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TESTING THE APPLICABILITY OF A CHECKLIST-BASED STARTLE MANAGEMENT METHOD IN THE SIMULATOR

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Several checklist-based methods have been proposed to help pilots manage startle in unexpected situations. In the current experiment, we tested how pilots reacted to using such a method, which featured the mnemonic *COOL*: Calm down – Observe – Outline – Lead. Using a motion-based simulator outfitted with a non-linear aerodynamic model of a small twin-propeller aircraft, twelve pilots practiced using the *COOL* method before performing four test scenarios involving startling events. Application of the full method in the test scenarios was high (90-100%), and pilots rated the method on average as useful (4 on a 1-5 point Likert scale). The first two steps of the method were seen as the "core" of the method. However, pilots also displayed difficulty with prioritizing dealing with immediate threats over executing the method. The results are promising, but they also warn us to be cautious when introducing a startle management method.

Recently, there is an increase in focus on training pilots to manage the startle effect. The term "startle" is often used to designate a combination of a true startle response (a reflexive increase in stress) and a surprise (a mismatch of information with one's mental model; Rivera et al., 2014). A surprise requires one to adjust the mental model to the situation, which can be very difficult under high stress. The inability to solve this can result in confusion, loss of overview and panic (Landman et al., 2017). It has been proposed that the training of piloting skills in a more unpredictable and variable manner makes performance more robust in surprising situations in operational practice (Casner, Geven & Williams, 2013; Landman et al., 2018). A different, more generalized approach to the problem is to teach pilots a startle management method based on a checklist. Three examples of such methods are "Unload-Roll-Power" (of a "mental upset"; Field et al., 2018), "Reset-Observe-Confirm" (ROC; Boland, 2018), and "Breathe-Analyze-Decide" (BAD; Martin, 2016). These methods can supplement existing decision-making aides for pilots and are mainly aimed to guide pilots through the first moments of being startled and surprised.

The current study was performed to obtain data regarding pilot evaluation of the usefulness of such a startle management method, and their ability to prioritize immediate threats over applying the method. To our knowledge, no such data has been published yet, although data suggest that pilots generally liked the ROC and URP methods (Boland, 2018; Field et al., 2018). If pilots find a startle management method useful and easy to apply in startling situations in the simulator, this would be a first step towards its validation and its implementation in training practice.

Method

Participants

Twelve Dutch, currently employed commercial airline pilots participated in the experiment. The pilots came from five different companies. Due to their initial pilot training, all pilots had some flying experience (i.e., circa 25 hours) in a small, multi-engine propeller (MEP) aircraft, similar to the one that was featured in the experiment. One pilot had more experience (i.e., 100 hours).

Table 1.
Characteristics of the participants.

	Mean (SD)
Age (years)	37.4 (12.7)
Experience large aircraft (hrs)	7172 (5549)
Experience small SEP/MEP (hrs)	265 (107)
Employed (years)	13.5 (10.8)

Table 2.
Characteristics of the participants (cont.).

	N
Aerobatics experience	2
Glider rating	4
Instructor	4
Rank: Captain	4
Rank: First officer	6
Rank: Second officer	2
Gender: male	12

Apparatus

The practice and testing took place in the SIMONA research simulator at the Delft University of Technology. This is a six-degrees-of-freedom full-motion simulator with a hydraulic hexapod motion system. The simulator has a collimated 180 degrees horizontal by 40 degrees vertical field of view for outside vision rendered with FlightGear. Sound effects were played over a 5.1 surround sound system.

The non-linear aerodynamic model of a Piper PA-34 Seneca III, a light twin-engine propeller aircraft was used. The flight deck was modeled after a generic multi-crew cockpit. The flight controls and instruments include a control column and pedals with force feedback, pitch trim on the column, throttle, gear, and flap lever with three flap settings: 0◦, 25◦ and 40◦. The (digital) instruments included a Primary Flight Display (PFD), a gear- and flap indicator, Exhaust Gas Temperature (EGT) display, RPM and torque indicators, fuel quantity and oil temperature/pressure displays.

Training intervention

The startle management method tested in the experiment was based on existing methods and it was taught using the mnemonic *COOL*:

- C - Calm down. Take a deep breath, sit upright, relax arms and shoulders and become aware of applied control forces.
- O - Observe. Take a step back and observe the situation. Call out the basic instrument readings: pitch, speed, bank angle, altitude and vertical speed. Call out what the aircraft seems to be doing (e.g., "continuously yawing to the right") as well as other unusual perceptions such as noise. Check secondary instruments and configuration if relevant.
- O - Outline. Following the observations, zoom in on the problem and formulate a hypothesis on the cause.
- L - Lead. Formulate a plan for immediate and/or future actions.

It was emphasized that immediate actions needed to fly the airplane took precedence, and that the method did not need to take up much time. Pilots were told that the purpose of the experiment was to test the usefulness of the method, and they were encouraged to apply it in the scenarios.

Tasks

The tasks were performed as single-pilot crew. For familiarization, pilots first flew four left-handed traffic patterns from takeoff to landing (see, Figure 1). Required settings (as displayed in Figure 1) were available on a checklist in the cockpit, and the stall alarm was demonstrated in the last pattern. Pilots then came out of the simulator to receive information on startle and surprise and instructions on the *COOL* method. They went back into the simulator and performed four practice scenarios. First, they flew a standard pattern in which they were asked to execute the *COOL* method approximately six times. They then performed an approach and landing with strong crosswind and a malfunctioning rudder. The third scenario consisted of a standard pattern with an RPM indicator failure on the left engine. In the fourth scenario, an engine failure occurred shortly after rotation.

Next, pilots were informed that they would perform four test scenarios. The scenarios were designed to offer a variety of instrument-related and controllability-related issues, most of which were familiar to the pilots. Each scenario consisted of flying a pattern (Figure 1) during which one of the following issues occurred. FLAP: when selecting flaps 25, the left flap malfunctioned and remained up, which caused a roll and a yaw moment. MASS: a heavy piece of cargo broke loose after rotate during takeoff, and shifted with a scraping noise towards the tail, causing a violent pitch-up moment. STALL: before leveling off, a bird struck the angle of attack vane, creating an impact sound and causing a continuous (false) stickshaker and (false) stall audio alarm. To provide enough space for a recovery, pilots were tasked to climb to 2000 ft in this scenario, after which they descended back to 1000 ft at downwind. UAS: an instrument malfunction caused the indicated airspeed to diverge from the actual airspeed by -1 kt every second, starting at rotate.

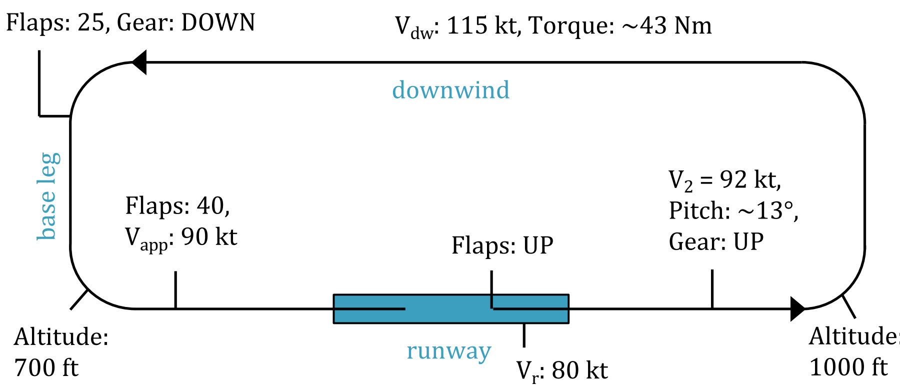

Figure 1.
The standard traffic pattern flown in the experiment.

Dependent measures

Following each test scenario, pilots filled in a questionnaire. They reported if they had applied the *COOL* method, and if so, which steps. An audio recording was used to confirm whether pilots called out the instrument readings (*Observe*). If applied, pilots rated the perceived usefulness of the method in the scenario on a 1-5 scale labeled: very little – little – moderate – much – very much. Pilots rated their perceived startle and surprise on a 0-10 point scale with the labels 'not at all' and 'extremely' at the endpoints. Pilots rated perceived anxiety on a similar visual-analogue scale (Houtman & Bakker, 1989), and mental effort on the Rating Scale for Mental Effort (RSME; Zijlstra & van Doorn, 1985). An open interview was performed at the end of the experiment, to collect pilot clarifications of ratings, their impressions of the method and suggestions for improvement (if any).

The audio recordings were also used to investigate if pilots inappropriately executed the method while there were immediate issues to attent to. For this, it was checked if pilots started *Obseve* before recovering the upset in MASS (bringing pitch angle back below 20 degrees).

Data analysis

The median startle and surprise scores are reported for each scenario as a manipulation check.
To evaluate usefulness of the *COOL* method, the number of pilots applying the steps in each scenario, as well as an overview of all usefulness scores, are reported for each scenario. Low ratings will be analyzed and discussed independently.

Results

Application of the *COOL* method

The self-reported application of the method is shown in Table 4. Even though application was encouraged, pilots sometimes did not apply the whole method. Averaged over the four scenarios, pilots applied the whole method in 89.6% of the cases. Application of *Observe* was reported by all pilots in all scenarios. This was confirmed in all audio recordings except one in UAS, however, two recordings were lost. As reasons for not applying the whole method, pilots named time-criticallity, distraction or not finding the method applicable.

In STALL, of the eight pilots who unloaded and of whom audio was available, one performed *Observe* before unloading. In MASS, of the eight pilots who exerienced a pitch angle exceeding 20 degrees, five executed *Observe* before recovering.

Table 4.
Self-reported application of the COOL method items.

	FLAP	STALL	MASS	UAS
Calm down (n)	11	12	10	12
Observe (n)	12	12	12	12
Outline (n)	12	12	10	12
Lead (n)	12	11	11	12
Full method (n)	11	11	9	12

Example of the *COOL* method application

Table 3 shows the audio transcript of a pilot executing the *COOL* method in STALL. As can be seen, the four steps seem to follow each other naturally. *Observe* started with the bigger picture (speed, attitude), and then zoomed in on the problem (vibrations, engine parameters, stick shaker, pitch-power). The pilot rated the method as useful in this scenario (4 out of 5), and reported moderate startle and surprise (respectively 6 and 7 out of 10).

Table 3.
An audio script showing an example of the COOL method being applied in STALL. Author comments are in [brackets].

Category	Pilot comments
Calm down	*Wow! I feel something. COOL!* [Pilot breathes]
Observe	*Observe! Speed 97. Pitch 12. 2000* [ft] *coming up. Heading 185. Gear up, flaps up. I feel vibrations? Engine torque normal. Quantities, temperatures... I have a shaker. Speed, pitch, power is okay.*
Outline	*I'm not stalling. No clue what it is. My first impression: a false stall warning.*
Lead	*Okay, heading 008. I'm on downwind. Descending to 1000* [ft].

Perceived usefulness of the *COOL* method

Pilots rated the method generally as useful in the test scenarios (see Figure 2), with medians of 4 in STALL, FLAP and UAS, and one median of 3 in MASS. All low individual scores (i.e., below 3) except for one score in MASS, were due to pilots finding the scenarios not difficult or startling enough. The low score in MASS was due to the scenario being *"too time-critical for the method to be applicable"* according to the pilot. Other critique or suggestions for improvement were: *"The method can be extended."* (someone suggested adding 'Options'), "*It slows you down / interferes with thinking.*", *"It is a bit too long."*, *"It may be too distracting in a more complex cockpit."*, *"Observe and Outline can be combined"*.

Pilots who gave high ratings remarked the following: *"The workload was okay."*, *" It is especially applicable when highly startled."*, "*It has a natural flow.*", *"Calm down and Observe are important and are the core of the method."*, *"It forces you to look around."* and *"It prevents tunnelvision"*.

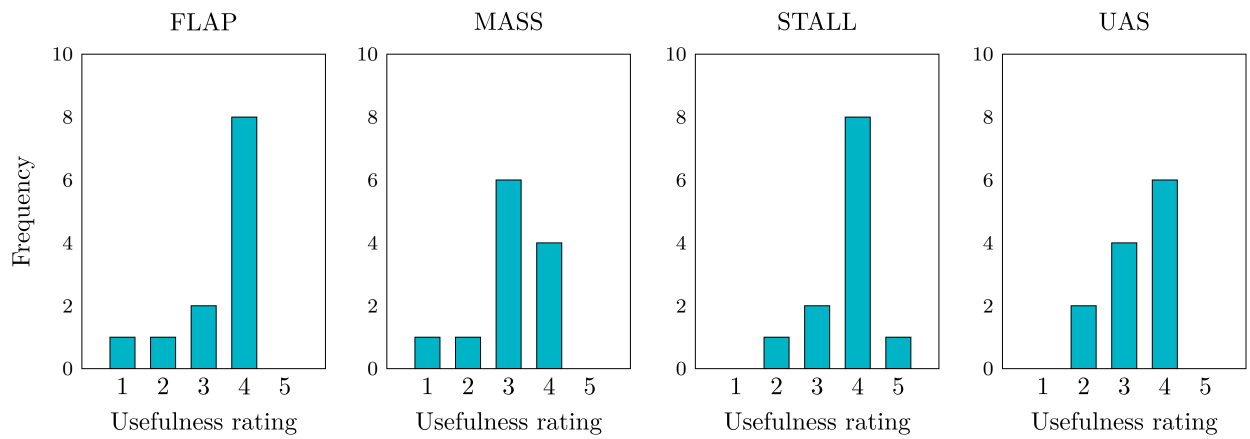

Figure 2.
Perceived usefulness of the COOL method in the four test scenarios.

Manipulation check

The pilots found the scenarios generally challenging, considering the scores in Table 4. Startle and anxiety were rated above the midpoint of the scale in all scenarios except UAS. All scenarios were rated very surprising (7-8), even though pilots knew that malfunctions would occur. Mental effort (RSME) was scored around 60, which is between "rather much effort" and "considerable effort" on the scale. MASS seemed to be the most challenging, possibly due to it being an unfamiliar problem, which caused considerable controllability issues.

Table 4.
Median ratings of startle, surprise, mental effort and anxiety in each scenario.

	FLAP	MASS	STALL	UAS
Startle (0-10)	6	6-7	6-7	4-5
Surprise (0-10)	7	8	7-8	7-8
RSME (0-150)	62	77	56	60
Anxiety (0-10)	5.25	6.40	5.15	4.30

Discussion

The results of the current experiment are promising for the applicability of checklist-based startle management methods. Following a practice session with the *COOL* method, and after encouragement to try the method, all pilots applied it in the test scenarios. Still, the steps: *Calm down*, *Outline* or *Lead* were skipped in some (circa 5 %) of the cases. This suggests that accurately applying the method in real situations might be difficult, because the stress level would likely be higher and there would likely be several months between practicing the method and applying it.

The method was rated highly useful in the test scenarios (4 out of 5). Pilots also had several suggestions for improvements. Summarized, the method could benefit from being simplified, especially as it is to be applied in more complex situations in operational practice. The last two steps (*Outline* and *Lead*) seemed not very necessary and could be left out. *Observe* could be simplified by reducing the number of parameters to check, and by focusing on their meaning (e.g. "airspeed is okay") instead of on their absolute values (e.g. "airspeed is 100 knots"). Pilots suggested that in a two-pilot crew, the first step (*Calm down*) could be applied by both, and the pilot monitoring could then perform *Observe*.

Some of the critique about the method being too distracting and complex may be due to pilots applying it at an inappropriate moment. Even though pilots were instructed to prioritize immediate threats, many (62.5 %) started to execute *Observe* when still dealing with an upset situation in MASS. This suggests that extensive training might be needed before pilots can accurately judge when to execute a startle management method and when to attend to more important matters.

In conclusion, the results show that pilots generally have a positive attitude towards a checklist-based startle management method. We recommend that training organizations, before introducing a startle management method, use pilots' evaluations to make improvements, maximize pilot acceptance, and also avoid negative side effects. Collecting data on the application and usefulness in operational practice is recommended as a next step.

Acknowledgements

The paper is based on a larger study on the effects of a checklist-based startle management method on performance measures, and it is planned to be part of a doctoral dissertation entitled: Managing Startle and Surprise on the Flight Deck.

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