HOW PERSONALITY, INTELLIGENCE, AND WORKING MEMORY PREDICT SITUATION AWARENESS AND FLIGHT PERFORMANCE

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Situation awareness (SA) and flight performance may be intrinsically connected. Good SA can lead to good aeronautical decision making, and consequently better flight performance. Forty-three pilots participated in the study. Participants completed personality tests, a test of fluid intelligence, and a test for working memory. Participants flew a 15-minute flight scenario in an Elite PI-135 BATD, where participants received six SA questions. Airspeed, altitude, and heading were the flight performance variables. Participants also completed a version of Letter Factory (LF), a generic test used as part of the air traffic controller selection test. Good SA for LF, openness, agreeableness, and fluid intelligence predicted SA in flight. Better SA led to fewer airspeed deviations from the target airspeed, and fewer heading deviations from the target airspeed. Higher fluid intelligence indicated less altitude deviation from the target altitude. Knowing these predictors of SA can be helpful for pilot training and selection tests.

Maintaining situation awareness (SA) is critical in dynamic environments, such as aviation. Good SA typically leads to good decision making and good performance. Certain underlying mechanisms (e.g., working memory, conscientiousness) may be important constructs that are beneficial for good SA (Durso, Bleckley, & Dattel, 2006). Knowing what can predict good SA and good performance in aviation can be beneficial to selection and training in aviation.

The purpose of this paper is twofold. First, the paper will explore which personality factors and cognitive constructs can predict SA and performance. Second, this paper will explore if SA and performance in aviation can be predicted by SA from another environment. That is, can good SA in one environment, specifically a novel environment to the user, carry over to predicting SA and performance in another environment (i.e., aviation)?

SA is the degree of understanding in a typically fast-paced environment (Durso, Rawson, & Girotto, 2007). It can be determined on 3 levels: perception of the relevant elements in the environment, understanding what the elements mean specific to the task, and predicting how the situation will change in the future (Endsley, 1995). Working memory (WM) is one construct that may be an underlying mechanism of good SA (Dattel et al., 2011). WM is the degree to which one can retain and process information while attending to additional information (Baddeley & Hitch, 1994).

Carretta and Ree (2003) have shown the importance of personality factors, such as conscientiousness, in successful pilots. More recently, Barron, Carretta, and Bonto-Kane (2016) have highlighted the importance of extraversion and agreeableness as important factors in performance rankings. In addition, fluid intelligence (or g') has been shown as predictors of successful aviation performance (Ree & Caretta, 1996).

These personality and cognitive constructs were tested on pilots who had at least a private pilots license. The pilots were also tested on a novel task that measures SA and performance. This novel task is used exclusively for applicants taking an air traffic controller selection test.

Method

Participants

Forty-three pilots holding at least a private pilots licenses volunteered for this study. Pilots were remunerated $30 for approximately 2 hours of participation.

Materials

Participants completed several batteries of test to measure personality, working memory, and fluid intelligence. Goldberg's Big-Five Factor Markers Personality checklist was used to measure personality (Goldberg, 1992). For Goldberg's checklist, participants select a rating on a 9-point scale of how they identify on 100 adjectives of traits (e.g., active, sympathetic, anxious).

To measure WM, participants completed the computer version of Operations Span (OSPAN; Turner & Engle, 1989). For OSPAN, participants were asked to calculate several simple mathematical equation (e.g., "Is "3 + 5 = 8," "Is 4 -2 = 1," then shown an answer (True or False), and then asked to determine which answer is correct. After the participant states if the answers were true or false, participants are then shown a random letter for 1 second. Following a set of equations interleaved with letters (3 to 7 mathematical operations and letters in a set), a participant was shown a screen prompting him or her to select all letters in the order which they appeared. The WM score was calculated by the number of letters recalled in correct order.

A 15-minute flight scenario was created in Microsoft Flight Simulator X configured to a glass instrument panel Cessna 172, equipped with a Primary Flight Display and a Multi-Function Display. The flight simulator used a PI-135 Elite Flight Simulator power quadrant, which included a yoke (aircraft steering wheel) and rudder pedals. Three out-the-window screens provided a 120° view. Participants took off on a pre-defined flight plan, but did not land the plane because the flight was intentionally stopped 15 minutes into the scenario, before the participants reached their destination. The flight was in VFR conditions (clear skies, no winds), and participants were instructed to maintain assigned speed and altitude and follow a pre-set flight track on the aircraft's Garmin G1000 map. While participants were flying, six SA questions specific to the flight were played over a headset. Questions were presented in the SPAM format (Durso & Dattel, 2004), in real time. Participants said their answers aloud into a microphone. Accuracy and response time were the measures for the SA questions. A 5-minute practice flight was developed so participants could become familiar with the flight instruments and flight controls.

Standard Progressive Matrices (Raven, 1989) was used to measure fluid intelligence. To measure SA in a novel task, the Letter Factory (LF) subtest of the Air-Traffic Selection and Training (AT-SAT) test was given to the participants (see Dattel & King, 2010). The test was obtained by the ATCPrep™.com Air Traffic Controllers' study software. The LF test represents four conveyor belts with bins (i.e., boxes) at the end of each. During the 15-minute LF simulation, letters appear at the top of the screen on either of the conveyor belts and move down toward the bottom of the screen. Before getting too close to the bottom, but only after a certain point, participants have to identify the letter and place it in the appropriate bin by clicking on the bin and then on the letter. Each bin can only contain letters A, B, C, and D (one of each) before it disappears, and a participant has the ability to add another bin when it becomes full. Bins are removed from the stock on the right side of the screen, and bins should only be removed from the stock if required (i.e. if a letter of the same color is on the conveyor belt and there is no bin of that color already near the belt). The stock needs to be replenished by clicking on a specific button once the box quantity is below a certain value. Any other letter other than A, B, C, or D is called defective, and participants are instructed to acknowledge the defective letters, if they appear, by clicking on a corresponding button. Periodically during the scenario, the simulation is frozen, and participants are asked a specific question about the scenario (e.g., which letter is closest to the bottom). To measure the performance, correct letter placement, correct defective letter identification, and correct timeliness of stock replenishment were recorded. Participants' answers to questions that appeared on the screen during the task were used to assess participants' SA.

Procedure

After participants signed a consent form, they were given the battery of tests. It took approximately 1 hour for the participants to complete the battery of tests. Participants then flew the 5-mintue practice flight, followed by the 15-minute flight scenario. During the flight scenario, participant answered 6 scenario-specific flight SA questions that were played over a headset every 2 to 3 minutes. Participants were instructed to follow a particular flight track to their destination airport, using the aircraft navigation display. Participants were instructed to maintain a specific heading and altitude at various points through the flight scenario. After completing the flight scenario, participants completed the LF test.

Results

Only about 65% of SA questions were answered correctly (M = 3.90, SD = 1.00). RT to answer SA questions are only calculated if the question is answered correctly. Due to the reduction in power for this measure, the SA analyses are only conducted for correct questions answered out of a total of six questions.

After entering the personality variables, WM, SA for Letter Factory, and fluid intelligence, a multiple linear regression showed that SA for Letter Factory, agreeableness, openness, and fluid intelligence predict SA in flight $F(2,25) = 3.186$, p=.012, adjusted R^2 = .346 where higher SA for Letter Factory, higher fluid intelligence, higher agreeableness, and lower openness predict higher accuracy in answering SA questions (see Table 1).

TABLE 1. Multiple Linear Regression

Variable	Beta	*t*	*p*
Constant		-1.662	.109
SA for LF	.367	2.439	.022
Extraversion	-.278	-1.672	.107
Agreeableness	.695	3.607	.001
Conscientiousness	.191	.992	.331
Neuroticism	-.210	-1.015	.320
Openness	-.434	-2.497	.019
Fluid intelligence	.451	2.850	.009
WM	.260	1.663	.105

A median split of OSPAN was conducted to categorize participants as high of low WM. Although not quite significant $t(34) = 2.010$, p = .052 participants with higher WM answered more SA questions correctly (M = 4.11, SD = .76) than participants with lower (M = 3.5, SD = 1.04) WM (see Figure 1).

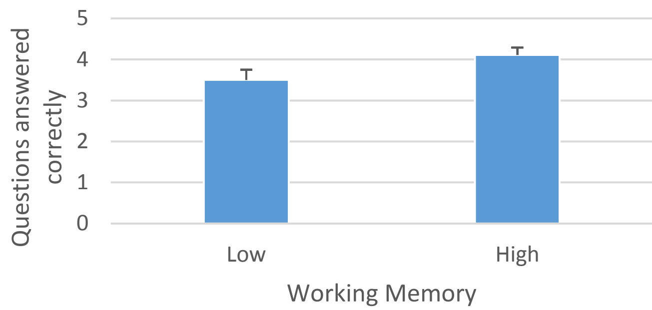

Figure 1. Bar graph of correctly answer questions by working memory.

Correlations conducted between personality factors and SA found that pilots who are more agreeable are more likely to answer more SA questions correctly (see Table 2).

TABLE 2. Bivariate Correlations Between Personality Factors and Situation Awareness

Variable	1	2	3	4	5
1. SA					
2. Extraversion	-.062 n = 35				
3. Agreeableness	.348* n = 35	.208 n = 40			
4. Conscientiousness	.119 n = 35	.362* n = 40	.364* n = 40		
5. Neuroticism	.137 n = 35	.307 n = 40	.571** n = 40	.530** n = 40	
6. Openness	.006 n = 35	.249 n = 40	.234 n = 40	.279 n = 40	-.039 n = 40

*p < .05
**p < . 01

Deviation from assigned airspeed, altitude, and heading were measured as performance variables. Heading deviation was measured from how far the aircraft was from the G1000 track. Thus, larger numbers for airspeed, altitude, and heading indicate greater deviation, and consequently poorer performance. Pearson correlations found that higher SA was related to less airspeed deviations from target airspeed and less heading deviations from target G1000 tracking. Additionally, higher fluid intelligence predicted less deviation in altitude from target altitude (see Table 3).

TABLE 3. Bivariate Correlations Between Situation Awareness, Fluid Intelligence, and Flight Performance Variables

Variable	1	2	3	4	5
1. SA					
2. Altitude deviation	-.185 *n* = 31				
3. Airspeed deviation	-.548** *n* = 31	.020 *n* = 37			
4. Heading deviation	-.359* *n* = 31	-.061 *n* = 37	.137 *n* = 37		
5. Fluid intelligence	.271 *n* = 36	-.335* *n* = 37	-.002 *n* = 37	.042 *n* = 37	
6. WM	.222 *n* = 36	.113 *n* = 37	-.097 *n* = 37	-.082 *n* = 37	.205 *n* = 43

*p < .05
**p < . 01

Discussion

Of the personality and cognitive constructs entered into the regression equation, higher agreeableness and higher fluid intelligence are shown as predictors of good SA for flight. These results support the findings previously shown for agreeableness and fluid intelligence as predictors of good performance in aviation. Thus, one can assume that good SA, as predicted by high fluid intelligence and an agreeable personality will carry over to good aviation performance. It is also of interest that good SA in a novel task (i.e., the LF task) can predict good SA for aviation.

In the regression model an inverse relationship with openness and SA in flight was found. Thus, the less likely one is open to new experiences, the better one's SA in flight. However, many pilots knew what their career would be from an early age. Therefore, pilots have probably stayed focused on their career for many years before realizing their goal, even at the expense of eschewing new experiences.

To further draw the connection between good SA in flight with good flight performance, a correlation with good SA and less airspeed deviation was found. In addition, a correlation with good SA and less heading deviation was found. Finally, in support of previous findings, the results from this study also found fluid intelligence was predictive of good aviation performance, where higher fluid intelligence is associated with less deviation from altitude.

This paper supports many of the previous findings showing how personality traits and cognitive constructs predict good aircraft performance. What this study adds is the connection between SA and these factors. If SA is an important predictor of aviation performance, then SA should continue to be researched as it relates to aviation personnel selection and training. Finally, the finding of SA in LF as a predictor of SA in aviation warrants further exploration if SA is an individual difference trait, where people with good SA have good SA in all dynamic environments, or if SA is specific to a particular industry, where it may be typical for one to have good SA in only one environment, but poor SA in a different environment.

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