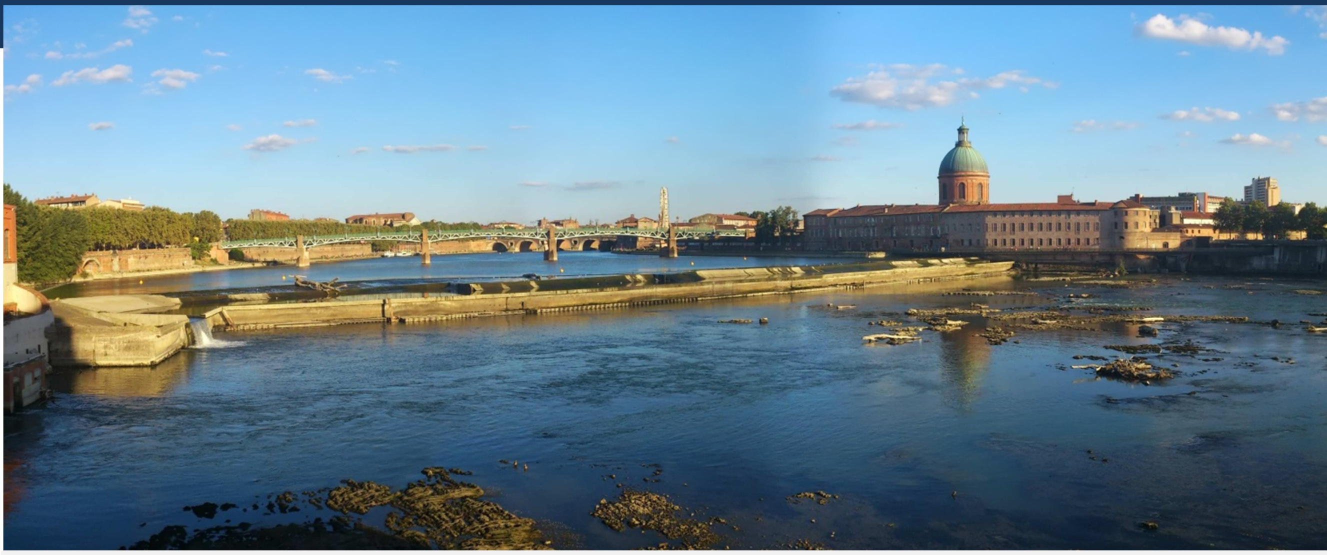

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Human factors evaluation of tangible devices for airplane cockpit

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Content

In airliner cockpits, pilots interact with aircraft systems via specialized interfaces, grouped into functional units and displayed on different screens dedicated to each of the crew's main activities. They operate these systems and digital displays with physical controllers: buttons, switches, pulls, joysticks… (Vinot et al. 2016). Recently, many aircraft manufacturers and suppliers have proposed innovative cockpit concepts based on the use of touch screens (Alapetite et al. 2012). The touch cockpit concept allows manufacturers to offer high-performance, adaptive (to the flight context and the new needs of air transport), and generic product lines to address civil or military avionics. However, contrary to current physical interactors, whose perception and manipulation are also promoted via the sense of touch and proprioception, the touchscreen interfaces suffer severe limitations in operational settings: they place a high demand on the visual channel to adjust the actions, thus eyes- free interaction is nearly impossible [8]; they are extremely complex to use during turbulent conditions (Cockburn et al. 2017); perception of the information can be difficult because the screen can get dirty or because of the presence of smoke in the cockpit (Vinot et al. 2016); and their usability is markedly reduced by stress or cognitive overload (Boy 2012). A possible avenue to improve the safety and efficiency of touch-based interaction in the cockpit can be to combine the advantages of touchscreen interfaces and physical controllers into tangible devices (Del Castillo and Couture 2016).

In the aviation domain, several studies have already put forward the advantages of tangibility. During an abstract piloting task, Pauchet et al. (Pauchet et al. 2018) showed that digital tangible interactors can reduce visual demand, mental workload, and require less visual attention, allowing participants to concentrate more on other cockpit tasks. Cockburn et al. established that the possibility to stabilize the interacting arm improve the user performance with touchscreens during turbulence (Cockburn et al. 2017). In addition, Case-Smith et al. previously showed that the distal effort is lower when the proximal effort is reduced (Case-Smith et al. 1989). In this respect, tangibility is also likely to improve physical interaction performance and safety.

To measure the usability of tangibility we conducted a human factor evaluation of two tangible interactive displays designed to address the severe limitations of touchscreens in airliner cockpits. Sixteen participants performed easy and difficult abstract piloting tasks under three levels of turbulence. During piloting, three parallel tasks were performed with the tangibles prototypes to characterize their pro and cons in terms of interaction robustness, situational awareness, and perception.

Our results confirmed that interaction performance degrades and muscular effort in the shoulder increases with turbulence. However, tangible interaction was associated with higher performance to the piloting task and with a higher situational awareness, most likely because this interaction mode had better visual properties and could free some critical attentional resources. Tangible interaction also allowed a general reduction of the physical effort because it helped to stabilize the user arm.

Keywords : Model-based architecture design, Task scheduling, Safety analysis