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EXTERNAL AIDS AND AGE DIFFERENCES IN PILOT COMMUNICATION

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The use of external aids (e.g., a kneepad) can reduce the demands of Air Traffic Control (ATC) communication on pilots' working memory during routine flight. Older pilots may especially benefit from such aids because of age-related declines in working memory, although cognitive declines may impair the ability to coordinate the use of these aids with concurrent flight navigation and control tasks. We investigated the use of two external aids that may vary in ease of coordination: a conventional knee pad and an electronic notepad, or e-pad. Participants were 6 older (50-65 years) and 6 younger (20-40) active instrument-rated pilots. While in a Frasca flight simulator, they listened to and read back complex (four-instruction) ATC messages while using the kneepad, e-pad, or no aid. Readback accuracy was analyzed by an Age x Aid x Instruction type (Heading, Altitude, Speed) ANOVA with Aid and Instruction as repeated measures. Accuracy was higher when pilots used either aid compared to no aid, and lower for older pilots. The findings suggested a greater aid benefit for older pilots, with a smaller age difference in the two aid conditions than in the no-aid condition. While the Age x Aid interaction was not significant, this interaction was significant for the altitude instruction readbacks. Despite the small sample size, our study replicates note-taking (kneepad) benefits for older as well as younger pilots' communication, and extends these findings to the novel e-pad. Results of a usability survey helped improve the e-pad interface. We will next investigate potential attentional costs of these aids for task coordination during simulated Frasca flight, as well as their benefits for communication.

Introduction

Communication in complex environments such as piloting and driving places heavy demands on operators' cognitive resources, occasionally contributing to problems that reduce safety and efficiency. It may especially challenge older pilots who tend to experience declines in working memory. External aids such as note-taking may help older pilots manage these demands, especially if these aids are part of the pilots' skill repertoire.

Note-taking provides environmental support (Craik & Jennings, 1992) that reduces working memory constraints on responding to Air Traffic Control (ATC) messages. Morrow, Ridolfo et al. (2003) found that note-taking reduced age differences among pilots on a readback task compared to a no-aid condition. However, note-taking in that study was investigated in a communication-only rather than multi-task environment typical of piloting. Note-taking involves visual components, and thus, according to multiple resource theory, may compete with concurrent visual tasks such as flight control for modality-specific attentional resources (Helleberg & Wickens, 2003). For example, writing on a kneepad often incurs heads-down time, drawing attention from the instrument panel, which supports flight control. Heads-down time can greatly affect a pilot's situation awareness (SA), especially during critical out-of-the-window times (e.g., detecting traffic) (Endsley, & Garland, 2000). Thus, external aids should be designed to minimize visual competition with concurrent flying tasks at hand, as well as to support communication.

Such high demands on cognitive resources may especially challenge older pilots because of their declining ability to allocate resources to multiple tasks. Tsang and Shaner (1998) found that older pilots exhibited age-related declines in time-sharing tasks under high levels of attentional demand. Time-sharing in this case related to performing concurrent tasks that were similar to navigating the plane and listening to ATC communications.

On the other hand, older pilots' high levels of expertise may help them compensate for these age-related cognitive declines, Studies of expertise in pilot communication and decision-making have found greater benefits for higher levels of expertise (e.g., Wickens, Stokes, Barnett, & Hyman, 1993; Wiggins & O'Hare, 1995). Morrow, Ridolfo et al. (2003) found that note-taking eliminated age differences in readback accuracy among pilots but not nonpilots. There is also some evidence that expertise reduces age differences in the ability to perform multiple tasks (Lassiter et al., 1997; Tsang & Shaner, 1998). Even so, expertise may be less likely to eliminate age-related declines in communication in complex, multi-task environments, such as aviation. Therefore, we investigated external aids that may vary in their ease and effectiveness of use in single- and multi-task flying environments.

We compared conventional note-taking (*kneepad*) with an electronic notepad positioned adjacent to the instrument panel *(e-pad)*. The e-pad resembles Mode Control Panel interfaces common in commercial flight management systems, but it functioned only as an external aid in the present study. All participants

were General Aviation, and were not familiar with this type of interface. Although the kneepad is more familiar to pilots, it may be easier to coordinate the e-pad with concurrent tasks because it is more integrated with the flight instruments, reducing heads-down time. Both aids should reduce age differences in communication compared to a no-aid condition (see Morrow, Ridolfo et al. 2003), and the e-pad is more likely to reduce age differences as concurrent task demands increase. Because use of external aids depends on the costs associated with perceptual access of information from the aid compared to accessing the information from memory (Fu & Gray, 2000), we first conducted the present study to explore the usability of the two aids primarily in a single-task environment.

Method

Participants

Twelve instrumented-rated pilots participated (minimum 500 total flight hours). Six were older (50-64 years), and six younger (20-40 years).

Table 1. *Mean Demographic and Cognitive Ability Scores*

	Older N=5[1]	Younger N=6	*Mean*	*Age t(10)*
Age	53.8	25.5	*38.36*	
Educ (years)	17.4	15.8	*16.55*	*1.0*
Speed_letter[2]	10.4	12.8	*11.7*	*2.1**
Speed_pattern[2]	18.7	19.75	*19.27*	*<1.0*
Total Flight hours	2975.6	1342.7	*2084.9*	*1.2*
Hours last 12 months	49.9	139.4	*156.6*	*1.7*
Total IFR hours	488.25	139.38	*278.9*	*2.1*
Self-rated Health	5.5	6.3	*6.0*	*1.0*

* p<.05

1. Only 5 of the 6 older pilots who participated filled out demographic and pilot questionnaires
2. Letter and Pattern Comparison tasks, a measure of processing speed (Salthouse & Babcock, 1991)

The two age groups did not differ significantly in years of education, flight experience, or self-rated health (see Table 1). We also included a measure often used to index speed of mental processing (Letter and Pattern Comparison tasks, Salthouse & Babcock, 1991). Typical of cognitive aging studies, younger pilots outscored older pilots on the Letter Comparison measure (the difference was in the same direction, but nonsignificant for the Pattern measure).

Apparatus

Participants performed all ATC communication tasks in a Frasca 142 flight simulator, configured as a single-engine, fixed wing light aircraft, including a full set of flight displays on the instrument panel and radio, and a three-screen out-the-window display. A touch screen display served as the e-pad (see Figure 1) and was placed adjacent to the instrument panel (Figure 2).

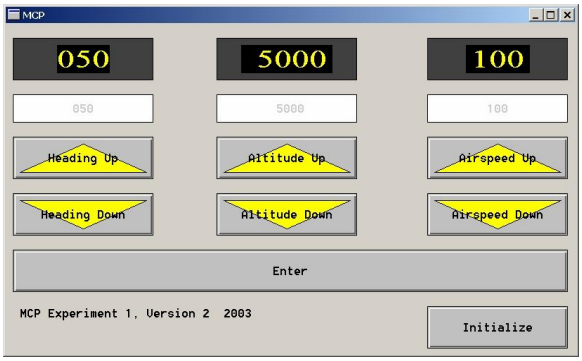

Figure 1. *E-pad touch screen display*

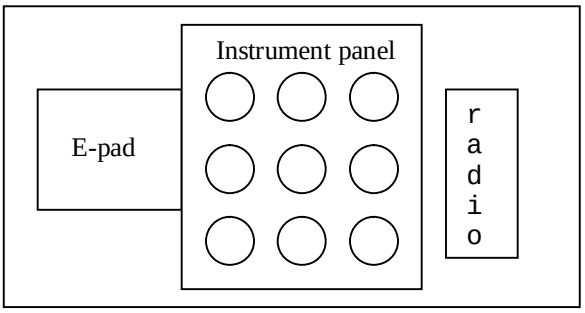

Figure 2. *E-pad, instrument, and radio layout*

Procedure

Participants listened to pre-recorded ATC messages for four flight scenarios. Each message directed the pilot to make heading, altitude, speed, and frequency or squawk changes (i.e., 4 instructions). In three scenarios, the participants used the kneepad, e-pad, or no aid while only listening to and reading back each message. In the fourth scenario, they flew the described route in the simulator as well as using the e-pad to support communication. They were given a practice session using the e-pad to familiarize themselves with this novel touch screen display.

In the kneepad condition, participants listened to the ATC instructions and wrote any notes on a kneepad strapped to their leg. In the e-pad condition, they entered heading, altitude, and speed changes into the

touch screen display (see Figure 1). Notes and e-pad button press responses were scored for comparison to readback accuracy. No aid was available in the third condition, so pilots read back messages from memory. In all three conditions, participants were allowed to use the radio, located to the right of the instrument panel, to enter frequencies or squawks (Figure 2). Participants could also ask for ATC message repeats. Readbacks and requests for repeats were tape recorded for later scoring and analysis.

After completing the first three scenarios (communication-only conditions), participants completed a questionnaire about the ease of using the e-pad display and task workload, including comparisons of the e-pad and kneepad aids. The same questionnaire was given after the fourth scenario in order to investigate whether e-pad usability varied in single task (communication only) and multi-task (i.e., communicating and flying) environments. At the end of the session, all participants completed a demographics and pilot experience questionnaire and the Letter and Pattern Comparison tasks (Salthouse & Babcock, 1991).

Results

Readback Accuracy

Readback accuracy (mean percent correct instructions repeated) was analyzed by an Age x Aid (kneepad, e-pad, no aid) x Instruction type (heading, altitude, speed) ANOVA with Aid and Instruction as repeated measures. As shown in Figure 3, accuracy was higher when pilots used either aid compared to no aid, $F(2,20)=31.8$, $p < .001$, and slightly lower for older pilots, $F(1,10)=5.6$, $p < .05$. There was also an effect of instruction, (H=97%, A=94%, S=91% correct, $F(2,20)=6.5$, $p < .01$, which is difficult to interpret because the three instruction typess were always presented in the same (standard) message positions (heading first, speed last).

While the Age x Aid interaction was not significant, $F(2,20)=1.1$, the pattern in Figure 3 suggests a greater aid benefit for older pilots, with a smaller age difference in the two aid conditions (Y=100%, O=98%) than in the no-aid condition (Y=88%, O=81%). Analysis of age and aid effects for each instruction revealed an aid benefit for all three instructions, but only a significant age decline for the altitudes ($p < .01$; $p > .10$ for heading and speed instructions). Moreover, the Aid x Age interaction was significant for altitudes, the most age-sensitive readback measure $F(2,20)=4.1$, $p < .05$.

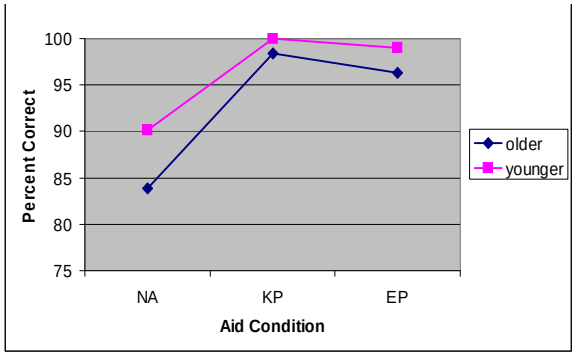

Figure 3. *Readback Accuracy.*

All aid values (i.e., notes written on the kneepad and values entered into the e-pad display) were also scored. There were no discrepancies between the accuracy of aids and readbacks.

Requests for Message Repeat

Analysis of mean number of requests for ATC message repeats revealed a similar effect of aid (KP=0.0, EP=0.48, NA=2.0 mean requests), $F(2,18)=5.9$, $p < .05$. The age difference in requests was not significant.

E-pad Benefits in Single- and Multi-task Environments

Mean readback accuracy in the two task conditions was analyzed by an Age x Task (single-task, multi-task) ANOVA with the latter a repeated measure. Performance did not vary by task condition (Single: 99%, Multiple: 98%), $F < 1.0$, or by age group (Y= 99%, O=97% $F(1,9)=2.3$, $p > .10$. While null findings must be treated cautiously because of the small sample size, this analysis suggests that communication benefits from the e-pad were not reduced by performing multiple tasks for older as well as younger pilots.

Discussion

Older and younger pilots more accurately read back complex ATC messages when using either the kneepad or the e-pad, compared to no aid. There was also some evidence that both aids reduced age differences in communication accuracy, consistent with environmental support theory (Craik & Jennings, 1992). This finding replicates the earlier finding of note-taking benefits for older as well as younger pilots' communication (Morrow et al., 2003), and extends these findings to the novel e-pad aid.

Both age groups were also more likely to request repeats of the ATC messages in the no aid condition. While either aid provided an external form of working memory for the readback task, pilots required more exposure to the information (i.e., more message presentations) when relying on memory, and they still made more errors without the support of the aids. Moreover, in actual operations, the increased frequency of ask for and receiving clarification from ATC would decrease communication efficiency and potentially impair concurrent task performance in multi-task environments. The absence of age differences in requests for repeat may reflect age-related differences in communication style that mask age differences in memory, or the possibility that the present study did not impose sufficient task demands to produce age differences on this measure. A follow-up study (see below) will vary task difficulty in multi-task environments to examine the latter possibility.

Limitations of the Present Study

The small sample size limits our ability to identify the effects of pilot age and external aids on communication. Nonetheless, the age difference on the Letter Comparison measure of processing speed suggests that the pilots in our sample were experiencing typical age-related changes in cognitive abilities. In addition, the pattern of aid benefits for the older and younger groups (smaller age differences in communication accuracy for the aid versus no-aid conditions) is similar to earlier studies with larger sample sizes (Morrow et al., 2003).

Designing the E-pad: Usability Issues

The fact that older pilots tend to experience typical age-related changes in speed of processing and working memory, coupled with findings that operators are less likely to use external aids as the cost of perceptual access increases (e.g., Fu & Gray, 2000), has important implications for designing novel aids such as the e-pad. To the extent that using the aid exacts perceptual-motor costs, older pilots may be less willing to use them. Therefore, an important goal of the present study was to improve e-pad usability. Questionnaire findings suggested that both age groups actually preferred using the kneepad over the e-pad. Participants' comments suggested the importance of the kneepad's familiarity. Although participants were given practice with the e-pad, the amount of practice could not compare pilots' years of experience with the kneepad. Consistent with this, workload ratings suggested greater difficulty using the e-pad in the multi-task condition (communication and flight control). Typically, (right-handed) pilots use their left hand on the yoke while writing on the kneepad with their right hand, as well as using their right hand to input radio frequencies and squawks. With the e-pad positioned to the left of the flight instruments and controls, pilots pointed out that they would either have to use their left hand to input into the e-pad and then switch to the right hand to input into the radio or use their right hand to cross over the yoke to input into the e-pad. Neither felt natural to them.

Other comments included the use of some unnecessary displays and controls (*enter* button), and lack of haptic feedback when pressing buttons. In response to these concerns, the e-pad interface was modified for the primary study. Changes included eliminating extraneous displays and buttons and reducing the screen size so that the display could be moved closer to the flight instruments in order to be more integrated with the instruments. The new display reduces clutter without reducing button size, and decreases screen brightness that interfered with lighting for the instrument panel (see Figure 4).

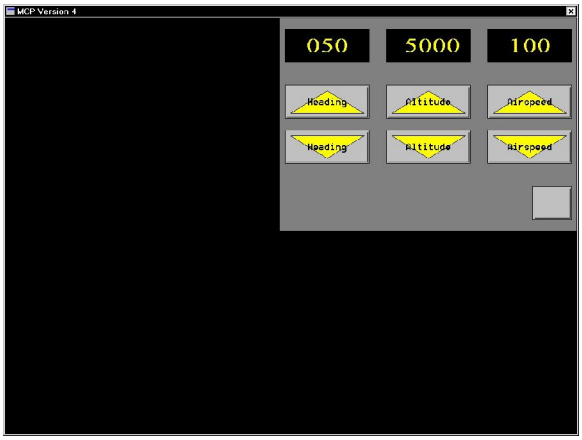

Figure 4. *New E-pad display screen*

Next Steps

In a follow-up study, we are now investigating whether the e-pad is more effective than the kneepad in reducing age differences in communication performance under demanding multi-task (navigation and flight control as well as communication tasks). In addition to the communication-only conditions used in the present study, scenarios are included that require the pilots to fly the route described by the messages while looking out the window for traffic as well as communicating with ATC. Flight performance and eye-tracking measures will be used to assess the impact of the external aids on communication performance and attentional

requirements of coordinating these aids with the concurrent flight tasks

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