Understanding the safety-relevance of visual cue perception at a Surface Manager HMI

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Overview

1. Motivation for empirical Risk Analysis of sociotechnical systems in ATM
2. Introduction to a new concept for Risk Analysis
3. Empirical Concept Evaluation
4. Results
5. Conclusions for further research

Definition of Risk:

“Risk is defined as the probability that an accident occurs during a stated period of time”

Blom (2003)
Motivation for the proof of concept study

- The predictive Risk Analysis on sociotechnical systems provide valuable estimations on the resulting ATM safety-performance.
- Traditional Risk Analysis rely on expert statements (subjective estimation).
- New concepts for model-based risk analysis have been evaluated (objective estimation). No direct evidence from current operations for validation.
- A pure empirical approach for Risk Analysis by means of Human-In-The-Loop Simulations often lacks statistic power when proving the system-safety against rare safety-critical events.
- An approach is needed that indicates risk predictively by objective measures.
- A Human-In-The-Loop approach is proposed for an empiric approach for Risk Analysis.

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Using visual cue perception as a risk indicator

Why using actions of the operator for visual cue perception as risk indicators?

- Operators involve visual information essentially for decision-making in safety-critical situations (e.g. virtual tower, flare initiation)
- We assume the safe decision-making as being strongly sensitive to the design of the visual provision of the traffic situation.
- There is a trend of computerization and automation in tower and flight deck operations, involving increasingly the visual stimulation for information perception in ATM (e.g. datalink and A-SMGCS).

Visual Cue Perception indicates the contribution of the system design to risk.
The provision of visual cues to the operator

Source Entzinger (2008)
The proof of concept study

- The objective is
  - To develop a concept for a methodology that identifies the safety-relevance of visual cues
  - To identify the relative importance of visual cues within a set of visual cues
  - To determine the relative contribution to risk by a specific visual cue
Introduction to the concept - Assumptions

- A system provides a set of cues visually to an operator
- The accident event as well as the related precursors (e.g. loss-of-separation or runway incursion) are defined as safety-relevant events
- The visual cue \( k \) might cause a safety-relevant event in the case of failed perception
- The unification of all failed perception events determines the resulting probability of the safety-relevant events
The Human-In-The-Loop Simulation approach

- An A-SMGCS-SMAN HMI serves as a test setup at Frankfurt airport
- Novices are selected as test persons (4 trained students, each one tested 10 hours), acting as tower controllers
- Measuring methods
  - Regular (periodic) questionnaires for the importance of visual cue when granting take-off clearances \(\Rightarrow\) demand of visual cues
  - Detecting runway incursions \(\Rightarrow\) runway incursion rate
  - In the case of a detected runway incursion: Instant (closed ended) questionnaire for the identification of the related visual cue that was not perceived adequately \(\Rightarrow\) Identification of the safety-relevance
  - Eye tracking measures \(\Rightarrow\) demand of visual cues
Modeling the visual demand in aerodrome control: The take-off clearance

Models bases upon
- Manual of operations (DFS)
- ICAO PANS-ATM Doc 4444
- Task Analysis in the scope of Virtual Tower research
  - Expert Judgment
  - Field evaluation
Event tree of the decision-making „take-off clearance“

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The test setup

- Surface Movement Manager
Results – Regular questionnaire $h_{VP_k}$

- Subjective rating of the importance of proposed visual cues on a scale from 1 (no agreement) to 4 (total agreement)
Results – Failure questionnaire $h_{PFk|RI}$

- Subjective rating of the contribution to runway incursion (yes/no-options)
Contribution of a visual cue to risk

- $VP_k$ Perception event of the visual cue $k$.
- $PF_k$ Perception failure event of the visual cue $k$.
- $RI$ Runway Incursion event.
- $p_{PF_k|RI}$ Conditional probability of failed perception $k$ when RI has occurred (event tree case 1) $\Rightarrow$ failure questionnaire $h_{PF_k|RI}$.
- $p_{VP_k}$ Probability to use the visual $k$ for granting the take-off clearance $\Rightarrow$ regular questionnaire $h_{VP_k}$.

$$P(RI|VP_k) = \frac{p_{PF_k|RI}}{p_{VP_k}} \cdot p_{RI}$$
## Results

| Visual cue                        | \( P(RI|VP_{k}) \) |
|----------------------------------|---------------------|
| Route (other a/c)                | 3.0 %               |
| Position (other a/c)             | 2.6 %               |
| Heading (other a/c)              | 2.4 %               |
| Speed (other a/c)                | 2.4 %               |
| Speed (target a/c)               | 2.1 %               |
| Route (target a/c)               | 2.0 %               |
| Altitude (other a/c)             | 2.0 %               |
| Position (target a/c)            | 1.4 %               |
| Heading (target a/c)             | 0.6 %               |
| Altitude (target a/c)            | ? \( (p_{VPk} = 0) \) |
Conclusion

- Questionnaires give valuable clues on the importance the demanded cues.
- The safety-relevance of visual cues was determined by the Failure Questionnaires. This offers a data-basis for further design evaluation early in the product life-cycle.
- A contribution to risk by a specific visual cue could be quantified. It suffers of non-calibrated estimates which might impair the results accuracy.
- The results of the Proof-of-concept study has little external validity as the novice test persons have no reference to real operations.
- Further research will concentrate on more objective measures of the visual cue perception, e.g. eye tracking analysis.
Thank you.

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