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A Fixation-Click Count Signature as a Visual Monitoring Enhancement Feature for Air Traffic Controllers

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Abstract. This paper presents an approach to capture the deliberate perception and comprehension behavior of Air Traffic Controllers (ATCOs) by utilizing their eyeball and hand movement. Hence, a new fixation-click count signature, involving ATCOs fixating on aircraft's track or label, before performing respective commands within a specified operational duration, is derived. 88 one-hour real time simulations involving a remote eye tracker and scenarios mimicking actual air traffic were conducted for participants from three expertise levels. Results show that this signature is common amongst all participants for both incoming and outbound aircraft. Furthermore, addition visual attention span is required with increasing commands issued, as a higher fixation count is exhibited with more clicks performed for the one-hour duration. This signature could also be used to differentiate the expertise levels of ATCOs, as experts were found to exhibit the most fixation count across all click counts, followed by intermediates and novices.

Keywords: Tactical Air Traffic Control · Eye Tracking Signature · Smart Human-Centered Systems

1 Introduction

New concepts of operations like the adoption of 4-Dimensional Trajectory Based Operations (4D-TBO), where the flight trajectory of aircraft can be predicted in a timely, accurate and consistent manner, and the increasing use of automation brought about dynamic changes in Air Traffic Control (ATC) in recent years. As a result, aircrafts are freer to fly on their own desired trajectories, creating a more complex air route structure with tighter separation standards [1, 2].

Future Air Traffic Controller (ATCO) tasks would likely be dedicated to performing more tactical monitoring activities presented on radar displays with lesser flight crew communication, thereby changing the way ATCOs operate [3]. This brings about a new set of challenges, as there is a lack of knowledge extraction and representation in present ATC systems, to determine how ATCOs monitor the dynamic flight objects on the radar display in order to maintain awareness of the air traffic situation. Studies also

show that radar display error constitutes 60% of ATCO operational error [4], while perception and vigilance in planning and radar monitoring is the most significant cognitive error of ATCOs [4, 5].

With a more complex air route design predicted in future, it is envisioned that an ATCO's operational performance during tactical radar monitoring sessions would be impacted. Therefore, there is a need to conduct studies to capture and evaluate an ATCO's perception and comprehension level, for current and future ATC operations [1, 6].

2 Fixation-Click Count Signature

To capture and evaluate the perception and comprehension level of ATCOs for their tactical monitoring activities, a fixation-click count signature is proposed. This signature seeks to capture the deliberate perception and comprehension behavior of ATCOs while performing tactical monitoring activities on the different flight objects on the radar display.

Fig 1. Flowchart of Fixation-Click Count Signature

In this signature, the eyeball and hand movement of an ATCO is utilised, which involves the ATCO fixating on the track or label of an aircraft, before performing respective commands within a specified operational duration. Examples of these commands are taking jurisdiction of incoming aircraft (UCO), handing over of out-bound aircraft to adjacent sector (TOC) and many more. Hence, if an ATCO would have perceived and comprehended an aircraft during the tactical monitoring activities, he / she would have at least fixated once on the aircraft (criteria 1) and clicked on the appropriate command (criteria 2), within a specific duration. Fig 1 shows a flowchart, depicting the process of how this signature works. Using these 2 criteria, a binary signature can then be created and evaluated across the 3 expertise levels for aircraft requiring a frequency change and across the one-hour duration.

3 Concept Test and Validation

For the experiment, a real-time simulator, the NLR ATM Research SIMulator (NARSIM), was used to generate and simulate air traffic scenarios in real time, with

every radar update at 9.8 seconds. Pseudo-pilots were used to facilitate the flying of aircraft, by following the same scenario script, so that events in the same scenario occurred at the same instant. A standard Controller Working Position (CWP), consisting of a 2K radar screen (50cm by 50cm) was used to display air traffic data in a given airspace sector, as seen in Fig 2.

Fig 2. Standard Controller Working Position (CWP)

A remote eye tracker, Tobii X2-30 was used to capture the eye data of the participants in a non-intrusive manner. Prior to this study, a separate study was conducted to determine the accuracy and precision of the eye tracker without a chinrest in this condition, which is found to be 3.5° and 1.1° respectively [7, 8]. Raw eyeball movement and radar data are extracted from the Tobii eye tracker and NARSIM respectively via an intelligent real-time post processing server that has been developed, which ensures that the two data streams are synchronous in time. These extracted data were then relayed to the Thales TopSky-HF software to record the data of the different test participants [9, 10].

88 one-hour experimental sessions of data were collected among male participants whose ages varied between 24 and 41 ($M = 29$, $SD = 5.34$). These sessions comprised 24 novice sessions (zero ATC experience, only ATC knowledge), 20 intermediate sessions (more than 50 hours of simulator ATC training and ATC knowledge, yet to handle live traffic) and 44 expert sessions (licensed ATCOs with more than three months of live traffic experience) [11].

Prior to the experiment, each participant involved in a session underwent an initial 9-point eye-tracker calibration exercise. Calibration was repeated until a satisfactory calibration was obtained that refers to Tobii Studio's qualitative calibration report.

Real time simulations were conducted for 88 one-hour experimental sessions, with different scenarios consisting of 60 aircraft each, that mimic operational air traffic, which is approximately to 1.2 times of that of the regular traffic volume. In each scenario, there is a mixture of climbing and cruising flight along the different airways (flight path). The airspace of interest in this real time study was based on an existing airspace sector, with information referenced from the publicly available SkyVector website [12].

4 Discussion of Results

4.1 Aircraft frequency change

For the activity of aircraft frequency change, the fixation-click count signature is evaluated both incoming and outbound aircraft for the ‘UCO’ and ‘TOC’ commands respectively, for a specified operational duration of 2 minutes. Such is performed from a total of 45 selected aircraft in the scenarios, comprising of 270, 225 and 495 novice, intermediate and expert instances across the 88 experimental sessions respectively.

Table 1. Number of Participants fulfilling Fixation-Click Count Signature Criteria for incoming aircraft

Incoming aircraft (UCO Command)	Novice	Intermediate	Expert
Number of participants who fulfilled both Criteria 1 and 2	235/270 (0.87)	212/225 (0.94)	455/495 (0.91)
Number of participants who fulfilled only Criteria 1	235/270 (0.87)	212/225 (0.94)	455/495 (0.91)
Number of participants who fulfilled only Criteria 2	270/270 (1)	225/225 (1)	495/495 (1)

Table 2. Number of Participants fulfilling the Fixation-Click Count Signature Criteria for outbound aircraft

Outbound aircraft (TOC Command)	Novice	Intermediate	Expert
Number of participants who fulfilled both Criteria 1 and 2	231/270 (0.86)	196/225 (0.87)	425/495 (0.86)
Number of participants who fulfilled only Criteria 1	231/270 (0.86)	196/225 (0.87)	425/495 (0.86)
Number of participants who fulfilled only Criteria 2	258/270 (0.96)	215/225 (0.96)	470/495 (0.95)

The number of participants across all 3 expertise groups, who have exhibited the aircraft frequency switch signature for incoming and outgoing aircraft by fulfilling the two criteria for all sessions, are seen in Table 1 and Table 2 respectively. In addition, both Table 1 and 2 also showcase the proportion of participants who have fulfilled only criteria 1 and criteria 2 for all sessions respectively.

From Table 1 and 2, it is observed that participants from all expertise groups can exhibit the fixation-click count signature, as an average of 91% of the participants fulfilled both Criteria 1 and 2 for ‘UCO’ command, while an average of 86% of the participants fulfilled both Criteria 1 and 2 for ‘TOC’ command. These observations showed that the two criteria forming the fixation-click count signature are noticeable actions for all participants for both ‘UCO’ and ‘TOC’ commands. Such meant that fixating on the aircraft and clicking on the respective commands on the aircraft’s label, whenever there is a need for a frequency switch, is a common action amongst participants. Therefore, the new fixation-click count signature could be used as a suitable measure to identify if a participant has perceived and comprehended an aircraft during this activity.

4.2 One-hour Duration

During the one-hour duration, the total number of fixation-click count signature exhibited was computed, together with its fixation count for each click. Fig 3 shows the distribution of the number of click count and fixation count for every radar update frame of 9.8 seconds each.

Fig 3. Distribution of Fixation and Click Count across all frames

Results show that within every radar update frame, a higher click count results in a higher fixation count on the flight objects. Such indicates that as more clicks (commands) were issued in a frame, more attention is needed on the flight objects visually, thereby giving rise to a higher fixation count.

Additionally, experts are found to exhibit 15% and 8% more fixation count than novices and intermediates respectively, whereas intermediates exhibited 6% more fixation count than novices, across all click counts. Such highlights that with more experience and expertise, participants tend to exhibit a higher fixation count regardless of click count. This further indicates a more focused attention span by participants with a higher level of expertise. This aspect to differentiate an ATCO's expertise level using the fixation-click count signature is an interesting phenomenon worth further study.

5 Conclusion

A fixation-click count signature involving the ATCO's fixation on the track or label, before clicking on respective commands within a specified duration based on operational requirements, is presented.

Using 88 one-hour real time simulations with a remote eye tracker, results show that this signature is a common action amongst participants across all expertise levels on aircraft requiring frequency switch (91% incoming and 86% outgoing aircraft). For one-hour duration, results indicate that for all participants, a higher fixation count is exhibited whenever there are more clicks performed. Such shows that more visual attention span is required whenever more commands are issued. Furthermore, experts

are found to exhibit the most fixation count across all click counts, followed by intermediates and novices. This shows that a higher level of expertise would likely give rise to a more focused attention span. As a result, this signature could be further explored and used to differentiate the expertise levels of ATCOs.

Operational standards based on the fixation-click count signature can also be derived and applied in future ATC systems in the form of alerts. Instructors can also better evaluate the awareness level of prospective ATCOs, paving the way for a hybrid cognitive system to be incorporated into future ATC systems.

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