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RESEARCH

Startle and surprise in helicopter operations: reported prevalence and application of mitigation strategies

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Abstract

Startle and surprise can impair pilot performance and affect flight safety. This study investigates the prevalence of different startle and surprise events among helicopter pilots, its impact on pilot stress and mental effort and the influence of training background. It also looks at currently used startle mitigation strategies and evaluates the usability of a previously proposed "Aviate, Breathe, Check (ABC)" startle management method (Piras et al. 2023). A survey among 234 helicopter pilots revealed that 96% had experienced impactful startle or surprise events during operations. Scenarios such as disorientation, tail rotor incidents, and flight into instrument meteorological conditions (IMC) were considered particularly stressful. Reported levels of stress and mental effort during startle and surprise events did not differ between pilots with higher and lower experience levels or between pilots with a different training background (military or civilian). Only 38% of pilots indicated they were specifically trained to deal with startle and surprise and only 1% were trained to use a breathing technique. Most pilots (90%) expressed openness to implementing the ABC method and expected benefits from using it. Concerns regarding time constraints in critical situations emerged as the primary objection to adopting this technique. Overall, the findings indicate that the introduction of a startle management method tailored for helicopter operations could significantly enhance safety, especially given the higher accident rates compared to fixed-wing operations. Future research should focus on developing effective training protocols that account for the unique challenges of helicopter flying.

Highlights

- 96% percent of helicopter pilots have experienced impactful startle and/or surprise in flight.
- Although 59,3% stated using a startle management method or strategy, only 1% of helicopter pilots use a breathing-based startle management method.
- No statistical difference in experienced stress or mental effort between military and civilian training background, and for different experience levels.
- 90% of helicopter pilots are open to using a startle management method such as the ABC method (Piras, 2023).
- A properly trained startle management technique could potentially have safety benefits for helicopter pilots.

Keywords Mental workload · CRM · Startle · Rotary · Situational awareness · Impairment

1 Introduction

Bringing helicopter accident rates down has been a strategic priority of the safety authorities in both Europe and the US for over two decades (Flight Safety Foundation 2020). Despite repeated safety initiatives the rotary-wing accident figures remain stubbornly high, with EASA data showing a ten-year average of approximately ten fatal accidents and fifty non-fatal accidents every year, equating to an average of one rotorcraft accident per week in Europe (EASA 2024a).

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Compared to fixed wing commercial air transport (CAT) operations, helicopter operations often occur in a riskier operational environment (de Voogt et al. 2009). Examples of tasks with particularly elevated operational risk include public service flying, such as emergency medical services (EMS), firefighting, and search and rescue (Hamlet et al. 2023). These figures, in part, reflect that rotary wing flying is often characterised by a high-level of unpredictability (de Voogt et al. 2009), tends to occur lower and closer to the obstacle environment, and often in more inhospitable environmental conditions compared to fixed wing aircraft (Hamlet 2023). In helicopter EMS for example, Chesters et al. (2014) found the accident rate in the UK, Germany, Australia, and the United States to be between 0.57 and 0.75 per 10,000 missions, equating to approximately 250–350 times the incidence of accidents found in CAT aeroplanes (EASA 2024b). Even when offshore helicopter CAT is compared to its fixed-wing counterpart, the statistics remain approximately ten times higher than scheduled airline services (Bye et al. 2018).

Frequently, these hazardous flying conditions are further complicated by operating in low-visibility conditions. Nascimento et al. (2012) exemplify this in a study where interviews with offshore helicopter pilots highlighted the opportunity for spatial disorientation to occur during night-time operations, making them inherently more hazardous. Other human factors pressures such as the nature of reactive tasking, and the occasionally life-saving nature of the flight can have a detrimental impact on perceived pressures, pilot decision-making, and risk-taking behaviours (Hart 1988). These notions lead to the hypothesis that helicopter pilots may experience more frequent and more severe startle and surprise events than fixed wing pilots, suggesting a greater need for a method for helicopter crews to manage the human response to unanticipated startling stimuli or serious emergency situations.

Startle and surprise are recognised as “a significant impediment to managing safety-critical situations” (EASA, 2024b p.28). The organisation also notes that, “not enough is known about how to mitigate it”. In response to several airline accidents involving startle and/or surprise in the previous decade (e.g., Air France 447; BEA, 2012), startle management methods have been introduced in leading airlines around the world (Landman et al. 2017a; Martin et al. 2015; Rivera et al. 2014). A recent study of line flying operations has shown that these methods are positively perceived by pilots (Vlaskamp et al. 2024a). To the authors’ knowledge, to date the applicability of such techniques has not been studied from the perspective of rotary wing flight operations.

The current study employs a survey approach to address the knowledge gap in understanding startle and surprise in helicopter operations. This includes gaining insights into the prevalence of the problem from a representative sample of helicopter pilots, determining what strategies they currently use to overcome startle and surprise, and ascertaining their views on the use of a dedicated management technique for rotary wing flying. The following introduction section provides an overview of startle and surprise theory and explains the startle management technique that is the focus of this research.

1.1 Startle and surprise: theory and recovery methods

Startle and surprise (S&S) can occur together or on their own (Field et al. 2018). The terms are often used interchangeably in aviation (Rivera et al. 2014; Landman et al. 2017a) as both trigger stress responses that impair flight deck communication and decision making (Martin et al. 2016Landman et al. 2017b)– compromising operational safety. Despite this, the two concepts possess important theoretical differences that are relevant to the development and usability of appropriate recovery technologies and techniques.

Startle is defined as a sudden involuntary reaction to an intense stimulus, such as a sudden loud noise (Rivera et al. 2014). The initial startle reflex occurs very fast, and is characterized by eye-lid closure, contraction of the face, neck and skeletal muscles, an increase in heart rate and arrest of ongoing behaviour (Rivera et al. 2014). Attentional resources are directed towards the stimulus as a mechanism of threat appraisal (Martin et al. 2015). If the stimulus is perceived as a real threat, the general stress response will remain, or even increase in intensity (Landman et al. 2017a; Martin et al. 2015). An example of a startling situation in aviation is a bird striking the cockpit window.

Surprise is defined as “a cognitive-emotional response to something unexpected, which results from a mismatch between one’s mental expectations and perceptions of one’s environment” (Rivera et al. 2014). It is of longer duration than startle. If this mismatch cannot be resolved, a feeling of stress and loss of control of the situation can arise, leading to an impairment of situation awareness and ultimately cognitive lockup (Landman 2017a). Attentional narrowing takes place, as attention is focused on trying to confirm the (incorrect) cognitive “frame”, instead of seeking out additional information (Landman et al. 2017a). Surprises are common among airline pilots, but often inconsequential (Kochan et al. 2005). Surprise in aviation often occurs alongside conflicting or ambiguous cues that impede successful reframing. For example, in situations where automation does not function as expected (automation surprise) or where complicated failures occur without a clear cause.

Approaches to mitigating S&S effects include surprise exposure through unpredictable and variable scenario simulator training (Landman et al. 2018). S&S recovery techniques, alternatively, center around breathing techniques and the purposeful reacquisition of situation awareness (Field et al. 2018). Simulator evaluations have revealed that such methods were appreciated by pilots (Field et al. 2018), positively affected performance (Landman et al. 2020), whilst Vlaskamp et al. (2024b) recent research showed that pilots reported positive effects from applying the method in operational practice. Pilots in the latter study reported experiencing a reduction in stress and improved situation awareness. Recurring feedback from pilots across studies has been to keep methods as simple as possible to minimise distraction and to maximise adoption (Landman et al. 2020; Piras et al. 2023; Vlaskamp et al. 2024b). Brevity and simplicity are likely also beneficial for helicopter pilots, as startle and surprise scenarios in their context are likely to be highly time-constrained due to operating at lower altitudes, and mentally taxing due to more use of manual flight. From different similar existing methods, the recently tested "Aviate, Breathe, Check" (ABC) mnemonic (Piras et al. 2023) was chosen to be the most appropriate for this research, due to its time-efficiency and focus on single-pilot operations. The procedural details of the ABC mnemonic are outlined in Fig. 1. Evaluation of the ABC mnemonic has so far been performed using a simulator study with 25 fixed-wing pilots (Piras et al. 2023).

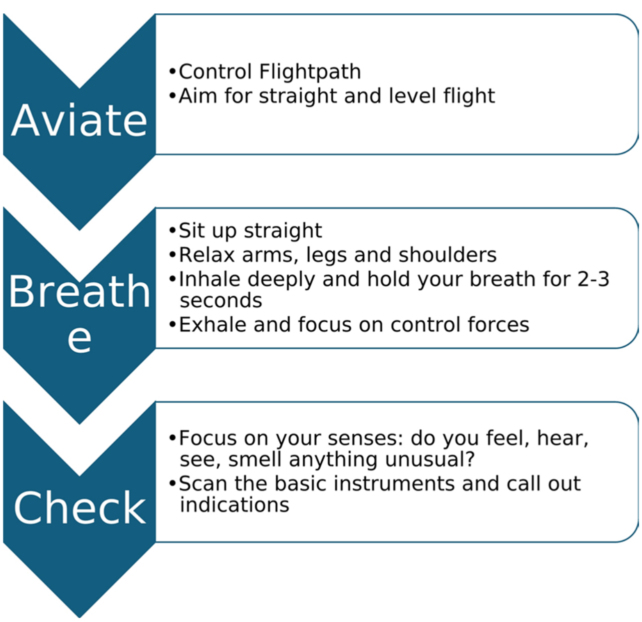

Fig. 1 ABC mnemonic procedure

1.2 Study rationale and research objectives

The objective of this study is to address the research gap between management techniques for startle and surprise developed for fixed wing operations and the state of knowledge about the same phenomenon in rotary wing operations. Little is known about the prevalence of startle and surprise in helicopter operations, or the strategies currently used by helicopter pilots to mitigate its effects (EASA 2024b, p.28). There are potential benefits to helicopter safety by developing a management technique validated from airline operations and adapted to rotary wing flying. An understanding of pilots' perception of effectiveness of such a method in different helicopter flight scenarios is critical to its design and credibility.

It is also possible that cultural differences between helicopter pilots and fixed wing pilots lead to lower perceived relevance of a S&S management technique than found in fixed wing pilots by Vlaskamp et al. (2024b). The current study offers insights into whether the adoption of a S&S recovery tool is affected by the cultural and experiential differences between helicopter and fixed wing pilots. Next to this, a comparison between military and civil trained helicopter pilots is also included. Research suggests that pilots of a military background possess greater risk propensity characteristics (Sicard et al. 2003), meaning that they are possibly more stress resistant. Also, a military background is likely to yield a broad range of experience (including with startle and surprise), which could facilitate sensemaking during surprise events (Landman et al. 2018). Therefore, pilots with a military background may not see as much benefit in a S&S management technique as pilots with a civil background.

The following research objectives were defined:

1. Investigate the prevalence of startle and surprise events across different helicopter operations and across those with military and civilian training backgrounds.
2. Investigate the cognitive impact of startle and surprise events across different helicopter operations, training backgrounds and flight experience.
3. Investigate which mitigation strategies helicopter pilots currently use for startle and surprise events.
4. Investigate whether helicopter pilots from different training backgrounds perceive the use of the ABC-method as feasible.
5. Investigate reasons behind objections to the use of a startle and surprise management method.

2 Method

2.1 Sample

The survey was advertised in the quarterly newsletter of the British Helicopter Association, posted on LinkedIn, and shared with the authors' contacts with helicopter experience. A varied sample of helicopter pilots responded, of which 234 provided usable data, although not all respondents filled in all fields. Related to the research objectives, a relatively equal number of pilots responded who had purely civil training background ($n=119$) or who had a military training background ($n=115$). Table 1 shows the demographic characteristics of the sample, which is further broken down by pilot training background (military or civilian), instructor status and operating experience.

2.2 Survey development

A custom survey was created for the purpose of addressing the research objectives and was published on the Qualtrics™ website. Ethical approval was received from Cranfield University (project ID: 24587). First, participants provided their informed consent. The rest of the survey is structured as follows:

1. **Demographics**: The first section gathered information about participants' age, rank, hours of flying experience, type of helicopter operation, instructor status and military or civilian training background.
2. **Startle and Surprise Experiences**: Participants were asked if they had ever encountered a startle and/or surprise event in their daily operations. Participants who provided a positive response were given a series of follow-up questions that asked them to choose from a list of eight scenarios that best fitted their event - lightning strikes, bird strikes, engine fires, automation surprises, failures with no clear cause, tail rotor events, inadvertent flight into Instrument Meteorological Conditions (IMC), and severe inflight disorientation. These scenarios were included based on discussions with senior training captains and were intended to encompass a range of scenarios that exemplified clear startling stimulus (such as lightning strike), surprising scenarios without a startling stimulus (such as a failure without clear cause or automation surprise), scenarios that contain both and to cover common contributing factors to helicopter accidents (spatial disorientation and loss of tail rotor effectiveness). An additional "other" option was also selectable from this list of scenarios, should participants feel their event did not align with the eight scenarios. Participants could provide additional information about their event in an open question. The final questions in this section asked participants to rate the stress and mental effort they experienced during their reported event on sliding scales ranging from 0 to 100.

Table 1 Demographic characteristics of the participants grouped by background: military and civilian

	Full Sample ($n=234$)		Military ($n=115$)		Civilian ($n=119$)	
	n	(%)	*n*	(%)	*n*	(%)
Flight Experience (Hours)						
0-999	15	(6)	4	(3)	11	(9)
1000–1999	26	(11)	7	(6)	19	(16)
2000–2999	36	(15)	20	(17)	16	(13)
3000–3999	44	(19)	24	(21)	20	(17)
4000–4999	30	(13)	21	(18)	9	(8)
5000+	83	(35)	39	(34)	44	(37)
Current Rank						
Captain (commander of the aircraft)	202	(86)	107	(93)	95	(80)
F/O	32	(14)	8	(7)	24	(20)
Instructor Status						
yes	103	(44)	43	(37)	60	(50)
no	131	(56)	72	(63)	59	(50)
Primary Operational Experience						
Military	62	(26)	60	(52)	2	(2)
Onshore CAT	16	(7)	4	(3)	12	(10)
Offshore CAT	42	(18)	11	(10)	31	(26)
SAR	30	(13)	21	(18)	9	(8)
Police/law enforcement	12	(5)	4	(3)	8	(7)
HEMS	20	(9)	4	(3)	16	(13)
Aerial Work	29	(12)	4	(3)	25	(21)
Other	23	(10)	7	(6)	16	(13)

Participants were also requested to indicate if they used any kind of strategy to respond to this event.

3. **Feasibility of the ABC Method**: The third section assessed the feasibility of the ABC-method (Piras et al. 2023). After a brief explanation of the method, participants were asked whether (assuming it can be performed in 10 s) they expected the described method could have been used in the startle and surprise event they experienced, and whether they think it would have been useful. Response to both questions were captured on a 3-point scale (1 = "No", 2 = "Maybe", 3 = "Yes").
4. **Suitability in Different Scenarios**: The final section evaluates the method's perceived suitability across the same eight scenarios that were presented previously, this time based on their hypothetical occurrence. For each scenario, respondents were asked to rate the usefulness of the ABC method on a 5-point Likert scale (1 = "Negative Effects", 2 = "Not Useful", 3 = "A Little Useful", 4 = "Moderately Useful", 4 = "Very Useful"). A further open question investigated potential barriers to using the method.

Finally, respondents were asked in open questions if they had ever been taught a startle and surprise management method in formal training and were invited to share any additional comments or suggestions.

2.3 Data analysis

Content analysis was used to identify key words in the open question responses (e.g., "What barriers do you see for using the ABC method?") to form codes of responses (e.g., "time"). To enhance consistency, triangulation was carried out by a second researcher, and differences discussed until agreement was reached. Similarly, for the startle and surprise encounter question, if participants chose to answer "other" for event category, their response was analysed with the same content analysis approach. Here, responses were examined to determine if they could align with predefined scenarios (e.g., "…" was considered as a "…" scenario), or whether a new scenario code was warranted. In the latter case, six new events were identified: collision / near miss; hoist event; incoming fire; crew action; system failure, and turbulence. Consequently, a total of 14 comparable events were available in the analysis.

Regarding the collected quantitative scale data and frequencies, Table 2 presents an overview of the null hypotheses that were tested. Due to the non-normal distributional properties of the data, non-parametric analyses were used. IBM SPSS (version 29) was used for the analysis.

Table 2 Statistical methods and hypotheses

Research Objective	Null-hypothesis	Survey Questions	Method	Rationale
1) Investigate the prevalence of startle and surprise between pilot training backgrounds	There is no significant difference between the percentage of pilots with a military or civilian background that experienced startle and/or surprise	• "Is your training background military or civil?" • "Have you ever experienced an event during flight where you were startled or surprised?"	Chi-square test	The chi-square test is appropriate for examining relationships between two categorical variables (training background and whether a startle/surprise event was experienced). It tests whether the observed distribution of responses differs significantly from what would be expected under the null hypothesis.
2) Investigate the cognitive effects of reported startle and surprise events across military/civil training background groups and flight experience groups.	A) There is no significant difference in the perceived stress or mental effort caused by reported startle and surprise events between pilots across six experience level groups.	• "How many rotary flying hours do you have?" • "Perceived stress level" • "Perceived mental effort"	Kruskal-Wallis test	The Kruskal-Wallis test was selected as a non-parametric alternative to ANOVA, appropriate for comparing stress and mental effort scores across more than two independent groups (i.e., six experience levels), as data was not normally distributed.
	B) There is no significant difference in the perceived stress or mental effort caused by reported startle and surprise events between pilots with a military and civilian background.	• "Is your training background military or civil?" • "Perceived stress" • "Perceived mental effort"	Mann-Whitney U test	The Mann-Whitney U test is a non-parametric method suitable for comparing two independent groups when the dependent variable (perceived stress or mental effort) is continuous but not normally distributed.
3) Investigate whether helicopter pilots from different training backgrounds perceive using a startle and surprise management method as feasible.	There is no significant difference between pilots with a military or civilian training background in openness to using the ABC-method	• "Is your training background military or civil?" • "Would use a method (if trained) in a startle/surprise situation?"	Chi Square test	The chi-square test is suitable for testing the association between two categorical variables: training background and stated openness to using the ABC-method..

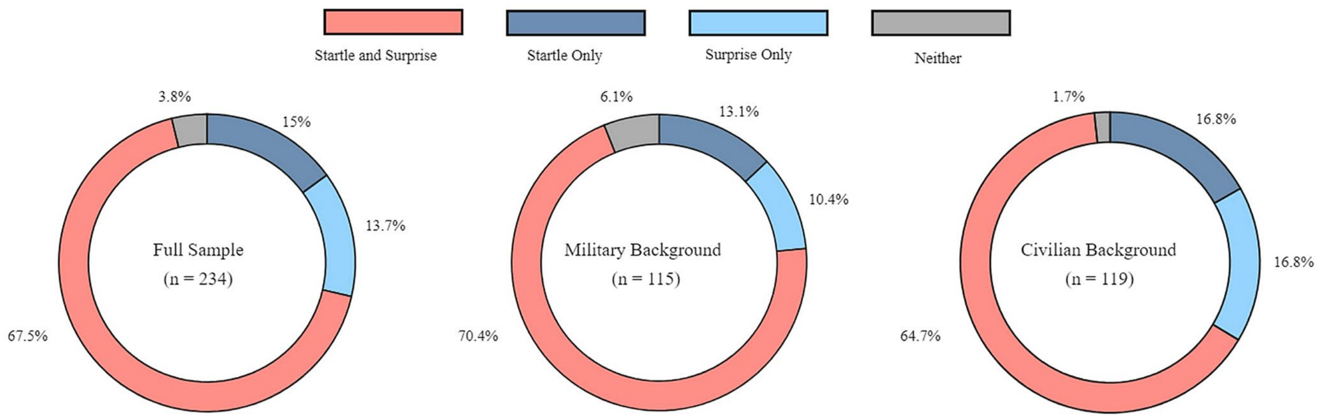

Fig. 2 Prevalence of startle and/or surprise in helicopter operations

Table 3 Frequency of startle and/or surprise in events recalled by helicopter pilots, listed in descending order of prevalence within the full sample

Scenario	Full Sample (n=207)	Military (n=100)	Civilian (n=107)
	n (%)	n (%)	n (%)
No Clear Cause	44 (21.3)	16 (16.0)	28 (26.2)
Bird Strike	30 (14.5)	13 (13.0)	17 (15.9)
Inadvertent IMC	26 (12.6)	12 (12.0)	14 (13.1)
Automation Surprise	19 (9.2)	7 (7.0)	12 (11.2)
System Failure	18 (8.7)	8 (8.0)	10 (9.3)
Disorientation	13 (6.3)	10 (10.0)	3 (2.8)
Collision / Near Miss	11 (5.3)	8 (8.0)	3 (2.8)
Tail Rotor Event	11 (5.3)	7 (7.0)	4 (3.7)
Engine Fire	9 (4.3)	4 (4.0)	5 (4.7)
Crew Action	6 (2.9)	2 (2.0)	4 (3.7)
Incoming Fire	6 (2.9)	5 (5.0)	1 (0.9)
Lightning Strike	5 (2.4)	2 (2.0)	3 (2.8)
Turbulence	5 (2.4)	3 (3.0)	2 (1.9)
Hoist Event	4 (1.9)	3 (3.0)	1 (0.9)

3 Results

3.1 Startle and surprise prevalence

The survey revealed startle and/or surprise to be common phenomena in helicopter operations: 225 of 234 pilots (96%) reported having experienced startle and/or surprise, see Fig. 2. There were insufficient participants (2) in the civilian training background "no startle and/or surprise experienced" category to meet the assumptions of a Chi-square test to statistically compare the prevalence of startle and surprise for pilots of military and civilian training background. Hence, null hypothesis 1 could not be tested.

Table 3 presents the frequency of each reported startle and/or surprise event. The most reported event was "no clear cause" for both pilots from military, 15%, and civilian, 26%, training backgrounds. This was followed by "bird strike", military = 13%, civilian = 16%, and "inadvertent IMC", military = 12%, civilian = 13%. The least commonly reported causes (< 5%) included turbulence encounters, crew action, lightning strikes, incoming fire, hoist events and engine fires. Based on the definition of the constructs, it is expected the following scenarios would be categorized as highly surprising: no clear cause, inadvertent IMC, automation surprise, system failure, disorientation, crew action, tail rotor event, incoming fire and hoist events. The highly startling scenarios included bird strike, collision/near miss, engine fire, lightning strike, turbulence.

3.2 Effects of startle and surprise

The perceived stress and mental effort scores, broken down across the 14 startle and surprise events (including the eight predefined events and six additional events that were added based on participant input), are presented as boxplots in Fig. 3.

All events showed significant stress scores, but most events also showed a large spread. Hoist/load events had both the highest scores for experienced stress (median = 94) and mental effort (median = 98.3). However, this scenario was also the least frequently recounted event (n = 4). Considering scenarios with more than 10 data points (i.e., eight scenarios, n = 172), *tail rotor* events caused both the most stress, median = 81, and mental effort, median = 88. In contrast, *bird strike* events caused both the least stress, median = 46, and mental effort, median = 48.

To investigate the effect of flying experience on perceived stress and perceived mental effort, separate Kruskal-Wallis H tests were conducted. Median stress scores and mental effort scores were not statistically significant different between the six flying hours categories (0-999, 1000–1999, 2000–2999, 3000–3999, 4000–4999 and 5000+), $\chi^2(5, N=209) = 3.30$ $p = 0.655$ and $\chi^2(5, N=209) = 1.71$, $p = 0.89$, respectively. There was no significant difference in perceived stress scores between pilots with a military

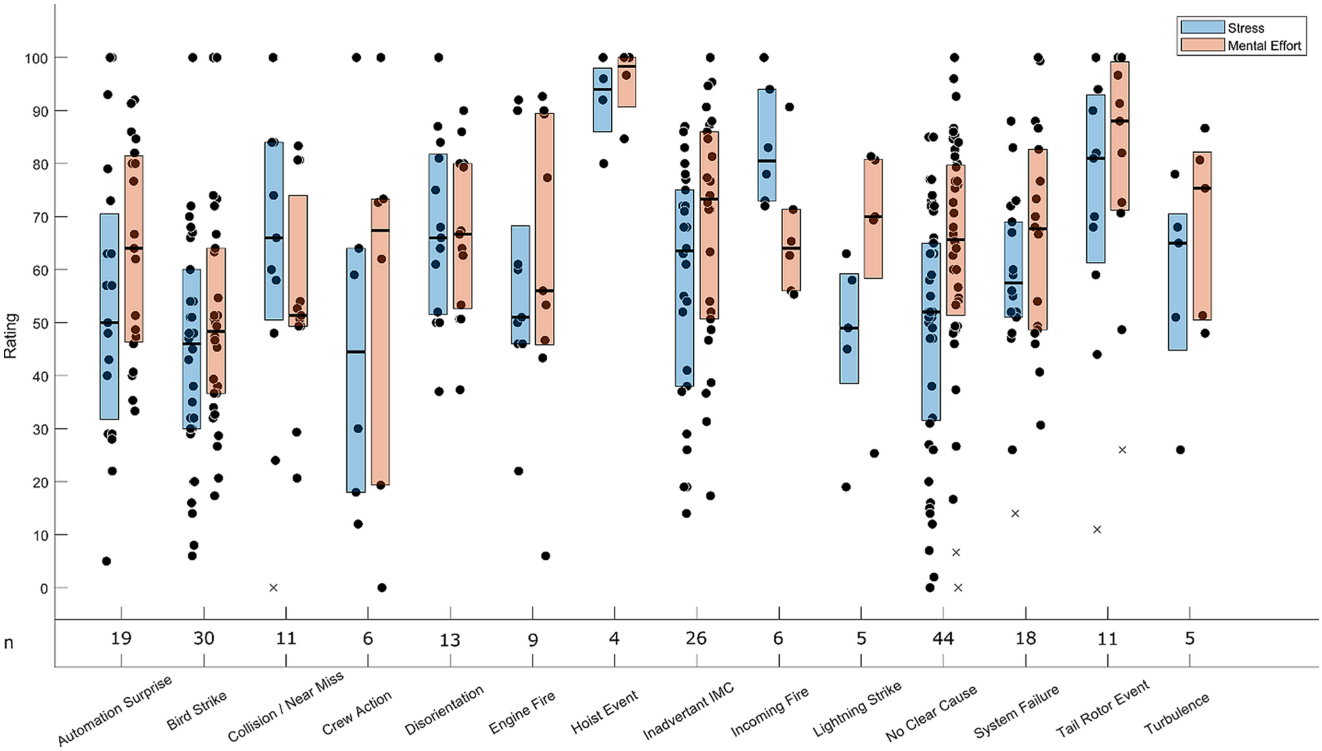

Fig. 3 Boxplots of helicopter pilots' ratings of stress and mental effort (rescaled to 0-100) experienced during their reported event. Grouped per event

background, median = 58, and for the pilots with a civilian background, median = 59. Likewise, the difference in mental effort was not significant, military background pilots, median = 67, civilian background pilots, median = 66. Mann-Whitney U tests revealed there was no significant difference between groups for stress score, U = 5217.00, $p = 0.59$, or mental effort, U = 5233.00, $p = 0.61$. Thus, null hypothesis 2 was not rejected– the perceived cognitive effects of startle and surprise are similar for events reported by pilots from military and civilian training backgrounds, and by pilots with different levels of flying experience.

3.3 Strategies currently used by helicopter pilots in startle and surprise situations

In total, 192 respondents indicated whether they had been taught a method to deal with startle and surprise. The minority of them ($n = 73$ / 38%) answered that they had been taught a method. Of these, 32 pilots explained which method they had been taught: 12 mentioned focusing on "flying the aircraft" first as their learned strategy, 11 "revert to trained procedures", such as checklists, recall items or a mnemonic. Only 2 pilots (1%) indicated they had been taught a method involving controlled breathing: "[take a] deep breath" and "similar to ABC".

Table 4 Strategies used by helicopter pilots in their reported startle and/or surprise events ($n = 107$)

Strategy	*n* (%)
Reverted to training	28 (26.2)
Follow procedure	26 (24.3)
Fly the aircraft	15 (14.0)
Mental focus	11 (10.3)
Controlled breathing	8 (7.5)
Apply CRM principles	7 (6.5)
Pause / Take time	6 (5.6)
Intervention	3 (2.8)
Review	3 (2.8)

Similar answers were given to the question on which strategy was used during the reported startle and/or surprise event. From 107 responses, "reverting to basic training", "following trained procedures" and "flying the aircraft" were the strategies most used, see Table 4. In the reported startle and/or surprise events, eight pilots (7.5%) reported having used a method based on controlled breathing.

3.4 Perceived feasibility and usefulness of the ABC-method

Of the 192 pilots who answered the question on willingness to use a S&S management method such as the ABC-method if trained, 92.8% answered yes or maybe. Only 7.2% replied negatively (see Fig. 4). Helicopter pilots with a civilian training background demonstrated higher openness to using the ABC-method (64.2%) compared to pilots with a military training background (53.6%). However, a Chi-square test showed there was no significant association between the type of respondent (military vs. civilian training background) and their response (Yes/No/Maybe), $\chi^2(2)=3.65$, $p=0.16$. Hence, null hypothesis 3 was not rejected. Free text comments also showed support for the ABC-method: "I like this and will share it", "put it in initial and recurrent training" and "good idea" were some of the positive comments. However, scepticism was also expressed by some pilots: "It could cost someone vital time trying to remember a mnemonic and what it stands for before then trying to recall how to apply the pre-determined, generic and possibly irrelevant letters" and "I am a CRM trainer and don't think…. [the method] will work in practice."

Of the 246 survey respondents, 191 pilots provided perceived usefulness scores for the ABC method on the eight hypothetical scenarios. The median perceived usefulness rating of the ABC method was "moderately useful" (median = 4) for all scenarios except tail rotor events. Here, the ABC method was perceived as being between "a little useful" and "not useful" (median = 2.5). The perceived usefulness scores are displayed in Fig. 5.

3.5 Barriers to using the ABC method

The answers to the open question "What barriers do you see for using the ABC method?" generated 144 responses, which were grouped into 10 themes. The themes were independently verified by two authors until full agreement was reached. Table 5 shows that the main expected barriers reported by the pilots were "insufficient time" (56.9%) and "insufficient mental capacity" (15.2%).

4 Discussion

The objective of this survey study was to determine the prevalence of S&S events in rotary wing operations, investigate the impact of these events on pilot stress and mental effort, and determine the strategies currently used by pilots to mitigate S&S effects. A further objective was to investigate the feasibility of adapting an S&S management technique validated from fixed wing airline operations– i.e., the ABC method - for rotary wing operations.

Like fixed wing airline pilots, helicopter pilots are susceptible to S&S, experience stress, and expend mental effort as a result. 96% of the 234 surveyed pilots reported having experienced startle and/or surprise, compared with 91% of 239 airline pilots in an earlier survey (Vlaskamp et al. 2024b). Hence, S&S events are not an unusual phenomenon in either type of operation and this supports previous research suggesting that almost all pilots can expect to experience S&S during their flying career (Vlaskamp et al. 2024b). The higher prevalence of reported events within helicopter operations could be due, in part, to the wider range of triggering stimuli that helicopter pilots are exposed to compared to fixed wing counterparts, owing to the close proximity to the ground, higher use of hand-flying and greater unpredictability (de Voogt et al. 2009; Hamlet., 2023; Morowsky and Funk 2016).

In the current study, the most frequently recounted S&S events by helicopter pilots were events with an unclear cause. However, these events were not those with the highest stress or mental effort ratings. Notable events, both high in prevalence and stress and/or mental effort, included tail rotor events and disorientation scenarios such as flight into instrument meteorological conditions (IMC). Though only a few reports were provided, incidents unique to rotary wing from the current study which returned the highest stress scores included events involving human external cargo and underslung loads. Together, these findings related to the stress and mental effort experienced during different scenarios will be

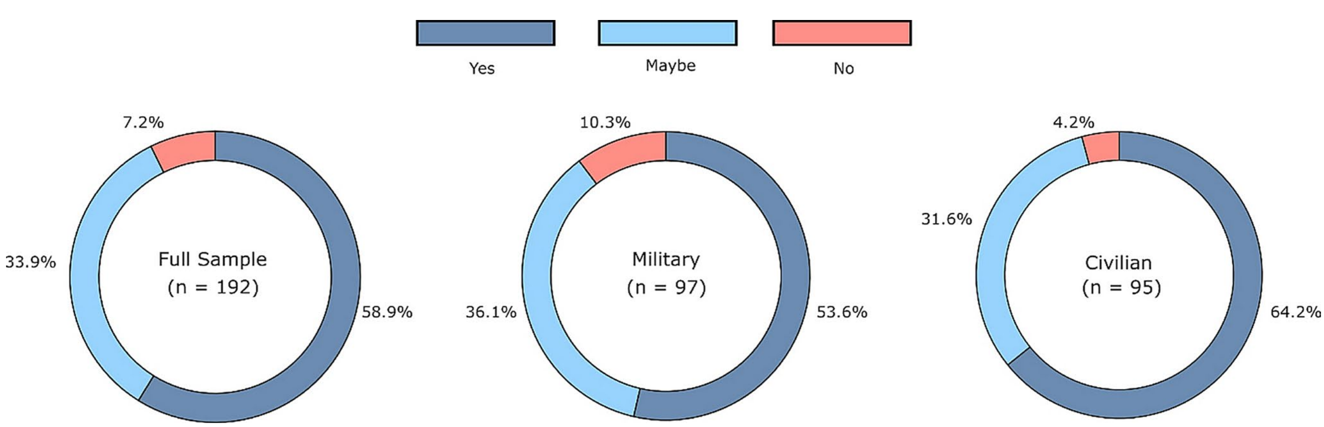

Fig. 4 Openness to use of a startle management method such as the ABC-method if properly trained, $n=192$

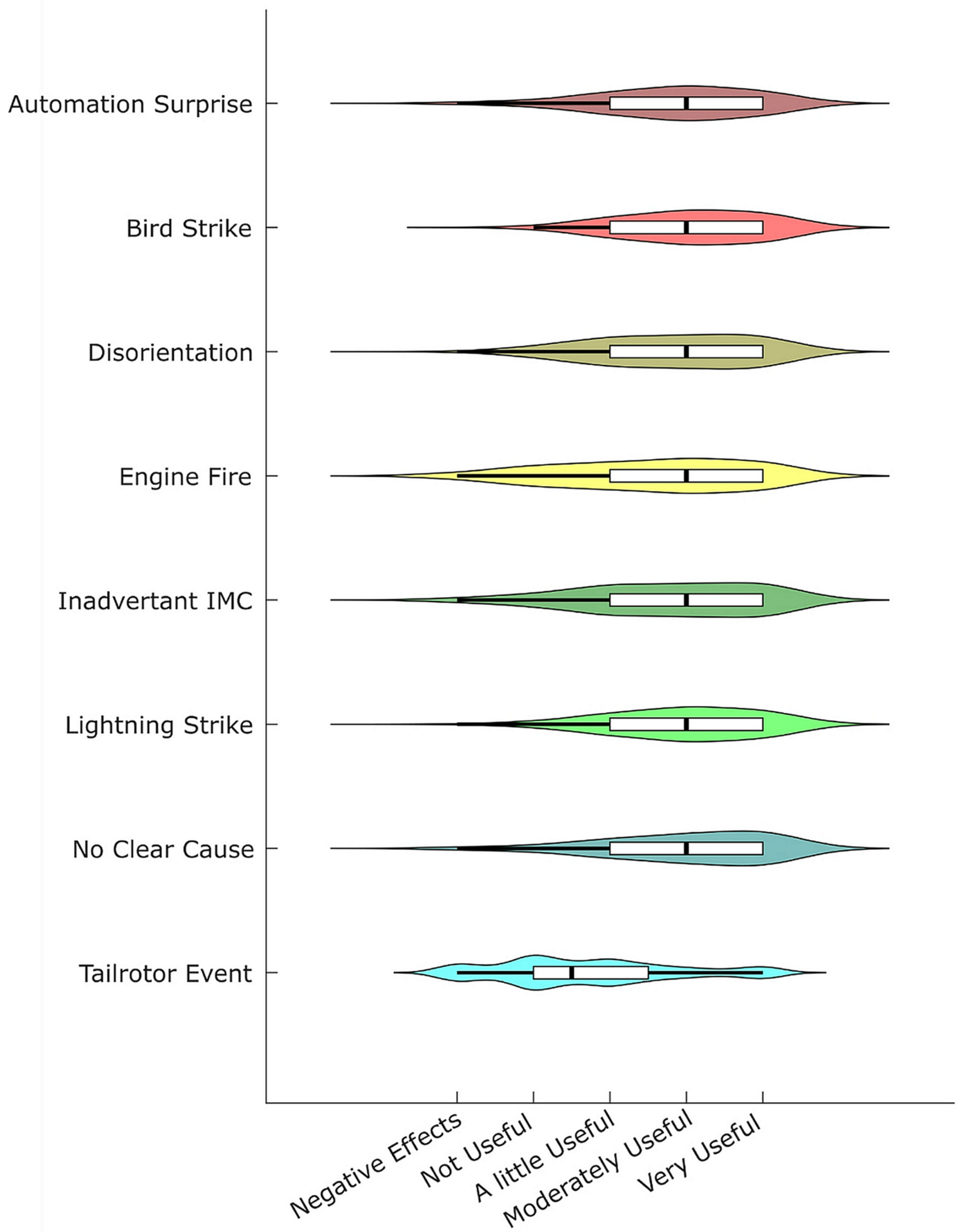

Fig. 5 Helicopter pilots' ($n=191$) perceived usefulness scores of the ABC method on eight hypothetical events summarized using boxplots

informative to future experimental research for the purpose of rotary wing scenario development.

Our results revealed no significant effect of pilot flight hours on reported stress or mental effort, suggesting that experience level has no impact upon an individual's likelihood to suffer negative effects from startle and/or surprise. This was unexpected as it conflicts with literature stating those with greater experience might enjoy more knowledge and sensemaking abilities to facilitate recovery from surprise (Landman et al. 2018). It should be interpreted with caution however: more experience means a higher probability of having been exposed to a more severe startle or surprise event, possibly cancelling out the expected positive effect of experience. Neither was any significant difference observed in these two metrics based on the pilots' training background. Again, conclusions should be drawn with caution: hypothetically the similar scores could also mean that military pilots experience more severe events but are less prone to startle and surprise.

Unlike some leading airlines which have established standard operating procedures that are practiced in recurrent training (Vlaskamp et al. 2024b), helicopter pilots do not currently benefit from any formal, trained strategies to manage startle and surprise. Although 38% of the

Table 5 Frequency of answers on the open question on expected barriers

Barrier	*n* (%)	Example comment
Insufficient time available	82 (56.9)	"No time" "10 s is too long"
Insufficient mental capacity/stress	22 (15.3)	"[lack of] Mental clarity to apply it"
Training issues	12 (8.3)	"Lack of training"
Other reason (e.g. doesn't fit with procedures)	10 (6.9)	"It doesn't flow well with emergency flows"
Unclear reason	10 (6.9)	"Focusing what to do to get rid of what I'm facing makes me feel better"
Method difficult to recall	3 (2.1)	"Have time to think about it"
Crew co-ordination	3 (2.1)	"It would be imperative that both crew members are on the same page from a CRM point of view"
No acceptance of method	2 (2.1)	"Acceptance by UK military"

respondents reported that they *had* been taught a method, these all referred to a generic training philosophy based on what might be described as "applying good airmanship". For example, "fly the aircraft", "aviate, navigate, communicate", and "revert to trained procedures" were the most frequent answers. Many respondents referred to personal techniques gained from experience. The generic nature of these responses suggests that there is very little awareness among the rotary wing community of the existence of formal SOPs for startle and surprise management, which are based on relatively recent research and are new even to fixed wing flying.

Among the current methods helicopter pilots use to recover from startle and surprise, only a small percentage (7.5%) used breathing-based elements like those employed in a range of dedicated recovery methods. Despite this, the majority of those surveyed (90%) expressed openness to the use of the ABC mnemonic and expected to benefit from it in most of the scenarios evaluated. The primary barrier to implementing the ABC mnemonic was a perceived lack of time to use the technique. This was in keeping with findings from fixed wing pilots which recently prompted the development of the ABC technique from other dedicated startle and surprise recovery methods owing to feedback that showed them to be overly long (Piras et al. 2023; Vlaskamp et al. 2024b). Over 50% of the helicopter pilots quoted time as a barrier. This suggests that there is a strong perceived need to take action within helicopter crews, a perception that can be partly explained by the relatively high proportion of low altitude and 'hands on' flying in helicopter operations (de Voogt et al. 2009; Hamlet. 2023; Morowsky and Funk 2016; Nascimento, Majumbar and Jarvis, 2012). Another factor could be the startle paradox. The startle paradox describes a hypothesis that the greater the stress provoked by a startle and surprise scenario, the greater the benefits gained from employing a recovery method, yet the more unnatural it feels to apply it owing to the urge to act immediately to address the problem (Vlaskamp et al. 2024b). Often however, a perceived lack of time does not equate to an actual lack of time, and emergency situations can be exacerbated from errors and poor decision-making taken in haste (Field et al. 2018). Conversely, techniques which slow down human motor responses and intuitive decision-making have been shown to be effective in increasing accuracy and preventing human error (Shinohara et al. 2013).

Pilots were most skeptical about the benefits of the ABC method in the hypothetic tail rotor emergency. Loss of tail rotor effectiveness events account for approximately 5–10 helicopter crashes per year in the United States (Saleh et al. 2022). They manifest in a sudden and unstable yaw rotation that must be corrected immediately by the pilot to prevent a rapidly escalating spin, resulting in loss of control. An analysis of 310 such events by Dequin (2019) proposed that many accidents result from insufficient pilot pedal input to counteract yaw. Tail rotor events are likely to be startling to pilots and require immediate intervention in flight path management or upset recovery (Saleh et al. 2022). For this reason, application of a management technique during tail rotor events and other types of emergency scenarios which occur when manoeuvring helicopters close to the ground (e.g., in hover, take-off, or landing phases), could be viewed as counter-intuitive by helicopter pilots. However, in some circumstances the handling of tail rotor emergencies can still benefit from taking the time to do so. The current survey results show that instances of startle and surprise triggered by tail rotor emergencies were among the top three events in terms of perceived mental effort and stress suggesting that they potentially have the most to gain from a reset.

After time pressure, the next most cited barrier to using the method was that pilots feared there would be insufficient mental capacity to perform the method. 22% of respondents questioned the ability of a pilot to effectively carry out a management technique because of the effects of stress induced by the startle or surprise response itself. Despite this concern, applied research from real-life fixed-wing line flying has demonstrated that, although pilots find application of S&S recovery methods difficult to implement in some circumstances (e.g., upset recovery maneuvers or emergency descent), 39% of pilots trained in the method said that they had already used it during line operations (Vlaskamp et al. 2024b) and were appreciative of the method. The study showed that 71 out of 85 airline pilots that used a company-trained, breathing-based startle management method after an actual startle and surprise event, rated the method as moderately or very useful. Pilots experienced benefits in stress reduction, decision making and perceived situational awareness. Nevertheless, it is not known in which types of situations they perceived this benefit and in what way the method helped. More research is needed to identify exact situational benefits. In emergency situations, pilots are accustomed to using limited memory items as part of a checklist structure where immediate intervention is required to maintain aircraft control. A basic S&S management method can be understood in the same way (Landman et al. 2018). Feedback from fixed wing line operations has highlighted the importance of simplicity to assist recall and application (Piras et al. 2023), which is likely to be particularly pertinent to helicopter operations owing to the high level of perceived time pressure reported.

Several limitations apply to the current study. Firstly, by its nature, startle and surprise events are highly subjective experiences where both the nature of the stimulus, and the perceived intensity of the event, can vary broadly between and within individuals. This makes comparisons between reported experiences problematic. Subjectivity is also impacted by survey design and the constraints of preordained responses, which do not leave room for the elaboration of experienced events. The requirement for participants to recollect past events could also be a factor influencing responses. Hindsight is known to impact the appraisal of adverse events (Hadjioannou et al. 2022) and the passing of time has also been shown to have a softening effect on their perceived severity (Fischoff & Beyth 1975). Despite the shortcomings of subjectivity, the benefits of widely canvassing the experiences of startle and surprise, and attitudes towards tailored recovery techniques, through a survey approach provide unique and valuable insights that will facilitate the future development of techniques to address the operational challenges faced by the helicopter pilot community. Furthermore, these insights are likely to have relevance to other civilian and military occupations where individuals work in complex and high-risk environments.

Further research should focus on the development of a S&S management method tailored to the specific characteristics and constraints of rotary wing operations. This could be based on the tested ABC method (Piras et al. 2023). Part of this body of work could involve the use of training needs analysis to produce recommendations that consider how to best incorporate a S&S management method in all levels of training, paying particular attention to tail rotor emergencies and spatial disorientation in degraded visual environments as worst case scenarios which significantly impact helicopter safety. Also, experimental research should investigate the effect of experience on S&S.

5 Conclusion

The results of this study show that there exists a high prevalence of S&S events coupled with a lack of specific S&S training in helicopter operations. Relatively high accident and incident rates in rotary wing flying and the success of S&S management methods in fixed wing airline operations suggest that the introduction of a method for helicopters could offer considerable safety benefits. The current survey results show evidence for a wide range of helicopter scenarios in which a S&S management method could possibly be applied. This would likely benefit safety, as has been demonstrated in fixed wing operations (Field et al. 2018; Landman et al. 2020). To achieve optimal levels of training design rigor and helicopter pilot acceptance, future research should establish crew training requirements to understand the challenges of implementing a relevant S&S management method within time-critical scenarios. The training should offer guidance to pilots regarding the appropriate moment to perform the method, especially in complex scenarios.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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