AGE, FLIGHT STRIP USAGE PREFERENCES, AND STRIP MARKING

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To accommodate new technologies, U.S. air traffic controllers must eventually convert from paper flight progress strips to Electronic Flight Data Replacements (EFDRs). It is anticipated that controllers may be reluctant to accept decision support tools (DSTs) and EFDRs. It would be useful to identify factors predicting EFDR resistance because failure to use these tools would reduce projected capacity gains. We analyzed data from 2 studies to determine if age and preferences for strips would predict strip marking and the ability to use a procedure that allowed removing strips early. In the first study, we found that older controllers said they preferred strips more than younger controllers and a preference for strips predicted two types of frequent strip markings. However, age did not predict overall strip marking. In the second study, we found that older controllers could use an experimental strip reduction procedure effectively. We expected that age alone would predict strip usage. The results suggest that age and a preference for strips may predict EFDR transition problems.

Introduction

Air traffic control (ATC) decision support tools (DSTs) are being developed for the Federal Aviation Administration's (FAA's) en route air traffic controllers. DSTs will integrate ATC information to enable controllers to increase services to pilots without decrements to aviation safety. The effectiveness of the DSTs will depend on the accuracy and completeness of flight plan information input to the software. Flight plan updates are currently recorded on paper flight progress strips but not all are entered in the computer. Conversion from paper strips to electronic flight progress data is necessary to update the DST's information.

At all but six en route centers, flight data are displayed on paper flight progress strips (see Figure 1). Flight strips contain information about an aircraft's flight plan. Besides containing printed flight plan data, flight strips also are used to record actions taken for an aircraft, including information not entered in the en route HOST computer, such as headings and speeds issued to pilots. Controllers write on flight strips as a reminder that they completed a task or need to do something later. Controllers write on, point to, or offset flight strips to communicate with another controller. Finally, controllers use times on strips to assess when several aircraft will arrive at a fix to determine whether they will conflict. Although most flight plan information is available on the computer, some controllers prefer strips instead of the computer for accessing flight plan information.

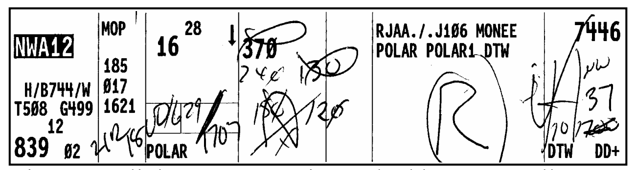

Figure 1. Flight progress strip marked by a controller.

Some DSTs include electronic flight progress data similar to what is printed or written on paper strips. Electronic flight data replacements (EFDRs) built into these DSTs incorporate important functions of paper flight strips. For example, speeds and headings currently written on a strip can instead be typed into a speed/heading field on an EFDR. Data can be entered in a free text field to annotate tasks that have already been completed or plan future tasks. Highlighting an entry can signal that something needs to be done with the aircraft. DSTs will identify potential conflicts in advance so controllers can resolve them more quickly and, thus, do not need to use strips for that purpose.

If, instead of writing on flight strips, a controller enters data into an EFDR, then the accuracy of the DST's data will be improved. The controller can use electronic flight data in essentially the same way as flight strips. Flight strips must be eliminated because, if controllers spend time writing, posting, sorting, and removing strips from the strip bay, they have less time to use a DST effectively. And, if controllers try to maintain both paper and electronic flight data, their workload could increase dramatically. It is anticipated that controllers may be reluctant to accept DSTs and EFDRs. Failure to use these tools would reduce projected capacity gains expected when the presence of EFDRs allows pilots to utilize more flexible routes. Thus, it would be useful to identify factors predicting resistance to EFDRs.

We wondered if a controller's age might predict EFDR resistance. Age seems important for three reasons. First, the U.S. air traffic controller workforce is aging. Second, a negative relationship has been found between age and cognitive functioning, performance, and learning new skills. Third, age is often claimed to be negatively related to acceptance of new technologies.

The controller workforce is aging. Most of the current ATC workforce was hired between 1981 and 1985 after the 1981 controller strike. Although most occupations include workers with a wide range of ages, the U.S. ATC workforce consists of a large group of employees of about the same age. The average age of 8,159 controllers hired between 1981-1983 was 26.3 and of another 4,278 controllers hired between 1985-1987 was 25.9 (Collins, Nye, & Manning, 1990). The General Accounting Office (GAO, 2002) reported that controllers' average age, as of June 30, 2001, was 43.

A negative relationship has been found between age, cognitive functioning, performance, and learning of new technologies. Many studies (see Light, 1991, for a review) found a negative relationship between age and performance on memory and cognitive ability tests. Many studies suggest that older controllers will have more trouble than younger ones with tasks involving remembering or problem-solving. This conclusion is supported by Heil's (1999) finding of a curvilinear relationship between age and performance on an ATC computer-based performance measure (CBPM) serving as a job performance criterion. Performance on the CBPM began declining for the 44-49 age group and the decline accelerated for the 50+ age group.

However, the practical significance of these results must be questioned. It appears that age-related decrements in cognitive processing are partly compensated for by expertise (Charness & Bosnman, 1990; Salthouse, 1990). The difficulty in describing compensation involves the tasks used in many aging studies, which are often different than those typically performed by older adults. For example, Salthouse, Babcock, Skovronek, Mitchell, & Palmon, (1990) found that older architects performed worse than younger ones on spatial visualization tests, regardless of their architectural experience. The architects indicated that the tests "seemed to involve processes similar to those used in producing or interpreting drawings of three-dimensional objects." Perhaps the ability tests were not similar enough to typical architectural tasks for older architects' experience to compensate.

Morrow, Leirer, Altieri, & Fitzsimmons (1994) examined how pilots' expertise compensated for age. They found that compensation occurred when the experimental materials and procedures were directly related to flying (e.g., ATC communications) but not when materials and procedures were only indirectly related to flying (e.g., memorizing a map.)

Age is claimed to be negatively related to acceptance of new technologies. It is often assumed that older adults are resistant to new technology (Meyer, Rogers, Schneider-Hufschmidt, Grace, Spaulding-Johnson, & Mead, 1998). The NPR/Kaiser/Kennedy School Survey of American adults on technology (2000) also found that adults over age 60 are less likely than younger adults to have a computer, and most older adults do not believe that not having a computer is a problem. On the other hand, Al-awar Smither & Braun, (1994) found that older adults' use of Automatic Teller Machines (ATMs) was more related to mechanical ability than age. Older adults who did not use ATMs had lower mechanical ability than those who did.

The applicability of these results to the ATC workforce is unclear. Age-related decrements have been found in some memory and performance tasks, but these decrements may be compensated for by experience, if the tasks are sufficiently familiar. And many aging studies assessed performance of adults older than most controllers. How might compensation affect the acceptance of an EFDR? Most EFDRs contain the same information as paper strips, but format it differently. Most data entry and retrieval methods for EFDRs (keyboard/ trackball vs. pen) are also different from writing on strips. So, on one level, using an EFDR to retrieve or record flight data may be considered similar to using strips but, on another level, could also be considered very different. We might expect an older controller would find it more difficult to learn and use an EFDR than a younger controller, depending on the perceived similarity between strip usage and EFDR interaction.

It is also possible that older controllers can use EFDR but will be more resistant than younger controllers. However, because they are younger than older participants in many research studies, "older" controllers may not be as resistant to new technology as other older adults. Assertions about older controllers' low resistance are supported by Hilburn & Flynn's (2001) findings from an ATM technology survey completed by 79 controllers at 7 European Centers. They found that older controllers *disagreed* more often than younger controllers with the statement "I do not trust new ATC technology, even though it is designed to make my job easier."

Presently, we do not have data concerning controllers' acceptance of an EFDR. Before those data become available we can, however, examine other information that may allow us to identify variables that predict resistance to new technologies. We are interested in relationships between age, preferences for using flight strips, and observed strip usage. Over the years, en route controllers developed strategies for controlling traffic that relied upon a set of tools (radar display, strips, procedures, etc.). Controllers' performance was evaluated on the basis of whether they used the tools properly. Thus, all controllers knew how to use the tools but not all relied upon them to the same degree. So when an EFDR that eliminates flight strips is introduced, then controllers must learn how to control traffic with the EFDR and unlearn how to control traffic with strips. It makes sense that the cognitive slowing that comes with age might interact with a preference for strips to make it difficult to control traffic in a different way.

Age alone might predict resistance to accepting EFDRs. If that is true, then older controllers should express strong preferences for using strips. Older controllers should also mark and manipulate strips more often and might also have more problems than younger controllers when changing the way they use strips. On the other hand, perhaps age is not the only factor that predicts resistance. Perhaps a preference for using strips is as strong a factor as age in predicting resistance. If this were true, then controllers who prefer using strips might mark and manipulate them more often and might also have problems changing procedures for interacting with flight data.

This paper presents data from two studies concerning controller age, reported strip preferences, and observed strip usage. The first study (Durso, Batsakes, Crutchfield, & Manning, under review) observed controllers' paper flight strip usage at five centers. The data relevant to this study were age and strip usage preferences for a subset of controllers, matched with their observed strip usage. The second study (Truitt, Durso, Crutchfield, Moertl, & Manning, 2000) tested a procedure that allowed controllers to take strips down early for certain flights. The data relevant to this study were subjects' age and strip usage during the experiment. The following hypotheses described our expectations about the results of these two studies:

Hypothesis 1: Older controllers will prefer using paper strips more than younger controllers. We expected that older controllers would prefer paper strips to obtain flight data more than younger controllers. Older controllers received more extensive training on the use of strips because nonradar control was more common and system failures occurred more often. Also, controllers are evaluated on their use of strips, so, over the years, older controllers have been evaluated more often than younger controllers on their use of strips.

Hypothesis 2: Older controllers and those who preferred using strips will mark and use them more often. Again, older controllers who were evaluated on their strip usage more often should have incorporated strip marking and usage behaviors into their daily activities.

Hypothesis 3: Older controllers, especially those who prefer using strips, will not be able to utilize a reduced strip marking/posting procedure as easily as younger controllers, especially those who do not prefer strips. If it is more difficult for older controllers to learn new tasks than younger controllers, then older controllers should not perform as well as younger controllers. Those who say they often use strips might also have problems changing their behavior.

Study 1

Method

This study observed how controllers at 5 en route centers marked and used strips. Trained observers recorded strip markings/actions made during 10-minute periods at randomly-selected sectors and positions. A subset of controllers was interviewed about why they made certain marks. This analysis addressed Hypotheses 1 and 2. We expected older controllers would prefer paper strips more than younger controllers. Older controllers and those who said they preferred strips should also mark and use them more often.

Subjects. Two hundred ninety-four controllers from the Kansas City, Chicago, Atlanta, Washington, and Cleveland centers were interviewed. Participants' ages ranged from 24-59. Participants were divided into two groups (less than age 40, N=146, M=34.88, SD=4.5; and age 40 or older, N=126, M=45.8, SD=4.7) based on a median split of reported age.

Procedure. Participants completed a biographical questionnaire. They also answered questions about their preferences for using flight strips, the HOST computer, or some other method to perform the following activities: Planning, identifying conflicts with aircraft/airspace, and identifying routes or aircraft type. Variables were derived from their responses to determine whether they preferred using strips for all activities, preferred strips for at least one activity, preferred strips and another information source (such as the computer), or did not prefer to use the computer for any activity. Observed strip markings were classified as: Issued clearances, coordinated/ planned clearances, incoming/outgoing radar/communications (e.g., transfer of radar control or communications for incoming/outgoing aircraft), non-clearance coordinations (e.g., pointout, control released/received), information updates, and non-markings (e.g., move, offset, point).

Results

Hypothesis 1: Older controllers will prefer using paper strips more than younger controllers. Table 1 compares controller age with strip preferences. Controllers who preferred using strips to perform all activities were older than those who did not ($X^2(1)= 11.72$, $p<.001$).

Table 1. Relationship of controller age with strip preference.

	Age			
Prefers strips for all activities	< 40	%	$\geq$ 40	%
Yes	21	14	40	32
No	125	86	86	68

Note: Some data were missing because not all controllers provided complete biographical information

Hypothesis 2: Older controllers and those who preferred strips will mark and use them more often than younger controllers. Age did not predict strip marking or usage, even when controlling for the number of aircraft present. On average, younger controllers made 14.8 total marks (SD=7.45), whereas older controllers made an average of 14.9 total marks (SD=7.18). Strip preferences were, however, related to strip marking. Controllers who preferred strips for all activities made more total strip markings/actions ($F(1,291)=10.95$, $p<.001$) and more incoming/outgoing radar/communications marks ($F(1,291)=16.19$, $p<.001$) than controllers who did not (Table 2). Also, controllers who preferred using strips to perform at least one activity made more issued clearance marks ($F(1,291) = 4.84$, $p < .03$) and incoming/outgoing radar/communications marks ($F(1,291) = 4.47$, $p<.04$) than those who did not prefer strips for any activity.

Table 2. Relationship of strip preferences with strip markings/actions.

Mark/action (Strip preference)	Mean	SD
Total marks		
Prefers strips for all activities	17.70	9.28
Does not prefer strips for all activities	13.81	6.26
Incoming/outgoing radar/comm		
Prefers strips for all activities	11.41	5.72
Does not prefer strips for all activities	9.06	5.03
Issued clearances		
Prefers strips for at least one activity	7.25	4.93
Does not prefer strips for any activity	4.74	2.28
Incoming/outgoing radar/comm		
Prefers strips for at least one activity	9.80	5.33
Does not prefer strips for any activity	7.16	4.09

Conclusions for Study 1

Hypothesis 1 was supported because older controllers preferred paper strips more than younger controllers. Hypothesis 2 was only partially supported because strip marking was related to strip preferences but not to age. Controllers who preferred strips for all activities made more total marks and more incoming/ outgoing radar/communications marks. Radar/ communications marks are notable because they were observed frequently but were rated less important by an independent group of controllers (see Durso et al., under review). Controllers who did not prefer using strips made fewer incoming/outgoing radar/ communications marks and fewer issued clearance marks. However, contrary to our prediction, age was not related to the number of strip markings/actions.

Study 2

Method

Data were obtained from a second study that assessed the utility of a procedure allowing controllers to remove strips early (Truitt, Durso, Crutchfield, Moertl, & Manning, 2000). Strips could be removed early for certain aircraft and reduced marking could be used for the remaining strips. This study addressed Hypothesis 3. We expected that older controllers, especially those who preferred paper strips, would not be able to utilize a reduced strip marking/posting procedure as well as younger controllers, especially those who did not prefer paper strips.

Subjects. Participants were 31 controllers from three facilities (Cleveland, Boston, and Jacksonville centers) who participated in one condition of a flight strip reduction study (Truitt et al., 2000). A few participants from Cleveland Center may have also participated in Study 1, but we could not determine if that occurred because the studies occurred two years apart and participants' confidentiality was assured. Participants' ages ranged from 26-50. Participants were divided into two groups (36 or younger, N=15, M=32.1, SD=3.4; and over 36, N=16, M=41.7, SD=4.2) based on a median split of their reported age.

Procedure. Participants completed a biographical questionnaire and ran two single-staffed air traffic scenarios on sectors they were accustomed to working. In the standard usage condition, strips were used according to established procedures, and in the strip removal condition, strips were removed according to an experimental procedure. When they finished running the two scenarios, participants were interviewed to assess their reaction to the experimental procedure and discuss their use of paper strips.

Age was compared with strip usage in both conditions. Another variable, called "strip preference," was also derived. A value of 1 was assigned if the controller made at least one very positive comment about paper strips during the post-experimental interview, such as: *I like strips*, *Strips are useful*, *I use strips frequently*, *I don't take strips down early*, *I prefer strips to using Flight Plan Readout*, *Information on strips is more accurate than information in the computer,* and *I use strips for planning*. A value of 0 was assigned if no positive comments were made about strips.

Results

Hypothesis 3: Older controllers, especially those who prefer paper strips, will not be able to utilize a reduced strip marking/posting procedure as well as younger controllers, especially those who do not prefer paper strips. The percentage of strips remaining at the end of the strip removal scenario was negatively correlated with age ($r = -.462$, $p < .01$). A repeated measures analysis of variance revealed a significant interaction between age (younger, older) and condition (standard usage, strip removal) for the percentage of strips remaining at the end of the scenario ($F(1,27) = 4.07$, $p < .05$). Table 3 shows the percentage of strips remaining as a function of age and condition. About the same percentage of strips remained for younger controllers in both conditions, whereas older controllers removed more strips in the strip removal condition.

Table 3. Percentage of strips remaining in bay as a function of age and condition.

Number of strips remaining in bay		
	Mean	SD
Younger		
Control condition	.483	.188
Experimental condition	.407	.171
Older		
Control condition	.471	.197
Experimental condition	.261	.148

A nearly significant interaction was also found between age, condition, and strip preference for the number of marks per strip ($F(1,27) = 3.34$, $p < .079$). Table 4 shows the number of marks per strip as a function of age, condition, and strip preference. Younger controllers made about the same number of marks per strip in the standard usage condition regardless of whether they preferred using strips. But in the strip removal condition, younger controllers who preferred strips marked the remaining strips more often than younger controllers who did not prefer strips. The reverse was true for older controllers. In the standard usage condition, older controllers who preferred strips marked them more often than those who did not prefer strips. However, in the strip removal condition, older controllers made about the same number of marks per strip regardless of their strip preference.

Table 4. Relationship between number of marks per strip and age, condition, and strip preference.

Age, condition, preference	# marks/strip	
Younger	Mean	SD
Standard usage condition		
Didn't prefer strips	3.46	1.61
Preferred strips	3.17	1.48
Strip removal condition		
Didn't prefer strips	2.93	1.30
Preferred strips	3.22	1.76

Older		
Standard usage condition		
Didn't prefer strips	2.81	0.78
Preferred strips	3.58	1.33
Strip removal condition		
Didn't prefer strips	2.57	1.13
Preferred strips	2.54	1.25

Conclusions for Study 2

Hypothesis 3 was only partially supported. Older controllers utilized the strip removal procedure as well as younger controllers. Contrary to expectations, in the strip removal condition, younger controllers left more strips posted and marked them more often than older controllers. Moreover, the number of marks per strip varied according to both strip preferences and age. Younger controllers who preferred strips continued to mark them in the strip removal condition, whereas even older controllers who preferred strips reduced their marking in the strip removal condition. Perhaps younger controllers felt more pressure to follow the rules. Perhaps older controllers responded more than younger controllers to the experiment's demand characteristics. Or maybe the experimental task was similar enough to normal operations that older controllers had no trouble with it. Regardless of the reason, the results contradicted our expectations about older controllers' performance when using a procedure that changed the way they used strips.

Discussion

Some hypotheses were confirmed by these analyses, but others were not. As expected, older controllers said they preferred strips more than younger controllers. And, as expected, a preference for strips predicted two types of frequent strip markings. However, age did not predict strip marking. Older controllers were also able to use an experimental strip reduction procedure effectively.

We expected that age alone would predict strip usage. However, these data suggest that a preference for strips may be as effective a predictor of strip usage, and perhaps EFDR transition problems, as age. Although we observed no age-related differences in the performance of a procedure that changed the way controllers used strips, age may still affect older controllers' use of an EFDR that uses electronic entries instead of paper strips. Moreover, if these results generalize to other tasks, then controllers who prefer strips may have problems transitioning to a strip-less system.

To accommodate new technologies, U.S. air traffic controllers must eventually convert from paper strips to EFDRs. The issue is not whether a transition will occur, but how it should proceed, given the resistance that may occur (Durso & Manning, 2002). It is clear that the factors associated with controllers' resistance to new technologies are complex. Additional research is needed to identify factors that predict EFDR resistance.

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