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Operator's behaviour measuring methodology inside off-road vehicle cabin, operator's focusing scheme

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Abstract. Operator's workplace design takes a priority to be developed in order to reach the highest possible level of Quality, Safety and productivity. Continual improvement of the workplace is yield from studies carried out on different approaches, each approach shall keep into consideration many aspects, in this research; the results will be used for feeding the productivity aspects with valuable and reliable input data using relatively simple engineering solutions. This research is made based on literature of the accumulated knowledge from diverse fields in which different studies and analysis are made to provide the necessary input for Human Centred Design process, adopting the-state-of-the-art technologies and methodologies used for data collection and analysis for Human behaviour inside the dedicated workplace. Better understanding of the operator's Gaze in addition to the change according to the mental and physical workloads inside the tractor cabin will lead to optimal designs for higher productivity operation.

Key words: off-road vehicle, operator's behaviour, eye tracking, focusing scheme.

INTRODUCTION

Human-centred-design approach is considered one of the most effective factors enhancing the productivity of vehicles used in the industrial and agricultural fields. The development of operator's workstation needs to be based on deterministic data which is validated, verified and dependable.

Due to the operational nature of multi-tasking off-road vehicles, operators need to spend long working hours; which increases the level of mental workload leading to human error. 'Li & Haslegrave (1999) introduced similar conclusion of which the vehicle design should be human oriented in order to maximize comfort and ability to perform the driving task perfectly and safely by reducing the human error possibilities'. Nowadays more and more agricultural machines are equipped with continuous measurement sensors e.g. measurement of soil resistance (Kroulik et al., 2015) to have more exact information on energy demand. This means that the driver attention is split by many signals.

Operating an off-road vehicle is a complex task, requiring a concurrent execution of various cognitive, physical, sensory and psychomotor skills (Young & Regan, 2007), additionally to control attached tools to perform in-field productive tasks such as agricultural and industrial operations. Ensuring the comfortable ride is considered essential for any vehicle, as well as executing happily and safely requested operational tasks, to that end, the driver ergonomics comes to play as considered as an important parameter that can't be neglected in the design phase of the vehicle (Hsiao et al., 2005).

Tractors are companions for many agriculture workers. Well-designed human – tractor interfaces, such as well-accommodated tractor operator enclosures can enhance operations productivity, comfort and safety Matthews (1977), Kaminaka et al. (1985), Liljedahl et al. (1996) and Hsiao et al. (2005).

Many studies have been carried on to find preferred locations of in certain types of tractor controls (Casey & Kiso, 1990), moreover; emphasizing how critical is the placement of controls in some tractors stating that, it actually creates an impediment to body movement (Hsiao et al., 2005).

When we are talking about automation, it is a general aim to improve comfort and safety (Sheridan, 1992; Endsley, 1996; Fukunaga et al., 1997; Scheding et al., 1999; Shen & Neyens, 2017), additionally, it is stated that, in the automated driving condition, driver responses to the safety critical events were slower, especially when engaged in a non-driving task. At the same time in their paper – dealing with driver visual attention 'Louw & Merat (2017) reached a conclusion shows that the drivers' understanding of the automated system increases as time progressed, and that scenarios which encourage driver gaze towards the road centre are more likely to increase situation awareness during high levels of automation'.

Generating dependable and deterministic data representing human behaviours inside the workplace using validated method will be beneficial for enhancing current cabin designs as well as the future cabin designs.

This research scope is the methodology part of studying operator's focusing scheme, which is one of the most beneficial behaviours to be recognized inside the tractor's cabin using simple engineering solutions to obtain useful results to be considered in the improvement of tractor's cabin design (i.e. upgrading notification system inside the tractor's cabin and allocating new equipment or components inside the tractor's cabin). In addition to enhancing the operation's work procedures design to increase the productivity of a specific agricultural operation (i.e. break time scheduling and feeding the risk analysis process with deterministic and/or probabilistic inputs).

Driving is not only a physical task but also visual and mental tasks. The eyes of a driver are indispensable in performing visual tasks such as scanning the road, and monitoring in-vehicle devices. Mental tasks are important during driving, and include such factors as understanding vehicle dynamics, making situation-dependent decisions, and judging time/space relationships (Kramer, 1990; De Waard, 1996; Brookhuis & De Waard, 2010; Marquart et al., 2015) were examined the eye-related measures of drivers' mental workload. The mental workload could be defined as the relation between demands resulted from various tasks to be performed on the operator and his ability to fulfil; with satisfactory; these demands Described those demands as multidimensional, as it involves tasks, operator and system demands together with other factors (Sporrong et al., 1998). Additionally; the studies showed that the need for well fitted architectural space to the operator's dimensions is considered crucial, additionally; the mental workload level is found to be increasing with the time passing.

For the purpose of this research, we focus on passive fatigue. This type of fatigue is characterized by being the indirect product of the human driver's exertion of a set of tasks whose demands are low, monotonous or repetitive (Saxby et al., 2013). These rules out any sort of physical fatigue or mental active fatigue.

A study conducted in 2015 by Gonçalves & Bengler claims that Highly Automated Driving (HAD) will be commercially available in a near feature, yet human factors issues like the influence of driver state can have a critical impact in the success of this driving paradigm and also in road and field safety. It is very likely that Driver State Monitoring Systems (DSMS) will play a bigger role than they have played so far.

However with this new driving paradigm shift is important to select highlight what is transferable from the previous systems. Due to lack of driving task engagement, driving performance metrics are no longer viable, creating opportunities for other approaches like detecting non-driving task engagement or fatigue countering behaviours. Eye based metrics will remain important.

MATERIALS AND METHODS

To the purpose of this research; the methodology part; the data extraction and analysis is limited to the laboratory test. However, the scope is subjected to be extended upon the accomplishment of the all research phases.

Selection of Operators

To the purpose of testing the methodology; one operator is selected to wear the eye-tracking equipment. The operator is mandated to spend several minutes inside the selected vehicle cabin to get familiar with the dashboard and equipment panels.

Selection of vehicle

CLAAS tractor (Model: ARES 567 ATZ) is selected to the purpose of accommodating the number of experimental trials (Fig. 1). This model has a covered workplace for the operator, which is helpful to control some of experimental conditions (i.e. temperature and humidity) keeping on the consistency of those parameters and conditions.

Figure 1. CLAAS tractor (Model: ARES 567 ATZ).

Selection of experimental field and operation

Experimental trials are conducted inside Szent István University Laboratories. In where the tractor is located. The operation part is limited to develop the operator's focusing scheme while exploring the cabin contents of the selected tractor. Spending several minutes as a familiarization process, the operator is introduced to the notification panel, main control panel and the side control panel components. However, and as previously stated, the scope of the full research is subjected to be extended to include several work fields for the same agricultural operation for 3 times for 5 operator with different work experience periods along 6 working hours.

Tobii Glasses 2 equipment

Tobii Glasses 2 (Fig. 2) is used to the purpose of obtaining the operator's focusing matrix from his/her real-time gaze analysis to predefined areas of interest. Which is feeding the research results with the main source of data regarding the target behaviour to be studied.

Building the mental-load topographical map on the areas of interest inside the workplace and accumulate it at the end of each working hour, will lead to measure the change of this topographical readings along working hours. Which is the behaviour to be studied 'Operator's focusing scheme and its change along working hours'.

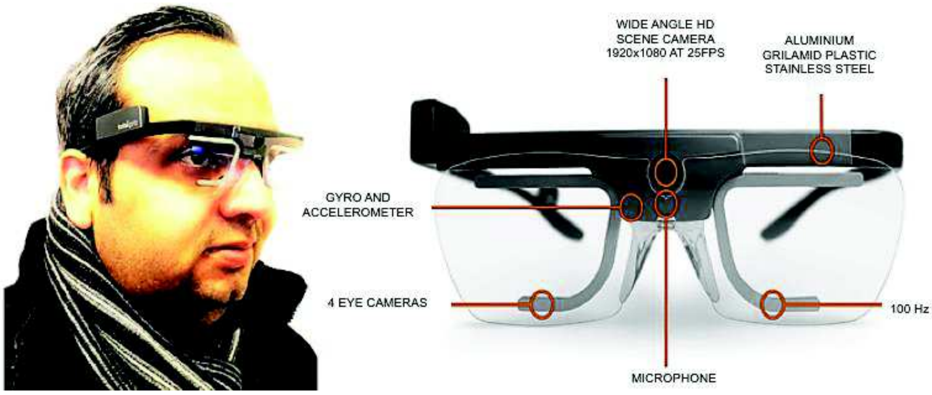

Figure 2. Tobii glasses 2.

Controller software

To record eye tracking data, the Tobii Glasses head unit must be fitted onto the test participant's head (similar to a standard pair of glasses). The system must then be calibrated separately for each participant. In the calibration process the test participant is asked to look at a Calibration Card held in-front of the participant for a few seconds. The researcher then starts the recording from Tobii Glasses Controller Software running on a Windows 8/8.1 Pro tablet or any Windows 8/8.1 or 7 computer. After the session, the researcher stops the recording and removes the head unit from the test participant. All interactions with the eye tracker (adding participants to test, initiating calibration, starting/stopping recordings etc.) are done through Tobii Glasses Controller Software.

The controller software also enables the researcher to view/hear the eye tracking session both in real-time (streamed through a wireless or wired connection) and after the recording. When viewing a recording, you can hear what was recorded on the integrated microphone of the Tobii Glasses 2 Head unit, the participant's gaze point also appears as a coloured dot on the scene camera video from the HD camera integrated in the Tobii Glasses 2 Head Unit.

Processing of raw data

The main processing tool of the operators' gazes is the Tobii Pro Lab (Fig. 3) which has a powerful post-analysis and visualization tools provide a full spectrum of qualitative and quantitative gaze data analysis and visualizations. Tobii Pro Lab logs events, defines areas of interest, calculates statistics, creates heat maps, and exports data for further analysis in other software.

Figure 3. Tobii pro lab – analyser software.

Tobii Pro Studio has three different types of fixation filters to group the raw data into fixations and Tobii Pro Lab uses one type of fixation filter to process the data. These filters are composed of algorithms that calculate whether raw data points belong to the same fixation or not. The basic idea behind these algorithms is that if two gaze points are within a pre-defined minimum distance from each other (Tobii Fixation and ClearView Fixation Filter), or possess a speed below a certain threshold (Tobii I-VT Filter), then they should be allocated to the same fixation. In other words, the user has kept the eyes relatively still between the two sampling points.

Areas of interest (AOIs)

The area of interest is a concept and a Pro Lab tool that allows the eye tracking researcher or analyst to calculate quantitative eye movement measures. These include fixation counts and durations. Using this tool, the researcher simply draws a boundary around a feature or element of the eye tracking stimulus whether it's a button on a web page or actor walking across a scene in a video clip. Pro Lab then calculates the desired metrics within the boundary over the time interval of interest.

Real world mapping

Wearable eye tracking devices; such as Tobii Pro Glasses 2; produce eye gaze data mapped to a coordinate system relative to the wearable eye tracker and the recorded video, not to static objects of interest in the environment around the participant wearing the eye tracker. For most statistical/numerical analysis to be meaningful, the collected eye tracking data needs to be mapped on to objects of interest and into a new coordinate system with its origin fixed in the environment around the participant.

RESULTS AND DISCUSSION

Experimental procedure

An operator is selected to wear the Tobii Glasses 2 equipment which is connected to the central device running Tobii controller software by which the calibration process of operator focusing is conducted and recording process is controlled.

The used tractor (CLAAS tractor (Model: ARES 567 ATZ)) is located inside Szent István University Laboratories. Main areas of interested (AOIs) are defined inside the tractor cabin.

The operator is mandated to go through the calibration process, start the recording process and get in the tractor cabin for several minutes to get familiarized with the cabin components paying attention to the selected AIOs while receiving verbal illustration regarding each component.

Thereafter, the recording process is stopped, and the recorded video is processed by the Tobii Lab pro software using the automatic real world mapping tool, heat maps representing operator's focusing scheme during the recording time are generated by the software, which leads to generate the statistic readings using MS Excel software.

Results

- In prior to start recording, the calibration process is done successfully and confirmed automatically by the Tobii controller software and the special calibration card (Fig. 4).
- 2 AOIs are selected inside the tractor cabin (Fig. 5) as follows:
  - AOI1: the notification panel in the tractor dashboard and the Air conditioning rotary switch.
  - AOI2: the side control panel in the tractor right side.
- The recorded video is processed using the Tobii Lab Pro software. The full recording time was about 520.53 seconds.

Figure 4. Calibration process using the special card and Tobii controller software.

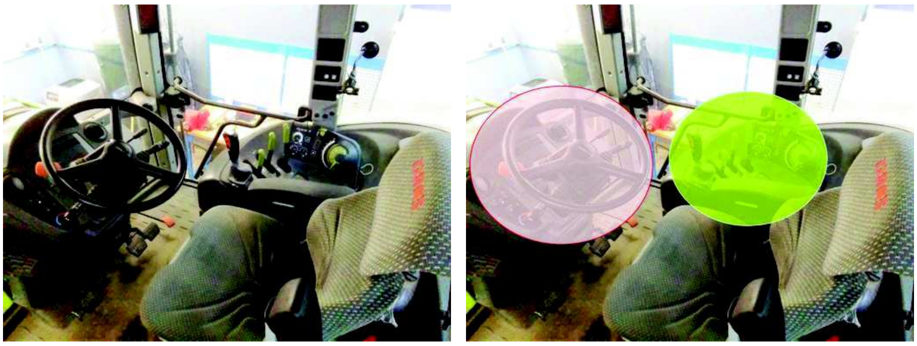

Figure 5. Tractor cabin and the selected AOIs locations.

- The AOI1 (Fig. 6) is represented into two components in the front dashboard. The Air conditioning rotary switch and the notification panel. From the variety of available data which the Tobii Lab Pro software is capable to provide, main collected data from AOI1 was limited to the accumulated gaze time spent on the selected components 'in seconds' and the counts representing the number of times in which each component is scanned by the operator (Table 1) and the heat map is generated (Fig. 7).

Figure 6. AOI1: the notification panel in the tractor dashboard and the Air conditioning rotary switch.

Table 1. AOI1: collected data

Total visit duration	AC rotary switch	Front dashboard	Sum	Total time o f interest duration	Total recording duration
Time (seconds)	0.67	100.11	100.78	290.13	520.53
Counts	4	239	243		

Figure 7. AOI1: Generated heat map.

- The AOI2 (Fig. 8) data is collected (Table 2) and the heat map is generated (Fig. 9).

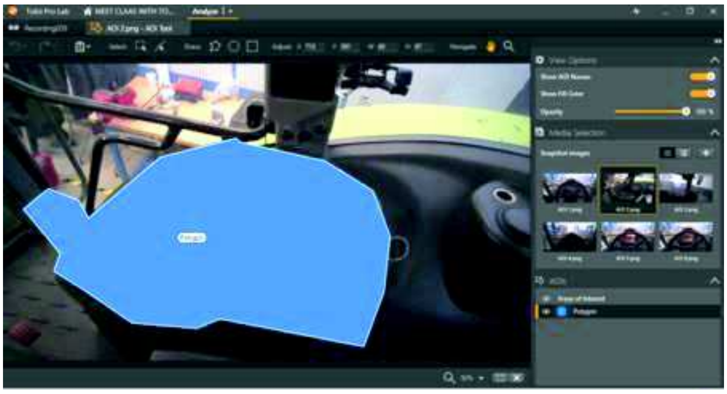

Figure 8. AOI2: the side control panel in the tractor right side.

Figure 9. AOI2: Generated heat map.

Table 2. AOI2: collected data

Total visit duration	Side control panel	Sum	Total time of interest duration	Total recording duration
Time (seconds)	33.88	33.88	54.94	520.53
Counts	77	77		

Discussion

The results showed very accurate and dependable data of the operators gaze on selected components inside previously defined AIO (i.e. the AC rotary switch in the AOI1). The used equipment and supporting software packages easily defined the time in which the operator paid his attention to the AC rotary switch (0.67 seconds) during the defined time of interest (520.53 seconds) during the familiarization with the tractor cabin. Such data is considered valuable to the designer of the front panel.

The operator's focusing scheme is represented in numbers and heat maps for the previously defined AIO (i.e. the side control panel in the AIO2). The resulted scheme is readable in term of number and sequence of hits representing the moments in which the operator paid attention to components inside the area of interest with ability to calibrate the sensitivity parameters and filters used to produce the data

CONCLUSIONS

The methodology used to generate deterministic results which are validated, verified and dependable to represent the operator's behaviour of the focusing scheme inside the workplace (tractor cabin).

The variety of filters and options available under the scope of the analyser software capability is found convenient to come over expected challenges during further research activities such as in-field experiments and outdoors activities.

Such generated results confirmed the feasibility of investing the followed methodology in studying more AOIs inside the tractor cabin to feed the design and/or development processes of the tractor cabin with valuable input data beside the conventional user experience feedback and continual research and development channels.

Additionally, by selecting a suitable time interval to generate operator's focusing scheme and providing comparison mechanism between generated schemes, the trend is found for the change of operator's focusing scheme along working hours. Which represents a dependable linkage between mental and physical workloads for the same operator inside his/her workplace for a specific productive operation along working hours. In other words, the fatigue indicator is became deterministic more than probabilistic value to be used in the design process of the operation (i.e. break times) to ensure the proper optimization for the productive operation.

Usability of research results

Increasing the efficiency and effectiveness of any agricultural or industrial operations that involves human operator – workplace interaction will be the main benefit of implementing this research methodology.

Current cabin designs are subjected to be enhanced with interactive guides and/or equipment for operators at the time in when and/or where it is expected to be needed because of the resulted numbers showing a decrement of focusing or response time.

Additionally, this research methodology is expected to be efficient comparison tool between prototypes of new cabin designs based on deterministic measures.

Future research

This research methodology is proposed to be developed for producing deterministic safety related measures to feed operator's workplace and operation design with the necessary inputs. Which might be dependable to produce the safety or risk assessment reports for certain vehicle or operation design.

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