Discriminability of Flight Maneuvers and Risk of False Decisions Derived from Dual Choice Decision Errors in a Videopanorama-Based Remote Tower Work Position

Norbert Fürstenau, Maik Friedrich, Monika Mittendorf, Markus Schmidt, and Michael Rudolph

German Aerospace Center, Inst. of Flight Guidance, Braunschweig, Germany
Norbert.fuerstenau@dlr.de

Abstract. Future remote control of small low traffic airports (Remote Tower Operation, RTO) will rely on the replacement of the conventional control tower out-of-windows view by a panoramic digital reconstruction with high resolution and pan-tilt zoom (PTZ) video cameras as basic sensor system. This provides the required visual cues for aerodrome traffic control without a local control tower. Here we show that with a 2 arcmin-per-pixel resolution panorama system even with the use of a manually controlled (analog) PTZ camera (with PAL TV-resolution and selectable zoom factor setting) experiments under operational conditions indicate a significant increase of decision errors under RTO as compared to the conventional out-of-windows view. We quantify the corresponding discrimination difference by means of detection theory (discriminability, decision criteria) and Bayes inference (risk of false decisions) using the response errors of tower controllers with regard to dual choice decision tasks. The results extend the performance and subjective data analysis of safety related maneuvers in 11.

Keywords: Remote Tower Operation, visual cues, videopanorama, field testing, aerodrome circling, flight maneuvers, two-alternative decisions, signal detection theory, Bayes inference.

1 Introduction

Since about ten years remote control of low traffic airports (Remote Tower Operation, RTO) has evolved as a new paradigm to reduce cost of air traffic control 1. It was suggested that technology may remove the need for local control towers. Controllers could visually supervise airports from remote locations by videolinks, allowing them to monitor many airports from a remote tower center (RTC) 234. It is clear from controller interviews that usually numerous out-the-window visual features are used for control purposes 567. In fact, these visual features go beyond those required by regulators and ANSP's (air navigation service providers) which typically include only aircraft detection, recognition, and identification 7. Potentially important additional visual features identified by controllers in interviews involve subtle aircraft motion. In

D. Harris (Ed.): EPCE/HCII 2013, Part II, LNAI 8020, pp. 105–114, 2013.

fact, the dynamic visual requirements for many aerospace and armed forces tasks have been studied, but most attention has been paid to pilot vision (e.g. 8). A degradation of dynamic visual cues due to limited video framerates and its effect on decision errors during the landing phase was reported 910. Another group of visual cues are derived from flight maneuvers within the range of observability in the control zone. They might be indicative of aircraft status and pilots situational awareness which is important with the higher volume of VFR traffic in the vicinity of small airports.

These considerations led to the design of the present validation experiment within the DLR project RAiCe (Remote Airport traffic Control Center, 2008 – 2012). The field test was realized within a DLR - DFS (German ANSP) Remote Airport Cooperation (RAiCon). Specifically dual-choice decision tasks (the subset of "Safety related maneuvers" in 11) are used for quantifying the performance difference between the standard control tower work environment (TWR-CWP) and the new RTO controller working position (RTO-CWP). The present data analysis is based on objective measures from signal detection theory (SDT) and Bayes inference utilized in previous simulation experiments for deriving video frame rate requirements 910.

Experimental methods and results are provided in sections 2 and 3. In section 4 alternative methods (SDT and Bayes inference) are used for deriving estimates of discriminability, decision bias, and risk of false decisions, based on the measured response matrices. We finish with a conclusion and outlook in section 5.

2 Methods

In what follows only those aspects of the remote tower validation trial relevant for analysis of the two-alternative decision tasks are presented and discussed. Further details of the full passive shadow mode validation trial are reported in 11. The focus here is on quantifying the difference of discriminability and risc of false decisions under TWR-CWP and RTO-CWP conditions derived by objective measures via SDT 12 and Bayes inference and based on the analysis of dual choice decision errors.

2.1 Participants

Eight tower control officers (ATCO's) from DFS were recruited as volunteer participants for the experiment. The average age was 30 (stdev 12) years with 10 (stdev. 10) years of work experience, and they came from different small and medium airports. They took part at the experiment during normal working hours and received no extra payment. They were divided into 4 experimental pairs for simultaneously staffing the control tower (TWR-CWP) and the RTO-CWP.

2.2 Experimental Environment and Conditions

The experiment was performed as passive shadow mode test under quasi operational conditions on the four days July 17 – 20 2012. The remote tower system used in the present experiment was located at the DFS-operated Erfurt-Weimar (EDDE) control tower. It was an improved version of the RTO-experimental testbed at Braunschweig airport which was in use since 2004 for initial verification and validation trials 123. Figures 1 show the sensor system and the RTO-CWP with 200° - videopanorama and operator console based on a reconstructed far view with five HD-format 40”-displays (892 x 504 mm, 1920x1080 pixel, pixel distance = 0.47 mm). A separate monitor (left) displays the pan-tilt zoom camera which is controlled via a pen-input interaction display with virtual joystick, 12 preset viewing directions and selectable zoom factors Z = 2, 4, 8, 16 (viewing angles 26° - 3°). Additional monitors include standard information sources, (middle row from right to left) flight plan data, approach radar and weather display. In contrast to the experimental TWR-CWP the RTO position (RTO-CWP) was on the TWR ground floor in a separate room without visual contact to the airfield. The TWR-CWP was located close to the operational ATCO, but they were instructed not to communicate with each other.

Fig. 1. Remote tower installation with 200°-panorama and pan-tilt zoom camera sensor system at the tower roof (left photo), and operators workplace with 40”-HD-format displays (right)

Pre-defined flight maneuvers were generated with a DLR DO228 twin turboprop engine test aircraft (D-CODE, length 15.03 m, body height x width 1.8 x 1.6 m, wing span 16.97 m, wheel diam. 0.65 m) performing aerodrome circling. The set of well defined maneuvers as decision tasks at given positions within the EDDE control zone is indicated in Fig.2. During the experiment sometimes additional low volume normal traffic took place which now and then lead to delays in the traffic circle. Average duration of a full circle (= one run) was ca. 10 min yielding typically 140 min of experiment duration per participant pair for the nominally 14 full circles.

An example traffic circle is shown in Figure 2 with a 3D plot of the logged on board GPS trajectory. Radio communication between D-CODE pilots and flight engineer and the experimenter at the tower was realized with a separate research frequency in addition to the standard A/C – TWR radio channel. The available time for participant’s responses to decision tasks was limited so that correct, incorrect and non-answers were possible. At position D an altitude variation is observed. Trajectory minimum represents a runway overflight at about 30 m above ground.

2.3 Experimental Design and Task

Based on the fixed set of events during a single circle (A, .., H, I in Fig. 2) the concrete dual choice event (situation) alternative (S1, S2) for decision making switched statistically between runs according to two mirrored scenarios with different task sequences. In this way during the 14 circles per experiment / participant for each event about 7 answers per event alternative and per participant were obtained for the analysis (TWR and RTO CWP condition as independent variables). The within subjects design (TWR vs. RTO-CWP) yields about N = 56 answers for averaging with the 8 participants.

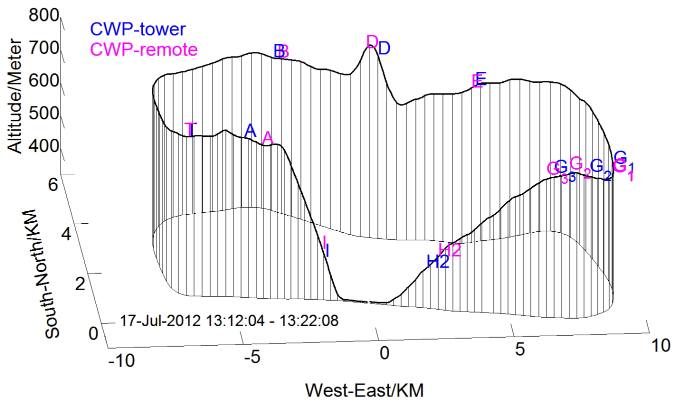

Fig. 2. DCODE trajectory measured with on-board satellite navigation. Letters indicate event positions with logged answers of TWR-CWP (blue) and RTO-CWP (red) operators to simultaneous task oriented on-line questioning. Distance between vertical lines = 5 s, projected to trajectory altitude minimum at ca. 350 m (sea level). Tower position (0, 0), height = 30 m.

During one aerodrome circling the two participants at the TWR and RTO-CWP had to simultaneously answer 19 different types of questions concerning the D-CODE maneuvers (events), object detection, and weather status. The following subset of 4 of the 9 event related questions were used for further evaluation by established objective methods (SDT and Bayes inference) for analysis of dual choice decision tasks (in brackets: maximum response time = interval until next task / question): 1. Does the aircraft perform repeated bank angle changes? (event position A; 30 s), 2. altitude variation ? (by 300 ft, event pos. D; 30 s), 3. landing light-off? Report status, event pos. G_2; 60 sec: switching-off not observable), 4. Landing gear-down? (Report during final approach (event pos. H_2, variable between 1.5 – 0.5 nm; 30 s). A subjective certainty rating on a 5-point scale was not evaluated for the present analysis.

Every pair of participants had to complete two experimental trials. For the first trial (duration approximately 140 min) in the morning till noon, the participants were randomly assigned to one of the two CWP's. Positions were changed for the second trial in the afternoon. The number of airport circles corresponding to the number of decisions for each specific event was between 10 and 14. With two alternative stimuli (S_1, S_2) per task each pair of participants was exposed to 5 – 7 stimuli of the same kind in random succession for each event under TWR and the same number under RTO conditions. The present data analysis is focused on deriving objective measures for the dual-choice decision tasks. Additional data evaluation is presented in a parallel paper 11 addressing performance (answers given, response times, and sources of information) and subjective measures (debriefing, questionnaires).

3 Results

The results can be organized in the form of response matrices which structure the measured estimates of conditional probabilities $p(y|S_1)$ = hit rate H, $p(y|S_2)$ = false alarms FA, $p(n|S_1)$ = misses M, $p(n|S_2)$ = correct rejections CR. Because participant's responses to event related questions were allowed to be positive, negative, and non-answers (no decision during the available time), we analyse two types of response matrices: a) (optimistic) neglecting non-answers, b) (pessimistic) interpreting non-answers as false decisions (M or FA). In this way we obtain for each of the decision tasks an optimistic and a pessimistic estimate with regard to decision errors which translates into corresponding risk, discriminability and subjective criteria (decision bias) values under analysis with signal detection theory (SDT) and Bayes inference.

Within the theoretical framework of detection theory the two alternative stimuli S_1, S_2 for each event define independent statistical variables. Each set of observations / decisions of a single subject for the 14 aerodrome circles with one of the events A, D, G_2, H_2 represents a sample of the randomly presented S_1- and S_2-alternatives, with the subjective responses assumed to be drawn from independent equal variance Gaussian densities ($\mu_{1,2}$, σ) for S_1 and S_2. Any quantitative discriminability difference between TWR and RTO is quantified by their corresponding coefficient $d' = \mu_1 - \mu_2 = z(H) - z(FA)$, and subjective decision bias (criterion) $c = 0.5(z(H) + z(FA))$, with z() = z-score as calculated from the inverse cumulative densities (see 4.2). Probabilities of alternative responses add to 1 ($H + M = 1$, $CR + FA = 1$) so that for the determination of d' and c, and graphical presentation in ROC space (receiver operating characteristic) the (H, FA) data set is sufficient.

Table 1 lists the corresponding hit and false alarm rates (± standard errors of mean ≈ 0.5 (95% conf. intervals)) for the four events to be analysed with respect to d' and c. In addition to H and FA the complementary rates CR and M are required for calculating the inverse conditional probabilities using Bayes inference (section 4.1).

Comparing the measured hit and false alarm rates for all four events under TWR and RTO conditions with non-answers not considered (optimistic case a): left two data columns), the RTO-CWP exhibits no significant difference as compared to the TWR-CWP. If however, the non-answers are interpreted as erroneous responses and correspondingly attributed to rates FA and M (pessimistic case b): right two data columns), significant differences TWR vs. RTO are obtained (smaller H(RTO), larger FA(RTO)) for event/task A (bank angle variation?), H (gear down?), G (lights off?), whereas for event/task D responses again exhibit not significant difference. The interpretation of the non-answers as erroneous responses appears to be justified due to increased uncertainty about the correct answer resulting in hesitation to respond at all

Table 1. Measured hit and false alarm rates ± stderr. of mean, for the four events and two conditions (TWR, RTO-CWP) with a) non-answers excluded (left two data columns) and b) non-answers attributed to error responses i.e. error rates FA and M (right two data columns)

Event with Alternatives S_1 or S_2	Distance ± stdev / km	CWP	a) Non-answers excluded		b) Non-answers included	
			$p(y\|S_1)$	$p(y\|S_2)$	$p(y\|S_1)$	$p(y\|S_2)$
A: bank angle var./ no var.	4.3 ± 0.4	TWR	0.92±.04	0.08±.04	0.81±.06	0.20±.05
	4.4 ± 0.4	RTO	0.93±.05	0.11±.05	0.60±.07	0.39±.07
D: Altitude var. / no var.	3.6 ± 0.6	TWR	0.80±.06	0.03±.03	0.77±.06	0.12±.06
	3.6 ± 0.6	RTO	0.73±.07	0.03±.03	0.70±.07	0.06±.04
G: lights off: y / no	7.0 ± 1.2	TWR	0.94±.04	0.25±.07	0.94±.04	0.28±.07
	4.0 ± 2.3	RTO	0.92±.06	0.63±.08	0.65±.08	0.72±.07
H: gear-down / up	2.2 ± 0.5	TWR	0.98±.02	0.06±.04	0.91±.04	0.22±.06
	2.1 ± 0.6	RTO	0.98±.02	0.07±.05	0.77±.06	0.37±.08

because tower controllers work ethics requires decision making with high certainty. This finding will be analysed and discussed in the next section. An extremely high FA difference TWR vs. RTO is observed both for case a) and b) for the "lights-off" event which is reflected also in a large difference of decision distance (correlated with response time).

4 Data Analysis and Discussion

There are of course several physical and psychophysical differences between the real out-of-tower view by human operators and the reconstructed far view with videopanorama and PTZ which leads to predictions concerning performance differences under the two conditions TWR and RTO-CWP due to technical limitations of the state-of the-art RTO technology 123. The measured performance, however depends on the usage of the different available information sources, e.g. videopanorama and PTZ. In the present work the measured performance difference is quantified in terms of SDT-discriminability difference d' and in terms of risk difference for detection errors as quantified by Bayes inference. The technical limitations leading to a prediction on RTO-performance are given by the systems modulation transfer characteristic (MTF), with the digital (pixel) camera resolution providing the basic limit (Nyquist criterion) for detectable objects (minimum resolvable visual angle $\delta\alpha \approx 2$ arc min $\approx$ 1/30° $\approx$ 0.6 m object size / km distance per pixel under maximum visibility. This is about half as good as the human eye (1 arcmin). Reduced visibility and contrast of course reduces the discriminability according to the MTF and the question arises how the discriminability difference TWR vs. RTO-CWP is affected. The gear-down situation with wheel diameter 0.65 m, e.g. can certainly not be detected before the wheel occupies, say, 4 pixels which for the 40" display (0.55 mm pixel size) means a viewing angle of ca 1 mm/2 m $\approx$ 0. 5 mrad corresponding to the visual resolution of the eye (1 arcmin) under optimum contrast. This estimate results in a panorama based gear-down detectability distance of < 500 m, leading to the conclusion that under RTO conditions this task requires usage of PTZ in any case for guaranteeing a high decision certainty. The same argument is valid for the other discrimination tasks.

4.1 Bayes Inference Analysis: Risk of False Decision

H, M, CR, FA are conditional probabilities which after the measurement are used together with the a-priori knowledge $p(S_i)$ as information for calculating via the Bayes theorem the risk of false decisions d_j, i.e. the (inverse) probability for occurrence of an actual situation conditional on the perceived one different from the actual one ($i \neq j$:

$$p(S_i|d_j) = p(d_j|S_i)\, p(S_i) / p(d_j) \tag{1}$$

with responses d_i, $i = 1, 2$, d_1 = yes, d_2 = no, and $p(y) + p(n) = 1$, $p(S_1) + p(S_2) = 1$, under TWR and RTO conditions. Of particular interest are the two probabilities for the risk of a situation contradicting the decision on the nature of the observed event. $p(S_1|n)$ is the probability (risk, likelyhood) of the aircraft with bank angle variation (situation S1, e.g. signaling some special situation during radio interruption) conditional the case that no variation is perceived. $P(S_2|y)$ is the probability for a situation with a/c not performing bank angle variation conditional on the false response "variation perceived". The following Table 2 contains the Bayes inference (risk) results for the four events. It clearly shows that for analysis b) these risks are on average at least two times as high for the RTO-CWP as compared to TWR- CWP, with the exception of event D.:

Table 2. Bayes inference for TWR and RTO-CWP from response data, for cases a), b)

Event with S_1 or S_2	CWP	a) Non-answers excluded		b)Non-answers included	
		$p(S_1\|n)$	$p(S_2\|y)$	$p(S_1\|n)$	$p(S_2\|y)$
A: bank angle var.	TWR	0.06	0.10	0.15	0.24
	RTO	0.06	0.13	0.33	0.46
D: Altitude var.	TWR	0.22	0.03	0.26	0.11
	RTO	0.26	0.03	0.30	0.06
G: lights off	TWR	0.06	0.26	0.06	0.29
	RTO	0.13	0.50	0.48	0.60
H: gear-down	TWR	0.03	0.04	0.14	0.15
	RTO	0.04	0.04	0.33	0.26

Important differences are observed for the analysis a) without non-answers considered (left two inference columns) as compared to the case b) with non-answers included (right two inference columns). The calculated risk for a situation occurring in contradiction to the perceived situation is very low for non-answers excluded and in most cases they increase significantly with non-answers included, which in fact is not surprising. Not expected was the result that in the RTO-CWP the risk in most cases at least doubles as compared to TWR-CWP. The altitude variation (event D) in contrast exhibits no significant difference which can easily be explained by the fact that due to the practically non-existent visual panorama visibility of the D-CODE at event position D the majority of decisions were made based on radar information.

4.2 Signal Detection Theory: Discriminability and Decision Bias

The Bayes inference analysis is supported by a more sophisticated evaluation of data from table 1 using SDT. In contrast to percentage correct (p_c) evaluation of subjects decisions on dual choice tasks it separates the decision maker's discriminability d' from the subjective decision bias c (= individual tendency to more conservative or more liberal decisions) 12.

Figure 3 depicts for analysis of case b) the (H, FA) data of the three tasks at H, A, G in ROC space together with two sets of pairwise ROC curves (one pair for TWR and RTO conditions each). One set (solid lines) is parametrized by discriminability d', the other (dashed) by the subjective decision bias c. E.g. d' = 3 means that the Gaussian densities mean values of perceived situations S_1, S_2 differ by 3 normalized stddev ($\sigma = 1$). Under the above mentioned conditions each (d', c)-ROC curve-pair is unambiguously determined by the single average (H, FA)-point. The d' and c values are calculated via standard procedures (inverse cumulative densities from the (H, FA) data). Dotted lines indicate estimates of standard deviations s(d') as described in 12, based on the binomial variation of measured proportions from sample to sample.

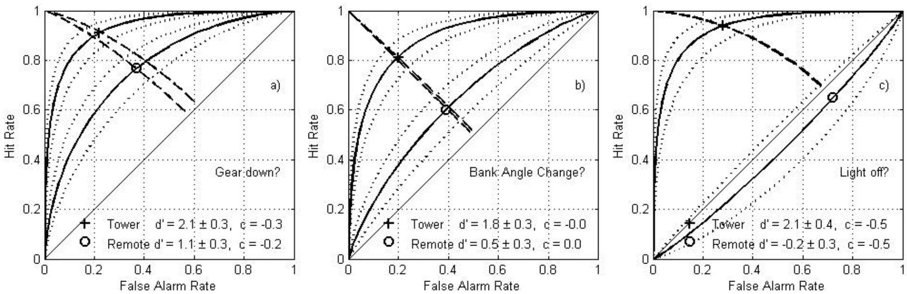

Fig. 3. Measured case b) data points in ROC space of average hit and false alarm rates for three of the four analysed events / tasks, in each case for the two TWR, RTO – conditions, together with the isosensitivity and isobias curves parametrized by discriminability d' and criteria c respectively. Dotted lines are standard deviations based on procedures described in 12

The following table 3 summarizes the discriminability and criteria (decision bias) data corresponding to Figure 3 a), b), c), and like table 2 includes event/task D (altitude variation) with both data analysis cases: optimistic a) and pessimistic b). Again, like with the Bayes inference the case a) analysis shows no significant difference between TWR and RTO-CWP conditions if the non-answers are not considered in the data analysis, with the exception of task G where even with non-answers not considered RTO exhibits a significant decrease of discriminability.

Also for case b) analysis the Bayes inference results are confirmed: again with the exception of task D (altitude change) significant decrease of discriminability is

Table 3. Discriminability d‘ and certainty c as obtained from z-scores based on response matrices (hit and false alarm rates). For uncertainties see Fig. 3.

Event	CWP	a)Non-answers excluded		b) Non-answers included	
		d’	c	d’	c
A	TWR	2.81	-0.01	1.75	-0.02
	RTO	2.72	-0.11	0.54	0.00
D	TWR	2.69	0.49	1.90	0.22
	RTO	2.48	0.62	2.07	0.52
G	TWR	2.24	-0.45	2.14	-0.49
	RTO	1.05	-0.86	-0.20	-0.48
H	TWR	3.63	-0.30	2.12	-0.30
	RTO	3.47	-0.30	1.07	-0.20

observed if non-answers are attributed to erroneous decision (M, FA), for task G (landing lights off) even zero detectability. Decision bias in most cases does not exhibit significant differences between TWR and RTO-CWP.

5 Conclusion

The present detailed analysis of two-alternative decision making with safety related aircraft maneuvers provides an answer to the observed discrepancy in the percentage correct (p_c) analysis of the corresponding observation data in 11 as compared to the subjective success criteria. The perceived safety was rated as insufficient [11] which agrees with the objective data of the present analysis. 11Nevertheless it only represents a first step towards quantification of RTO performance and safety compared to TWR-CWP. Neglecting non-decisions during simultaneous decision making at TWR- and RTO-CWP shows mostly no significant difference of error risk and discriminability d’ whereas the interpretation of non-decisions as false responses (misses or false alarms) leads to significant error increase under RTO as compared to TWR conditions and correspondingly to reduced d’. This (worst case) result comes not unexpected for the state-of-the-art technology (2 arcmin visual resolution (Nyquist limit) of panorama = half the human eye performance, and manually controlled PTZ). It may be expected that increased automation (e.g. automatic PTZ-object tracking based on movement detection and data fusion with Mode-S transponder and approach radar) and future 1-arcmin panorama resolution with improved contrast will increase discriminability. A confirmation of the initial results presented in the present paper and in 11 requires more field trials under comparable conditions with improved statistics and subjects instructions requesting forced decisions for avoiding non-answers.

Acknowledgement. We are indepted to DFS personnel N. Becker, T. Heeb, P. Distelkamp, and S. Axt for support during preparation of the experiment. Many thanks are due to C. Möhlenbrink and A. Papenfuß for performing part of the online interviews during the exercises. A. Grüttemann was responsible for the onboard data acquisition and served as flight engineer. We acknowledge the support of the DLR flight experiments department and in particular cooperation with pilots G. Mitscher and P. Bergmann.

References

1. Schmidt, M., Rudolph, M., Werther, B., Möhlenbrink, C., Fürstenau, N.: Development of an Augmented Vision Video Panorama Human-Machine Interface for Remote Airport Tower Operation. In: Smith, M.J., Salvendy, G. (eds.) Human Interface, Part II, HCII 2007. LNCS, vol. 4558, pp. 1119–1128. Springer, Heidelberg (2007)
2. Fürstenau, N., Schmidt, M., Rudolph, M., Möhlenbrink, C., Papenfuß, A., Kaltenhäuser, S.: Steps towards the Virtual Tower: Remote Airport Traffic Control Center (RAiCe). In: Proc. EIWAC 2009, ENRI Int. Workshop on ATM & CNS, Tokyo, March 5-6, pp. 67–76 (2009)
3. Schmidt, M., Rudolph, M., Papenfuß, A., Friedrich, M., Möhlenbrink, C., Kaltenhäuser, S., Fürstenau, N.: Remote airport traffic control center with augmented vision videopanorama. In: Proc. 28th IEEE-DASC 2009, Orlando, pp. 4.E.2-1–4.E.2-15 (2009)
4. Hannon, D., Lee, J., Geyer, T.M., Sheridan, T., Francis, M., Woods, S., Malonson, M.: Feasibility evaluation of a staffed virtual tower. The Journal of Air Traffic Control, 27–39 (Winter 2008)
5. Ellis, S.R., Liston, D.B.: Visual features involving motion seen from airport control towers. In: Proc.11th IFAC/-IFIP/IFORS/IEA Symposium on Analysis, Design, and Evaluation of Human-Machine Systems, Valenciennes, France, September 31-October 3 (2010)
6. Ellis, S.R., Liston, D.B.: Static and motion-based visual features used by airport tower controllers. NASA TM-2011-216427, Ames Research Center, Moffett Field, CA (2011)
7. Van Schaik, F.J., Lindqvist, G., Roessingh, H.J.M.: Assessment of visual cues by tower controllers. In: Proc. 11th IFAC/IFIP/IFORS/IEA Symposium on Analysis, Design, and Evaluation of Human-Machine Systems, Valenciennes, France, August 31-September 3 (2010)
8. Watson, A.B., Ramirez, C.V., Salud, E.: Predicting visibility of aircraft. PLoS ONE 4(5), e5594 (2009), doi: 10.1371/journal.pone.0005594 (Published online May 20, 2009)
9. Fürstenau, N., Mittendorf, M., Ellis, S.R.: Remote Towers: Videopanorama frame rate reqirements derived from visual discrimination during simulated aircraft landing. In: Schaefer, D. (ed.) Proc. SESAR Innovation Days, Eurocontrol (2012) ISBN 978-2-87497-024-5
10. Ellis, S.R., Fürstenau, N., Mittendorf, M.: Frame Rate Effects on Visual Discrimination of Landing Aircraft Deceleration: Implications for Virtual Tower Design and Speed Perception. In: Proceedings Human Factors and Ergonomics Society, 55th Annual Meeting, Las Vegas, NV, USA, September 19-23, pp. 71–75 (2011)
11. Friedrich, M., Möhlenbrink, C.: How realistic can a concept be tested? A field trial for validating a remote tower operation concept. In: 10th USA/Europe Air Traffic Management Research and Development Seminar (ATM 2013) (submitted, 2013)
12. MacMillan, N.A., Creelman, C.D.: Detection Theory. Psychology Press, Taylor and Francis (2005)