AVIONICS TOUCH SCREEN IN TURBULENCE: SIMULATION FOR DESIGN (PART 2: RESULTS)

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Consumer market touch screens ubiquity has driven the avionics industry to launch in depth evaluations of touch screen for cockpit integration. This paper is a follow-up from ISAP 2015 paper where a methodology for turbulence simulation design was discussed. One of the challenges was to verify touch screen compatibility with in flight use under turbulent conditions, ranging from light to severe. The avionics industry recognized early on the need to alleviate such usability risk and the results of our evaluations enabled us to define recommendations for our HMI designs. Using our validated turbulent profiles, basic touch screen interaction performances were analyzed and this paper will focus on the results we gathered using our turbulence simulator.

Designing profiles for turbulence simulator

In our prior paper (Hourlier & Servantie, 2015), we presented the process that led to the design and validation of representative turbulence profiles and the selection of an hexapod as the best simulator for acceptable validity. In flight accelerometer (both linear and rotation) collections were performed to provide us with a baseline for choosing between possible simulation solutions. Given the 6 axis accelerometer profiles that were collected, a number of potential candidate simulation platforms were selected. They were reviewed in terms of performance and cost. A hexapod structure (figure 1) capable of reproducing those profiles with acceptable validity was selected. 6 simulated profiles were designed to mimic the “inflight” references. Tests were performed with pilots to validate the best profiles for each level of turbulence.

Figure 1: The Hexapod at ENSAM with the test bench on top

The selected profiles were then used to evaluate validate specific complex touch/gestures in light to severe turbulent conditions, using all the potential of touch interactions for novel cockpit Human Machine Interfaces. The result of these tests is presented here.

Using a turbulence simulator for interaction design

Once our selected turbulence profiles were validated by pilots, they were used for evaluation of technical solutions in the design of Avionics touch interactions. We needed first to assess the performance of basic interactions with regard to the 3 levels of turbulence relevant to the certification process: light, moderate and severe. This evaluation ran over a period of two weeks with 30 subjects in 2014. The results that are presented here are linked to our validated (Thales proprietary) levels of turbulence and should be considered as suggestions for design, as many other factors can influence touch interaction (existence of finger/palm rests or anchors to cite but the most obvious one).

Population and means

Population. 30 subjects performed this evaluation: 5 left handed, 25 Right handed; 4 women, 26 men; 6 aged 20—29, 11 aged 30-39, 8 aged 40-49, 5 aged 50-59; 7 men had more than 100h of piloting experience (5 with significant flight experience); 9 reported being sometimes sea sick or simulator sick.

Means & Method. The detailed account of the materiel used can be found in our prior paper (Hourlier & Servantie, 2015).

- The Hexapod (+/-2g, +/- 50cm Y,X,Z displacements and 3 axis angular acceleration), property of ENSAM Bordeaux was fitted with a specific “cage” replicating the conformation of the Thales AV2020 cockpit design.
- An in-house recording system collected all interactions with the touch screen (time stamps, screen XY localization).
- Videos using GoPro cameras were recorded: one filming the screen interactions, the other filming the subject. A wireless headset enabled communications between subjects and experimented. An emergency stop button was always accessible to the subject (but was never used)
- Four turbulence profiles (table 1) were preprogramed on the hexapod and could be played on demand: none, light, moderate and severe.

Table 1.

Turbulence profiles used for tests (acceleration in m/s^2)

Turbulence level	None	Light	Moderate	Severe
Maximum	-	2,29	5,52	8,11
Mean	-	0,65	1,53	2,60
Median	-	0,57	1,32	2,29

A typical run would comprise successive 4mn evaluations of basic interactions in successive turbulence profiles (no turbulence, light turbulence, moderate turbulence and severe turbulence). An individual session would last 1h30mn on average. A pause in the middle was added to accommodate the test subject, the experience being somewhat tiring.

Protocol. Subjects were asked to perform, at various levels of turbulence, simple tasks replicating basic interactions with Touch devices. These were: Press, Release, Double tap and Long press.

- Press & Release. A colored circle (Ø 7-12-15-18 mm) would appear on a black screen at random places along with a target (cross) at another random position. The task being to drag the circle to the cross and release on the center of as precisely as possible to make it disappear (speed and precision measurements collected).
- Double tap. A colored target circle (Ø 7-12-15-18-28 mm) would appear on a black screen at random places. The task being to double tap on its center as fast as possible to make it disappear (speed and precision measurements collected).
- Long press. A colored target circle (Ø 18mm) would appear on a black screen at random places. The task being to press it at least 2 seconds on its center to make it disappear (movement and precision measurements collected).

The objective of these trials being to identify size and time related recommendation for efficient touch interactions in turbulent conditions.

Results

All results presented here account for finger rest interactions (except for the few mentioned in table 2). Basic results are presented as an error rate outcome with regards to the analyzed variables.

For instance the figure 2 presents the error rate when pressing a target button in 3 conditions no, light or moderate turbulences. For example, if one considers 10% an acceptable error rate, the figure presents the size of the interacting zone radius 13.5mm for moderate turbulence (the zebra arrow) and 8mm for light turbulence (the dotted arrow). For example, if one wants to secure an interaction with a round button in moderate turbulence for an expected success rate of 90%, one should choose a 27mm diameter interaction zone.

To obtain our results, numerous trials were recorded. See table 2 for reference.

Discussion

The overall Gaussian shape of our data representation (figures 2 to 6) and their increasing logic with higher turbulence accredit the validity of our data and enable us to obtain explanatory mathematical transfer function from turbulence level to interaction error.

From the double tap spatial analysis we can recommend double tap effective zones and from the temporal analysis we can recommend on the delay before addressing a double tap as a single one and also recommend on the size of the zone to reduce the time delay.

From these results one can also analyze the involuntary finger movements (given a certain level of turbulence) and thus recommend a threshold before considering a movement as a drag. For instance such results could serve to differentiate between dragging a map and creating a marker on the map.

Finally, as analyzed for press interactions, (figure 7) the error rate can be more than 50% higher without finger rest in moderate turbulence level. Hence, in an aeronautical environment, FINGER REST is MANDATORY.

Table 2.

Occurrence collected during our basic tests

Interaction type	**No Turbulence**	**Light Turbulence**	**Moderate Turbulence**	**Severe Turbulence**
Press*	180/*514	482/*573	480/*367	342/*168
Release**	100	100	100	100
Double tap	307	306	186	121
Long press	182	369	322	248

*Without finger Rest for comparison (figure 7). **Protocol limited to 100 interactions for technical reasons.

Press analysis

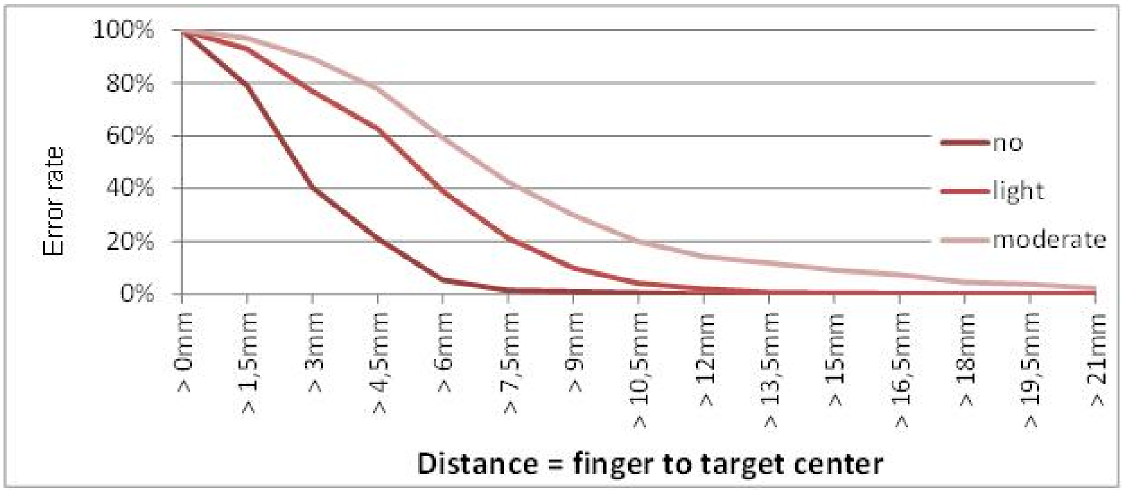

Figure 2: Error rate according to distance (touch to target in mm) and turbulence level for finger press

Release analysis

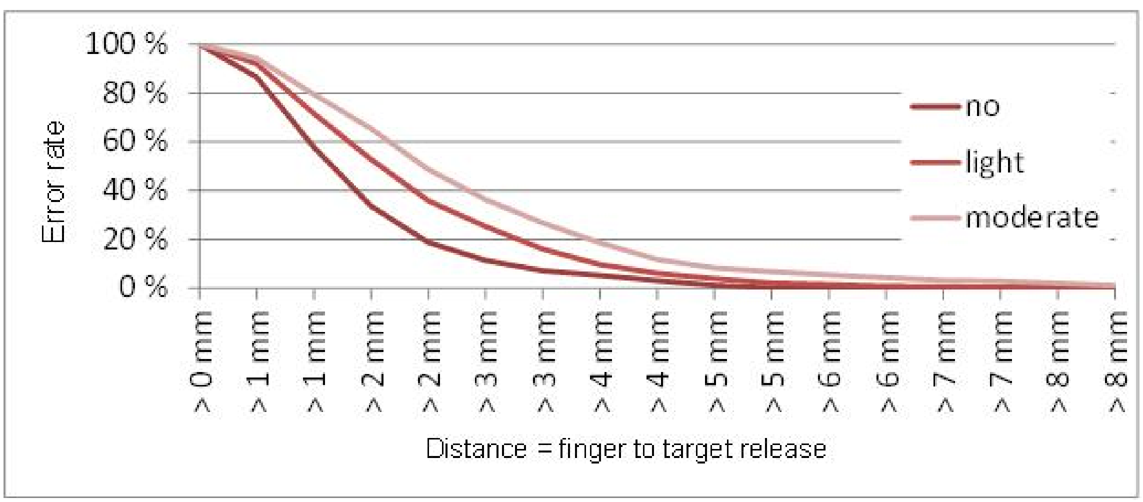

Figure 3: Error rate according to distance (release from target in mm) and turbulence level for finger release

Double tap analysis

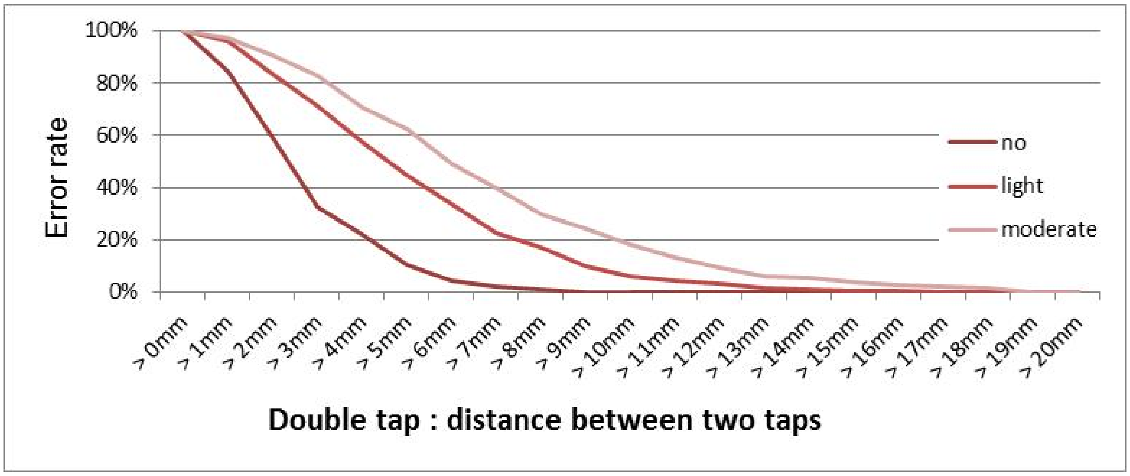

Figure 4: Error rate according to distance between taps (in mm) and turbulence level

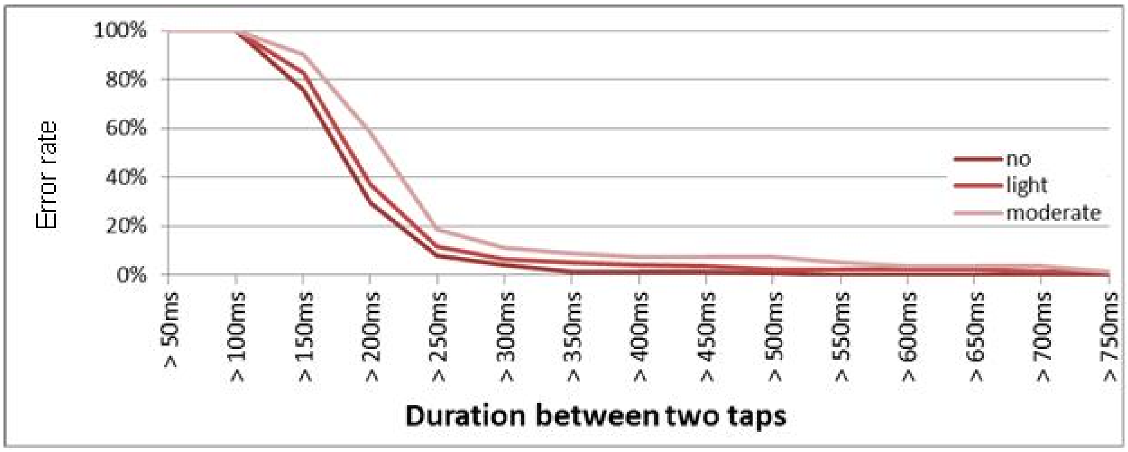

Figure 5: Error rate according to duration between taps (in ms) and turbulence level

Long press analysis

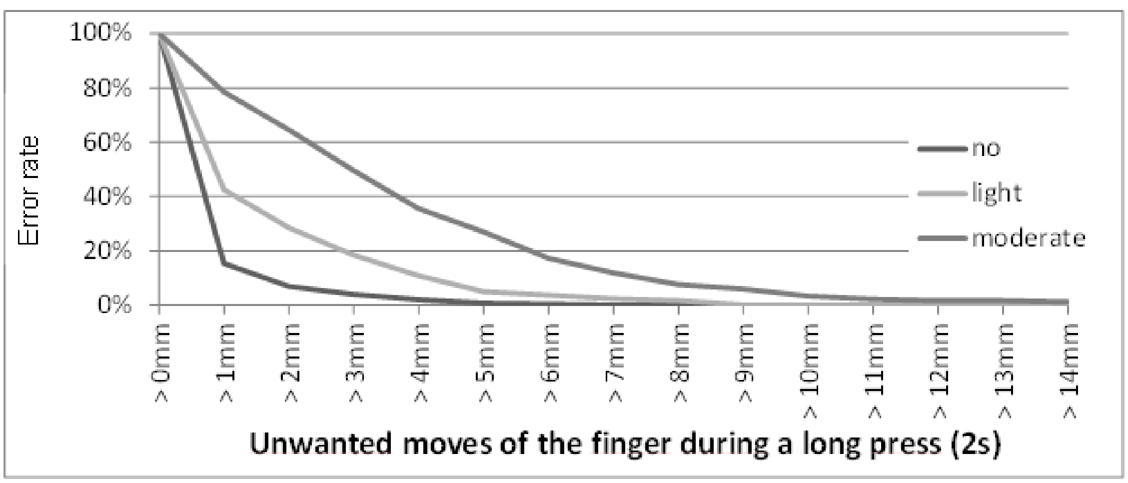

Figure 6: Error rate according to distance for a 2s long press and turbulence level

Error rate with and without finger rest (FR)

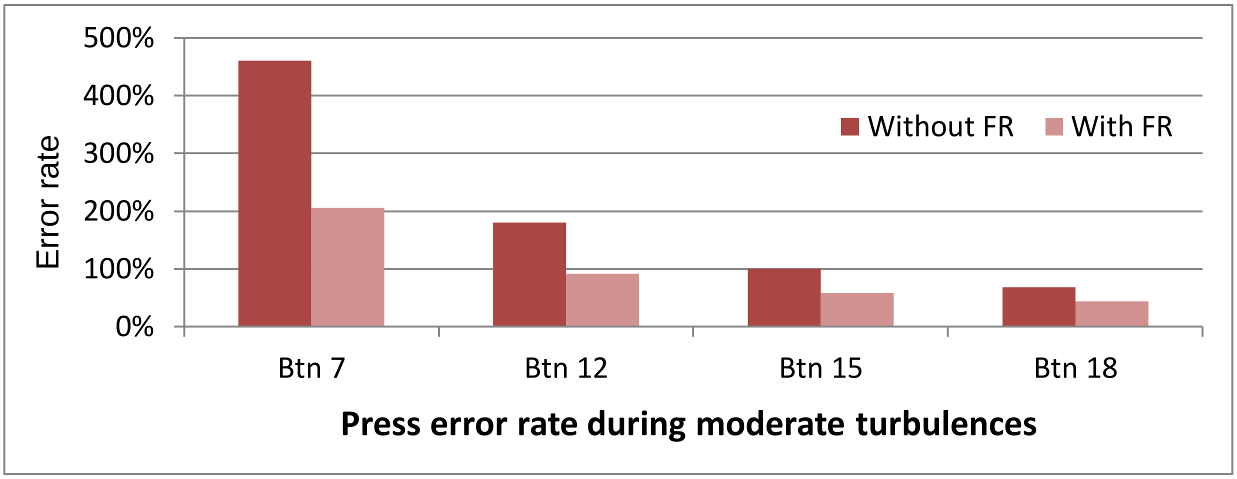

Figure 7: Error rate for various button sizes (in mm) with or without finger rest in moderate turbulence level.

References

Hourlier, S. & Servantie, X., (2015) Avionics touch screen in turbulence: simulation for design, proceedings of the 18th International Symposium on Aviation Psychology, May 4-7, Dayton Ohio