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While cockpit navigational aids might assist general aviation pilots with awareness of terrain, aircraft and weather, the ability to maintain accurate and comprehensive cognitive representations of the aviation environment remains a critical cognitive aviation task. The present research reports on the relationship of age, pilot experience and cognitive health to situation awareness scores for 27 licensed private pilots in a simulated flight protocol. ANOVA and linear regression analyses revealed that *age*, recent *pilot-in-command hours* and the cognitive health indices of *working memory* performance and *reaction time* (auditory stimuli) were uniquely associated with three levels of pilots' situation awareness scores. Implications regarding private pilot situation awareness skill maintenance are discussed.

Despite assistance from cockpit navigational aids, the ability of the mind to form an accurate, comprehensive representation of the current and near future flight situation remains a critical cognitive task for all pilots. It is generally accepted that situation awareness builds upon three levels of cognitive processing (Endsley, 1988; 1995). The first level is the perception and processing of multi-modal stimuli into meaningful units of information. At the second level this information is assembled into a comprehensive schema of the aviation environment. The third level projects current information into a proposed future schema that anticipates a near future state of the environment.

Pilot situation awareness performance has been examined with respect to age, working memory processes and pilot experience (Endsley, 2000). Age has been proposed as a factor associated with all three levels of situation awareness performance due to the reductions in information processing speed, working memory capacity, inhibition and attentional processes that accompany normal aging (Bolstad & Hess, 2000). In a study by Coffey, Herdman, Brown and Wade (2007) older pilots were found to miss more critical events (nearby air traffic and instrument malfunctions) in a simulated flight environment than younger pilots. Similarly, Kennedy, Taylor, Reade and Yesavage (2010) reported that older pilots had a greater likelihood of landing in unsafe weather conditions and performed less well on flight control tasks than their younger cohorts.

Working memory, as described by Baddeley and Hitch (1974) is a model of short-term memory processes which encode, store and manipulate information from the environment in order to achieve a goal (e.g. memorize a phone number). Endsley (2000) suggests that working memory supports the main processes related to situation awareness. Morrow, Leirer, Altieri and Fitzsimmons (1994) found that recall of auditory material was most likely to be forgotten by older pilots and this phenomenon was not mediated by expertise. Morrow et al. suggest that declines in working memory were associated with poorer performance by the older participants, as it was the storage of the recent auditory information that appeared to significantly impact the performance of older participants. Corroboration for the findings involving working memory is reported by Taylor, O'Hara, Mumenthaler, Rosen and Yesavage (2005) who proposed that reduced ability to store and manipulate representations in working memory was associated with older age and that this effect resulted from declines in speed of processing and reduced ability to inhibit less relevant stimuli.

Some researchers have investigated the mediating effects of total flight hours and expertise on pilot situation awareness. Kennedy et al. (2010) studied older and younger novice and expert pilot groups and found age-related reductions in performance for most of the simulated flight tasks. Expertise did not reduce the effect of age, except in the case of banking performance in a holding pattern. Morrow et al. (1994) and Morrow, Menard and Stine-Morrow (1999) observed benefits of expertise for older pilots when reading back visually presented material, but no significant benefit was afforded by expertise for material with an auditory presentation.

While the literature indicates that age, experience and cognitive factors might be important factors in all levels of situation awareness, it is not clear how each factor uniquely contributes to performance in each level of situation awareness. In the present study we examined the relationship of age, experience and cognitive health to situation awareness scores of licensed private pilots using a simulated experimental flight protocol. We examined these factors individually at each level of situation awareness and found that age and recent pilot-in-command hours were associated with level 1; age, working memory, reaction time (auditory stimuli) and recent pilot-in-command hours were associated with level 2; and, working memory and reaction time (auditory stimuli) were associated with level 3 situation awareness performance.

Method

Participants

As part of a larger general aviation study (*N*=54) we examined the relationship of age, experience and cognitive health to three levels of situation awareness for 27 licensed private pilots (female pilots = 3).

Table 1.

Pilot Characteristics by Age Group

	Pilot Characteristics by Age Groups			
	Younger Pilot Group (*N*=16)		Older Pilot Group (*N*=11)	
	Range (Mean)	Standard Deviation	Range (Mean)	Standard Deviation
Age (years)	27-50 (40.1)	7.1	52-76 (59.4)	7.6
Length of Pilot Certification (years)	.5-25 (9.3)	7.2	.5-40 (22.3)	13.7
Pilot-in-Command in past 12 months (Hours)	10-60 (31.8)	16.2	0-32 (8.2)	11.9
Total Flight Time (Hours)	99-1000(322.6)	249.3	90-1309 (397.2)	370.4

Pilot ages ranged from 27 to 76 years and for purposes of analysis were categorized into younger (27 to 50 years) and older (52 to 76 years) pilot groups. Table 1 displays the mean age, years certified as a pilot, recent pilot-in-command hours and total flight hours logged. Participants in this analysis were certified to a maximum of private pilot and possessed a current private pilot license.

Procedure

Four main measures were administered in the order described here. The DCAT™ and the auditory Perceptual Detection Test were our indices of cognitive health.

Pilot demographics and flight experience questionnaire. A pilot demographic and flight experience questionnaire was completed at the start of each session. Total years licensed and recent pilot-in-command hours (previous 12 months) were obtained from the pilots' flight logs. As expected, older pilots had flown more years than younger pilots (22.3 and 9.3 years, respectively), $F(1,25)=10.57$, $p=.003$. Older pilots, however, had significantly fewer recent pilot-in-command hours (8.2 and 31.8 hours, respectively), $F(1,25)=17.05$, $p<.001$.

Cognitive health measure 1: DCAT™. The DCAT™ is a computerized touch-screen system comprised of six individually scored sub-tests. Responses are made by touching the screen or depressing switches at desk top height. The DCAT™ produces *z*-scores (standard deviations from the age-group mean) that reflect both accuracy and timing of the responses (DriveABLE, 1997). Only subtest 6, the index of working memory, is reported on here. Subtest 6, *Identification of Driving Situations*, consists of selecting one of four response options to questions regarding judgment and situation awareness pertaining to brief (5 to 10 seconds) video clips of driving scenes. Information is presented in visual and auditory form during the video clip. The questions pertain to how the participant should respond in a situation, or what was the most dangerous element of the situation. While subtest 6 does not include scenarios found in general aviation, responses are supported by working memory and efficient integration of auditory and visual information. An analyses showed that older pilots ($M= -.16$) demonstrated significantly lower z-scores on the DCAT™ Subtest 6 index of working memory, than did the younger pilots ($M= +.78$), $F(1,25)=5.20$, $p=.031$.

Flight simulator environment. Pilots flew a Cessna 172 medium-fidelity simulator. The simulator was an actual Cessna 172 cockpit with instruments and controlled linked with Microsoft® Flight Simulator ®. The system incorporates three large screens for approximately 120 degrees of horizontal visual field of view and 45 degrees of vertical field of view. All participants spent approximately half an hour in a warm-up phase of simulated flight in order to become accustomed to the flight simulator controls and to reduce learning effects. The experimental protocol required the pilot to fly three left-hand circuits in a low cognitive workload condition. For this condition the airfield was uncontrolled, the terrain was unremarkable and the pilot interacted with no other aircraft during the first circuit, one other aircraft during the second circuit, and two other aircraft during the third circuit. Pilots were required to provide details of their call sign, aircraft type and location at routine points during the circuit via radio communication. The simulated aircraft in the scenarios also provided this information through scripted radio calls.

Situation awareness tasks. In order to assess pilots' situation awareness a protocol, based on the Situation Awareness Global Assessment Technique by Endsley (1998; 2000) was utilized. SAGAT is structured around probes, which are interjected during the task and require participants to respond to questions pertaining to situation awareness. Probe questions were developed to reflect three levels of situation awareness. Pilots indicated (from memory) their current heading, airspeed and altitude, and the call sign and aircraft type of the other aircraft in the circuit (Level 1); where they believed they were in the circuit at the time of the simulator freeze and where all additional aircraft were located (Level 2); and where they predicted their aircraft would be in 2 minutes, and where the other circuit aircraft would be in three minutes (Level 3). The probe occurred at the beginning of the "base" leg of the circuit when there was only one other aircraft in the circuit. Raw scores for each level of situation awareness were converted to percent correct for comparison purposes.

Cognitive health measure 2: Auditory perceptual detection task. An auditory perceptual detection task was used to measure perceptual-motor responses to an external stimulus. The auditory perceptual detection task required thumb switch responses to randomly occurring beeps (range: 10 to 20 seconds) presented via a headset. Reaction time between stimulus onset and response was recorded for all correct hits.

Results

Age Differences and Situation Awareness

Figure 1 shows the mean situation awareness scores as a function of age. Separate one-way ANOVAs were used to compare younger vs. older pilots for each of the situation awareness scores. Level 1 situation awareness scores were marginally higher for younger (M=59) than for older pilots (M=48), $F(1,23)= 3.3$, $p=.085$. Level 2 situation awareness scores were significantly higher for the younger (M=98) than the older (M=82) pilots, $F(1,23)=7.9$, $p=.01$. There were no significant differences between level 3 situation awareness scores for younger (M=85) and older (M=79) pilots.

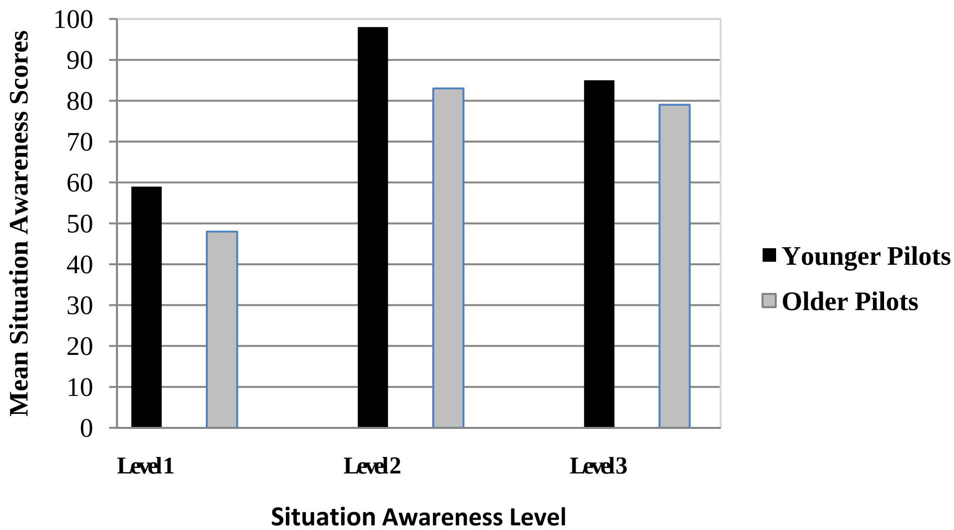

Figure 1. Mean Situation Awareness Performance by Age Groups and Situation Awareness Level

Correlation of Situation Awareness Performance with Pilot Age, Experience and Cognitive Health

As shown in Table 2, there was a moderate negative relationship of pilot age to level 1 situation awareness performance and a moderate positive relationship of recent pilot-in-command hours to level 1 situation awareness. For situation awareness levels 2 and 3, a moderate negative relationship was found between situation awareness performance and auditory reaction times and age. In addition, for both situation awareness levels 2 and 3, moderate positive correlations were found between working memory scores and recent pilot-in-command hours.

Table 2.

Relationship of Situation Awareness Performance with Pilot Age, Experience and Cognitive Health

Pearson Bivariate Correlation Analysis				
Situation Awareness Level	Perceptual Detection Task *Cognitive health: reaction time*	DCAT™ 6 *Cognitive health: working memory*	Pilot Age	Recent Pilot-in-command Hours
Level1: *perception*			-.49	.44
Level 2: *schema*	-.50	.46	-.49	.40
Level 3 *future schema*	-.41	.50	-.50	

Note All correlations are significant at the $p < .05$ level (two-tailed)

A partial correlation analysis of age and recent pilot-in-command hours with situation awareness levels 1 and 2 showed that when controlling for pilot-in-command hours the relationship between age and situation awareness remained marginally significantly ($p<.1$). However, when controlling for age, the pilot-in-command and situation awareness performance relationship was no longer significant ($p>.1$). This indicated that age might be a more reliable predictor of level 1 or 2 situation awareness performance than pilot-in-command hours.

Linear Regression Analysis

A model utilizing recent pilot-in-command hours and age accounted for 28% of the variance in level 1 situation awareness, $F(2,22)=4.30$, $p=.027$. A model predicting 54% of the variance in situation awareness level 2 scores was produced using cognitive health indices and age, $F(3,20)=7.84$, $p=.001$. Similarly, a model produced with our two cognitive health indices accounted for 35% of the variance in level 3 situation awareness scores.

Discussion

This study examined the relationship of pilot age, experience and cognitive health to three levels of situation awareness. Age and recent pilot-in-command hours uniquely predicted 28% of the variance in perception and storage of environmental stimuli as represented by level 1 situation awareness scores. Age and cognitive health measures predicted more than half the variance in level 2 scores, which reflected the pilots' comprehensive schema of the current situation. Approximately one third of the variance in scores pertaining to accurate representation of the future aviation situation was predicted by our cognitive health measures which incorporated working memory and reaction time to auditory stimuli.

The present findings are useful to stakeholders designing education programs with the goal of maintaining or increasing situation awareness skills for private pilots. Stakeholders developing private pilot education programs addressing situation awareness should consider the impact of older age, fewer recent flight hours by older pilots and reductions in cognitive health on the individual levels of situation awareness. Targeted strategies such as maintaining flight currency and engaging in cognitive activities to enhance working memory and reaction time might be useful in maintaining the situation awareness abilities of private pilots. These strategies appear important for maintenance of level 1 and 2 situation awareness, which is integral to forming accurate current mental representations of the environment and the basis for producing useful schema of future situations.

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