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An Alternative Method of Identification of a Failed Engine in Twin-Engine Propeller Aircraft

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Introduction

TransAsia Flight 235

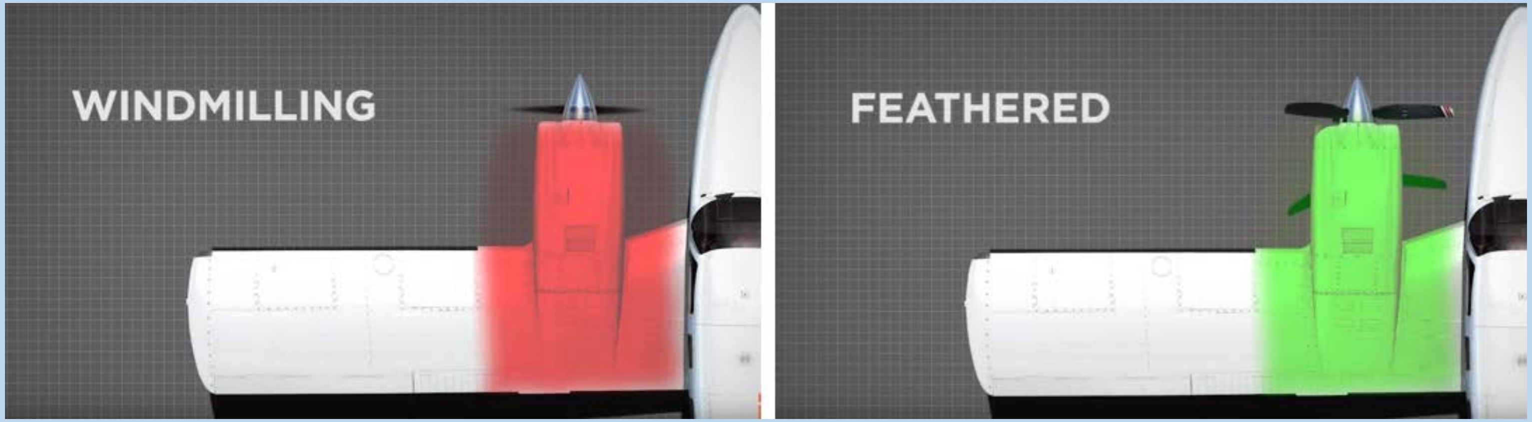
- ATR 72-600 aircraft
- Uncommanded feather of the right engine
- Captain reduced throttle of the left engine and shut it down
- No power at 1,500 feet AGL, engine restart attempts unsuccessful
- Uncontrolled stall and crash
- 43 fatalities

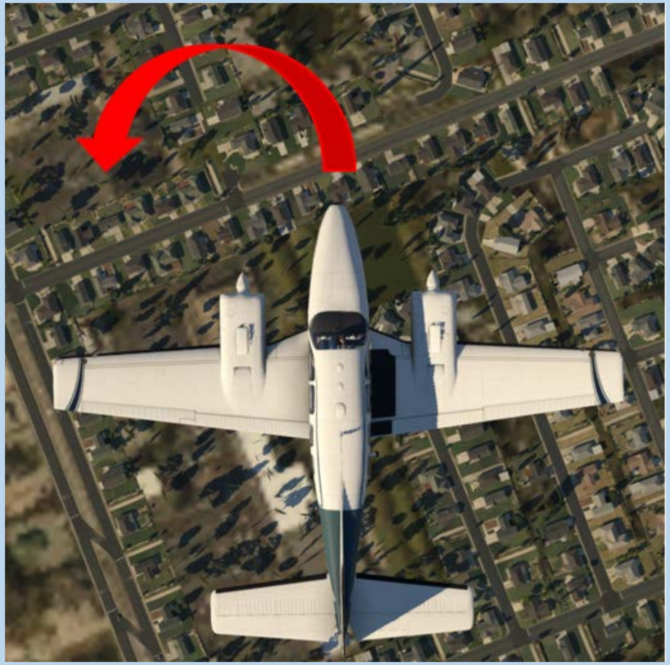
Engine misidentification

- Turboprops: From 1985 to 1997, almost 50% of in-flight engine shutdowns involved a shutdown of the working engine (Sallee & Gibbons, 1999)
- Turbofans: From 1958 to 1997, 29% of in-flight engine shutdowns involved a shutdown of the working engine (Sallee & Gibbons, 1999)
- Twin-engine helicopters: 40% of interviewed pilots admitted moving the throttle of a working engine in emergency in real life/simulator (Wildzunas et al., 1999; as cited in Aviation Safety Council, 2016)

Dangers of twin-engine propeller aircraft operations

- Failed engine creates drag due to the windmilling propeller
- Asymmetric thrust follows, resulting in a significant yaw
- Climb performance loss of up to 80% (Federal Aviation Administration, 2016)





Identify-Verify-Feather

- Identify: “Dead leg – dead engine”
  - Compensate for the yaw by applying rudder
  - Dead leg (not pushing the rudder pedal) is on the side of dead (failed) engine
- Verify: Confirm correct identification
  - Pull back the throttle of the identified engine
  - Expect no change in the direction of flight and engine sound
- Feather the propeller of the failed engine

Source: (Gardner, Schiff, & Bringloe, 2011)

Purpose of the study

- Current method is believed to be too resource-demanding
  - An alternative method was proposed and tested
- The alternative method was based on the visual sensory channel
- Participants flew three flights with simulated engine failures
- Response times and accuracy of identification were measured and compared between two groups (Traditional vs Alternative)

Hypotheses

- H01: There is no difference in accuracy of engine identification between participants using the traditional and the alternative method.
- H02: There is no difference in response time across the three flights between participants using the traditional and the alternative method
- H03: There is no difference in average response time for all three flights between participants using the traditional and the alternative method

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Lit. Review

Human Capabilities and Limitations

- Stress
  - Stress can affect operator's judgment and assessment of the situation
  - Evidence that conflicts with expectations may be explained away or ignored (Kontogiannis & Malakis, 2009)
- Workload
  - Increase in workload can impair performance (Casto & Casali, 2013) and lead to problems with task prioritization (Morris & Leung, 2007)
  - Pilot error can become the source of increased workload (Morris & Leung, 2007)
  - Planning for the increase in workload helps avoid detriments to performance (Andre & Heers, 1995)

Human Capabilities and Limitations

- Attention
  - Human brain can handle up to four tasks concurrently without decrease in performance (Fisher, 1984; Julesz, 1981; James, 1980; as cited in Strayer & Drews, 2007)
  - Attention can be influenced by anxiety, making pilot’s gaze behavior more chaotic (Allsop & Gray, 2014)

Haptic vs Visual Sensory Channels

- 80% of information we perceive is visual (Geruschat & Smith, 2010)
- People are more likely to notice visual cues (Hecht & Reiner, 2008) over haptic or auditory
- Information coming through the visual channel gets priority even if an operator knows that it is less reliable than the haptic channel (Xu, O’Keefe, Suzuki, & Franconeri, 2012)

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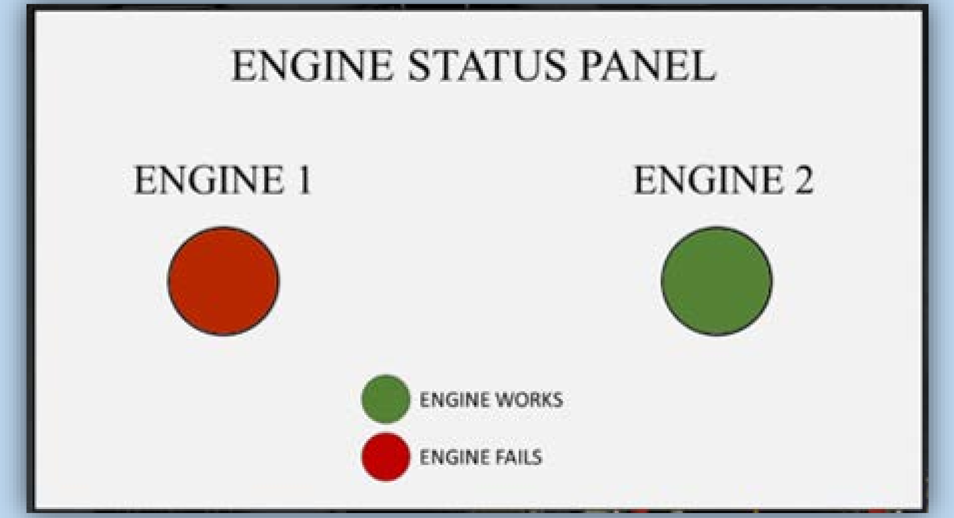
Method

Materials and Apparatus

- X-Plane 11 flight simulation software
- Engine Status Panel
  - Indicates which engine has failed based on the fuel flow value
- Training video
  - Explained basic concepts and the method of identification of a failed engine
- Pre- and post-flight questionnaires
  - Demographics
  - Confidence in correct engine identification
- Three simulated takeoffs
  - Flight 1: Left engine failure 30 sec after rotation
  - Flight 2: Right engine failure 20 sec after rotation
  - Flight 3: Right engine failure 45 sec after rotation



Procedure

- 50 student pilots who did not have multi-engine rating (MEL) and had not started their training were sampled
  - Students received $20 for participation
- Participants were assigned to two groups
  - Traditional Group
  - Alternative Group
- Participants watched a training video
- Participants flew a practice flight
  - Engine failure was demonstrated
  - Participants were given an opportunity to practice the procedure
- Participants performed three takeoffs
  - Engine failure was simulated by failing fuel pumps on the corresponding engine
  - Participants were asked to announce verbally which engine had failed and comment aloud their actions after the failure

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Results

Results: Demographics

- 42 Males & 8 Females
- Mean age $M = 20.22$ years ($SD = 2.67$ years)
- Mode age 18 years
- Average flight experience $M = 145.90$ hours ($SD = 75.45$ hours)

Result: Hypotheses testing

- H01: Difference in accuracy of identification between group
  - All participants feathered the correct engine
  - H01 retained
- H02: Difference in response time across flights and between groups
  - 2x3 mixed ANOVA within-subject variable test was not significant
  - H02 retained

Group	Flight	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Traditional	1	5.231	.649	3.927	6.535
	2	4.830	.441	3.943	5.718
	3	5.224	.576	4.067	6.381
Alternative	1	3.984	.649	2.680	5.288
	2	2.693	.441	1.806	3.580
	3	2.586	.576	1.429	3.744

Result: Hypotheses testing

- H03: Difference in response time between groups
  - 2x3 mixed ANOVA between-subjects variable was significant at $F(1,48) = 10.83$, $p = 0.002$
  - Alternative Group ($M = 3.09$ seconds, $SD = 1.84$ seconds) was faster at identification than Traditional Group ($M = 5.09$ seconds, SD = *2.43* seconds)
  - H03 rejected

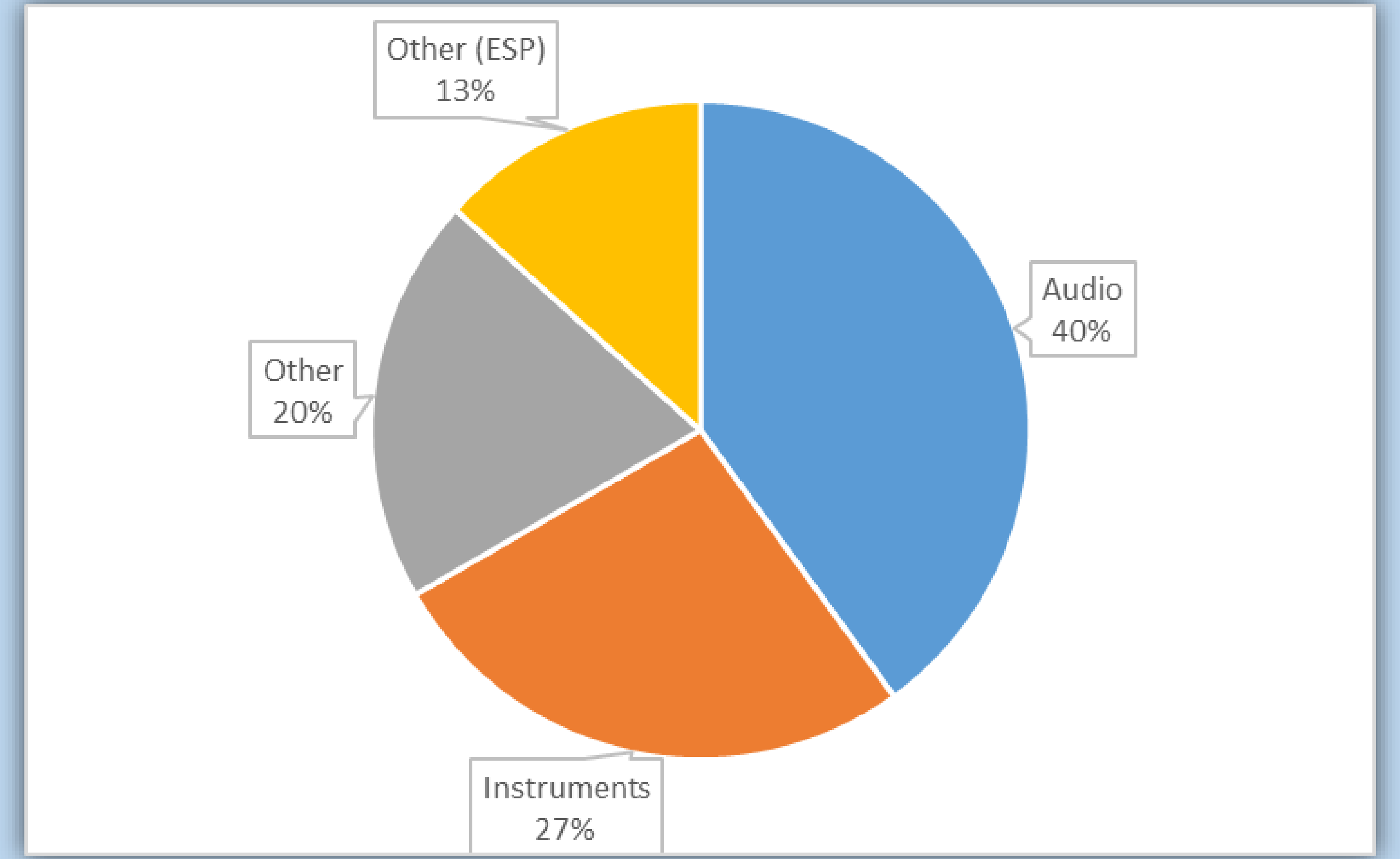
Result: Qualitative data

Participants' assessment of identification of a failed engine

Do you feel that you identified a failed engine correctly for each of the three flights?	Flight 1		Flight 2		Flight 3	
	Yes	No	Yes	No	Yes	No
Traditional Group	25	0	25	0	23	2
Alternative Group	25	0	25	0	25	0

Do you feel that you identified a failed engine in adequate amount of time during each of the three flights?	Flight 1		Flight 2		Flight 3	
	Yes	No	Yes	No	Yes	No
Traditional Group	23	2	24	1	24	1
Alternative Group	24	1	24	1	25	0

Results: Suggestions for improvement



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Discussion

Discussion

- Alternative Group was significantly faster at identifying a failed engine than Traditional Group
- Some Traditional Group participants reported using visual cues for identification
- Alternative Group participants were generally more confident in correct identification
- Alternative Group participants reported being generally less confused in regard to which engine was failing
  - Traditional Group: $M = 2.28$, $SD = 1.27$. Alternative Group: $M = 1.84$, $SD = 1.03$.

Limitations

- The response time was reducing from Flight 1 to Flight 3 for Alternative Group
  - With more power, there could be a significant difference
- 8 participants (6 in Traditional Group and 2 in Alternative Group) moved the wrong throttle initially, but feathered the correct engine propeller
  - Increased response time
  - Might have hastily moved the throttle
  - Possible confusion due to no experience in multi-engine aircraft
  - Observing participant actions could help avoiding the issue in future research
- Participant behavior was not consistent
  - Did not retract landing gear
  - Did not power up

Further research

- Perform similar experiment with multi-engine-rated pilots
  - Determine how past experience affects the ability to use the new method for identification
  - Possibly make further changes to the method
- Identify engine parameters most indicative of the failure
  - Fuel flow was used, but is not enough
  - Several parameters might need to be used
  - Examples: Fuel Flow + Exhaust Gas Temperature

Suggestions

- Particular benefit to General Aviation
  - Reason: Lack of sophisticated systems in GA aircraft
  - Reduce risk of human error in emergency situations
  - Engine Status Panel can be installed aside from other instruments (to avoid clutter)
  - Newly-built aircraft are equipped with glass cockpits, hence the panel can be shown on a display

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Conclusion

Conclusion

- Currently recommended method of identification might be too confusing and resource-demanding
  - This is dangerous in case if an engine fails on takeoff (high-workload)
- Using a method based on the visual sensory channel requires less time for identification of a failed engine
- A panel with a visual indicator is recommended to be installed in GA aircraft to reduce the risk of engine misidentification

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