Reducing Peak Workload in the Cockpit

A Human in the Loop Simulation Evaluating New Runway Selection Tool

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Problem area

When Air Traffic Control instructs the pilots of an aircraft that is already progressing in the approach to land on a different runway than planned, the result is a sudden peak in workload for the pilots. The Late Runway Change tool was developed to mitigate for this peak. The tool is available on a multi-touch input display which allows the pilots to enter the new runway in the Flight Management System with merely a few touches. The objective of the research was to investigate whether the tool decreases crew workload when a runway change is instructed by Air Traffic Control fairly late in the approach towards the runway.

Description of work

An experiment was used to compare workload between the new tool and the conventional cockpit. Workload was measured by means of a self-rating after each experiment run, as well as eye blink frequency during each run.

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AUTHOR(S)
T.J.J. Bos
G.D.R. Zon
W.F.J.A. Rouwhorst

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Results and conclusions

Both the objective and subjective data point towards a tendency of lower workload with the new tool. The data derived from the self-rating scale showed significant differences and the data from the eye blink frequency a trend towards lower workload hen using the Late Runway Change tool. Therefore, it is concluded that The tool has a positive effect on workload in case of a late runway change and is therefore considered very promising for further development.

Applicability

The results are proven to be applicable for the hardware and software implemented for the specific case of a late runway change. Also, it provides confirmation of the usability of eye tracking during an experiment to measure workload.

GENERAL NOTE

This report is based on a presentation held at the H-Workload symposium, Dublin, June 28-30, 2017.

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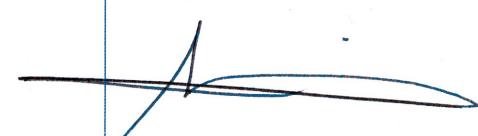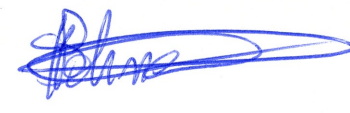
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AUTHOR(S):

T.J.J. Bos	NLR
G.D.R. Zon	NLR
W.F.J.A. Rouwhorst	NLR

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Summary

In efforts to increase safety and reduce peak workload situations in the cockpit, a tool with a different interaction style was developed for use in case of a runway change instructed by Air Traffic Control during approach. In an experiment a workload comparison was made between the new tool and the conventional cockpit. Workload was measured by means of a self-rating after each experiment run, as well as eye blink frequency during each run. Results show that the self-rated workload decreases with the new tool for one of the two crew members and the blink frequency suggests a workload decrease for the other crew member. Considering the fact that the crew used the tool after only a few training runs, and the positive feedback provided by the crews it is concluded that the tool has a positive effect on peak workload.

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Abbreviations

ACRONYM	DESCRIPTION
ATC	Air Traffic Control
DNW	German-Dutch Wind Tunnels
FMS	Flight Management System
LRC	Late Runway Change
NLR	Netherlands Aerospace Centre
PF	Pilot Flying
PM	Pilot Monitoring
TLX	Task Load Index

1 Introduction

In the evaluation of new tools and human machine interfaces in the cockpit it is useful to investigate how pilots interact with the new tool and what effect the tool has on the pilots' workload. In this study eye tracking data was collected and self-ratings of workload. This paper describes the tool, the research method, results, discussion and conclusion.

1.1 Research question

When Air Traffic Control (ATC) instructs the pilots to land on a different runway than planned, at a time the aircraft is already progressing in the approach, this results in a sudden peak in workload for the two crew members. The pilot in the role of Pilot Flying (PF) then needs to change the flight path towards the new runway while the Pilot Monitoring (PM) updates the Flight Management System (FMS), like tuning the Instrument Landing System frequencies, new approach radio frequencies, new go-around altitude in order to allow the precision approach to be continued correctly and have all other new settings ready in case of a go-around. Reprogramming the FMS is time-consuming and meanwhile requires the PM's visual attention at a moment when the PM should be monitoring and assisting in the flying task.

As a solution a Late Runway Change (LRC) tool was developed (Figure 1), which is available on a multi-touch input display allowing the pilots to enter the new runway in the FMS with merely a few touches. The objective of the research was to investigate whether the tool decreases crew workload in the particular scenario that a runway change is instructed by Air Traffic Control, fairly late in the approach towards the runway.

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Fig. 1. Picture of the display on which the LRC is running

1.2   Task load and Workload

With the introduction of the tool, the number of system inputs required reduces, compared to the conventional cockpit. In other words the *task load* reduces, the actual quantifiable load a task encompasses. Task load is different from *workload*, which is the load perceived or experienced by the person performing the task. This depends e.g. on the person's knowledge of and experience with the task at hand.

The workload experienced by the pilot can be measured by self-rating scales and more objectively by means of physiological measurements such as eye blink frequency as a measure of visual workload. Research with air traffic controllers suggests that workload negatively correlates with blink rate, i.e. a higher workload results in a lower blink rate [1][2]. In a visually demanding task such as flying, with a workload increase, more focused attention is required and the visual load increases. This decreases the blink rate [1].

2   Method

In an experiment in a research flight simulator, a facility of the Aerospace Centre, NLR in the Netherlands, ten flight crews flew ten scenarios (Figure 2). In the experiment, several tools were evaluated. In two of the scenarios a late runway change was instructed by simulated ATC: once with the new functionality and once with the conventional A320 cockpit functionality. The sequence of the scenarios was randomised. Before the start of the experiment, the crews were briefed regarding the functionality and were given hands-on experience to get familiar.

Fig. 2. Picture of the touch input display including the late runway change tool

After each run, the pilots rated their workload through the NASA-Task Load Index (NASA-TLX [3]). NASA-TLX consists of two parts: a rating of workload aspects and a pair-wise comparison of the aspects in terms of their importance for the task. For a comparison of the task between the LRC tool and the conventional cockpit, we decided that the rating part of the NASA-TLX would suffice. And in the analysis all workload aspect ratings were included, assuming equal importance.

In addition to the subjective measures, the Dikablis Essential eye-tracker (Ergoneers) was used on both PF and PM to investigate their division of attention and to assess the pilots' blink frequency as a measure of visual workload. The blink frequency in the time interval starting with the ATC instruction and ending 180 seconds later was analysed. Both pilots were subjected to eye-tracking because we were interested in workload of the crew as a whole. Also if a shift in workload would take place between the two crew members (as a result of a new tool) this was of interest.

3 Results

Figure 3 shows the overall results for the NASA-TLX ratings for the pilot flying and the pilot monitoring separately.
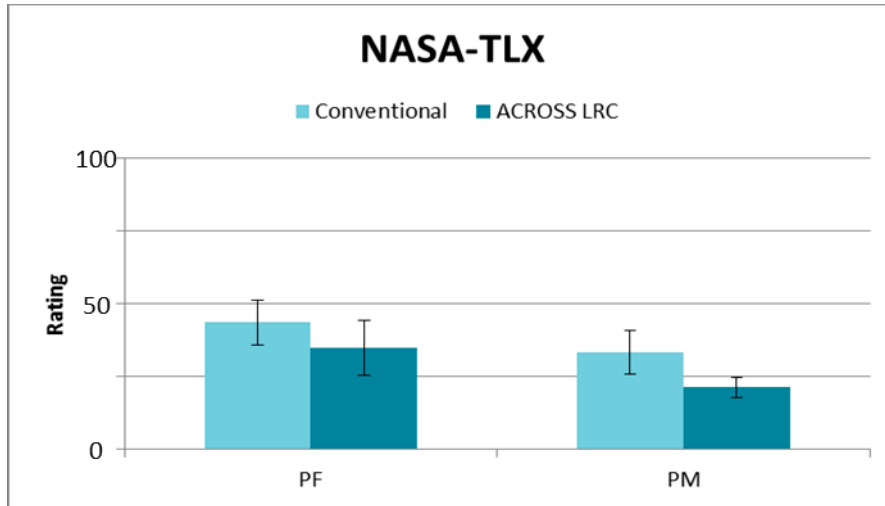

Fig. 3. Average post-run ratings for NASA-TLX for pilot flying and pilot monitoring with and without Late Runway Change functionality (0: very low, 100: very high)

Paired samples t-test yielded **significant results for the pilot monitoring ($t(8)$ = 2.532, p < .05).** The pilots monitoring rated the workload lower when the late runway change functionality was turned on. For the pilot flying the difference was not significant.

The blink rate for both pilots was assessed during the 180 seconds interval starting after the runway change instruction was provided by (simulated) ATC (Figure 4).
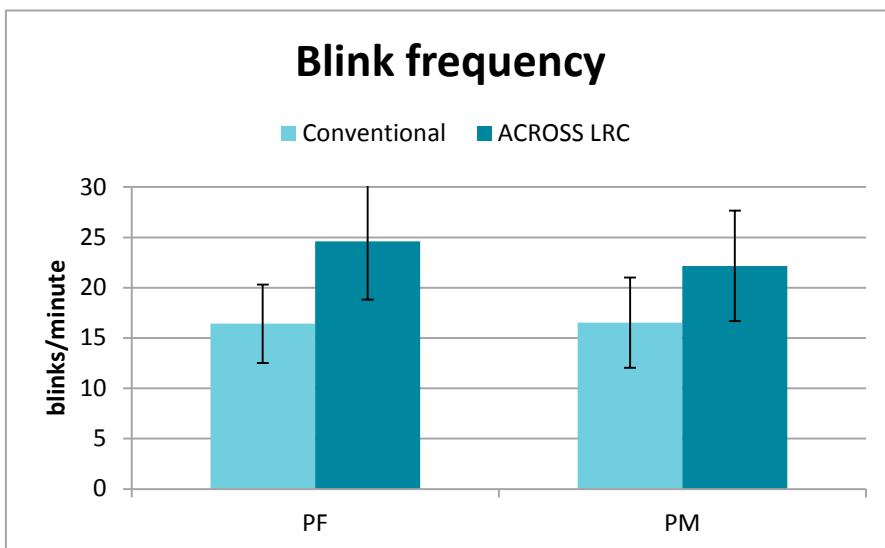

Fig. 4. Average blink frequencies in the 180 second after the runway change instruction, for the pilot flying and pilot monitoring in the two conditions

The blink rates were not significantly different between the two conditions, neither for pilots flying nor for pilots monitoring. However, a trend was visible for the PF that indicates a lower blink frequency during the conventional

condition compared to the late runway change functionality condition ($t(9) = 1.988$, $p = .077$), suggesting that the LRC technology decreases the PF's workload.

In the post-experiment questionnaire, both pilots flying and pilots monitoring agreed that the Late Runway Change functionality decreased workload (M $_{pilot\ flying}$ = 4.5, M $_{pilot\ monitoring}$ = 4.6 on a five-point scale, where 1='completely disagree' and 5='completely agree').

Pilots in the role of pilot monitoring commented that using the touch screen for runway changes was very effective, quick and easy (6 out of 10 pilots).

4   Discussion and conclusion

Late runway changes normally increase the workload of both pilots. The PF changes heading to maneuver the aircraft to line up for the other runway and the pilot monitoring is in that case the one entering the new runway specifics in the FMS, like tuning the Instrument Landing System frequencies, new approach radio frequencies, new go around altitude in order to allow the precision approach to be continued correctly and have all other new settings ready in case of a go-around.

The use of the new tool resulted in lower NASA-TLX ratings of the PM, which is according to expectations. The blink frequency using the LRC function seemed higher, indicating a lower workload but was not significantly higher, even though blink rate is considered a good indicator for workload. The interval at which the late runway changes took place was quite long (180 s), and in this interval other tasks may already have taken the pilots' attention, which may be the reason that the blink rate was not significantly lower. Furthermore, blink frequency is subject to high variation between participants which decreases the chances of finding statistically significant differences. Nevertheless, given that the significant different subjective data and the trend in the objective data both point towards a tendency of lower workload with the new tool, it is concluded that the LRC tool has a positive effect on workload in case of a late runway change and is therefore considered a very promising tool for further development.

5   Acknowledgements

6   References

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