air traffic management: III. Implications of age for training and job performance of air traffic controllers.* (DOT/FAA/AM-62/3). Oklahoma City, OK: FAA Civil Aeromedical Research Institute. Available from: National Technical Information Service, Springfield, VA 22161; order # N62-10353.

VanDeventer, A.D., & Baxter, N.E. (1984). Age and performance in air traffic control specialist training. In VanDeventer, A.D., Collins, W.E., Manning, C.A., Taylor, D.K., & Baxter, N.E. Studies of poststrike air traffic control specialist trainees: I. Age, biographical factors, and selection test performance related to academy training success. (DOT/FAA/AM-84/6). Washington, D.C. Federal Aviation Administration Office of Aviation Medicine. Available from: National Technical Information Service, Springfield, VA 22161; order # ADA147892.

APPENDIX A

PERFORMANCE CATEGORIES FOR PEER AND SUPERVISOR RATING SCALES

A. Coordinating
Coordinating with other controllers to minimize traffic problems; coordinating clearances, changes in aircraft destinations, altitudes, etc. as appropriate; initiating and receiving handoffs and pointouts in an effective manner; presenting the rationale for instructions to pilots or other controllers as necessary.

B. Communicating and Informing
Using clear, concise, accurate language to get message across unambiguously; talking only when necessary and appropriate; employing proper phraseology to ensure accurate communications; notifying pilots/controllers/ other personnel of information that might affect them as appropriate; issuing advisories and alerts to appropriate parties; providing complete and accurate position relief briefings; providing accurate and legible flight strip information; listening carefully to requests and instructions (e.g., from pilots, other controllers) and ensuring that they are understood; attending to readbacks and ensuring that they are accurate.

C. Maintaining Attention and Vigilance
Scanning properly for air traffic events, situations, potential problems, etc.; keeping track of equipment/ weather status; identifying unusual events, improper positioning of aircraft, equipment malfunctions, etc.; recognizing when aircraft have potential for loss of separation; verifying visually that control instructions are followed; recognizing potential problems in adjacent sectors; remaining vigilant during slow periods.

D. Managing Multiple Tasks
Keeping track of a large number of aircraft/events at a time; conducting two or more tasks simultaneously (e.g., issuing instructions while scanning the screen; monitoring pilot communications while writing on strips); remembering and keeping track of aircraft and their positions; remembering what you were doing after an interruption; returning to what you were doing after an interruption and following through; providing pilots with additional services as time allows.

E. Prioritizing
Taking early or prompt action on air traffic problems rather than waiting or getting behind; knowing what to do first and which are the most important situations to work on; recognizing that some problems or situations are less important and can wait; preplanning before busy periods; organizing the board and using flight strips effectively to keep priorities straight for handling air traffic situations; quickly and decisively determining appropriate priorities.

F. Technical Knowledge
Knowing the equipment and its capabilities and using it effectively; knowing aircraft capabilities/limitations (speed, wake requirements, size, minimums) and using that knowledge; keeping up-to-date on letters of agreement, changes in procedures, regulations, etc.; keeping up-to-date on seldom used procedures or skills.

G. Maintaining Safe and Efficient Air Traffic Flow

Reacting to and resolving potential conflictions effectively and efficiently; using proper air traffic separation techniques effectively to ensure safety; sequencing aircraft effectively for arrival or departure; sequencing aircraft to ensure efficient/timely traffic flow; controlling traffic in a manner that ensures efficient traffic flow; controlling traffic in a manner that minimizes traffic problems (e.g., conflictions, traffic flow problems) for other controllers and pilots.

H. Reacting to Stress
Remaining calm and cool under stressful situations; handling stressful air traffic conditions in a professional manner.

I. Teamwork
Working smoothly with supervisors and other controllers in the facility; pitching in and helping other controllers as necessary; accepting and reacting constructively to appropriate criticism from supervisors or peers; avoiding arguments and interpersonal conflicts with other controllers, supervisors, or pilots.

J. Adaptability/Flexibility
Reacting effectively to difficult equipment problems, changes in weather, traffic situations, etc., or to unexpected actions on the part of other controllers or pilots; using contingency or "fall-back" strategies effectively when unforeseen/unanticipated air traffic problems emerge or if first plan doesn't work; asking for help when it's needed; developing/executing innovative solutions to air traffic problems; dealing effectively with situations for which there may not be clearly prescribed procedures, situations which require novel thinking; adapting to equipment updates, new kinds of procedures, etc.