

The Effect of Personality Traits and Flight Experience on Pilots' Cognitive and Affective Responses to Simulated In-Flight Hazards

Chen, J.; Landman, H.M.; Stroosma, O.; van Paassen, M.M.; Mulder, Max

DOI

[10.1027/2192-0923/a000283](https://doi.org/10.1027/2192-0923/a000283)

Publication date

2025

Document Version

Final published version

Published in

Aviation Psychology and Applied Human Factors

Citation (APA)

Chen, J., Landman, H. M., Stroosma, O., van Paassen, M. M., & Mulder, M. (2025). The Effect of Personality Traits and Flight Experience on Pilots' Cognitive and Affective Responses to Simulated In-Flight Hazards. *Aviation Psychology and Applied Human Factors*, 14(2), 104–113. <https://doi.org/10.1027/2192-0923/a000283>

Important note

To cite this publication, please use the final published version (if applicable).
Please check the document version above.

Copyright

Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

Takedown policy

Please contact us and provide details if you believe this document breaches copyrights.
We will remove access to the work immediately and investigate your claim.

Green Open Access added to TU Delft Institutional Repository

'You share, we take care!' - Taverne project

<https://www.openaccess.nl/en/you-share-we-take-care>

Otherwise as indicated in the copyright section: the publisher is the copyright holder of this work and the author uses the Dutch legislation to make this work public.



The Effect of Personality Traits and Flight Experience on Pilots' Cognitive and Affective Responses to Simulated In-Flight Hazards

Jiayu Chen¹, Annemarie Landman^{1,2}, Olaf Stroosma¹, M. M. van Paassen¹, and Max Mulder¹

¹Department of Control and Operations, Delft University of Technology, Delft, The Netherlands

²Department of Training and Performance Innovations, Netherlands Organization for Applied Scientific Research (TNO), The Netherlands

Abstract: We investigated the effect of personality traits and flight experience on pilot cognitive and affective responses across seven startling and surprising scenarios performed in motion-based simulators. A dataset of 89 airline pilots from four studies was used. The personality traits measured were trait anxiety, decision-related action orientation (AOD), and failure-related action orientation (AOF). Pilot self-reported responses in scenarios were standardized by obtaining z scores of startle, surprise, stress, and mental workload. Only trait anxiety was found to be significantly positively correlated with stress. No significant effects of AOD, AOF, or flight hours were found on pilots' responses. The results indicate trait anxiety may affect pilots' responses to stressful scenarios, even though pilots are selected based on low trait anxiety.

Keywords: individual difference, aviation, flight hours, state anxiety

Loss of control in-flight (LOC-I) was the most significant contributor to fatal accidents in commercial aircraft worldwide between 2003 and 2023 (Airbus, 2024). The events leading up to LOC-I can include system failures, software errors, or weather events. Such events require pilots to respond appropriately in potentially highly demanding and stressful circumstances. However, unforeseen threats are likely to cause startle and surprise, which may have detrimental effects on pilot performance (Casner et al., 2012; Kochan et al., 2005; Landman et al., 2017b; Wickens, 2002).

Startle is a brief, fast physiological reaction to a sudden, intense, or threatening stimulus (Koch, 1999). The startle response consists of concurrent processes, the startle reflex itself, and the “fight-or-flight response” (Martin et al., 2015). The startle reflex involves the involuntary physiological reflexes and inhibition of muscular activities (e.g., eye blinks, head ducks; Koch, 1999; Rivera et al., 2014), which can prepare the body for protection against adverse circumstances (Blumenthal, 2015). The response is more severe when an individual's arousal or stress level is already

high (i.e., fear-potentiated startle; Martin et al., 2015). As the startle reflex occurs, the slower fight-or-flight response develops, which is an acute physiological stress response including the release of cortisol, activation of the autonomic nervous system, rapid breathing, increased heart rate, increased blood pressure, and sensory arousal (Jansen et al., 1995, Papadimitriou & Priftis, 2009). The startle response can inhibit cognitive processing and muscular activities, causing deterioration of task performance with increased response time and lower response accuracy (Thackray & Touchstone, 1983).

Surprise, on the other hand, is a cognitive and emotional response caused by a mismatch between expectations and perceived information (Meyer et al., 1997). The occurrence of surprise is thought to alert individuals of this mismatch and motivate them to resolve it. If the mismatch is not resolved, then the situation is not well understood. This makes it more difficult to select and focus on relevant information, make projections, and take appropriate actions. To solve this mismatch, effortful goal-directed cognitive processing is required, which is particularly difficult

to perform under high stress (Landman et al., 2017a). If the mismatch is not resolved immediately, the sense of a “loss of grip” on the situation may further increase stress. Stress (or state anxiety) is thought to negatively affect cognition performance, as it impairs goal-directed attentional control, and to reduce available working memory (Eysenck et al., 2007; Lewis & Linder, 1997). Attention may be drawn to irrelevant threat-related stimuli or worries, and focusing on and processing task-relevant information becomes more difficult. However, stress may also cause an increased mobilization of mental effort to perform the task well, which may have a positive effect on performance.

Individuals exhibit considerable variability in their perception and response to stressful stimuli (Ebner & Singewald, 2017), which could affect their ability to perform under stress. Neuroticism, one of the Big Five personality traits, is characterized by emotional instability and sensitivity to negative emotions (McCrae et al., 2005). This was found to be strongly related to the severity of the startle reflex (Wilson et al., 2000), symptoms of prolonged state anxiety (Jylhä & Isometsä, 2006), psychological stress (Vollrath & Torgersen, 2000), and impaired decision-making performance under pressure (Byrne et al., 2015). Conscientiousness, the Big Five personality trait of being responsible, diligent, and careful (McCrae et al., 2005), was found to be positively correlated with electrodermal stability when pilots encountered social stress (Hidalgo-Muñoz et al., 2021). Not surprisingly, a combination of low Neuroticism and high Conscientiousness has shown to be a favorable personality profile when it comes to coping with stress (Afshar et al., 2015). Compared to Neuroticism, trait anxiety represents a more specific facet of sensitivity to negative emotions, as it specifically refers to the tendency of appraising situations as threatening and the proneness of responding with (more) stress to these situations (Spielberger, 1975). A meta-analysis suggested that pilots characterized by low Neuroticism and low trait anxiety were more likely to succeed in military aviation training (Campbell et al., 2009), although more factors are likely involved.

Another more specific trait than Neuroticism and Conscientiousness, which could be relevant to pilot performance in startling and surprising situations, is trait self-control. This is defined as one's ability to alter or override dominant response tendencies and to regulate behavior, thoughts, and emotions (Heatherton & Tice, 1994). Trait self-control is associated with stress-reducing coping styles (Englert et al. 2011). Individuals with high trait self-control strength are able to achieve desirable responses and inhibit undesirable responses, and they are more successful in achieving their goals (Tangney et al., 2018). Kuhl (1992) developed measures for action and state orientation. Action orientation refers to the tendency to detach from irrelevant con-

cerns, initiate goal-related actions more effectively, and more persistently focus on tasks until these are completed. By contrast, state orientation refers to the tendency to be distracted by alternative goals and affective states and to have difficulty in initiating actions to achieve goals. Highly action-oriented individuals were found to show increased down-regulating of stress and were able to maintain more control over behavior and attention in demanding situations (Jostmann et al., 2005; Kuhl & Beckmann, 1994; Landman et al., 2016).

The current study focused on the effects of pilot trait anxiety and self-control on their cognitive and affective responses to startling and surprising events. These traits could be very relevant for aviation, as these may affect a pilot's stress level and coping mechanisms in highly demanding situations. Flight experience may be an important mitigator, and therefore this characteristic was also included in the analysis. More insight into these relationships is useful for the development of personalized training interventions for pilots. Three hypotheses were formulated:

Hypothesis 1 (H1): Higher trait anxiety is positively correlated with pilots' perceived startle and stress in simulated in-flight emergency events due to increased sensitivity to threat.

Hypothesis 2 (H2): Higher action orientation is negatively correlated with pilots' perceived startle, surprise, stress, and mental workload due to an increased focus on tasks and goals and less on emotional states and distractions.

Hypothesis 3 (H3): More extensive flight experience is negatively correlated with perceived startle, surprise, stress, and mental workload, as unexpected situations would be less novel for pilots, less demanding, and therefore less threatening.

The second, more exploratory goal of the current study was to analyze the relationships between pilots' perceived surprise, startle, stress, and mental workload during simulated startling and/or surprising events. Insights into the strength of these relationships are useful for a better understanding of the processes associated with the responses of startle and surprise and for the development of measuring instruments for startle and surprise. Three additional hypotheses were formulated and tested for this second objective:

Hypothesis 4 (H4): Startle is positively correlated with stress, as startle is expected to initiate a generalized stress response.

Hypothesis 5 (H5): Perceived mental workload is positively correlated with stress, as highly perceived

demand is likely to induce stress and because stress may cause the mobilization of more mental effort.

Hypothesis 6 (H6): Perceived surprise is positively correlated with perceived mental workload, as solving a mismatch following surprise is expected to be effortful.

Method

Participants

The dataset was established from four previous experiments, which involved a total of 89 commercial airline pilots. These experiments will be referred to as *Study 1* (Landman et al., 2017b), *Study 2* (Landman et al., 2018), *Study 3* (Landman et al., 2020), and *Study 4* (Piras et al., 2023). The relevant characteristics of all participating pilots are summarized in Columns 2–4 of Table 1. All participants were required to hold a valid commercial pilot license. All studies complied with the tenets of the Declaration of Helsinki, and informed consent was obtained from all participants.

Tasks and Apparatus

An overview of the test scenarios is presented in Table 2. A more detailed description of the apparatus, tasks, and conditions can be found in the respective publications. All tasks were performed in motion-base simulators, namely, the Desdemona flight simulator in Study 1 and the SIMONA Research Simulator in Studies 2–4. Experimental procedures included briefing, familiarization, a pretest session, a ground theory session on startle and surprise (only for Studies 3 and 4), a training session (only for Studies 2–4), a test session, and a debriefing. Some studies divided participants into a experimental group and a control group (Studies 2–4), but since no significant effects of these treatments were found on the dependent measures for the current study, participants in these studies were regarded as one group.

During the briefing, participants were instructed about the flight tasks, the aerodynamic model, and the simulator and its features. After this, they completed questionnaires on demographic information, flight experience, and personality traits (see “Dependent Measures” section). In the training session for Study 2, participants in the experimental group were required to complete tasks under more variations in the mixed order, which includes various wind directions, wind strengths, and malfunction timings. The control group repeatedly conducted the same task under one of the variations and performed tasks in a more repetitive

sequence. During the ground theory session of Studies 3 and 4, participants in the experimental group were introduced to the theory of startle and surprise and to the rationale behind the experimental training intervention. The control group received only the introduction to startle and surprise. After each test scenario in each study, participants were asked to indicate their ratings on startle, surprise, stress, and mental workload (see “Dependent Measures” section).

Independent Measures: Personality Traits and Flight Experience

Action Versus State Orientation

As measures of trait self-control, two subscales of the Action Control Scale (ASC-90) were used (Kuhl & Beckmann, 1994), namely, decision-related action orientation (AOD), and failure-related action orientation (AOF). The third subscale of the ACS-90, on performance-related action orientation (AOP), was not included. This scale relates more to intrinsic motivation to persevere in tasks and not to dealing with high demand and threat. The AOD and AOF each consist of 12 items describing self-regulatory situations. For each situation, participants indicated which of two alternatives best describes how they would usually respond: an action-oriented or state-oriented option. To analyze the results, scores are assigned (1 = *action-oriented*, 0 = *state-oriented*) and summed. Higher scores indicate a stronger disposition toward action orientation, with a score of 7 or higher typically reflecting trait action orientation and a score of 6 or lower indicating trait state orientation. Action-oriented and state-oriented individuals have been shown to be equally well represented (Kuhl, 1992). The ACS-90 was reported to have sufficient construct validity (Diefendorff et al., 2000) and good internal consistency (Cronbach's $\alpha > .70$; Blunt & Pychyl, 1998).

For the current sample who completed these scales (Studies 1 and 4: $N = 45$), the AOD and AOF subscales had high internal consistency, $\alpha = .844$ and $\alpha = .821$, respectively. Overall, our sample significantly scored above the norm on AOD, $M = 9.1$, $SD = 2.7$ ($t = 4.59$, $p < .001$) and AOF, $M = 8.2$, $SD = 3.2$ ($t = 7.62$, $p < .001$), which indicates that pilots in this sample were considerably more action-oriented than the general population.

Trait Anxiety

Trait anxiety was measured by the Y-2 Form (trait scale) of the State-Trait Inventory (STAI; Spielberger, 1984) in Studies 1, 3, and 4. Trait anxiety is defined as a relatively stable behavioral disposition to respond anxiously to a wide range of threatening stimuli. Participants were required to indicate how they generally feel on 20 statements on 4-point Likert scales. In previous studies, Cronbach's α

Table 1. Characteristics of the participants

Study	No. of participants	Age (years) <i>M</i> (<i>SD</i>)	Flight hours (hr) <i>M</i> (<i>SD</i>)	STAI-trait score <i>M</i> (<i>SD</i>)	AOD score <i>M</i> (<i>SD</i>)	AOF score <i>M</i> (<i>SD</i>)
Study 1	20	36.3 (7.9)	6,987 (3,804)	29.0 (6.2)	36.3 (7.9)	8.2 (3.0)
Study 2	20	41.2 (8.7)	8,441 (5,467)	N/A	N/A	N/A
Study 3	24	38.5 (12.0)	7,358 (5,580)	27.0 (9.2)	N/A	N/A
Study 4	25	43.2 (9.2)	9,930 (6,281)	29.1 (5.0)	9.0 (3.0)	8.2 (3.4)

Note. AOD = decision-related action orientation; AOF = failure-related action orientation; N/A = not available; STAI = State-Trait Inventory.

Table 2. Test scenarios and measured personality traits

Study	Between-Subject Factors	Scenarios	Events in the Scenarios	Scales on Personality Traits
Study 1	None.	1-1 Stall	In the presence of a strong tailwind, the pitch trim was adjusted toward 48% of its maximum capacity in 3 seconds	STAI Form Y-2 AOD subscale AOF subscale
Study 2	High variability and unpredictability training session versus low variability training session.	2-1 Airspeed indicator failure 2-2 Single engine failure 2-3 Rudder failure	Upon rotation, the indicated airspeed decreased with 1 kt/s from the actual airspeed When the speed reached 55 kt, thrust in the right engine dropped in 20s to 40% The rudder effectiveness decreased to 20% as the pilot rolled out of the turn towards downwind leg	None
Study 3	Training session with the experimental training intervention or without.	3-1 Flap asymmetry 3-2 False stall warning 3-3 Airspeed indicator failure 3-4 Mass shift	When selecting Flaps 25, the left flap remained up When reaching 1500 ft, a bird struck the angle of attack vane Same as Scenario 2-1 Upon rotation, a piece of cargo broke loose and shifted towards the tail	STAI Form Y-2
Study 4	Training session with the experimental training intervention or without.	4-1 Flap asymmetry 4-2 Mass shift	Same as Scenario 3-1 Same as Scenario 3-4	STAI Form Y-2 AOD subscale AOF subscale

for the scale ranged from .86 to .95 (Spielberger et al., 1971), and the test-retest reliability coefficients were found to range from .86 to .73 over a retest interval of 20 days and 104 days, respectively (Hedberg, 1972).

For the current sample (Studies 1, 3, and 4: $N = 69$), the trait anxiety scores, $M = 28.3$, $SD = 7.0$, were significantly lower than in the general population (36.7 , $t = -9.93$, $p < .001$).

Flight Experience

Pilots listed their flight hours on large jet aircrafts after briefing.

Dependent Measures: Cognitive and Affective Responses

An overview of the personality traits measured in each study, with mean values and SDs obtained in the different samples, is shown in the last three columns of Table 1.

Perceived Startle and Surprise

Startle and surprise were measured in Studies 1, 3, and 4 using nonvalidated Likert scales ranging from 0 (= *not at all*) to 10 (= *extremely*) by answering the questions: “How startled were you by [the stimulus]?” and “How surprised were you by [the stimulus]?”; here, “[the stimulus]” was substituted by the potentially startling/surprising event in the scenario. In Study 2, a nonvalidated 5-point Likert scale was used instead to collect responses to the same questions, with 1 = *not at all* and 5 = *extremely*.

Perceived Stress

Ratings of acute stress were measured using the anxiety scale (Houtman & Bakker, 1989). The anxiety scale applied in Studies 1 and 4 was the 11-point Likert-type version ranging from 0 to 10, while a continuous visual analogue scale version was applied in Studies 2 and 3. The visual analogue scale was a 10-cm-long horizontal line, with tick marks at 1-cm intervals labeled 0 and *not at all* at the left endpoint and 10 and *extremely* at the right endpoint.

Table 3. Means (*M*) and standard deviations (*SD*) of the pilot responses

Study	Scenario	Surprise <i>M</i> (<i>SD</i>)	Startle <i>M</i> (<i>SD</i>)	Anxiety <i>M</i> (<i>SD</i>)	Workload <i>M</i> (<i>SD</i>)
Study 1	Scale range	[0–10]	[0–10]	[0–10]	[0–100]
	1-1	8.0 (1.8)	3.9 (2.1)	3.7 (1.6)	66.0 (15.4)
Study 2	Scale range	[1–5]	[1–5]	[0–10]	[0–100]
	2-1	3.6 (0.7)	2.9 (1.1)	5.1 (2.1)	67.3 (19.4)
	2-2	2.4 (0.6)	2.0 (0.7)	3.6 (2.0)	57.0 (16.7)
	2-3	3.2 (1.0)	2.8 (0.9)	5.8 (2.0)	72.3 (14.9)
Study 3	Scale range	[0–10]	[0–10]	[0–10]	[0–150]
	3-1	6.3 (2.5)	5.3 (2.3)	4.4 (2.1)	56.8 (20.7)
	3-2	6.4 (2.3)	7.0 (2.0)	4.2 (2.3)	51.5 (18.8)
	3-3	6.3 (2.4)	4.8 (2.5)	3.7 (2.2)	55.1 (20.8)
	3-4	7.2 (2.3)	6.3 (2.3)	5.5 (2.1)	69.8 (23.2)
Study 4	Scale range	[0–10]	[0–10]	[0–10]	[0–150]
	4-1	5.5 (2.2)	4.6 (2.0)	3.7 (1.8)	64.8 (17.8)
	4-2	7.2 (1.7)	6.7 (2.0)	5.7 (2.1)	80.3 (16.7)

Table 4. Correlations between STAI-trait, AOD, AOF scores, flight hours, and *z* scores of the cognitive and affective responses

	STAI-trait	AOD	AOF	Flight hours	<i>z</i> (Startle)	<i>z</i> (Surprise)	<i>z</i> (Stress)	<i>z</i> (Mental workload)
STAI-trait	–				.183	–.048	.332*	.188
AOD	–.444**	–			.045	.067	–.116	–.019
AOF	–.447**	.347*	–		.005	.175	–.070	–.115
Flight hours	–.069	–.035	.189	–	–.141	–.095	–.051	–.161

Note. * $p < .05$, two-tailed. ** $p < .01$, two-tailed.

Perceived Mental Workload

In Study 1, mental workload was measured using a unidimensional scale ranging from 0 (= *very low workload*) to 100 (= *very high workload*) (Hill et al., 1992). Considering the task (e.g., stall recovery) required very little physical effort, the score was used as an indication of mental workload. In Study 2, mental workload was rated using the mental demand subscale of the NASA-TLX (Hart et al., 1988), a 21-point scale ranging from 0 (= *low*) to 100 (= *high*). In Studies 3 and 4, the English version of the Rating Scale Mental Effort (RSME; Zijlstra, 1993) was used as an indication of perceived mental workload. The RSME consists of a 150-mm line marked with nine anchor points, each accompanied by a descriptive label indicating a degree of effort. Participants were instructed to indicate their invested effort by placing a cross on the continuous line, resulting in a score between 0 and 150. If participants invest less mental effort than the workload required for completing the task successfully, mental effort can differ from mental workload. In all four experiments, however, all pilots declared beforehand that they would do their best to perform well in the test, which leads us to assume that their invested mental effort coincides with the perceived workload imposed by the task. Similar conclusions were found in the NASA-TLX validation study (Hart et al., 1988), where the factor “mental effort” was consistently related to overall workload from single cognitive laboratory tasks to simulations in motion-based simulators.

Data Analysis

For each of the dependent measures, *z* scores were calculated per participant per scenario. This means that each score reflects how a pilot responded relatively to other pilots in the same scenario, and that we corrected for different ranges of different scales. To investigate the effects of personality traits and flight hours on dependent measures, the averaged *z* scores of startle, surprise, stress, and mental workload were obtained for each pilot by averaging scores in different scenarios. Then, we calculated Spearman's correlations between the independent measures (STAI-trait, AOD, AOF, flight hours) and the dependent measures (*z* scores of startle, surprise, stress, and mental workload).

With regard to relationships between the dependent measures obtained in repeated-measures scenarios, the “between and within formulation” (Hox, 2010) was applied. The working principle of this formulation is that the total sample variances can be decomposed into within-individual variance and between-individual variance. Both between-individual and within-individual correlation matrices were obtained from the *z* scores of startle, surprise, stress, and mental workload per participant per scenario.

Missing Values

In Study 2, three cases of stress ratings were missing. In Study 4, three scenarios were presented incorrectly for

Table 5. Pooled within-individual correlation matrices of cognitive and affective responses

	<i>z</i> (Startle)	<i>z</i> (Surprise)	<i>z</i> (Stress)	<i>z</i> (Mental workload)
<i>z</i> (Surprise)	.316**	–		
<i>z</i> (Stress)	.265**	.236**	–	
<i>z</i> (Mental workload)	.258**	.454**	.469**	–

Note. ** $p < .01$, two-tailed.

three respective participants, leading to loss of the data on all their responses in these scenarios. All missing values were replaced by the mean value of the available responses of the rest of participants in the corresponding scenario. The substituted values were 2.65% of stress ratings and 1.33% of surprise, startle, and mental workload ratings, with regard to the total number of data.

Results

Effects of Personality Traits and Flight Hours on Pilot Responses

Table 3 summarizes the means and SDs of pilot responses in each scenario performed in the four studies. The measures show that most of the scenarios were experienced as startling, surprising, or both, as most of the mean scores are above the midpoint of the scales.

Table 4 lists the Spearman correlations between STAI-trait, AOD, AOF scores, and flight hours and the *z* scores of the pilot responses. The STAI-trait score was significantly positively correlated with perceived stress. Pilots with higher trait anxiety levels reported higher stress with regard to the simulated events. Neither AOD nor AOF were significantly correlated with the dependent measures. No significant correlations were observed between flight hours and any of the pilot responses.

The STAI-trait scores were significantly negatively correlated with the AOD and AOF scores. These results suggest that pilots with higher trait anxiety also tended to have lower decision-related and failure-related action orientation. Moreover, the AOD and AOF scores were significantly positively correlated. Pilots who were more action-oriented in AOD were more likely to be action-oriented in AOF, and vice versa.

Correlations Between Pilot Responses

The pooled within-individual correlation matrix (Table 5) shows the average correlations between four responses for each pilot. In Table 6, the estimated between-individual correlation matrix presents the correlations between

Table 6. Estimated between-individual correlation matrices of cognitive and affective responses

	<i>z</i> (Startle)	<i>z</i> (Surprise)	<i>z</i> (Stress)	<i>z</i> (Mental workload)
<i>z</i> (Surprise)	.673**	–		
<i>z</i> (Stress)	.569**	.536**	–	
<i>z</i> (Mental workload)	.402**	.492**	.695**	–

Note. ** $p < .01$, two-tailed.

responses based on the average responses across all pilots. For within-individual correlations, the strongest significant correlations were observed between the *z* scores of mental workload and stress and between the *z* scores of mental workload and surprise. This means that pilots who rated a certain scenario as more mentally demanding, also were likely to rate it as more stressful and surprising. For between-individual correlations, the highest significant correlations were observed between the *z* scores of surprise and startle and between the *z* scores of mental workload and stress. This means that pilots who generally scored higher than others on surprise, also generally scored higher than others on startle, and pilots who scored generally higher than others on mental workload, also scored generally higher than others on stress.

Discussion

For the main objective, in line with Hypothesis 1, trait anxiety was found to correlate significantly and positively with perceived stress during simulated in-flight events. Pilots with higher trait anxiety experienced more stress during these events. This relationship supports the basic hypothesis from the interaction model of stress (Endler, 1997), in that trait anxiety could interact with the stressful situation (i.e., the unexpected failure) leading to an increase in acute stress. Given that increased stress could disrupt the balance between a pilot's goal-directed and stimuli-driven system (Eysenck et al., 2007), it could be more difficult for pilots with higher trait anxiety to manage their attention effectively. The finding highlights the importance of personalizing pilot training to individual differences. For instance, pilots with higher trait anxiety may benefit from specialized stress interventions, such as repeated exposure to simulated high-stress scenarios, to reduce sensitivity to unexpected events (Saunders et al., 1996; Staal, 2004). No evidence was found, however, that trait anxiety affected mental workload in the presented situations. An analysis of pilot performance was considered beyond the scope of the current study, as differences between scenarios made it difficult to standardize and pool pilots' performance variables.

In addition, many of the included studies did not involve a control condition where baseline measures of pilot performance without startle or surprise were obtained.

Contrary to Hypothesis 2, our findings did not indicate that higher action orientation was associated with lower ratings of startle, surprise, stress, or mental workload in the scenarios. One possible explanation is that action orientation perhaps did not impact the pilots' responses themselves, but it instead contributed to better coping mechanisms to these responses. However, the absence of significant correlations may also be caused by the high homogeneity of our sample (see Table 1). The participant pilots exhibited lower trait anxiety and higher action orientation (both AOF and AOD) compared with the general population, and standard deviations were relatively small. All participants were active commercial airline pilots, and they volunteered for a study they knew would assess their ability to cope with in-flight failures. This self-selection most likely resulted in a sample with generally high action orientation, even relative to the average pilot. Similarly, contrary to Hypothesis 3, we found no significant correlation between flight experience and surprise, startle, stress, or mental workload. This suggests that both novice and experienced pilots could possibly benefit from targeted training interventions for mitigating effects of high stress, startle, or surprise.

For the secondary objective, in line with Hypotheses 5 and 6, significant correlations were found between all dependent measures, both for within-individual and between-individual correlations. The strongest within-individual correlations were found between stress and mental workload and between surprise and mental workload. Thus, pilots who rated a certain scenario as more mentally demanding were also highly likely to rate this scenario as more stressful and surprising. Stress may increase invested mental effort in task performance and in focusing attention on task-relevant instead of threat-related stimuli (Eysenck et al., 2007). Also, if certain pilots experience difficulty with responding to the failures, this may increase both high mental workload and stress. For surprise, efforts to understand "what is going on" and reframe a situation following the surprise event were likely to cause higher mental workload (Landman et al., 2017a). Interestingly, the within-individual correlation between startle and stress was not one of the strongest correlations. It seems that stress in the scenarios was affected by other factors besides startle, such as task difficulty. For the between-individual correlations between dependent measures, the strongest correlations were observed between startle and surprise and between stress and mental workload. The strong correlation between startle and surprise implies that the propensity to be startled is possibly related to the propensity to be

surprised. It could also be attributed to the fact that we did not separately manipulate startle and surprise in the scenarios presented. The strong correlation between stress and mental workload implies that pilots who tend to experience more stress are also those who experience the highest workload, possibly due to being less skilled. However, the latter was not substantiated by significant correlations between flight hours and mental workload.

Limitations

When considering the findings of the current study, a number of limitations need to be mentioned. First, a variety of different scenario were used to obtain the dataset for this study. Events in scenarios were considered, on average, moderately startling or surprising by the pilots (i.e., scored around the midpoint of the scales). However, no complex flight system failures or checklists were included, and all scenarios were flown manually at a relatively low altitude. This limits the generalizability of results to those types of events. Also, many of the presented scenarios differed from the pilots' daily operational tasks. All scenarios were performed in a single-pilot setting and using a simplified twin-prop aircraft model that most pilots had limited experience with. Apart from the unfamiliarity, high workload was induced by requiring pilots to fly manually, instead of simulating complex tasks involving system management, higher levels of automation, crew teamwork, and resource management or emphasizing planning and navigation. Second, regarding the measures of the cognitive and affective responses, the rating scales used for surprise and startle were not psychometrically validated to provide insights for future research. Outcomes responses were measured on unidimensional scales, which might be generally less accurate than multidimensional scales. The third limitation of this study is that we did not apply formal corrections the correlation analyses. While this decision was intentional to avoid overly conservative adjustments that might mask meaningful relationships, it increases the risk of Type I errors. This means that some of the significant correlations reported in this study could have occurred by chance rather than representing true underlying relationships. To address these possible biases, future research could possibly be performed in an actual training environment, employing a simulated aircraft type that pilots also work in. This allows for more complex, high-demand tasks. Additionally, future studies should focus on objective or real-time physiological measures to investigate the potential causal relationships between startle, surprise, stress, and mental workload. Moreover, correction methods are recommended to applied, such as Bonferroni correction, to strengthen the reliability of current findings.

Conclusion

In conclusion, the current study provides data on pilot responses for different simulated emergency events, which are useful for applications in future research. Within the aviation context, data on the effects of pilot personality traits on reactions in surprising situations are scarce. The current study contributes to the literature by providing insights into the effects of trait anxiety and trait self-control.

References

- Afshar, H., Roohafza, H. R., Keshteli, A. H., Mazaheri, M., Feizi, A., & Adibi, P. (2015). The association of personality traits and coping styles according to stress level. *Journal of Research in Medical Sciences*, 20(4), 353.
- Airbus. (2024). *A statistical analysis of commercial aviation accidents 1958–2023*. <https://accidentstats.airbus.com/>
- Blumenthal, T. D. (2015). Presidential address 2014: The more-or-less interrupting effects of the startle response. *Psychophysiology*, 52(11), 1417–1431.
- Blunt, A., & Pychyl, T. A. (1998). Volitional action and inaction in the lives of undergraduate students: State orientation, procrastination and proneness to boredom. *Personality and Individual Differences*, 24(6), 837–846.
- Byrne, K. A., Silasi-Mansat, C. D., & Worthy, D. A. (2015). Who chokes under pressure? The big five personality traits and decision-making under pressure. *Personality and Individual Differences*, 74, 22–28.
- Campbell, J. S., Castaneda, M., & Pulos, S. (2009). Meta-analysis of personality assessments as predictors of military aviation training success. *The International Journal of Aviation Psychology*, 20(1), 92–109.
- Casner, S. M., Geven, R. W., & Williams, K. T. (2012). The effectiveness of airline pilot training for abnormal events. *Human Factors*, 55(3), 477–485.
- Diefendorff, J. M., Hall, R. J., Lord, R. G., & Streat, M. L. (2000). Action-state orientation: Construct validity of a revised measure and its relationship to work-related variables. *Journal of Applied Psychology*, 85(2), 250.
- Ebner, K., & Singewald, N. (2017). Individual differences in stress susceptibility and stress inhibitory mechanisms. *Current Opinion in Behavioral Sciences*, 14, 54–64.
- Endler, N. S. (1997). Stress, anxiety and coping: The multidimensional interaction model. *Canadian Psychology/Psychologie canadienne*, 38(3), 136.
- Englert, C., Bertrams, A., & Dickhäuser, O. (2011). Dispositional self-control capacity and trait anxiety as relates to coping styles. *Psychology*, 2(6), 598–604.
- Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion*, 7(2), 336.
- Hart, S. G., Staveland, L. E., Hancock, P. A., & Meshkati, N. (1988). Development of NASA-TLX (task load index): Results of empirical and theoretical research. *Advances in Psychology*, 52, 139–183.
- Heatherton, T., & Tice, D. M. (1994). *Losing control: How and why people fail at self-regulation*. Academic.
- Hedberg, A. G. (1972). *Review of state-trait anxiety inventory* (Vol. 3). American Psychological Association.
- Hidalgo-Muñoz, A. R., Mouratille, D., El-Yagoubi, R., Rouillard, Y., Matton, N., & Causse, M. (2021). Conscientiousness in pilots correlates with electrodermal stability: Study on simulated flights under social stress. *Safety*, 7(2), 49.
- Hill, S. G., Iavecchia, H. P., Byers, J. C., Bittner, A. C. Jr., Zaklade, A. L., & Christ, R. E. (1992). Comparison of four subjective workload rating scales. *Human Factors*, 34(4), 429–439.
- Houtman, I. L. D., & Bakker, F. C. (1989). The anxiety thermometer: A validation study. *Journal of Personality Assessment*, 53(3), 575–582.
- Hox, J. J. (2010). *Multilevel analysis: Techniques and applications* (2nd ed.). Routledge/Taylor & Francis Group.
- Jansen, A. S. P., Van Nguyen, X., Karpitskiy, V., Mettenleiter, T. C., & Loewy, A. D. (1995). Central command neurons of the sympathetic nervous system: Basis of the fight-or-flight response. *Science*, 270(5236), 644–646.
- Jostmann, N. B., Koole, S. L., Van Der Wulp, N. Y., & Fockenberg, D. A. (2005). Subliminal affect regulation: The moderating role of action vs. state orientation. *European Psychologist*, 10(3), 209.
- Jylhä, P., & Isometsä, E. (2006). The relationship of neuroticism and extraversion to symptoms of anxiety and depression in the general population. *Depression and Anxiety*, 23(5), 281–289.
- Koch, M. (1999). The neurobiology of startle. *Progress in Neurobiology*, 59(2), 107–128.
- Kochan, J., Breiter, E., & Jentsch, F. (2005). *Surprise and unexpectedness in flying: Factors and features*. 2005 International Symposium on Aviation Psychology (pp. 398–403). https://corescholar.libraries.wright.edu/isap_2005/59
- Kuhl, J. (1992). A theory of self-regulation: Action versus state orientation, self-discrimination, and some applications. *Applied Psychology*, 41(2), 97–129.
- Kuhl, J., & Beckmann, J. (1994). *Volition and personality: Action versus state orientation*. Hogrefe & Huber Publishers.
- Landman, A., Groen, E. L., Van Paassen, M. M., Bronkhorst, A. W., & Mulder, M. (2017). Dealing with unexpected events on the flight deck: A conceptual model of startle and surprise. *Human Factors*, 59(8), 1161–1172.
- Landman, A., Groen, E. L., van Paassen, M. M., Bronkhorst, A. W., & Mulder, M. (2017). The influence of surprise on upset recovery performance in airline pilots. *The International Journal of Aerospace Psychology*, 27(1–2), 2–14.
- Landman, A., Nieuwenhuys, A., & Oudejans, R. R. D. (2016). Decision-related action orientation predicts police officers' shooting performance under pressure. *Anxiety, Stress, & Coping*, 29(5), 570–579.
- Landman, A., van Middelaar, S. H., Groen, E. L., van Paassen, M. R. M., Bronkhorst, A. W., & Mulder, M. (2020). The effectiveness of a mnemonic-type startle and surprise management procedure for pilots. *The International Journal of Aerospace Psychology*, 30, 104–118.
- Landman, A., van Oorschot, P., van Paassen, M. M., Groen, E. L., Bronkhorst, A. W., & Mulder, M. (2018). Training pilots for unexpected events: A simulator study on the advantage of unpredictable and variable scenarios. *Human Factors*, 60(6), 793–805.
- Lewis, B. P., & Linder, D. E. (1997). Thinking about choking? Attentional processes and paradoxical performance. *Personality and Social Psychology Bulletin*, 23(9), 937–944.
- Martin, W. L., Murray, P. S., Bates, P. R., & Lee, P. S. Y. (2015). Fear-potentiated startle: A review from an aviation perspective. *The International Journal of Aviation Psychology*, 25(2), 97–107.
- McCrae, R. R., Costa, P. T. Jr., & Martin, T. A. (2005). The NEO-PI-3: A more readable revised NEO personality inventory. *Journal of Personality Assessment*, 84(3), 261–270.
- Meyer, W. U., Reisenzein, R., & Schützwohl, A. (1997). Toward a process analysis of emotions: The case of surprise. *Motivation and Emotion*, 21(3), 251–274.

- Papadimitriou, A., & Priftis, K. N. (2009). Regulation of the hypothalamic-pituitary-adrenal axis. *Neuroimmunomodulation*, 16, 265–271.
- Piras, M., Landman, A., van Paassen, M. M., Stroosma, O., Groen, E., & Mulder, M. (2023). *Easy as ABC: A Mnemonic Procedure for Managing Startle and Surprise*. 22nd International Symposium on Aviation Psychology, 39. https://corescholar.libraries.wright.edu/isap_2023/3
- Rivera, J., Talone, A. B., Boesser, C. T., Jentsch, F., & Yeh, M. (2014). Startle and surprise on the flight deck: Similarities, differences, and prevalence. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 58(1), 1047–1051.
- Saunders, T., Driskell, J. E., Johnston, J. H., & Salas, E. (1996). The effect of stress inoculation training on anxiety and performance. *Journal of Occupational Health Psychology*, 1(2), 170–186. <https://doi.org/10.1037/1076-8998.1.2.170>
- Spielberger, C. D. (1975). Anxiety: State-trait-process. In C. D. Spielberger (Ed.), *Stress and anxiety* (Vol 1, pp. 115–143). Hemisphere Publishers.
- Spielberger, C. D. (1984). *State-trait anxiety inventory: A comprehensive bibliography*. Consulting Psychologists Press.
- Spielberger, C. D., Gonzalez-Reigosa, F., Martinez-Urrutia, A., Natalicio, L. F. S., & Natalicio, D. S. (1971). The state-trait anxiety inventory. *Revista Interamericana de Psicologia/Interamerican Journal of Psychology*, 5(3–4).
- Staal, M. A. (2004). *Stress, cognition, and human performance: A literature review and conceptual framework*. Technical Report NASA/TM–2004–212824. NASA. https://hs1.arc.nasa.gov/publications/20051028105746_IH-054%20Staal.pdf
- Tangney, J. P., Boone, A. L., & Baumeister, R. F. (2018). High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. In R. F. Baumeister (Ed.), *Self-regulation and self-control* (pp. 173–212). Routledge.
- Thackray, R. I., & Touchstone, R. M. (1983). *Rate of initial recovery and subsequent radar monitoring performance following a simulated emergency involving startle* (Technical report). Civil Aerospace Medical Institute.
- Vollrath, M., & Torgersen, S. (2000). Personality types and coping. *Personality and Individual Differences*, 29(2), 367–378.
- Wickens, C. D. (2002). Situation awareness and workload in aviation. *Current Directions in Psychological Science*, 11(4), 128–133.
- Wilson, G. D., Kumari, V., Gray, J. A., & Corr, P. J. (2000). The role of neuroticism in startle reactions to fearful and disgusting stimuli. *Personality and Individual Differences*, 29(6), 1077–1082.
- Zijlstra, F. (1993). *Efficiency in work behavior. A design approach for modern tools*. Delft University of Technology.

History

Received November 24, 2024

Accepted November 29, 2024

Published online February 12, 2025

Acknowledgment

An earlier version of this paper won the Best Paper Proceedings Award at the 35th Conference of the European Association for Aviation Psychology (Athens, Greece, September 23–26, 2024).

Publication Ethics

Informed consent was obtained from all participants included in the studies.

All procedures in studies involving human participants were performed in accordance with the ethical standards of the Delft University of Technology's Human Research Ethics Committee.

ORCID

Annemarie Landman

<https://orcid.org/0000-0003-3678-9210>

M. M. van Paassen

<https://orcid.org/0000-0003-4700-1222>

Jiayu Chen

<https://orcid.org/0009-0006-0084-1661>

Olaf Stroosma

<https://orcid.org/0000-0002-4578-3171>

Max Mulder

<https://orcid.org/0000-0002-0932-3979>

Jiayu Chen

Department of Control and Operations

Delft University of Technology

Kluyverweg 1

2629 HS Delft

The Netherlands

j.chen-12@tudelft.nl



Jiayu Chen received her MSc in Aerospace Engineering from the Northwestern Polytechnical University in 2021. She is currently a PhD candidate in the section Control and Simulation, Aerospace Engineering, Delft University of Technology.



Annemarie Landman received her PhD in Aerospace Engineering at Delft University of Technology in 2019. She is currently working as a scientist in the Training and Performance Innovations department at TNO Human Factors, and as assistant professor at the section Control and Simulation.



Olaf Stroosma received his MSc in Aerospace Engineering from Delft University of Technology in 1998. He is currently a senior researcher at the section Control and Simulation, Aerospace Engineering, Delft University of Technology, where he manages the SIMONA Research Simulator facility.



M. M. van Paassen is an associate professor in the section Control and Simulation, Aerospace Engineering, Delft University of Technology, where he received his PhD in Aerospace Engineering in 1994.



Max Mulder is a full professor in the section Control and Simulation, Aerospace Engineering, Delft University of Technology, where he received his PhD (cum laude) in Aerospace Engineering in 1999.