Gaze Behaviour and Visual Attention : A Novel Method for an Eye Tracking Study and a Comparative Analysis Using Pilots with Varied Flight Experience

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25 years in Naval Aviation (Commander)

- **Commanded warships -ExO** (Guided Missile Frigate)

- **Commanding Officer**

Maritime Air Squadron (IL-38 SD) Anti-submarine and Electronic Warfare Maritime Patrol Aircraft with ASM.

14 years as Aviation Academic : Senior Lecturer

(New Zealand, UAE and Australia)

Why this research?

Lack of adequate research (eye-tracking studies)

- Responses to unexpected in-flight events in the modern cockpit.
- Possible “sampling error” leading to contradictory results.
- Statistical power analysis

This research study explored:

- **Conceptualisation and validation of a novel method** for collation of copious amount of gaze data and extraction of precise data for analysis.
- Gaze data analysis
  - related to complexities of the in-flight situation in the cockpit
  - related to experience in flying
  - Identification of optimal scan strategy of expert pilots
- **Credible results :**
  - **large sample size (153 pilots)**
  - **Multi-variate regression analysis**
- Identify its applications for training purposes and towards promoting flight safety.

Research Question

How do pilots react to anticipated or unanticipated in-flight non-normal events in the glass cockpit?

Research Method

- Quantitative method of objectively testing and collecting data of pilots' gaze responses in the glass cockpit
- Qualitative method of open-ended survey questionnaire.

Target Sample- 50 pilots in each group. ⟷ **Achieved (Total Number) : 153 Pilots**

Test Group 1 (TG1) - Student Pilots.

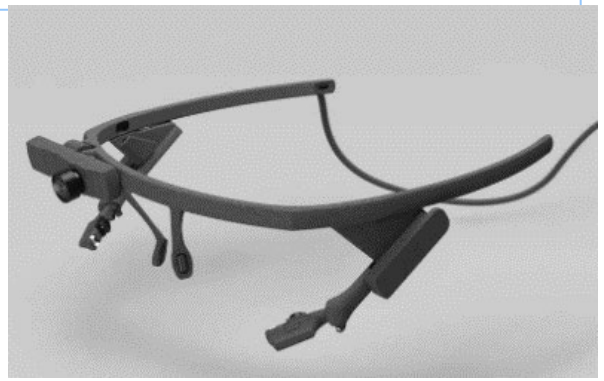
: Student pilots of CQU (MCC Qualified) : Completed SIM sessions for **49 Pilots**

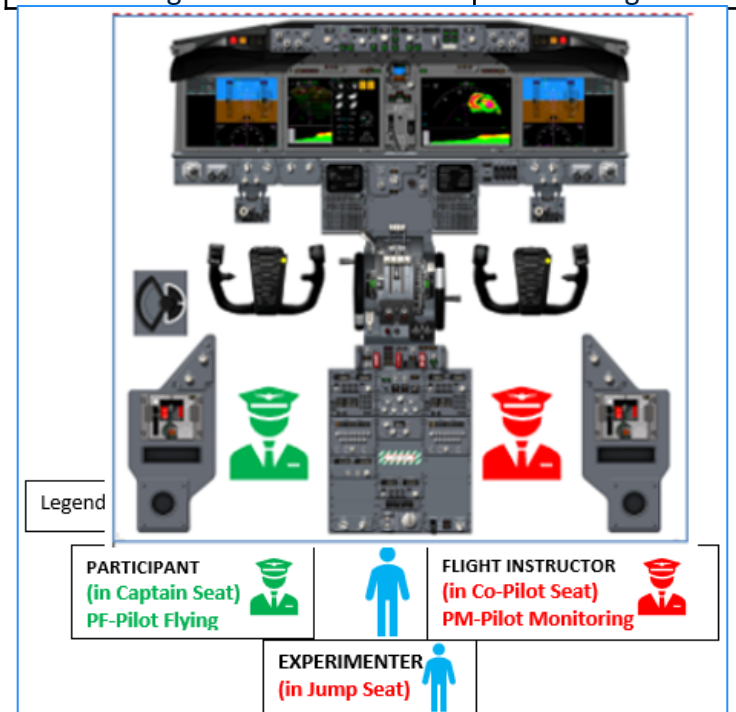
Test Group 2 (TG2) - Experienced Pilots.

: Commercial pilots who are type rated on any multi-engine aircraft. : Completed SIM sessions for **50 Pilots**

Test Group 3 (TG3) - Expert Pilots. Commercial pilots who are type rated on a twin-jet commercial aircraft (such as B737/A320 etc) : Completed SIM experimental sessions for **54 Pilots**

Sampling rate	200 Hz
Accuracy	0.6°
Eye tracking technique	Dark pupil with 3D model
Eye tracking	Pupil measurement; Relative size in eye camera pixels + absolute size in mm through 3d eye model
Slippage compensation	Yes, 3D eye tracking model
Calibration procedure	9-point and 5-point
Weight	45 g

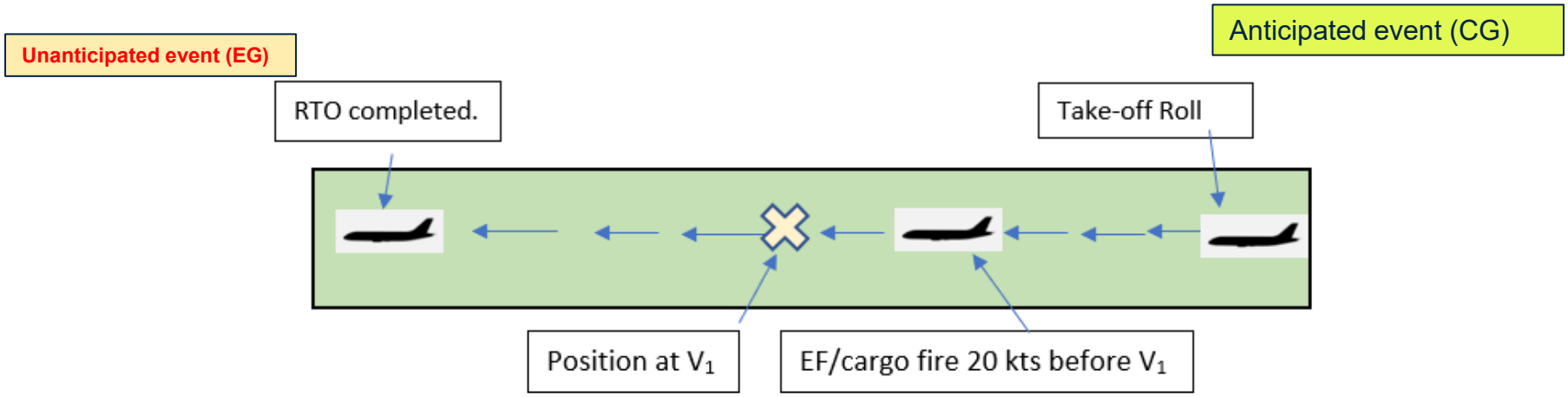




Experimental Setup

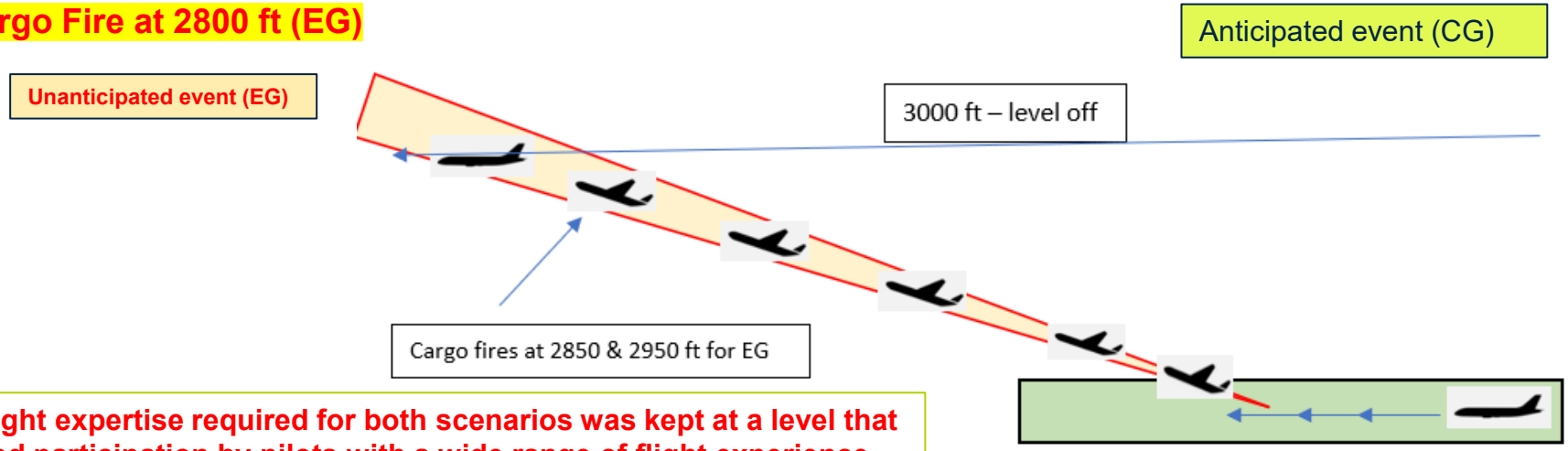
Scenario 1- Engine Failure: 20 kt before V_1 (CG) – As per Pre-Flight Brief (Anticipated event)

Cargo Fire : 20 kt before V_1 (EG)



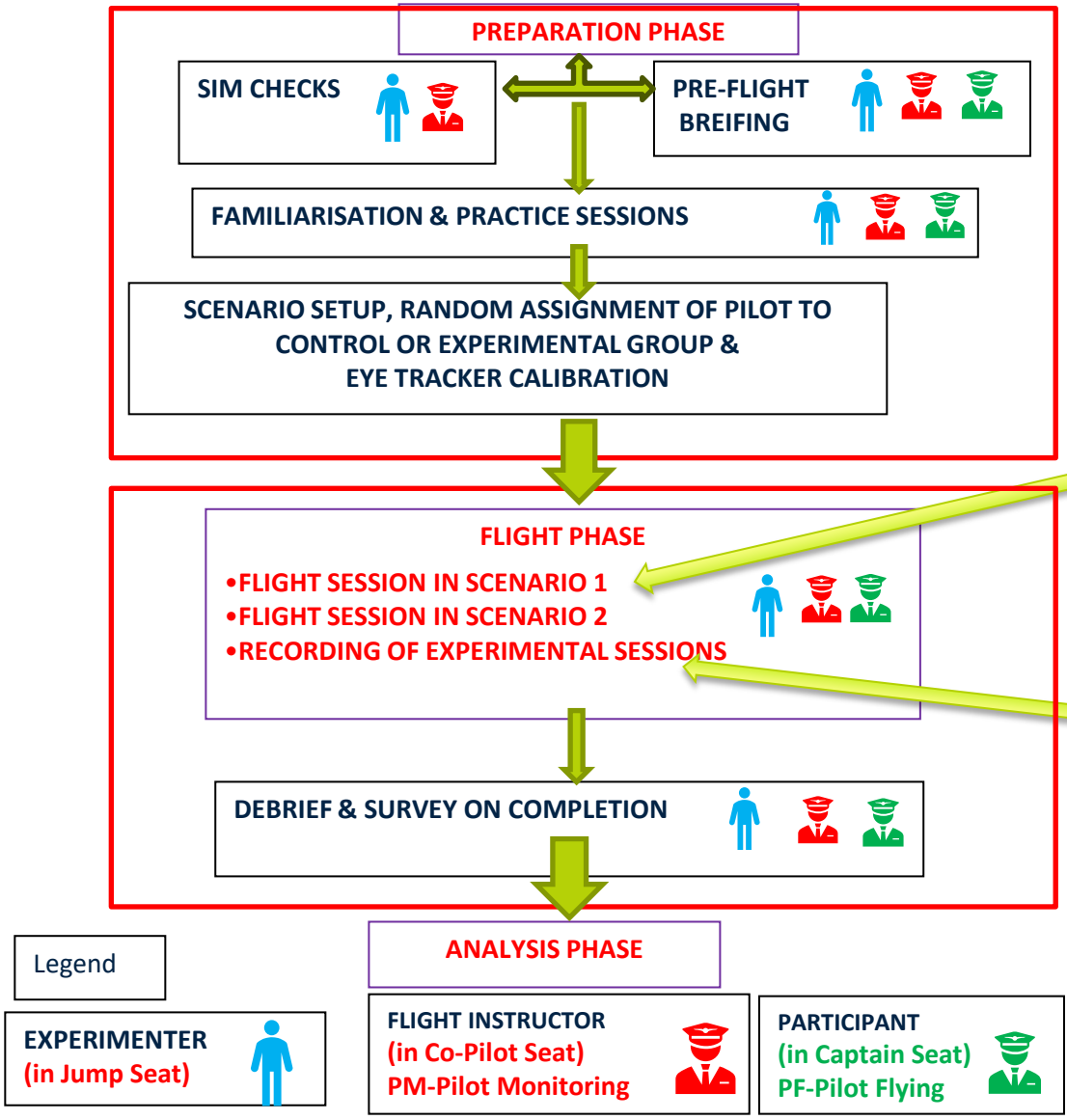
Scenario 2- Climb and levelling out at 3000 ft (CG) – As per Pre-Flight Brief (Anticipated event)

Cargo Fire at 2800 ft (EG)



The flight expertise required for both scenarios was kept at a level that enabled participation by pilots with a wide range of flight experience

EXPERIMENTAL FLOW CHART



INDEPENDENT VARIABLES

- Control Group/Experimental Group
- Test Groups 1/2/3
- Flight Experience (Total Hrs)

DEPENDENT VARIABLES

- Eye Diameter
- Gaze Time & Fixations in AOIs
- Blink rates
- Sequence Analysis Metrics

Null Hypotheses

- Research Question. *How do pilots react to anticipated or unanticipated non-normal in-flight events in the glass cockpit?*

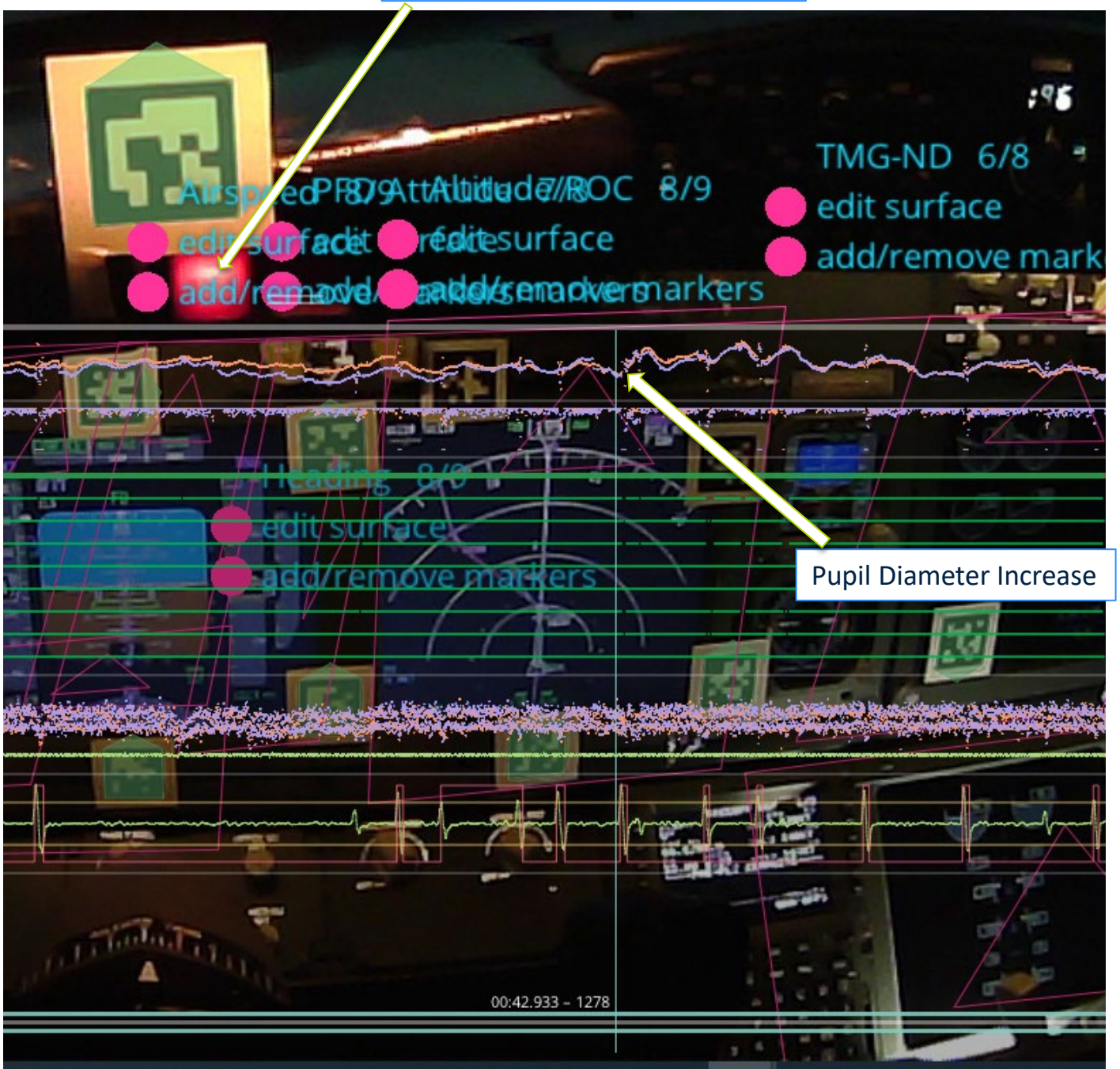
- The following null hypotheses (H_0) are presumed for this experimental study:

  (i) **H_0.** The gaze scans (time spent in AOIs) remain the same for all groups of pilots (student/experienced/expert) under anticipated (CG) or unanticipated (EG) in-flight events.

  (ii) **H_0.** The fixations (in AOIs) remain the same for all groups of pilots under anticipated (CG) or unanticipated (EG) in-flight events.

  (iii) **H_0.** The pupil diameter variations as a response to increase in cognitive load remain the same for all groups of pilots under anticipated (CG) or unanticipated (EG) in-flight events.

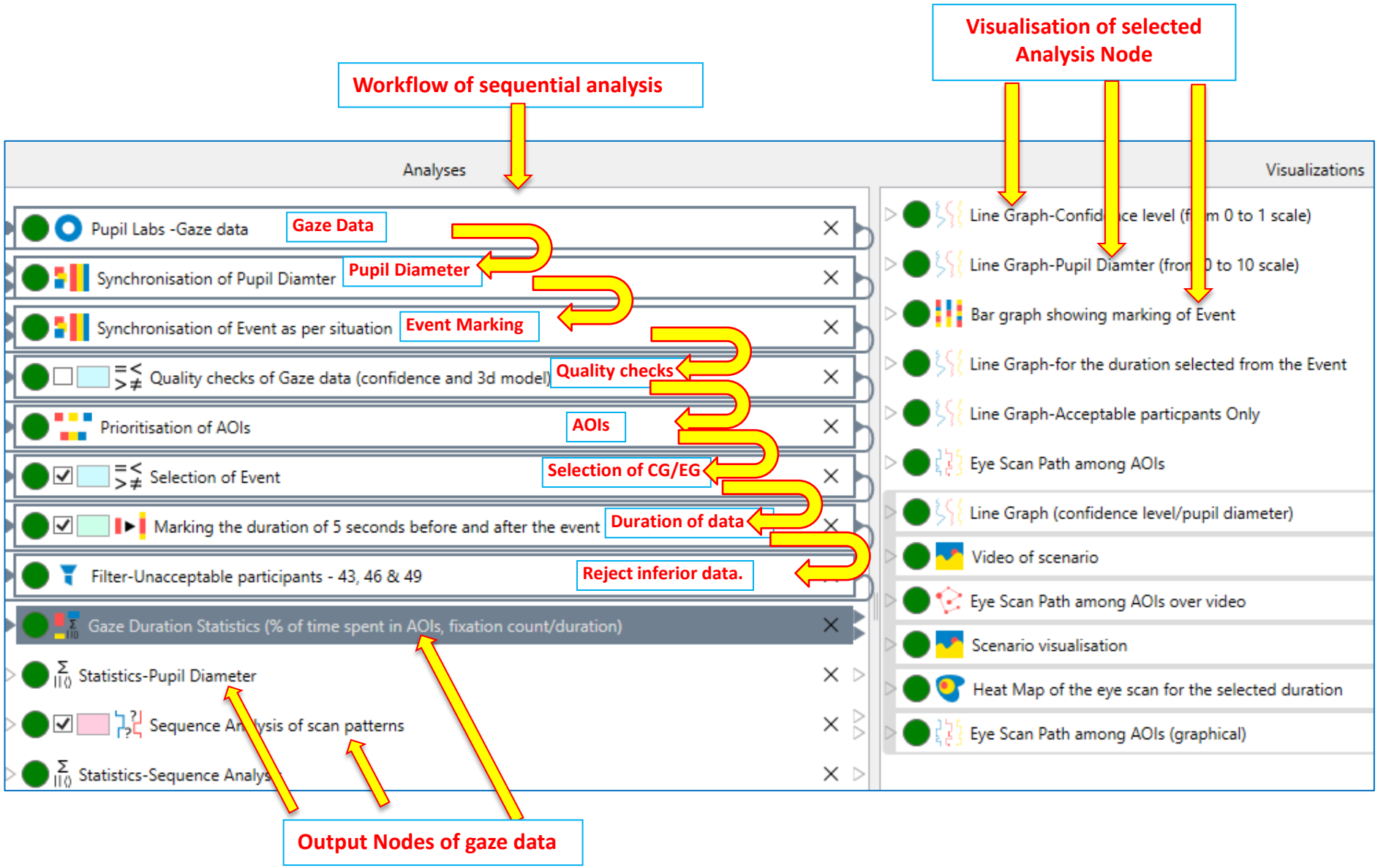
Experimental Group – Cargo Fire



Pupil Diameter Increase

EXPORT OF DATA FROM PUPIL PRO TO BLICKSHIFT ANALYTICS SOFTWARE

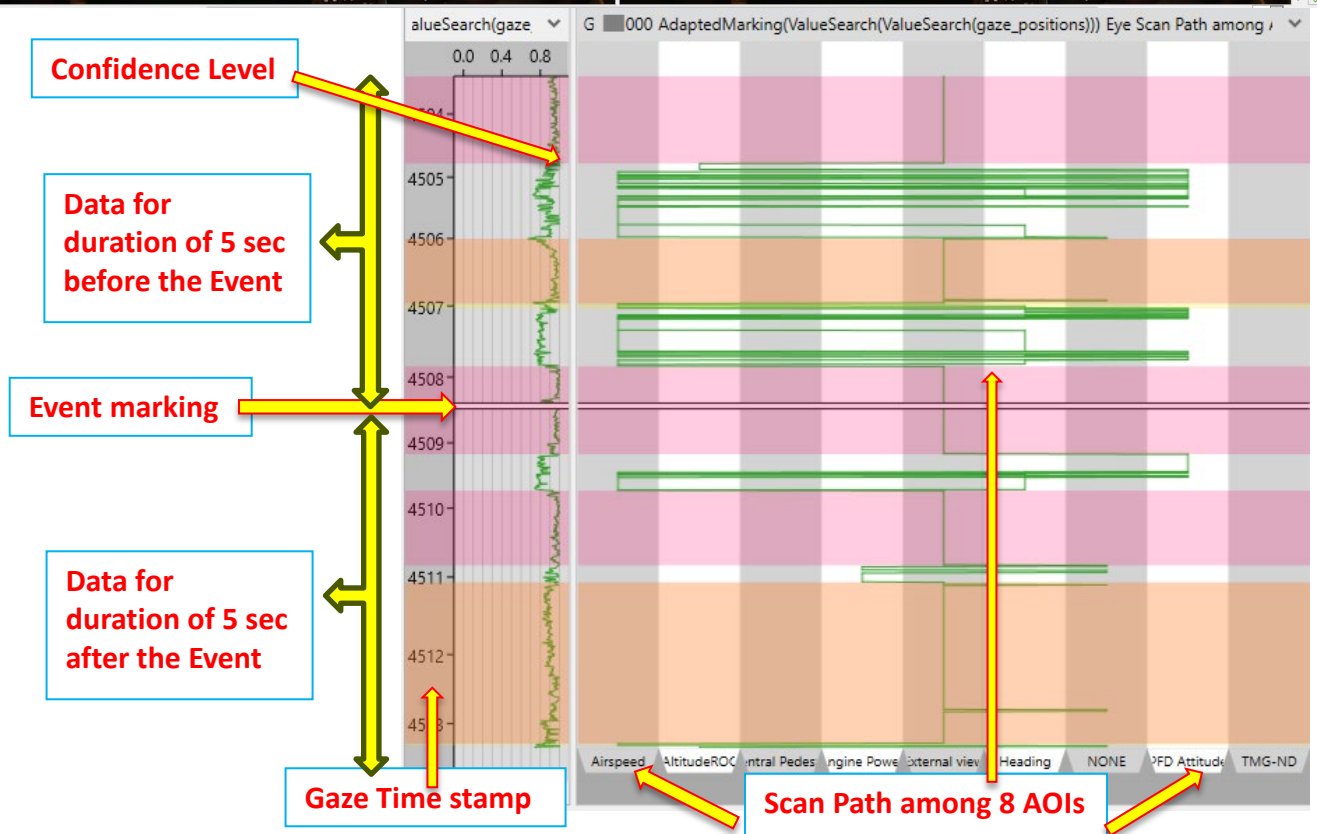
NOVEL METHOD



SAMPLE CHARACTERISTICS OF ELIGIBLE PARTICIPANTS

Pilots	Sample	Age		Flight Experience(Hrs)	
Test Group		*(Min/Max)*	*(Mean/SD)*	*(Min/Max)*	*(Mean/SD)*
Novice -TG 1 - Situation 1	42	19.5/48	27.5/7.6	75.5/300.5	247/97
Novice -TG 1 - Situation 2	47	19.5/48	27.7/7.8	75.5/300.5	238/102
Experienced -TG2- Situation 1	45	23/57.5	37.9/11.8	300/17500	4123/3006
Experienced -TG2- Situation 2	48	23/57.5	39/12	300/17500	4043/2739
Expert -TG3 - Situation 1	46	33/57.5	48.5/9.4	3000/32500	14577/7626
Expert -TG3 - Situation 2	49	28/57.5	48.2/9.8	3000/32500	14368/7773
All Pilots - Situation 1	133	19.5/57.5	38.3/12.9	75.5/32500	6514/7742
All Pilots - Situation 2	144	19.5/57.5	38.3/13	75.5/32500	6279/7699

VISUALISATION OF SAMPLE PARTICIPANT IN SCENARIO (EXPERIMENTAL GROUP).

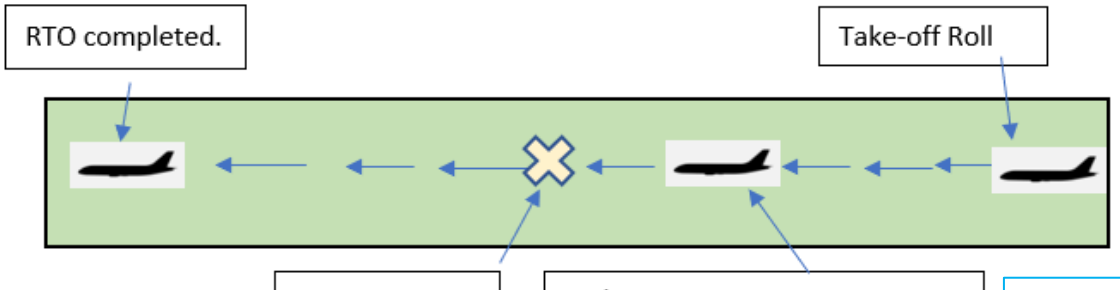


Situation 1- Engine Failure: 20 kt before V_1 (CG) – As per Pre-Flight Brief

- **Cargo Fire : 20 kt before V_1 (EG)**

Anticipated event (CG)

Unanticipated event (EG)

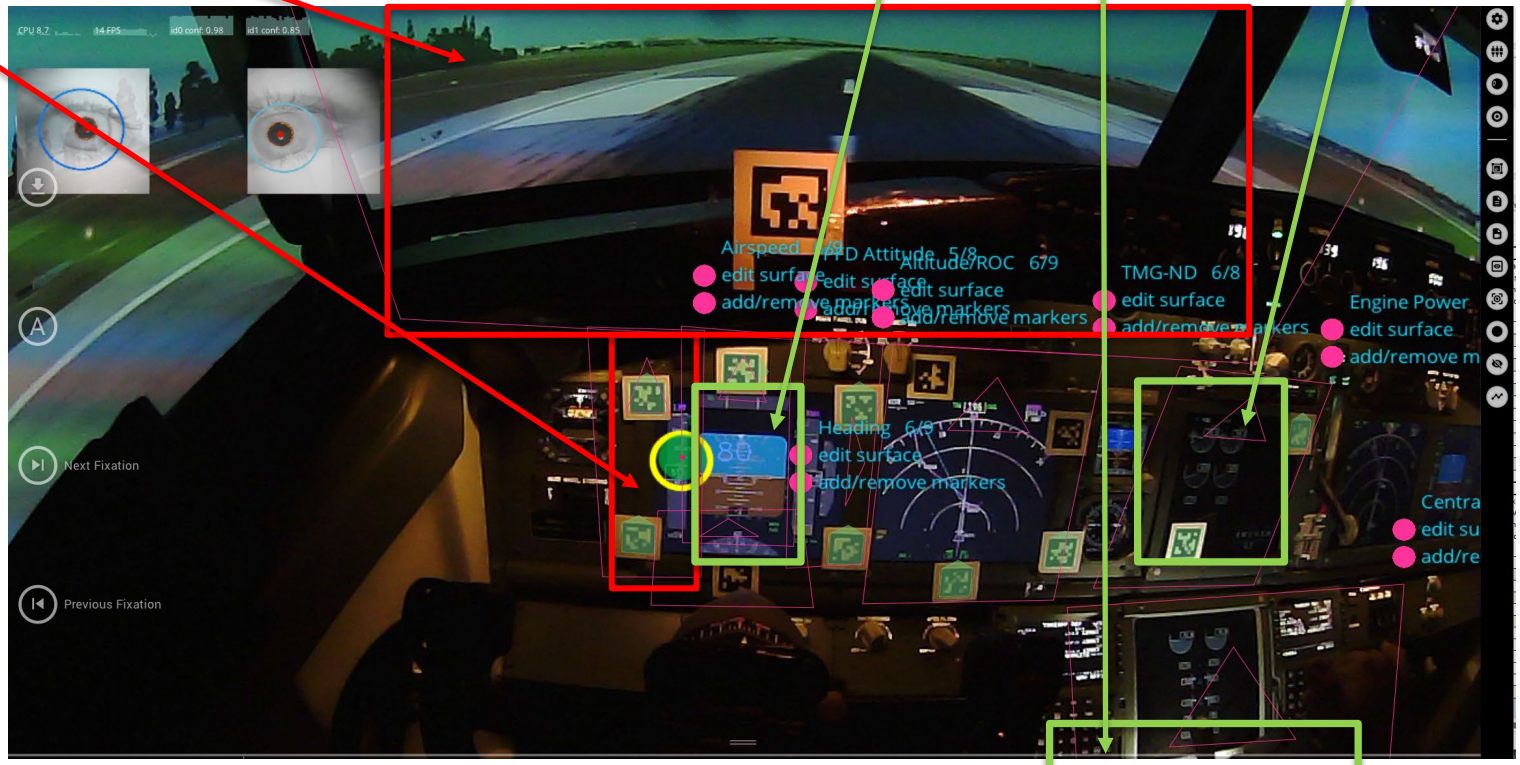


70 to 85% of total gaze data in prime AOIs

Prime Areas of Interest (AOIs)
Airspeed & External View

10 to 20% of total gaze data in non-prime AOIs

Non-Prime Areas of Interest (AOIs)
PFD Attitude, Central Pedestal & Engine Power



Scenario 2- Take-off and Climb at ROC 500ft/min; and level out at 3000 ft (CG) – As per Pre-Flight Brief
- **Cargo Fire at 2800 ft (EG)**

Anticipated event (CG)

Unanticipated event (EG)

3000 ft – level off

Cargo fires at 2850 & 2950 ft for EG

70 to 85% of total gaze data in prime AOIs

Prime Areas of Interest (AOIs)
PFD Attitude & AltitudeROC

10 to 20% of total gaze data in non-prime AOIs

Non-Prime Areas of Interest (AOIs)
Airspeed & External View & TMG-ND

RESULTS- Null Hypothesis Validation: **Gaze Duration Analysis on AOIs**

Summary of Results: GDS: Multi-Variate Regressions with three IVs (Independent Variable) for evidencing Null Hypotheses (Scenario 1)

DV	Regression Weights with IV	Beta Coefficient	Adjusted R^2	F	t-value	p-value	H_0 supported	G* Power
1	"CG/EG" AS	-0.168	0.068	4.255	-0.828	0.409	No	99.9%
1	"Student/Expert" AS	0.710	0.068	4.255	2.853	**0.005**	Yes	99.9%
1	"Experienced/Expert" AS	0.768	0.068	4.255	3.143	**0.002**	Yes	99.9%
2	"CG/EG" Δ AS	0.734	0.003	1.122	0.306	0.760	No	98.0%
2	"Student/Expert" Δ AS	-4.218	0.003	1.122	-1.431	0.155	No	98.0%
2	"Experienced/Expert" Δ AS	-4.829	0.003	1.122	-1.669	0.098	No	98.0%
3	"CG/EG" EV	-12.137	0.174	10.351	-3.380	**0.001**	Yes	100%
3	"Student/Expert" EV	-18.232	0.174	10.351	-4.132	**0.000**	Yes	100%
3	"Experienced/Expert" EV	-13.565	0.174	10.351	-3.130	**0.002**	Yes	100%
4	"CG/EG" Δ EV	-7.242	0.099	5.847	-1.939	**0.055**	No	99.9%
4	"Student/Expert" Δ EV	-16.688	0.099	5.847	-3.636	**0.000**	Yes	99.9%
4	"Experienced/Expert" Δ EV	-6.316	0.099	5.847	-1.402	0.163	No	99.9%

Note. *p < 0.05.

(DV-1) Dependent Variable: AS: "% time spent in prime Area of Interest (AOI) Airspeed (for a duration of 5 sec after event)

(DV-2) Dependent Variable: Δ AS: "Change in % time spent in prime Area of Interest (AOI) Airspeed (for a duration of 5 sec after the event - for a duration of 5 sec before the event)

(DV-3) Dependent Variable: EV: "% time spent in prime Area of Interest (AOI) External View (for a duration of 5 sec after the event)

(DV-4) Dependent Variable: Δ EV: "Change in % time spent in prime Area of Interest (AOI) External View (for a duration of 5 sec after the event - for a duration of 5 sec before the event)

(IV-1) Independent Variable (Predictor): CG/EG : Control Group or Experimental Group

(IV-2) Independent Variable (Predictor): "Student/Expert" : Student Pilots compared with Expert Pilots.

(IV-3) Independent Variable (Predictor): "Experienced /Expert" : Experienced Pilots compared with Expert Pilots.

RESULTS - SUMMARY

H_0. The gaze scans (time spent in AOIs) remain the same for all groups of pilots (student/experienced/expert) under anticipated (CG) or unanticipated (EG) in-flight events. **The Null hypothesis is rejected.**

- The distribution of time spent in prime AOIs is not the same between CG and EG in both Situations (S1 & S2) within each group of pilots (Student/Experienced/Expert) and with all pilots (Student & Experienced & Expert) considered together.

H_0. The gaze scans (time spent in AOIs) remain the same amongst all groups of pilots (student/experienced/expert) under similar situations (in-flight events). **The Null hypothesis is rejected.**

The distribution of time spent in prime AOIs is not the same amongst all groups of pilots (student/experienced/expert) under similar situations.

H_0. The fixations (in AOIs) remain the same for all groups of pilots under anticipated (CG) or unanticipated (EG) in-flight events.

The Null hypothesis is rejected.

The distribution of Fixation Counts in prime AOIs is not the same between CG and EG in both Situations (S1 & S2) within each group of pilots (Student/Experienced/Expert) and with all pilots (Student & Experienced & Expert) considered together.

H_0. The fixations (in AOIs) **remain the same amongst all groups of pilots (student/experienced/expert) under** similar situations (**in-flight events). The Null hypothesis is rejected.**

The distribution of Fixation Counts in prime AOIs is not the same amongst all groups of pilots (student/experienced/expert) under similar situations.

H_0. The pupil diameter variations as a response to increase in cognitive load remain the same for all groups of pilots under anticipated (CG) or unanticipated (EG) in-flight events. The Null hypothesis is rejected.

- The distribution of pupil diameter variations as a response to increase in cognitive load is not the same between CG and EG in both Situations (S1 & S2) within each group of pilots (Student/Experienced/Expert) and with all pilots (Student & Experienced & Expert) considered together.

H_0. The pupil diameter variations as a response to increase in cognitive load remain the same amongst the three test groups of pilots (when under similar situation). The Null hypothesis cannot be rejected. ($p > 0.05$)

The pupil diameter variations as a response to increase in cognitive load remains the same amongst all groups of pilots (student/experienced/expert) under similar situations (in-flight events).

Comparison and analysis Pupil diameter variations as a response to increase in cognitive load- in Situation 1 & 2

RESULTS - SUMMARY

- A Novel Method is available for
  - collation and extraction of precise gaze data.
  - Statistical analysis provided significant results.
  - Power analysis added credibility to the results.

- Can be used by any researcher in a simulator for
  - Simulation pf any non-normal event
  - Collection of gaze data during response
  - Comparison between pilots with varied flight experience, background, age etc
  - Identifying optimal gaze pattern for
    - Training doctrine improvisation.
    - Inputs to cockpit design for ergonomic and HCI interface related developments.
    - Use of experts' gaze strategy as templates for novice pilots.

THANK YOU 🙏

QUESTIONS