RETINA Validation Report

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00.00.03	09/03/2018	Reviewed version	UNIBO	Recommendations from SJU
00.00.04	26/03/2018	Final version-2nd round	UNIBO	Update after project partners review

RETINA

Resilient Synthetic Vision for Advanced Control Tower Air Navigation Service Provision

This project has received funding from the SESAR JU under grant agreement No 699370.

Executive Summary

This validation report (VALR) describes the results from the validation activities within the RETINA project.

The document provides a review of the validation activities that were carried out in the RETINA project and supplies detailed information on the results of the eleven validation exercises run at the UNIBO and CRIDA facilities.

The aim of the planned validation was to demonstrate the positive impact of the V/AR tools proposed by RETINA in the air service navigation provision in terms of human performance, efficiency and resilience, safety, with the final target of achieving V1.

For each RETINA solution identified in D2.1, namely Head Mounted Display and Spatial Display, a proof-of-concept was implemented and validated in a laboratory environment by means of human in the loop real-time simulations where the external view was provided to the user through a high fidelity 4D model in an immersive environment that replicated the out-of-the tower view.

During the validation, both subjective qualitative information and objective quantitative data were collected and analysed to assess the RETINA concept.

The results showed that the RETINA concept is a promising solution to improve the human performance in the control tower, increasing resiliency at airports to low visibility and preserving safety.

Nevertheless, the Augmented Reality technology is not yet mature enough for full deployment in a safety critical environment. Further research is required to demonstrate the most mature RETINA conceptual solution, i.e. Head Mounted Display, in a real environment.

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1 Introduction

1.1 Purpose of the document

This document provides the report on the use of augmented reality in the airport control tower proposed by the RETINA project described in [1] and [2]. It describes the results of the exercises defined in the Validation Plan [3][1] and how they were conducted.

The document also provides the degree of achievement of the objectives through the assessment of the success criteria defined in [3][1].

1.2 Intended readership

This document is intended to be used by RETINA's members, by the SJU official reviewers and by the SESAR 2020 partners addressing the definition of the performance framework.

1.3 Structure of the document

The document is structured in the following sections:

- Section 2: This section contains a summary of different aspects included in the Validation Plan D4.1 [3][1]. Therefore, the section describes the validation context, a summary of the experimental scenarios, the main assumptions of the experiments and a summary of the validation results.
- Section 3: This section describes the results for Exercises 1-10 (Performed at the University of Bologna) and Exercise 11 (Performed at CRIDA). Moreover, the success criteria are assessed for each validation objective depending on the result obtained during the experiments.
- Section 4: This section includes conclusions and recommendations in terms of technical feasibility and operational benefits.
- Appendix A: This appendix includes results of exercises 1-10 for each subject.
- Appendix B: This appendix reports responses to EXE 11 questionnaire for each subject.

1.4 Acronyms and Terminology

Term	Definition
AR	Augmented Reality
A-SMGCS	Advanced-Surface guidance and control system
ATC	Air traffic Control
ATCO	Air traffic Control Officer

Term	Definition
ATM	Air Traffic Management
CTOT	Calculated Take Off Time
EOBT	Estimated Off Block Time
FOV	Field Of View
GND	Ground
HMD	Head mounted Display
IMC	Instrumental Meteorological Conditions
KPA	Key Performance Area
LVP	Low Visibilities Procedures
PSR	Primary Surveillance Radar
RTS	Real Time Simulation
RVR	Runway Visual Range
RWY	Runway
SA	Situational Awareness
SD	Spatial Display
SESAR	Single European Sky ATM Research Programme
SMR	Surveillance Movement Radar
SSR	Secondary Surveillance Radar
TWY	taxiway
TWR	Tower
VALP	Validation Plan
V/A	Virtual/Augmented
V/ART	Virtual/Augmented Reality Tools
V/ARTT	Virtual/Augmented Reality Tower Tools
VMC	Visual Meteorological Condition
VR	Virtual reality

Table 1 Acronyms and terminology

2 Context of the Validation

As described in the Validation Plan [3], the scope of this validation report is to demonstrate the positive impact of the V/AR tools proposed by RETINA in the air service navigation provision in terms of human performance, efficiency, resilience, and safety, with the final target of achieving V1.

2.1 Summary of the Experimental Plan

For each RETINA solution identified in the Operational Concepts Description [2], namely Head Mounted Display and Spatial Display, a proof-of-concept was implemented and validated in a laboratory environment by means of human in the loop real-time simulations where the external view was provided to the user through a high fidelity 4D model in an immersive environment that replicates the out-of-the tower view.

During the validation both subjective qualitative information and objective quantitative data were collected and analysed to assess the RETINA concept. More details can be found in [3][1].

2.2 Summary of Experimental Scenario

Bologna airport was chosen as the reference scenario for the validations [2]; it has a moderately complex layout (one runway, several taxiway, more than one apron) with moderate traffic (between 200 and 300 movements per day). Bologna is a single runway (12 and 30) airport with a main taxiway T and several taxiway and aircraft stand taxilanes. The runway has a 12/30 orientation with an asphalt strip of 2803x45 m. Figure 1 shows the layout of the Bologna airport.

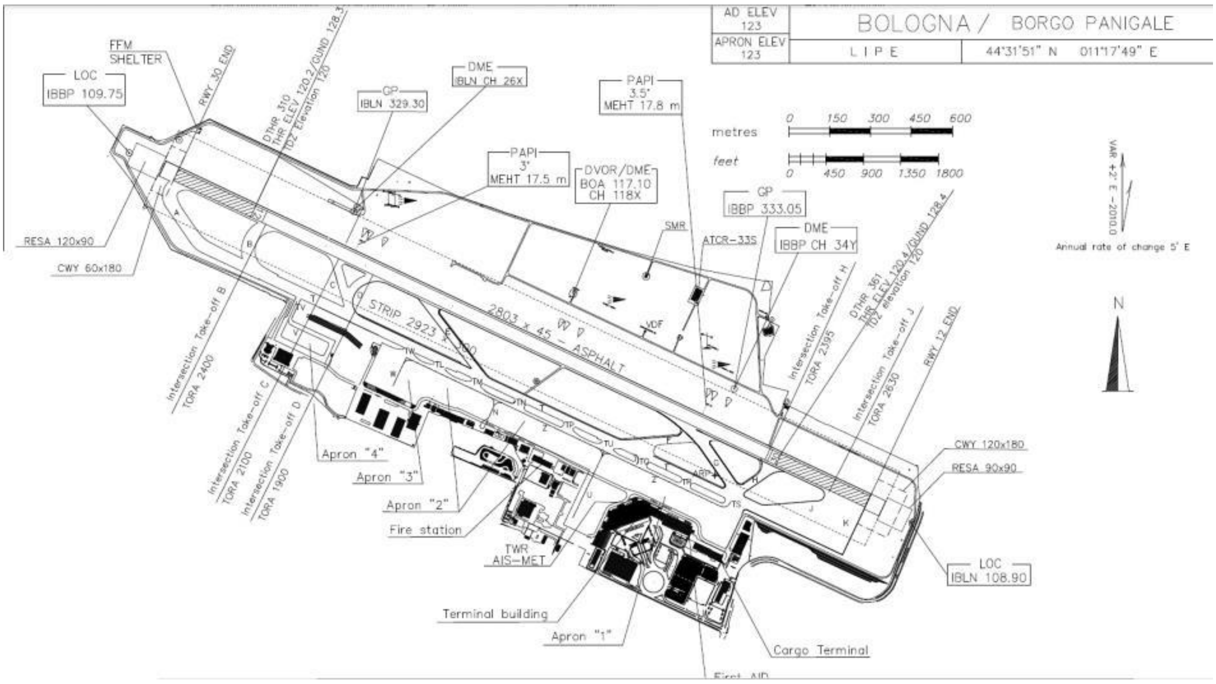


Figure 1 Bologna airport layout

In Bologna airport the following ATC equipment and procedures are available:

- Primary Surveillance Radar and Secondary Surveillance Radar (PSR/SSR);
- Surface Movement Radar (SMR);
- Low Visibility Procedures able to manage more than one aircraft at the same time;
- Apron Management Procedures;
- ILS CAT 3B;

Reference traffic scenarios

The baseline traffic scenario was derived from real air traffic data from Bologna airport recorded during July 2017 and adapted to the exercise needs. As a reference, a 40 minutes traffic sample from 11:20 to 12:00 UTC was considered: it consists of 7 departures and 4 arrivals meaning an average of more than one operation (take-off or landing) every 3 minutes. Traffic peaks were also reported in the sample. Considering the characteristics of Bologna airport, this was used as “medium-high traffic” sample in the validation exercises. A “medium traffic” sample used in the exercises was derived from the medium-high sample by simply removing 1 arrival and 2 departures, i.e. it consisted of 5 departures and 3 arrivals.

Local traffic regulation in CONDI VIS 2

Runway 12 is used preferentially and it is mandatory if RVR is less than 550m. Arriving aircraft vacate runway 12 only via taxiway G,H and J and runway 30 only via B. Departing aircraft enter runway 12 only via A and runway 30 via J. The stopbar at the Runway Holding point CAT II and III are activated. Minimum spacing between arriving aircraft is 10NM if LVP are not in force, 12NM in case LVP in force, 15NM to permit departure between arrivals and LVP in force. In case of LVP, in order to ensure that the radio path of the ILS is free, the TWR controller will clear for take off a departure only if it will overfly the LOC antenna before the arriving aircraft is 4NM on final.

Local traffic regulation in CONDI VIS 3

Only runway 12 is used. Intermediate holding point (IHP) T1 on main taxiway is activated, the follow-me is positioned on the taxiway T abeam TS on TWR request in case of arrival. Departing aircraft taxi to IHP T1 initially and then to RHP A. Further departures start taxi only once the previous one is between T1 and RHP A. Arriving aircraft vacate the runway only via J and follow the follow-me until the parking. Simultaneous push back operations are allowed only from stands belonging to not contiguous blocks (for examples, simultaneous pushback are possible from stands in Q and S blocks but not from stands in Q and R blocks). Minimum spacing between arriving aircraft is 15NM in case of no departure and 16NM in case of departure. In order to ensure that the radio path of the ILS is free, the TWR controller will clear a departure for take off only if it will overfly the LOC antenna before the arriving aircraft is 4NM on final. Such restrictions are integrated with a full capacity in LVP restriction in terms of maximum movements that the ATCO can manage together: 2 departures and 2 arrivals, i.e. maximum of 4 movements together.

2.3 Experiment Assumptions

When the RETINA Project was defined, some assumptions were made with respect to various risks that could have impacted the ability to successfully conduct various project activities.

The assumptions are divided into: calculation assumptions and analysis and experimental assumptions. Table 2 provides an overview of the experiment assumptions applicable to the exercises.

Identifier	Description
EA-1	PSR and SSR position and identification data are always available for HMD and SD during validation
EA-2	SMR position and identification data are always available for HMD and SD during validation.
EA-3	Meteo data are always available for HMD and SD during validation.
EA-4	NAVAIDS status information is always available for HMD and SD during validation.
EA-5	The ATCO are familiar with the airport scenario
EA-6	The ATCO are familiar with the RETINA tool

Table 2 Experiment Assumptions

2.4 Deviations from the planned activities

A deviation from the Validation Plan was performed to limit the number of exercises. The plan reported in the VALP consists in 14 exercises divided into four batches. During the exercises preparation it was realized that no distinction of roles between Tower and Ground position was necessary due to the simplicity of the selected scenario. Thus, the subjects were asked to perform all tasks as tower and ground controller during the same exercise. This modification of the plan improved the user experience widening the variety of data collected.

As effect of this deviation, 11 exercises were carried out for each controller as reported in the table below.

Batch	CONDIVIS	EQUIPMENT			
		BASELINE	HMD		SD
Batch1	CONDIVIS1	**EXE1** MEDIUM-HIGH TRAFFIC	**EXE2** MEDIUM-HIGH TRAFFIC		**EXE3** MEDIUM- HIGH TRAFFIC
Batch2	CONDIVIS2	**EXE4** MEDIUM TRAFFIC	**EXE5** MEDIUM TRAFFIC	**EXE7** MEDIUM-HIGH TRAFFIC	**EXE6** MEDIUM TRAFFIC
Batch3	CONDIVIS3	**EXE8** MEDIUM TRAFFIC STANDARD RESTRICTIONS	**EXE9** MEDIUM TRAFFIC STANDARD RESTRICTIONS	**EXE 10** MEDIUM TRAFFIC LIMITED RESTRICTIONS	
Batch 4	**EXE11** USABILITY TEST				

Table 3 Experimental Plan

2.5 Validation Exercises description, scope

The scope of the validation was to assess the impact of the introduction of RETINA solutions on the ATCO working methods considering three Key Performance Areas, namely human performance, efficiency and safety. There were a total of 11 exercises performed in two locations. Four batches of validation exercises with the corresponding purposes were performed using two different validation platforms at two different locations. The first three batches were performed at the Virtual Reality and Simulation Laboratory of the University of Bologna whilst the four batch was carried out at CRIDA Premises.

2.5.1 Batch 1 - 3

The first three batches of validation exercises were performed at UNIBO's premises. These exercises addressed three visibility conditions, namely CONDI VIS 1, CONDI VIS 2 and CONDI VIS 3, for the two solutions identified (HMD and SD). CONDIVIS3 exercises include a specific exercise in which the restrictions due to low-visibility procedures are removed. Thus they are not performed on SD solution to keep the number of exercises to a reasonable level. For each exercise performed on a RETINA solution, a similar exercise was conducted adopting the baseline equipment in order to compare data obtained vs success criteria and validation targets identified below. Each exercise was performed by three ATCOs. The number of subjects for the first three batches of exercises is limited in order to keep the validation to a reasonable duration. Moreover, the results described in the following sections and reported in Appendix A show that the variance of data collected on the three subjects is very limited. Thus the selected sample, although limited in size, can be considered as representative.

The detailed planning of the exercises is shown in Figure 2.

UNIVERSITÀ DI BOLOGNA
Department of Industrial Engineering
FORLÌ CAMPUS

RETINA VALIDATION SCHEDULE
Venue: Via Fontanelle,40, Forlì

Date	Time	Subject	Experiment	Experiment Description
31 Oct 2017	9:00-17:00	ATCO_1	BATCH_1	CONDIVIS 1 Exercises
1 Nov 2017	Holiday			
2 Nov 2017	9:00-17:00	ATCO_2		
3 Nov 2017	9:00-17:00	ATCO_3		
20 Nov 2017	10:00-17:00	ATCO_2	BATCH_2 & BATCH_3	CONDIVIS 2 Exercises
21 Nov 2017	10:00-17:00	ATCO_1		CONDIVIS 2 Exercises
22 Nov 2017	9:00-13:00	ATCO_1		CONDIVIS 3 Exercises
22 Nov 2017	13:00-17:00	ATCO_3		CONDIVIS 3 Exercises
23 Nov 2017	9:00-13:00	ATCO_3		CONDIVIS 2 Exercises
24 Nov 2017	10:00-17:00	ATCO_2		CONDIVIS 3 Exercises

Figure 2 RETINA Exercises planning

The solutions were validated in a laboratory environment by means of human-in-the-loop real-time simulations where the external view was provided to the user through a high fidelity 4D model in an immersive environment that replicated the out-of-the tower view.

The validation platform is described in [3][1] and it consists of five main modules. The core system is the **4D model** of the reference scenario which communicates through data exchange protocols with the following four subsystems:

- Out of the Tower View Generator (OOT): it provides the ATCO with a consistent and photorealistic view of the out of the tower scene.
- Augmented Reality Overlay Application (AR App): it derives the relevant Augmented Reality Overlays and deploys them on the appropriate ATCO Head-Up Interface (being either Spatial Display or Head Mounted Display).
- Head Down Equipment (HDE): it consists of a simplified interface that replicates the actual head down equipment in the control tower.
- Pseudo-pilot application (PP App): it allows the pseudo-pilot to monitor and update the state of the 4D model according to the commands provided by the ATCO.

Figure 3 RETINA Validation Platform. The AR App derives the relevant Augmented Reality Overlays and deploys them on the appropriate ATCO Head-Up Interface (being either Spatial Display or Head Mounted Display). The baseline equipment serves to compare data obtained vs success criteria and validation targets identified below.

2.5.2 Experiment description and execution

For each batch of exercises the following procedure was applied.

1. Briefing: the subject was briefed with an introduction about the project scope and the technologies used.
2. Informed consent: according to [4][3] each subject was asked to read and sign the informed consent form.
3. Calibration of systems: where necessary a quick calibration of the systems (tracking, HMD) was performed.
4. Familiarization with systems: a 20 minute familiarization exercise was proposed to the user at the beginning of each batch. This session included familiarization with voice communication to pseudopilots, with the head down interface and with the head up interface.
5. Execution of exercises: the exercises were executed and at the end of each exercise a questionnaire was administered to the subject.
6. Debriefing: at the end of each batch of exercises a debriefing session was organized to collect subjective feedback.

2.5.2.1 Baseline and solution scenarios

The baseline scenario refers to the current traffic management operations performed at Bologna airport, considering the traffic sample selected for the validation exercises. The arrivals and departures were handled by ATCOs according to the current working methods and procedures.

The solution scenarios refer to RETINA solutions. They are described in D4.1 VALP Section 2.2 [3].

2.5.2.2 Metrics and indicators

The following table lists the methods and techniques used in the exercises to obtain the chosen metrics and indicators.

Validation Exercise 1-10	
Subjective Measurements	• Questionnaires: They were administered to the participants after each run. They were used to assess workload, performance and information accessibility. The answers to questions are analysed to assess information provided relevant to the objectives. • Debriefs: they were placed at the end of each batch to record the opinions and feelings of participants with respect to the operational concept. • Observations: an observer checked the behaviour of the subjects along the whole duration of the exercises with respect to safety objectives (i.e. capability of detecting safety critical events that were randomly simulated during the exercises – at least one for each exercise)
Objective Measurements	• Head down time • Head up time • Number of switches head-down/head-up • Throughput

Table 4 Methods and technique used during the EXE 1-10

2.5.2.3 Batch 1 results

RETINA Experiment Batch 1 covered the following visibility conditions, named CONDI VIS 1:

- VMC scenario: visibility equal or greater than 5km and ceiling equal or greater than 1500ft (VFR flight available).
- IMC scenario: there are no conditions for the visual flights (only Special VFR). Visibility condition 1 (CONDI VIS 1) is considered whereas the visibility is sufficient for the pilot to taxi and to avoid collision with other traffic on taxiways and at intersections by visual reference, and for personnel of control units to exercise control over all traffic on the basis of visual surveillance.

All the exercises in Batch 1 were performed in a VMC scenario.

The following charts compare the results[1] relevant to Human Performance and Efficiency using the following metrics.

Objective metrics

Fig. 4 shows **Head Down Time vs Head Up Time** in CONDIVIS1 for Baseline, RETINA Spatial Display, RETINA Head Mounted Display Equipment. Both RETINA solutions provide a substantial reduction of Head-Down Time compared to the baseline equipment. The reduction effect is remarkable when adopting the HMD solution whereas with this solution the time the user spends head-down drops to 8% of the Total Duration of the Exercise (Baseline 41% - Spatial Display 15%).

Fig.5 shows the **number of switches between Head Down and Head Up positions** along the exercise duration. Both RETINA solutions provide a substantial reduction of number of switches compared to the baseline equipment. The reduction effect is remarkable when adopting the HMD solution whereas with this solution the number of switches between Head Down and Head Up positions drops to 82 along the exercise duration (Baseline 356 - Spatial Display 213).

Fig. 6 shows the **throughput (expressed as the number of aircraft safely managed in the unit of time)** in CONDIVIS1 for Baseline, RETINA Spatial Display, RETINA Head Mounted Display Equipment. Both RETINA solutions provide an increase in the number of aircraft safely managed by the operator in the unit of time compared to the baseline equipment.

Subjective metrics

Fig.7 shows the results of the NASA TLX **workload** assessment in CONDIVIS1 for Baseline, RETINA Spatial Display, RETINA Head Mounted Display Equipment. Based on these results, it is possible to observe that the perceived workload is slightly reduced with either Spatial Display or Head Mounted Display equipment with respect to the baseline equipment.

Fig. 8 shows the results of questionnaires about **information accessibility** in CONDIVIS1 for Baseline, RETINA Spatial Display, RETINA Head Mounted Display Equipment. Both RETINA solutions provide slight improvements to information accessibility in terms of both availability and quality of the information.

[1] Average on three subjects

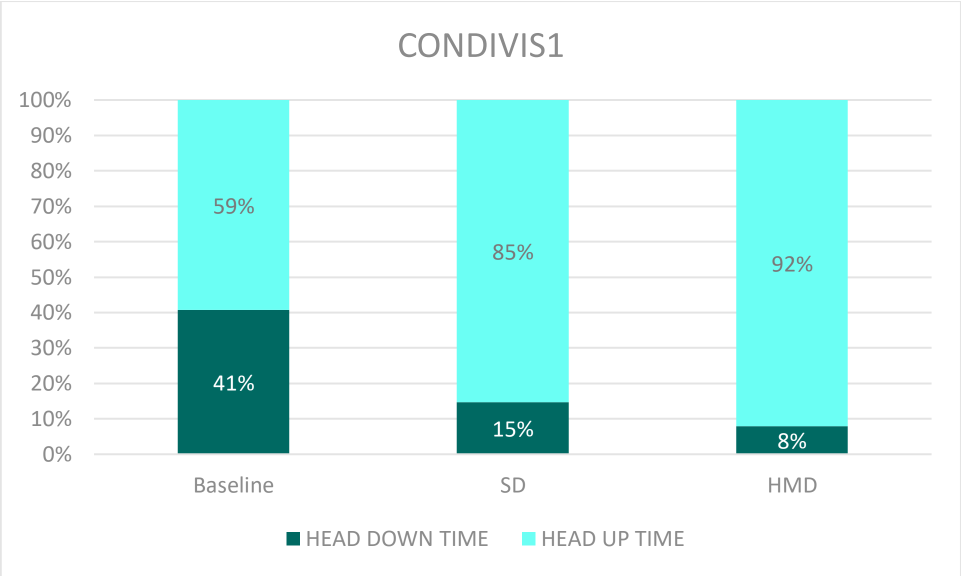


Figure 4 Share of time spent Head-Down/Head-Up by the user in CONDIVIS1 exercises. Average values on three subjects.

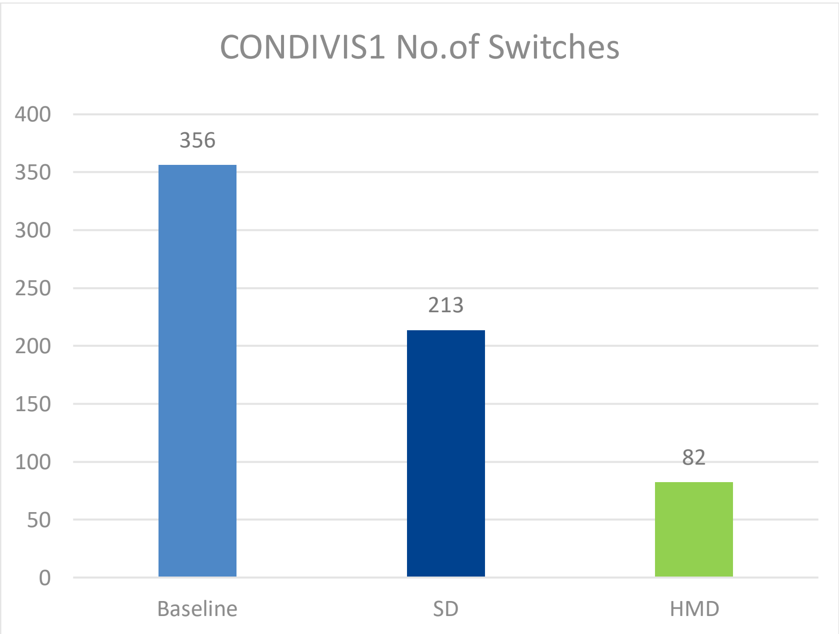


Figure 5 Number of switches between Head-Down/Head-Up Positions in CONDIVIS1 Exercises. Average values on three subjects.

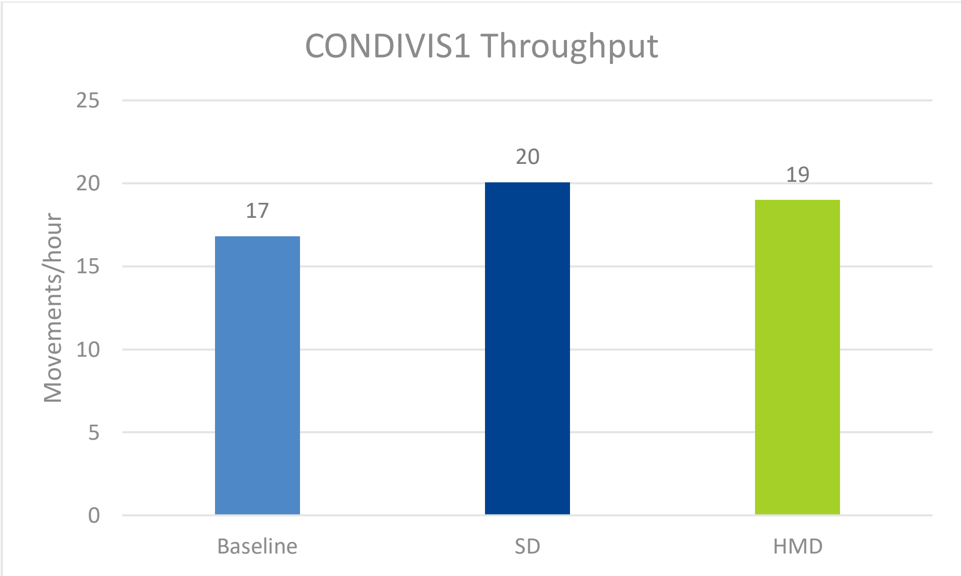


Figure 6 Throughput in CONDIVIS1 Exercises. Average values on three subjects.

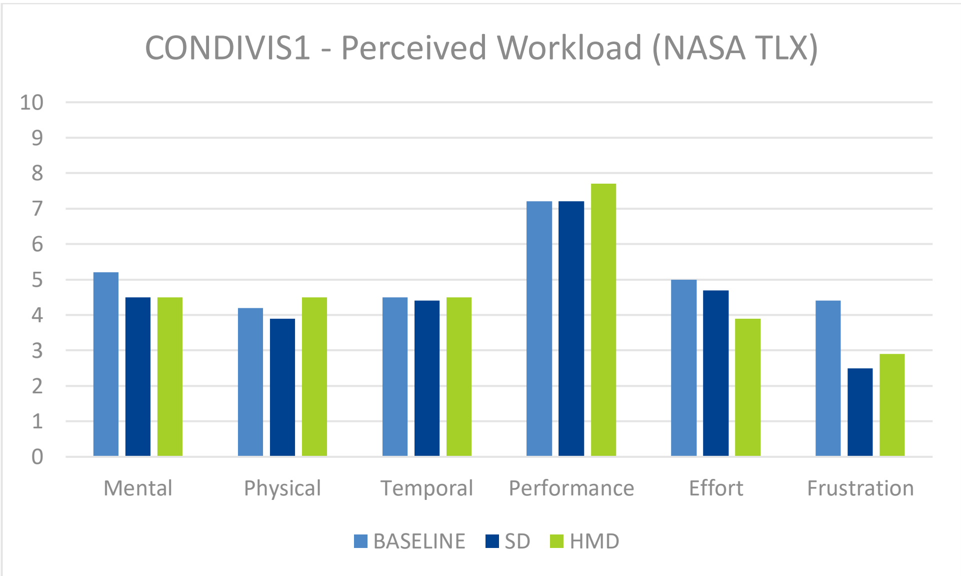


Figure 7 Perceived workload in CONDIVIS1 was measured using NASA TLX questionnaires with the following equipment: baseline (light blue), Spatial Display (blue), Head Mounted Display (green). Average values on three subjects.

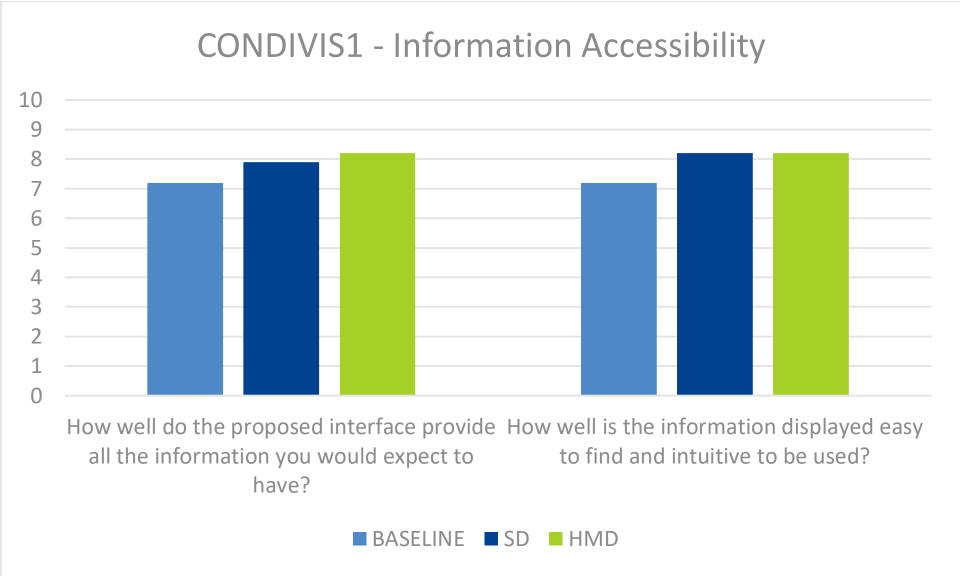


Figure 8 Information accessibility in CONDIVIS1 with the following equipment: baseline (light blue), Spatial Display (blue), Head Mounted Display (green). Average values on three subjects.

2.5.2.4 Batch 2 results

RETINA Experiment Batch 2 covered the visibility condition named CONDIVIS2:

> IMC visibility CONDITION 2: Visibility condition 2 (CONDI VIS 2) is considered whereas the visibility is sufficient for the pilot to taxi and to avoid collision with other traffic on taxiways and at intersections by visual reference, but insufficient for personnel of control units to exercise control over all traffic on the basis of visual surveillance.

The following charts compare the results[2] relevant to Human Performance and Efficiency using the following metrics.

<u>Objective metrics</u>

Fig. 9 shows **Head Down Time vs Head Up Time** in CONDIVIS2 for Baseline, RETINA Spatial Display, RETINA Head Mounted Display Equipment. The latter equipment is used in two different traffic scenarios, namely Medium and Medium-High traffic scenarios. Both RETINA solutions provide a substantial reduction of Head-Down Time compared to the baseline equipment. The reduction effect is remarkable when adopting the HMD solutions whereas with these solutions the time the user spends head-down drops to 10% of the Total Duration of the Exercise (Baseline 61% - Spatial Display 21%) in medium traffic conditions. A significant reduction of Head-Down Time is obtained with HMD even when traffic is increased to medium-high level.

Fig.10 shows the **number of switches between Head Down and Head Up positions** along the exercise duration. Both RETINA solutions provide a substantial reduction of number of switches compared to the baseline equipment. The reduction effect is remarkable when adopting the HMD solutions whereas with these solutions the number of switches between Head Down and Head Up positions drops to 75 along the exercise duration (Baseline 279 - Spatial Display 161). A significant reduction of the number of switches is obtained with HMD even when traffic is increased to medium-high level.

Fig. 11 shows the **throughput (expressed as the number of aircraft safely managed in the unit of time)** in CONDIVIS2 for Baseline, RETINA Spatial Display, RETINA Head Mounted Display Equipment. The latter equipment is used in two different traffic scenarios, namely Medium and Medium-High traffic scenarios. Both RETINA solutions provide an increase in the number of aircraft safely managed by the operator in the unit of time compared to the baseline equipment. The results confirm that the HMD solution is effective in achieving higher volumes of traffic.

<u>Subjective metrics</u>

Fig.12 shows the results of NASA TLX **workload** assessment in CONDIVIS2 for the Baseline, RETINA Spatial Display, and RETINA Head Mounted Display Equipment. The latter equipment is used in two different traffic scenarios, namely Medium and Medium-High traffic scenarios. Based on these results, it is possible to observe that the perceived workload is slightly reduced with either Spatial Display or Head Mounted Display equipment with respect to the baseline equipment.

[2] Average on three subjects

Fig. 13 shows the results of questionnaires about **information accessibility** in CONDIVIS1 for Baseline, RETINA Spatial Display, RETINA Head Mounted Display Equipment. The latter equipment is used in two different traffic scenarios, namely Medium and Medium-High traffic scenarios. Both RETINA solutions provide slight improvements to information accessibility in terms of both availability and quality of the information.

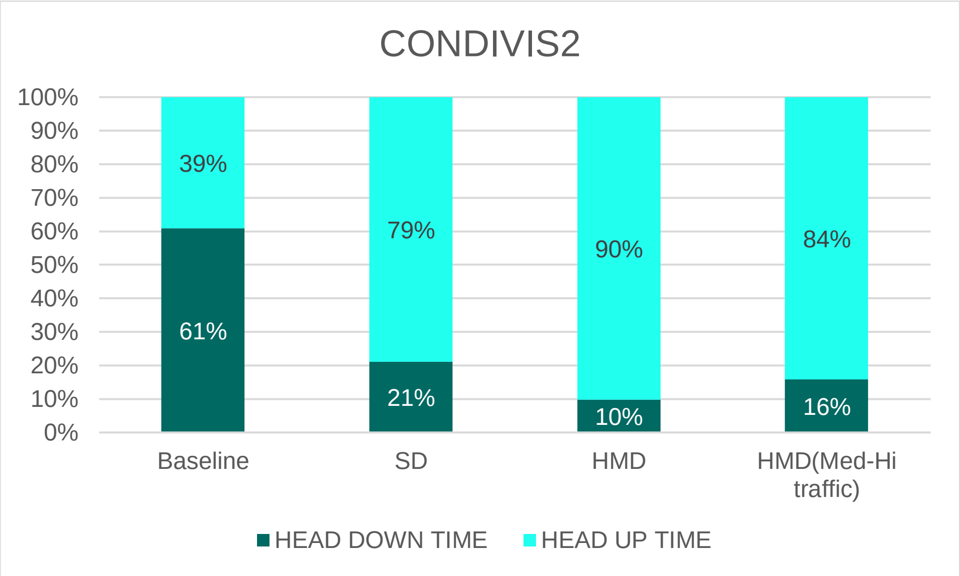


Figure 9 Share of time spent Head-Down/Head-Up by the user in CONDI VIS2 exercises. Average values on three subjects.

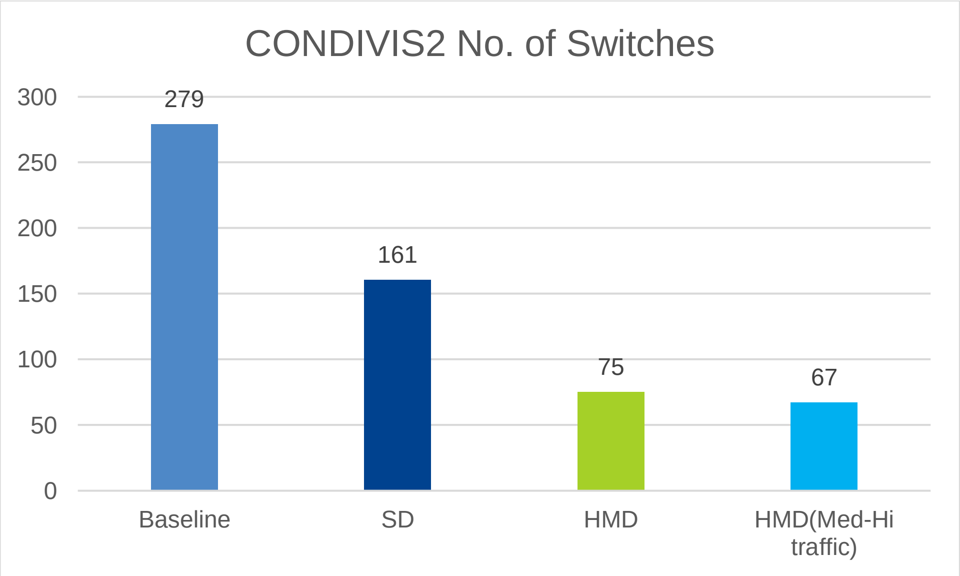


Figure 10 Number of switches between Head-Down/Head-Up Positions in CONDIVIS2 Exercises. Average values on three subjects.

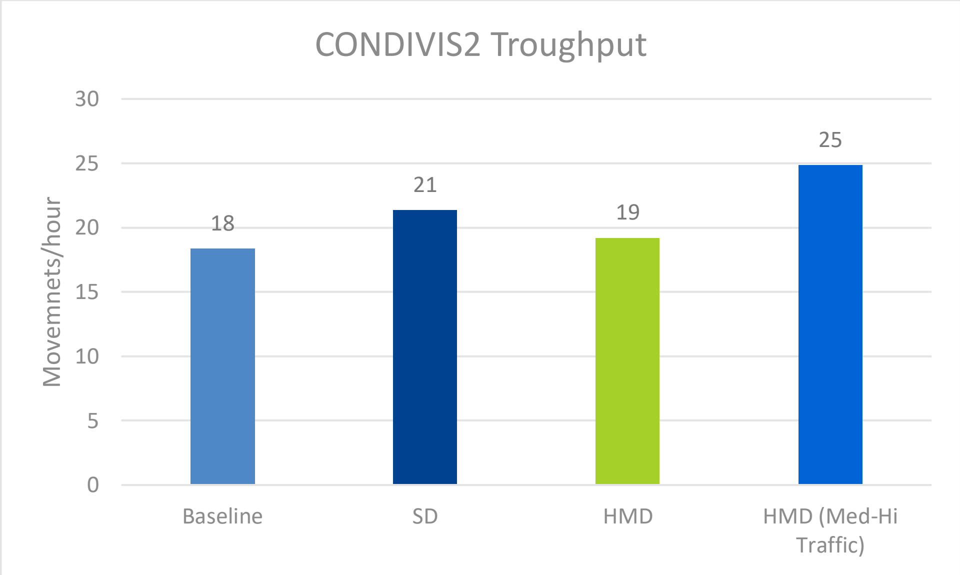


Figure 11 Throughput in CONDIVIS2 Exercises. Average values on three subjects.

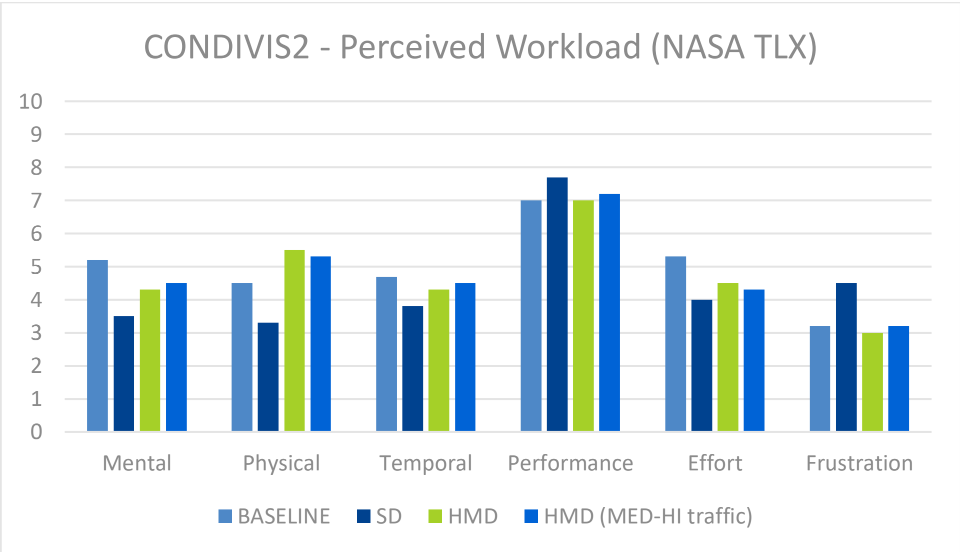


Figure 12 Perceived workload in CONDIVIS2 was measured using NASA TLX questionnaires with the following equipment: baseline (light blue), Spatial Display (blue), Head Mounted Display (green). The fourth bar of each set represents an increased traffic scenario with HMD equipment. Average values on three subjects.

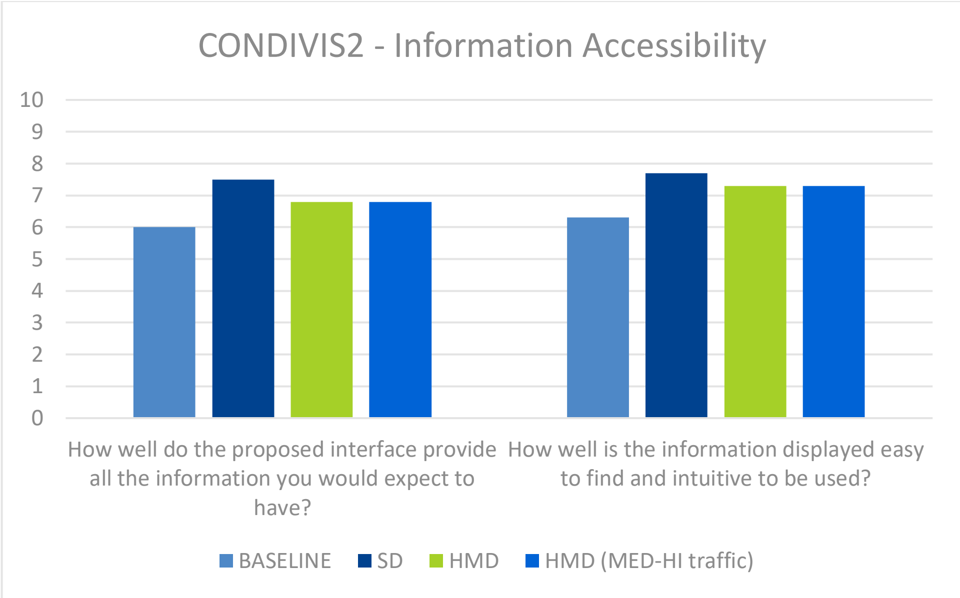


Figure 13 Information accessibility in CONDIVIS2 with the following equipment: baseline (light blue), Spatial Display (blue), Head Mounted Display (green). The fourth bar of each set represents an increased traffic scenario with HMD equipment. Average values on three subjects.

2.5.2.5 Batch 3 results

RETINA Experiment Batch 3 covered the following visibility conditions, named CONDI VIS 3:

- IMC visibility: Visibility condition 3 (CONDI VIS 3) is considered whereas the visibility is sufficient for the pilot to taxi but insufficient for the pilot to avoid collision with other traffic on taxiways and at intersections by visual reference, and insufficient for personnel of control units to exercise control over all traffic on the basis of visual surveillance. For taxiing, this is normally taken as visibility equivalent to an RVR of less than 400 m but more than 75 m.

In the case of CONDI VIS 3, two types of scenarios were analysed, characterised by restrictions that apply to Low Visibility Conditions:

- Standard restrictions: the ATCO manages the traffic applying the current regulations LVP.
- Limited restrictions: LVP restrictions (ground-side) are removed.

Specifically, the “limited restrictions” scenario is the following:

- The use of Intermediate holding points is removed;
- The use of J exit taxiway is confirmed;
- The minimum spacing between aircraft on final is confirmed;
- The capacity constraints on the number of departures managed together (i.e. 2) is removed;
- The constraints on simultaneous pushback from contiguous blocks is removed.

The following charts compare the results[3] relevant to the Human Performance and efficiency using the following metrics.

<u>Objective metrics</u>

Fig. 14 shows **Head Down Time vs Head Up** Time in CONDIVIS3 in both Standard and Limited restriction scenarios compared to the Baseline. RETINA Solution Head Mounted Display Equipment provide dramatic reduction of **Head Down Time vs Head Up Time** in both Standard (11%) and Limited restriction (9%) scenarios compared to the Baseline (74%).

Fig. 15 shows the **number of switches between Head Down and Head Up positions** along the exercise duration in CONDIVIS3. RETINA Solution Head Mounted Display Equipment provide dramatic reduction of **the number of switches** in both Standard (55) and Limited restriction (78) scenarios compared to the Baseline (193).

Fig. 16 shows the **throughput (expressed as the number of aircraft safely managed in the unit of time)** in both Standard and Limited restriction scenarios compared to the Baseline. It is interesting to notice that, when restrictions apply, the throughput in CONDIVIS3 with HMD solution is reduced compared to the baseline whilst, as expected, the introduction of RETINA HMD solution makes it possible to test

[3] Average on three subjects

the removal of some restrictions. Thus, the results confirm that HMD solution is effective in achieving higher volumes of traffic.

Subjective metrics

Fig 17 shows the results of NASA TLX **workload** assessment in CONDIVIS3. Based on these results it is possible to observe that, despite a slight increase in physical effort required by the use of a wearable device, the perceived workload is generally reduced with Head Mounted Display equipment with respect to the baseline equipment.

Fig. 18 shows the results of questionnaires about **information accessibility** in CONDIVIS3. HMD solutions provide good improvements to information accessibility in terms of both availability and quality of the information. The effect is more evident when low visibility restrictions are relaxed.

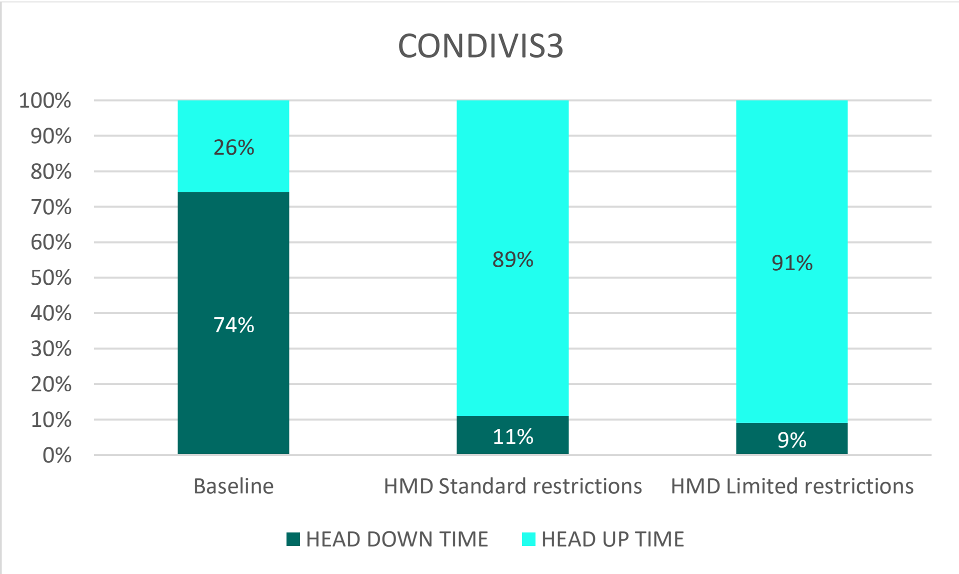


Figure 14 Share of time spent Head-Down/Head-Up by the user in CONDIVIS3 exercises. Average values on three subjects

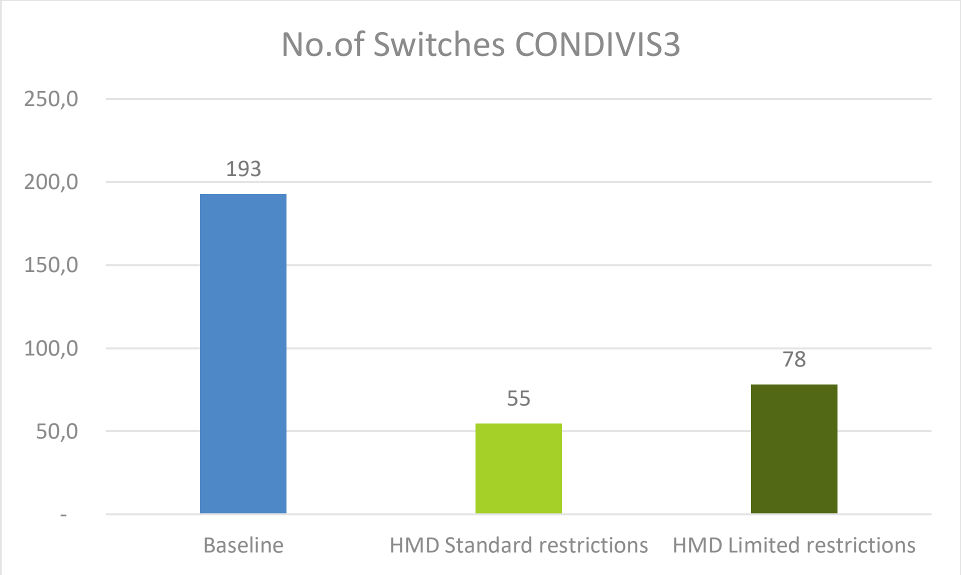


Figure 15 Number of switches between Head-Down/Head-Up Positions in CONDIVIS2 Exercises. Average values on three subjects.

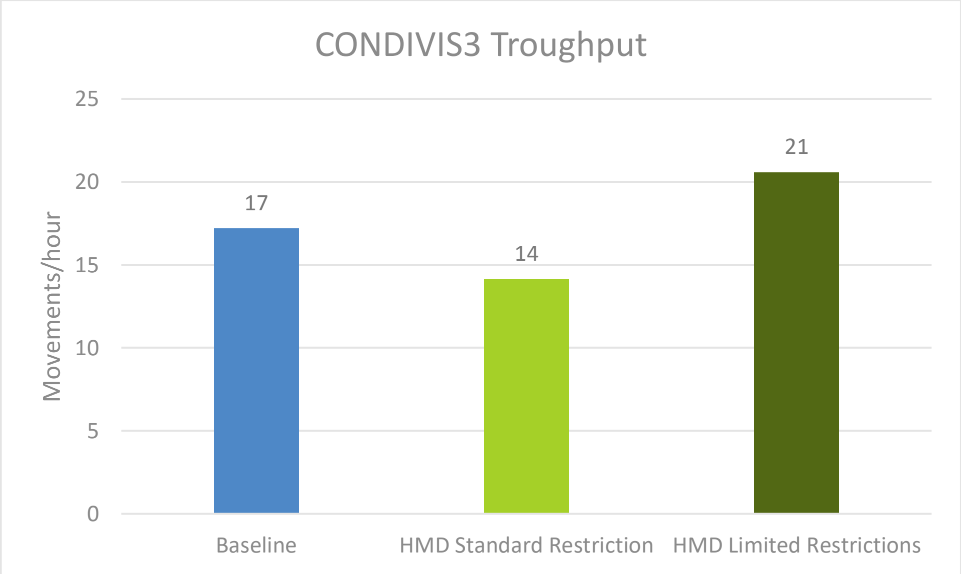


Figure 16 Throughput in CONDIVIS3 Exercises. Average values on three subjects.

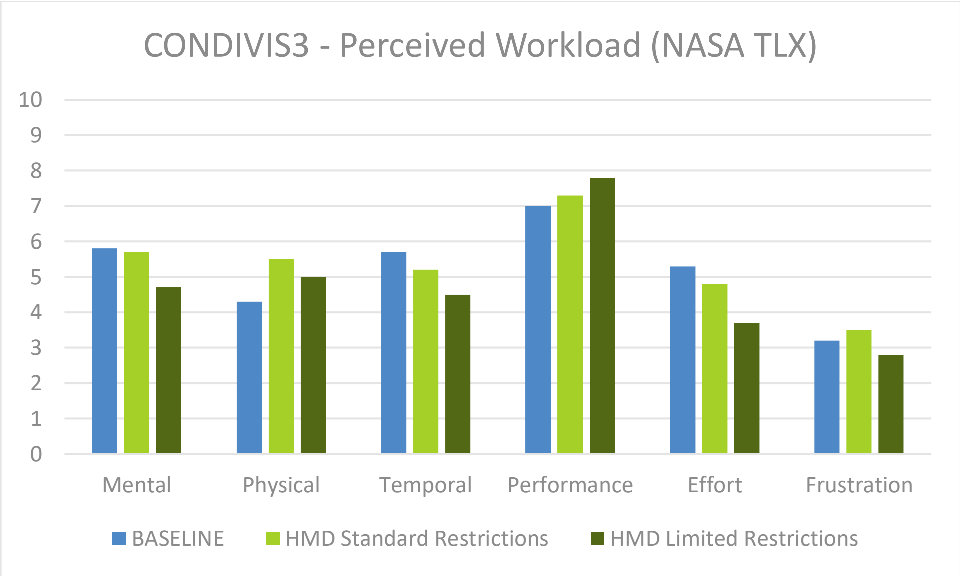


Figure 17 Perceived workload in CONDIVIS3 was measured using NASA TLX questionnaires with the following equipment: baseline (light blue), Head Mounted Display with standard restrictions (green), Head Mounted Display with Limited Restrictions (dark green). Average values on three subjects.

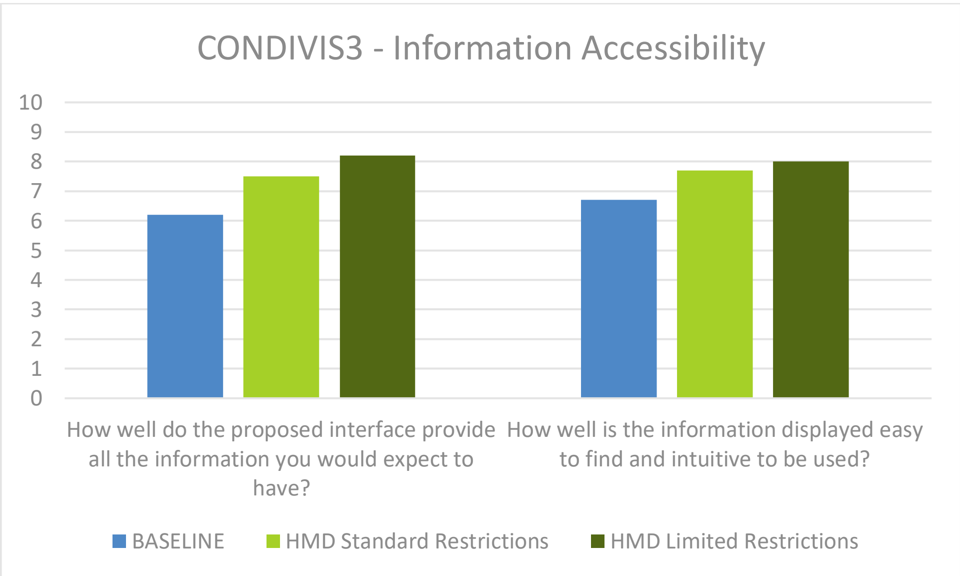


Figure 18 Information accessibility in CONDIVIS1 with the following equipment: baseline (light blue), Head Mounted Display with standard restrictions (green), Head Mounted Display with Limited Restrictions (dark green). Average values on three subjects.

The impact of the use of the HMD equipment on the ATCOs working method was globally positive. In HMD Limited restrictions the traffic was managed successfully and not hardly.
The overall conclusion is that all movements were handled in a proper and regular way, without a significant loss of attention or increase in controller effort.

2.5.3 Batch 4

The final exercise took place at the CRIDA premises. This complimentary exercise was conducted in a laboratory environment by means of human-in-the-loop real-time simulations and addressed the controller's acceptability of the HMI (the augmented reality overlaid text and graphic elements) through the collection of subjective, qualitative information.

The main objective of this exercise was the reception of acceptability and feedback of the controller of the different characteristics of the HMD. This objective was fulfilled by collecting subjective assessment through a questionnaire delivered to each controller after they had finished the test.

The total duration of the Exercise was of 1 hour, divided in several steps:

1. **Presentation about the RETINA project**: the Exercise started with a description of what the RETINA project is and what are its objectives.
2. **Description of the Exercise**: a description of what are the Exercise objectives and full description about the different characteristics of the Exercise.
3. **Presentation and calibration of the HMD**: Once the controller had clearly understood what was expected of their contribution, the HMD was presented to them and then calibrated. This calibration was performed right before the test, with the test displayed but not initiated. This helped the controller to familiarize with the HMD, its features and the different characteristics of the Exercise test.
4. **Exercise test**: The test itself is further explained in Sections 2.4.1.2.1 and 2.4.1.2.2.
5. **Subjective assessment**: Once the Exercise test ended, the controller was provided with a copy of the questionnaire designed for the Exercise.

Fifteen controllers performed the Exercise, all of them part of Spain's ANSP. Every controller was volunteering to make this Exercise.

2.4.1.2.1 Displays description of the Batch 4 exercise

The different visual holograms displayed on the HMD are the following:

- **Airport layout**. The airport layout was provided by UNIBO to ensure consistency between Exercises. The layout had some parts removed from the display to comply with the concept of Augmented Reality of the HMD. The parts remaining in the display regarding the airport layout are the runway, all the taxiways and the stands; while, for example, buildings and the apron floor were removed.

  The different elements changed colour depending on the status of the element: grey for inactive, green for open and red for occupied. This holds for runway, taxiways and stands.

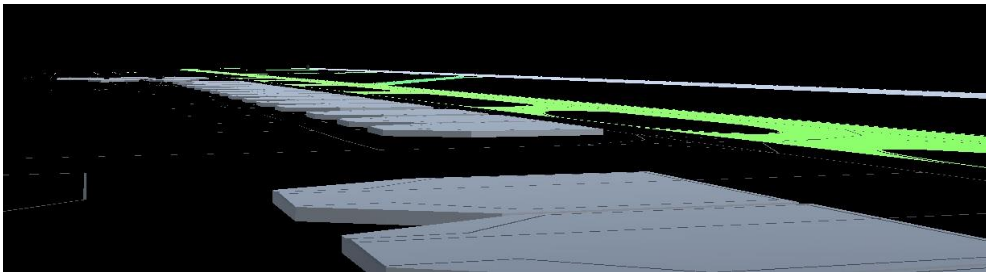


Figure 19 Bologna's airport layout

- **Static Information Overlays**. Two different overlays were displayed on the HMD that are static. This was achieved by making the overlays move with the head movement, thereby staying at the same position independently of where the controller is looking. These overlays are the meteorological overlay and the time display.
  Both of them were set to the left upper corner of the display, while remaining at the deepest position in terms of view to avoid that these overlays cover other essential information for the controller.

Figure 20 Static information overlays

- **Flight tags**. A flight tag was attached to each aircraft displaying different information depending on its state. There were two differentiated parts on the tag:
  - An upper part displaying flight information depending upon if the flight was a departure (callsign, aircraft type, EOBT, CTOT and ground speed) or an arrival (callsign, aircraft type, distance to threshold, height and speed).
  - A lower part that showed the current state of the aircraft (i.e. “Ready for Push-Back”, “Taxiing to RWY12”, etc.).

  Vehicle tag. A tag was also attached to a vehicle that performed a runway inspection. This tag was smaller than the flight tags, filled in red with white text. This text always was “SAFETY”.
  All tags are always of the same size disregarding the position of the object they are referring to (aircraft or vehicle).

Figure 21 Example of aircraft labels. Left for departure flights, right for arrival flights

Figure 22 Vehicle label

- **Other graphical displays**. The rest of the displays compose the models of the aircraft and the car, the trail to follow by an arrival, and a crosshair.

  The aircraft model used is a model of the B738 provided by UNIBO (SEE FIGURE) and the car model was a simple aggrupation of boxes. Every model passed through a filter to reduce its number of polygon while maintaining its appearance. This improved the performance of the HMD avoiding lag when moving the head. The colours used were white for departing flights, yellow for arriving flights and blue for the vehicle.

  The trail of the arrival flights was also displayed in yellow, joining the aircraft itself to the threshold of the runway where it is landing.

  The last graphical display was a crosshair that informed the controller of the exact point that he/she's looking at.

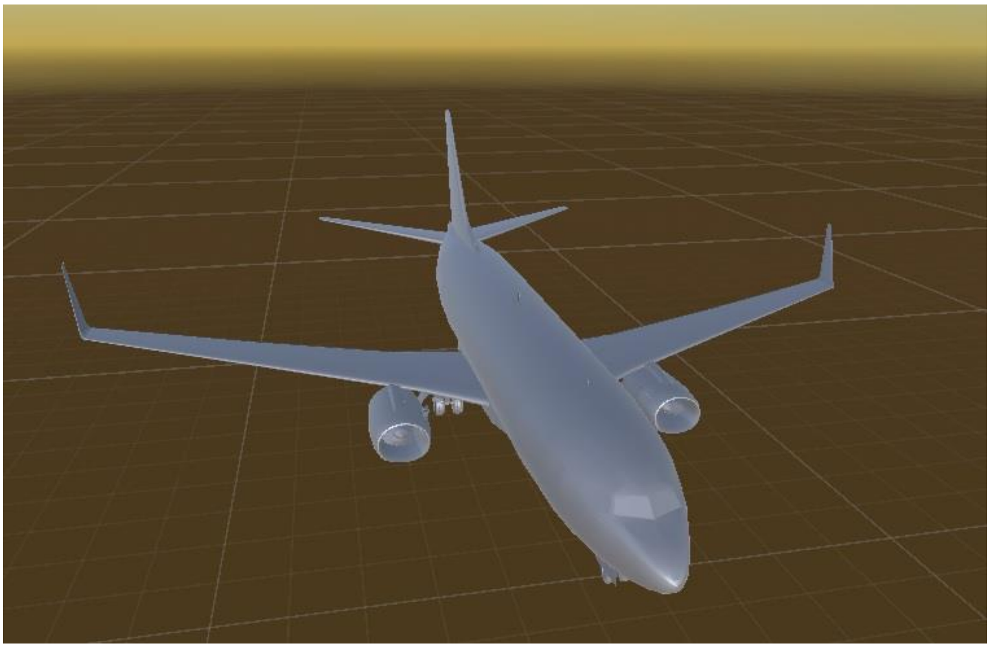


Figure 23 Aircraft Model

The application's initial point is located at the coordinates of the control tower of the airport at the same height of the control room. All the displays were positioned in real scale at real distances, improving the controller awareness of the Exercise. Figure 24 was taken from the Exercise test.

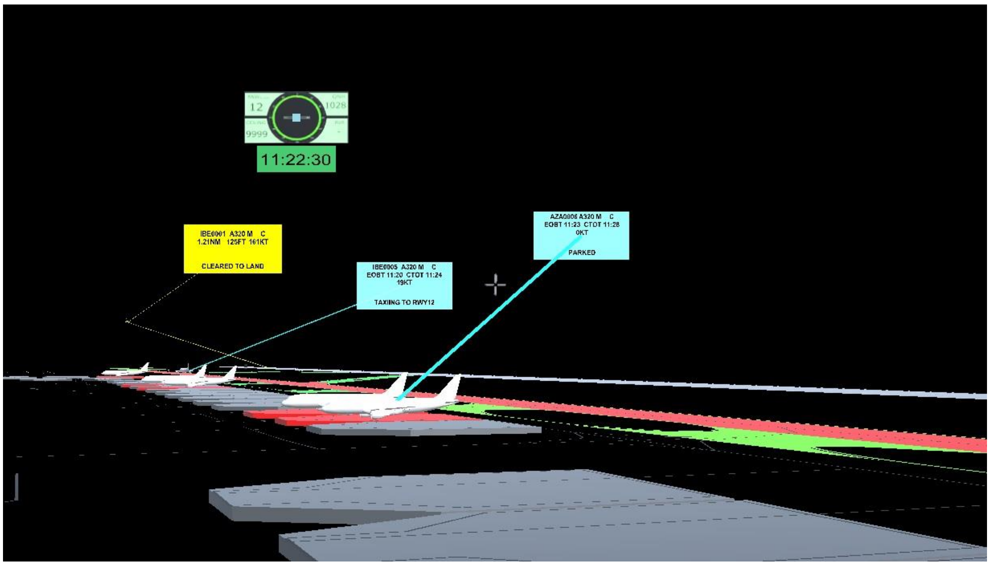


Figure 24 Example of the Exercise test

2.4.1.2.2 Working description of the Batch 4 test

The test of Batch 4 was implemented in the HMD by means of an application. This application ran the scenario fully described in the Validation Plan [3][1]: 40 minutes with a medium-high traffic scenario (11 total movements, 7 departures and 4 arrivals) plus a runway inspection. This scenario was simulated for the airport of Bologna.

As opposed to the rest of the Exercises, this Exercise does not depend on a Pseudo-pilot to perform actions on the aircraft. Instead, this Exercise proposes two different and simple interactions to allow the controller to perform his tasks:

- **Moving the tags**. By clicking on the upper part of the tag, the controller was able to fix the tag on its position, then drag it wherever they want and by clicking again the tag will remain at that position. This tag will still follow the object at the same speed that the object is moving.
- **Simple "actions" on the aircraft**. By clicking either on the lower part of the tag or the object models, the controller was able to perform 3 different authorizations on the aircraft. These authorizations included: authorization for push-back, authorization for clearance to enter the runway and authorization for take-off. Each of them could be performed when the text of the lower part of the tag is either "Ready for push-back", "Waiting for clearance to RWY12" or "Ready for Take-Off", respectively. They are single actions that would make the aircraft continue its movement after a 5 seconds delay.

These interactions were implemented as a first hint of what the capabilities of using a HMD solution are. Their definition and performance must be re-evaluated in further experiments and validations. These interactions themselves do not form part of the validation objectives of this Exercise, but allowed the controllers to better focus on the real validation objectives.

3 Validation Exercises Results

3.1 Summary of Validation Results

Here the results of the different Validation Exercises are summarised. The summary is presented in Table 5. This shows the summary of results compared to the success criteria identified within the Validation Plan [3].

Validation Exercise ID	Obj. ID	Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Objective Status
EXE1-EXE2	OBJ-RETINA-VALP-HP-01	To assess the impact of the HMD solution on Human Performance in normal visibility conditions.	CRT-HP-01-001	Solution HMD reduces the head down time (eye tracking) in normal visibility conditions.	Solution HMD reduces head down time in normal visibility conditions by a factor of 5 compared to the baseline equipment. Baseline (41%) – HMD (8%)	OK
			CRT-HP-01-002	Solution HMD increases the accessibility of the information (subjective assessment) in normal visibility conditions.	Subjective rates about information accessibility in normal visibility conditions are higher when using HMD solution compared to the ones obtained with baseline equipment.	OK
			CRT-HP-01-003	Solution HMD reduces the number of switch head down/head up (eye tracking) in normal visibility conditions.	Solution HMD reduces the number of switch head down/head up in normal visibility conditions by a factor of 4.5 compared to the baseline equipment. Baseline (356) – HMD (82)	OK
			CRT-HP-01-004	Solution HMD increases the capability of achieving the following tasks in normal visibility conditions: aircraft and vehicle identification on the manoeuvring area (GND), monitor of wind and QNH changes, monitor of incursion into closed/restricted taxiway.	Subjective assessment about performance (question number 4 in NASA TLX) in normal visibility conditions provides higher rates when using HMD solution compared to the ones obtained with baseline equipment.	OK

Validation Exercise ID	Obj. ID	Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Objective Status
			CRT-HP-01-005	Solution HMD reduces the workload (NASA TLX) in normal visibility conditions.	When using HMD solution in normal visibility conditions all workload components are reduced except Physical Workload, which is slightly increased compared to the one obtained with baseline equipment.	OK
EXE5, EXE7,EXE 4	OBJ-RETINA-VALP-HP-02	To assess the impact of the HMD solution on Human Performance in CONDI VIS 2	CRT-HP-02-001	Solution HMD reduces the head down time in CONDI VIS 2 (eye tracking).	Solution HMD reduces head down time in CONDI VIS 2 by a factor of 6 compared to the baseline equipment. Baseline (61%) – HMD (10%)	OK
			CRT-HP-02 - 002	Solution HMD increases the accessibility of the information in CONDI VIS 2 (subjective assessment)	Subjective rates about information accessibility in CONDI VIS 2 are higher when using HMD solution compared to the ones obtained with baseline equipment.	OK
			CRT-HP-02 - 003	Solution HMD reduces the number of switch head down/head up in CONDI VIS 2 (eye tracking)	Solution HMD reduces the number of switch head down/head up in CONDI VIS 2 by a factor of 3.5 compared to the baseline equipment. Baseline (279) – HMD (75)	OK
			CRT-HP-02 - 004	Solution HMD increases the capability of achieving the following tasks in CONDI VIS 2: runway incursion detection (TWR), aircraft and vehicle identification on the manoeuvring area (GND), monitor of wind/QNH/visibility changes, monitor of incursion into closed/restricted taxiways.	Subjective assessment about performance (question number 4 in NASA TLX) in CONDI VIS 2 provides equal rates when using HMD solution compared to the ones obtained with baseline equipment.	OK
			CRT-HP-02 - 005	Solution HMD reduces the workload (NASA TLX) in CONDI VIS 2	When using HMD solution in CONDI VIS 2 all workload components are reduced except Physical Workload, which is slightly increased compared to the one obtained with baseline equipment.	OK

Validation Exercise ID	Obj. ID	Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Objective Status
EXE8, EXE9, EXE10	OBJ-RETINA-VALP-HP-03	To assess the impact of the HMD solution on Human Performance in CONDI VIS 3.	CRT-HP-03 - 001	Solution HMD reduces the head down time in CONDI VIS 3 (eye tracking).	Solution HMD reduces head down time in CONDI VIS 3 by a factor of 6.5 compared to the baseline equipment. Baseline (74%) – HMD (11%)	OK
			CRT-HP-03	Solution HMD increases the accessibility of the information in CONDI VIS 3 (subjective assessment).	Subjective rates about information accessibility in CONDI VIS 3 are higher when using HMD solution compared to the ones obtained with baseline equipment.	OK
			CRT-HP-03	Solution HMD reduces the number of switch head down/head up in CONDI VIS 3 (eye tracking).	Solution HMD reduces the number of switch head down/head up in CONDI VIS 3 by a factor of 3.5 compared to the baseline equipment. Baseline (193) – HMD (55)	OK
			CRT-HP-03	Solution HMD increases the capability of achieving the following tasks in CONDI VIS 3: rwy incursion detection (TWR), aircraft and vehicle identification on the manoeuvring area (GND), monitor of wind/QNH/visibility changes, monitor of incursion into closed/restricted taxiways.	Subjective assessment about performance (question number 4 in NASA TLX) in CONDI VIS 3 provides higher rates when using HMD solution compared to the ones obtained with baseline equipment.	OK
			CRT-HP-03	Solution HMD reduces the workload (NASA TLX) in CONDI VIS 3	When using HMD solution in CONDI VIS 3 all workload components are reduced except Physical Workload and Frustration, which are slightly increased compared to the ones obtained with baseline equipment.	OK
EXE1, EXE3	OBJ-RETINA-VALP-HP-04	To assess the impact of the SD solution on Human Performance in normal visibility condition	CRT-HP-04 - 001	Solution SD reduces the head down time in normal visibility condition (eye tracking).	Solution SD reduces head down time in normal visibility conditions by a factor of 2.5 compared to the baseline equipment. Baseline (41%) – SD (15%)	OK

Validation Exercise ID	Obj. ID	Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Objective Status
			CRT-HP-04 - 002	Solution SD increases the accessibility of the information in normal visibility condition (subjective assessment).	Subjective rates about information accessibility in normal visibility conditions are higher when using SD solution compared to the ones obtained with baseline equipment.	OK
			CRT-HP-04 - 003	Solution SD reduces the number of switch head down/head up in normal visibility condition (eye tracking).	Solution SD reduces the number of switch head down/head up in normal visibility conditions by a factor of 1.5 compared to the baseline equipment. Baseline (356) – SD (213)	OK
			CRT-HP-04 - 004	Solution SD increases the capability of achieving the following tasks in normal visibility conditions: rwy incursion detection (TWR), aircraft and vehicle identification on the manoeuvring area (GND), monitor of wind/QNH/visibility changes, monitor of incursion into closed/restricted taxiways.	Subjective assessment about performance (question number 4 in NASA TLX) in normal visibility conditions provides equal rates when using SD solution compared to the ones obtained with baseline equipment.	OK
			CRT-HP-04 - 005	Solution SD reduces the workload in normal visibility condition (NASA TLX).	When using SD solution in normal visibility conditions all workload components are reduced.	OK
EXE6, EXE4	OBJ-RETINA-VALP-HP-05	To assess the impact of the SD solution on Human Performance in CONDI VIS 2	CRT-HP-05 - 001	Solution SD reduces the head down time in CONDI VIS 2 (eye tracking).	Solution SD reduces head down time in CONDI VIS 2 by a factor of 3 compared to the baseline equipment. Baseline (61%) – SD (21%)	OK
			CRT-HP-05 - 002	Solution SD increases the accessibility of the information in CONDI VIS 2 (subjective assessment).	Subjective rates about information accessibility in CONDIVIS 2 are higher when using SD solution compared to the ones obtained with baseline equipment.	OK
			CRT-HP-05 - 003	Solution SD reduces the number of switch head down/head up in CONDI VIS 2 (eye tracking).	Solution SD reduces the number of switch head down/head up in CONDI VIS 2 by a factor of 1.5 compared to the baseline equipment. Baseline (279) – SD (161)	OK

Validation Exercise ID	Obj. ID	Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Objective Status
			CRT-HP-05 - 004	Solution SD increases the capability of achieving the following tasks in CONDI VIS 2: aircraft and vehicle identification on the manoeuvring area, rwy incursion detection (TWR) and monitor of wind/QNH/visibility changes.	Subjective assessment about performance (question number 4 in NASA TLX) in CONDI VIS 2 provides higher rates when using SD solution compared to the ones obtained with baseline equipment.	OK
			CRT-HP-05 - 005	Solution SD reduces the workload in CONDI VIS 2 (NASA TLX).	When using SD solution in CONDI VIS 2 all workload components are reduced except Frustration, which is increased compared to the one obtained with baseline equipment.	OK
EXE 4, EXE5, EXE7	OBJ-RETINA-VALP-EF-01	To assess the impact that the HMD solution has on Efficiency in COND VIS 2 compared to the baseline equipment.	CRT-EF-01 - 001	Solution HMD increases the number of aircraft safely managed in CONDI VIS 2	In CONDIVIS2 HMD provides an increase in the number of aircraft safely managed by the operator in the unit of time compared to the baseline equipment. The results confirm that HMD solution is effective in achieving higher volumes of traffic.	OK
			CRT-EF-01 - 002	Solution HMD provides acceptable levels of workload in CONDI VIS 2	Workload levels using HMD in CONDIVIS2 are acceptable, even in medium-high traffic conditions.	OK
EXE8,EXE 9,EXE10	OBJ-RETINA-VALP-EF-02	To assess the impact that the HMD solution has on Efficiency in COND VIS 3 compared to the baseline equipment.	CRT-EF-02 - 001	Solution HMD increases the number of aircraft safely managed in CONDI VIS 3	When restrictions apply, the throughput in CONDIVIS3 with HMD solution is reduced compared to the baseline whilst, as expected, the introduction of RETINA HMD solution makes it possible to test the removal of some restrictions. Thus, the results confirm that HMD solution is effective in achieving higher volumes of traffic.	OK
			CRT-EF-02-002	Solution HMD provides acceptable levels of workload in CONDI VIS 3	Workload levels using HMD in CONDIVIS3 are acceptable. When restrictions are removed, all workload components are slightly reduced.	OK

Validation Exercise ID	Obj. ID	Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Objective Status
EXE1, EXE2, EXE3	OBJ-RETINA-VALP-SAF-01	To assess the impact that the RETINA solutions have on Safety in CONDI VIS 1	CRT-SAF-01 -001	Solution HMD preserves/increases the capability of achieving the following tasks in CONDI VIS 1: monitoring of holding points(GND)	The capability of the user to monitor holding points is preserved using HMD in CONDIVIS1.	OK
			CRT-SAF-01 -002	Solution SD preserves/increases the capability of achieving the following tasks in CONDI VIS 1: rwy incursion detection (TWR), ATCO to monitor the separation of traffic on final.	The capability of the user to detect rwy incursions and monitor the separation of traffic on final is preserved using SD in CONDIVIS1.	OK
EXE4, EXE5, EXE6, EXE7	OBJ-RETINA-VALP-SAF-02	To assess the impact that the RETINA solutions have on Safety in CONDI VIS 2	CRT-SAF-02 -001	Solution HMD preserves/increases the capability of achieving the following tasks in CONDI VIS 2 : monitoring of holding point (GND).	The capability of the user to monitor holding points is preserved using HMD in CONDIVIS2.	OK
			CRT-SAF-02 -002	Solution SD preserves/increases the capability of achieving the following tasks in CONDI VIS 2: rwy incursion detection (TWR), monitor of the traffic separation on final	The capability of the user to detect rwy incursions and monitor the separation of traffic on final is preserved using SD in CONDIVIS2.	OK
			CRT-SAF-02 -003	Solution HMD preserves/increases the capability of achieving the following tasks in CONDI VIS 2: rwy incursion detection (TWR), monitor of the traffic separation on final	The capability of the user to detect rwy incursions and monitor the separation of traffic on final is preserved using HMD in CONDIVIS2.	OK

Validation Exercise ID	Obj. ID	Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Objective Status
EXE8, EXE9, EXE10	OBJ-RETINA-VALP-SAF-03	To assess the impact that the RETINA HMD solution has on relevant safety-critical tasks in CONDI VIS 3	CRT-SAF-03-001	Solution HMD preserves/increases the capability of achieving the following tasks in CONDI VIS 3: detect deviation from taxi clearance (GND)	The capability of the user to detect deviations from taxi clearance is preserved using HMD in CONDIVIS3.	OK
EXE11	OBJ-RETINA-HF-01	Assess the readability and meaningfulness of textual information displayed by the information overlays with RETINA HMD solution.	CRT-HF-01-01	Controllers appreciate meaning, fonts type, dimension, colour of the information displayed by the overlays.	Responses were on average above 10 out of 20. Comments centred on the flight tags being too large, the colors being too many, and the use of red should be limited to warnings.	OK
	OBJ-RETINA-HF-02	Assess the readability and meaningfulness of graphical objects, symbols and representations in the information overlays with RETINA HMD solution	CRT-HF-02-01	Controllers appreciate symbols, objects and type of information displayed on the information overlays	Responses were on average above 10 out of 20. Comments were generally OK and focused on the METAR being unreadable	OK
	OBJ-RETINA-HF-03	Assess the consistency and completeness of the information displayed by the overlays with RETINA HMD solution	CRT-HF-03-01	Controllers confirm that the displayed information is coherent and complete to manage the traffic in a safe manner	Responses were on average above 10 out of 20. Comments were mixed. Some wanted more info and others thought there was too much. Expanding flight tags could be a possible solution	OK
	OBJ-RETINA-HF-04	Assess the timeliness and prioritization of the information displayed by the overlays with RETINA HMD solution	CRT-HF-04-01	The displayed information is timely and correctly prioritised	Responses were on average above 10 out of 20. Comments were focused on the movement of labels tend to make them get lost, the static METAR overlay was too present and should stay put relative to the ground.	OK
	OBJ-RETINA-HF-05	Assess the adequacy of information from the overlays with RETINA HMD solution	CRT-HF-05-01	Controllers consider the displayed information to be adequate to perform their tasks	Responses were on average above 10 out of 20. Comments were focused on the tags tilting being distracting and that they should avoid each other automatically when the aircraft overlap.	OK

Validation Exercise ID	Obj. ID	Objective Title	Success Criterion ID	Success Criterion	Exercise Results	Objective Status
	OBJ-RETINA-HF-06	Assess the practicability and intuitiveness of commands on HMI objects, with RETINA HMD solution	CRT-HF-06-01	Controllers consider information finding and sorting quick, easy, practical and intuitive	Responses were on average above 10 out of 20. Comments were focused on the tags tilting being distracting and that they should avoid each other automatically when the aircraft overlap.	OK
	OBJ-RETINA-HF-07	Assess the adequacy of feedbacks of commands / actions on HMI objects, with RETINA HMD solution	CRT-HF-07-01	HMI objects provide adequate feedbacks for each controller input	Responses were on average above 10 out of 20. Comments were focused on combining the glasses with a keyboard or some other form of additional input.	OK
	OBJ-RETINA-HF-08	Assess the impact that the information overlays have on supporting the controller in the decision making process with RETINA HMD solution	CRT-HF-08-01	Controllers confirm that the outputs and triggers provided by the different tools and displayed on the HMI support them during the decision making process.	Responses were on average above 10 out of 20. Comments were regarding including conflict alerts.	OK

Table 5 Summary of Validation Results

3.2 Detailed analysis of RETINA Validation Results per Validation objective

The following paragraphs detail results analysis for each objective defined in [3][1].

3.2.1 OBJ-RETINA-VALP-HP-01 Results

Success Criterion 001: Solution HMD reduces the head down time (eye tracking) in normal visibility conditions

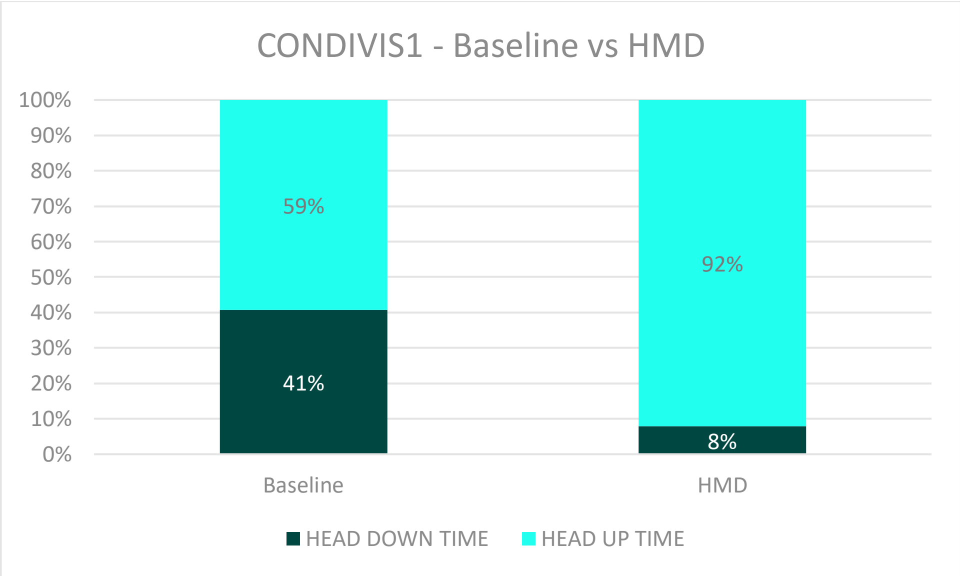


Figure 25 Share of time spent head up/head down by the user in CONDIVIS1 exercises. Baseline vs HMD. Average values on three subjects.

Fig. 25 shows that solution HMD reduces head down time in normal visibility conditions by a factor of 5 compared to the baseline equipment. Baseline (41%) – HMD (8%). The results are **OK**.

<u>Success Criterion 002</u>: Solution HMD increases the accessibility of the information (subjective assessment) in normal visibility conditions

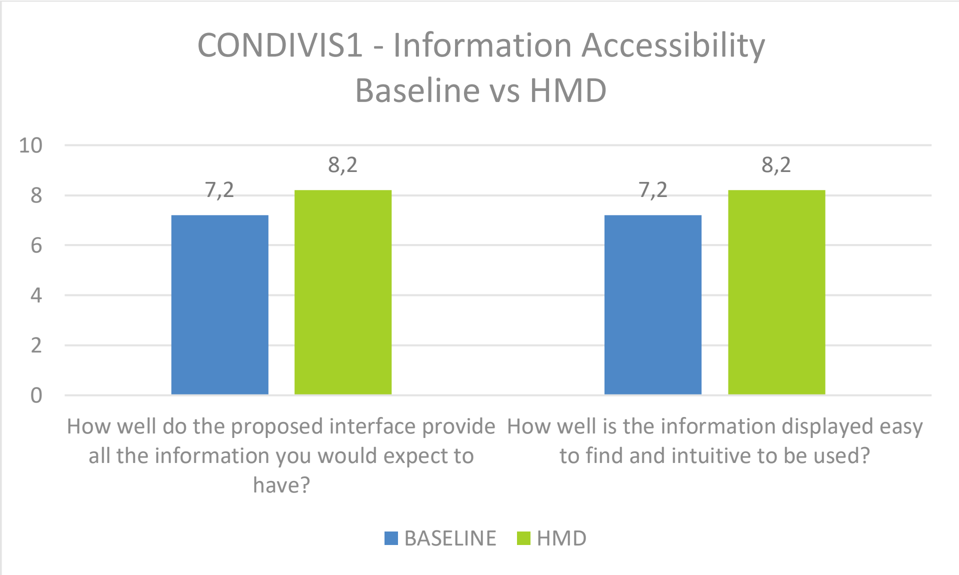


Figure 26 Information accessibility in CONDIVIS1. Baseline vs HMD. Average values on three subjects.

Fig. 26 shows that subjective rates about information accessibility in normal visibility conditions are higher when using HMD solution (8,2 – 8,2) compared to the ones obtained with baseline equipment (7,2 – 7,2).The results are **OK**.

<u>Success Criterion 003</u>: Solution HMD reduces the number of switch head down/head up (eye tracking) in normal visibility conditions.

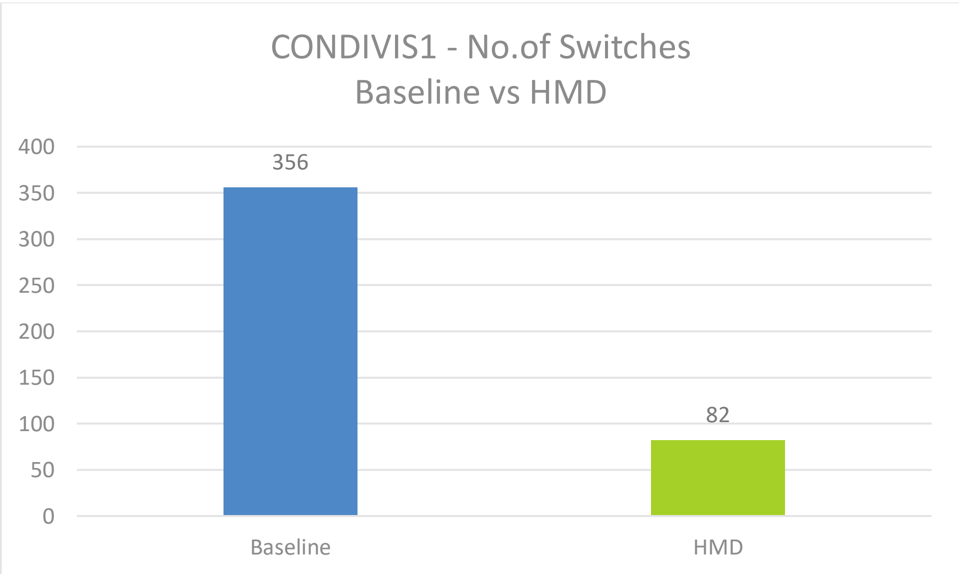


Figure 27 Number of switches between Head-Down/Head-Up Positions in CONDIVIS1 Exercises. Baseline vs HMD. Average values on three subjects.

Fig. 27 shows that solution HMD reduces the number of switches head down/head up in normal visibility conditions by a factor of 4.5 compared to the baseline equipment. Baseline (356) – HMD (82). The results are **OK**.

<u>Success Criterion 004</u>:. Solution HMD increases the capability of achieving the following tasks in normal visibility conditions: aircraft and vehicle identification on the manoeuvring area (GND), monitor of wind and QNH changes, monitor of incursion into closed/restricted taxiway.

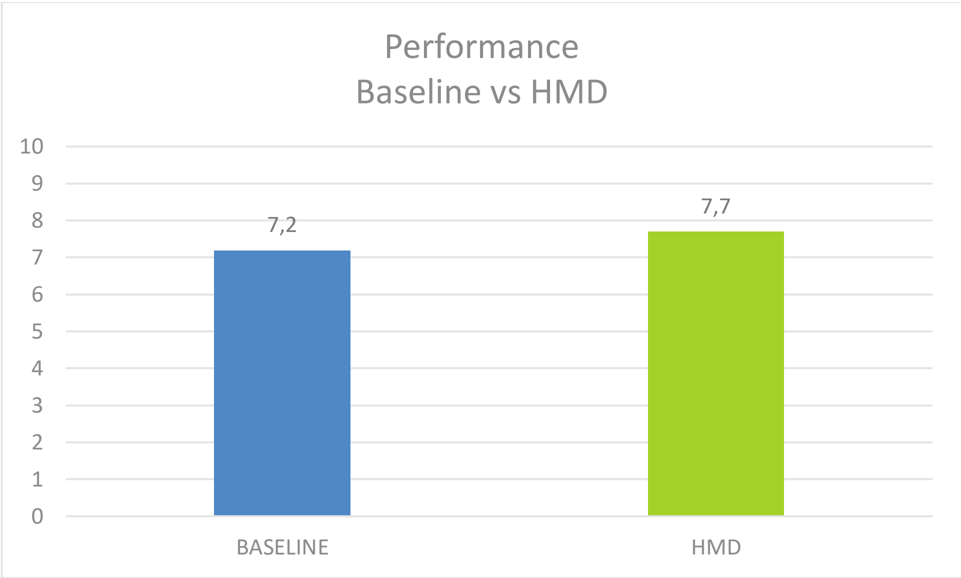


Figure 28 Results of subjective assessment about performance in normal visibility conditions. Baseline vs HMD. Average values on three subjects.

Fig. 28 shows that subjective assessment about performance (question number 4 in NASA TLX) in normal visibility conditions provides higher rates when using HMD solution compared to the ones obtained with baseline equipment. It is worth mentioning that question number 4 in NASA TLX was tailored to the tasks defined in the specific success Criterion, i.e. aircraft and vehicle identification on the manoeuvring area (GND), monitor of wind and QNH changes, monitor of incursion into closed/restricted taxiway. The results are **OK**.

<u>Success Criterion 005</u>:. Solution HMD reduces the workload (NASA TLX) in normal visibility conditions

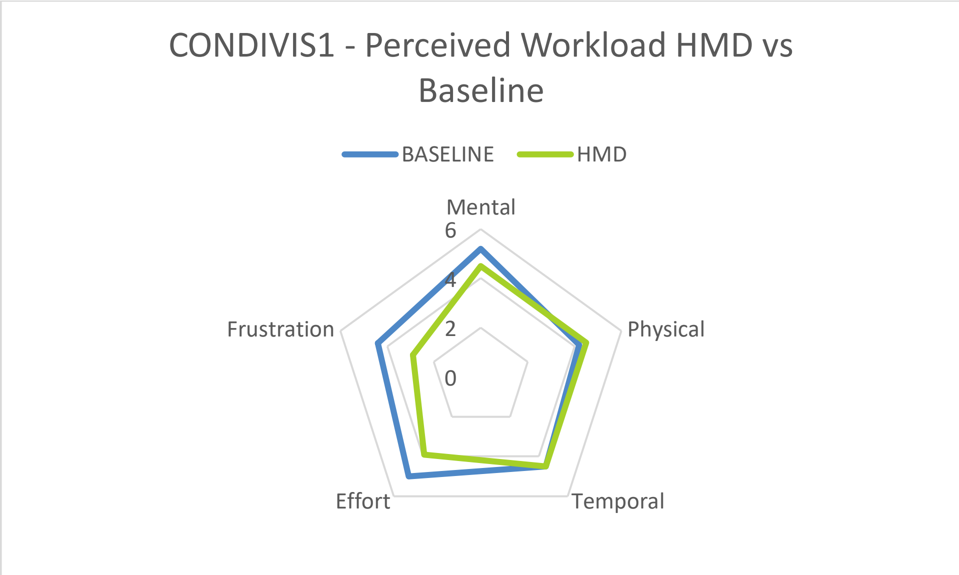


Figure 29 Radar chart of workload five components (as defined in NASA TLX questionnaire) for CONDIVIS1. Baseline vs HMD. Average values on three subjects.

Fig. 29 shows that, when using HMD solution in normal visibility conditions, all workload components are reduced or maintained except Physical Workload that is slightly increased compared to the one obtained with baseline equipment. The results are **OK**.

3.2.2 OBJ-RETINA-VALP-HP-02 Results

Success Criterion 001: Solution HMD reduces the head down time in CONDI VIS 2 (eye tracking)

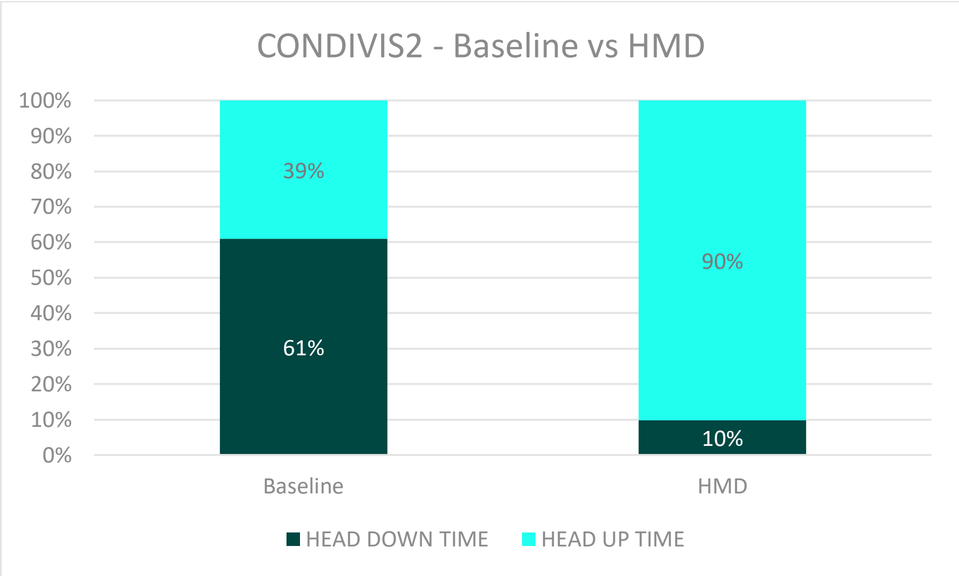


Figure 30 Share of time spent head up/head down by the user in CONDIVIS2 exercises. Baseline vs HMD. Average values on three subjects.

Fig. 30 shows that solution HMD reduces head down time in CONDIVIS2 by a factor of 6 compared to the baseline equipment. Baseline (61%) – HMD (10%). The results are **OK**.

Success Criterion 002: Solution HMD increases the accessibility of the information in CONDI VIS 2 (subjective assessment)

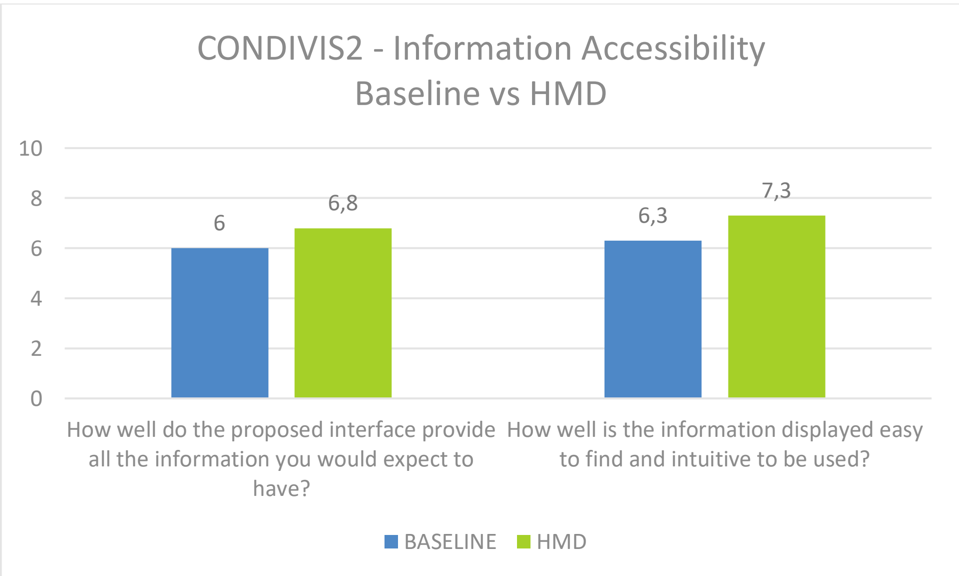


Figure 31 Information accessibility in CONDIVIS2. Baseline vs HMD. Average values on three subjects.

Fig. 31 shows that subjective rates about information accessibility in CONDIVIS2 are higher when using HMD solution (7,3 – 6,8) compared to the ones obtained with baseline equipment (6,3 – 6).The results are **OK**.

Success Criterion 003: Solution HMD reduces the number of switch head down/head up in CONDIVIS 2 (eye tracking)

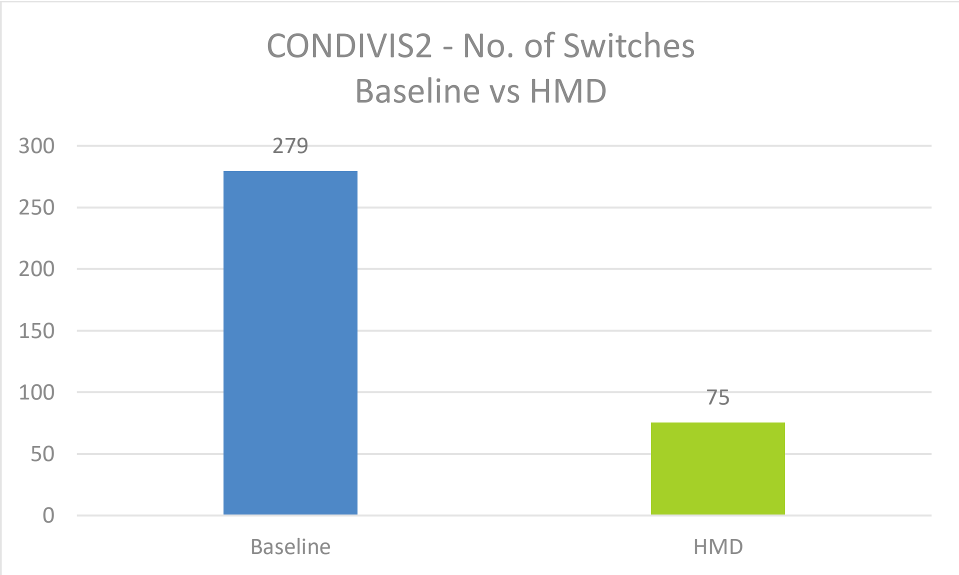


Figure 32 Number of switches between Head-Down/Head-Up Positions in CONDIVIS2 Exercises. Baseline vs HMD. Average values on three subjects.

Fig. 32 shows that solution HMD reduces the number of switches head down/head up in CONDIVIS2 by a factor of 3.5 compared to the baseline equipment. Baseline (279) – HMD (75). The results are **OK**.

Success Criterion 004: Solution HMD increases the capability of achieving the following tasks in CONDI VIS 2: runway incursion detection (TWR), aircraft and vehicle identification on the manoeuvring area (GND), monitor of wind/QNH/visibility changes, monitor of incursion into closed/restricted taxiways.

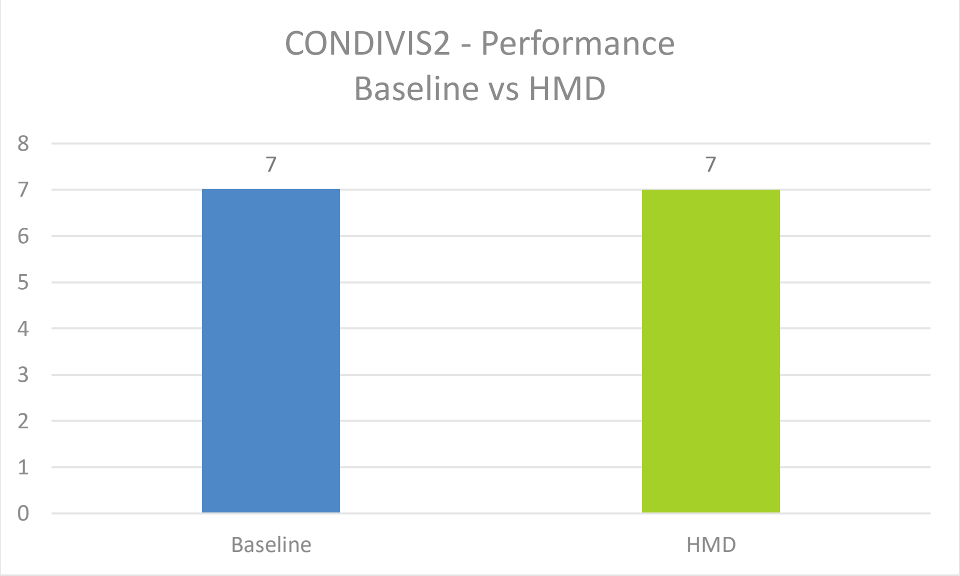


Figure 33 Results of subjective assessment about performance in CONDIVIS2. Baseline vs HMD. Average values on three subjects.

Fig. 33 shows that subjective assessment about performance (question number 4 in NASA TLX) in CONDIVIS2 provides equal rates when using HMD solution compared to the ones obtained with baseline equipment. It is worth to notice that question number 4 in NASA TLX was tailored to the tasks defined in the specific success Criterion, i.e. runway incursion detection (TWR), aircraft and vehicle identification on the manoeuvring area (GND), monitor of wind/QNH/visibility changes, monitor of incursion into closed/restricted taxiways.

The results are **NOT OK**, since the capability is maintained but it is not increased. It is worth to notice that, since the capability is not decreased, this result does not affect the success of the validation.

<u>Success Criterion 005</u>: Solution HMD reduces the workload (NASA TLX) in CONDI VIS 2.

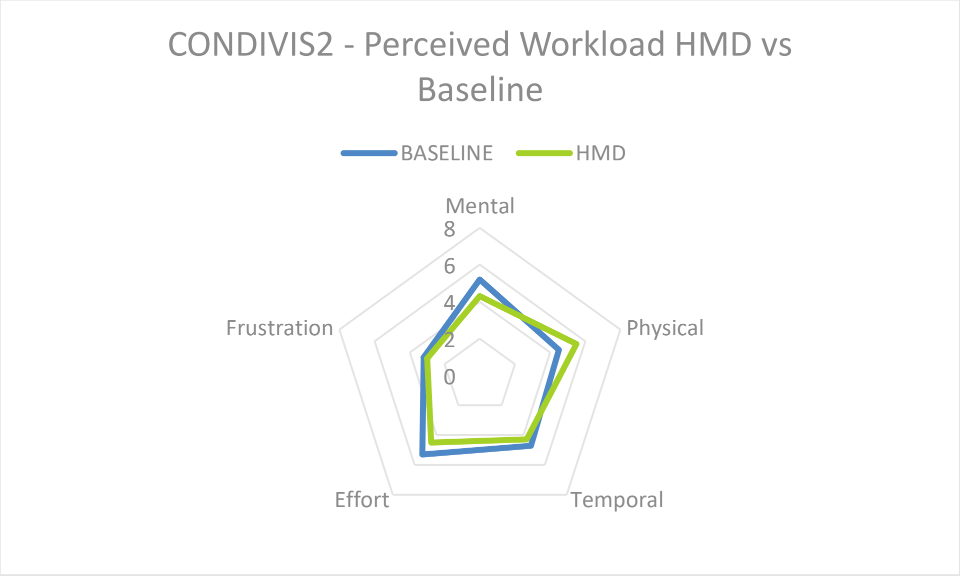


Figure 34 Radar chart of workload five components (as defined in NASA TLX questionnaire) for CONDIVIS2. Baseline vs HMD. Average values on three subjects.

Fig. 34 shows that, when using HMD solution in CONDIVIS2, all workload components are reduced except Physical Workload, which is slightly increased compared to the one obtained with baseline equipment. The results are **OK**.

3.2.3 OBJ-RETINA-VALP-HP-03 Results

Success Criterion 001: Solution HMD reduces the head down time in CONDI VIS 3 (eye tracking).

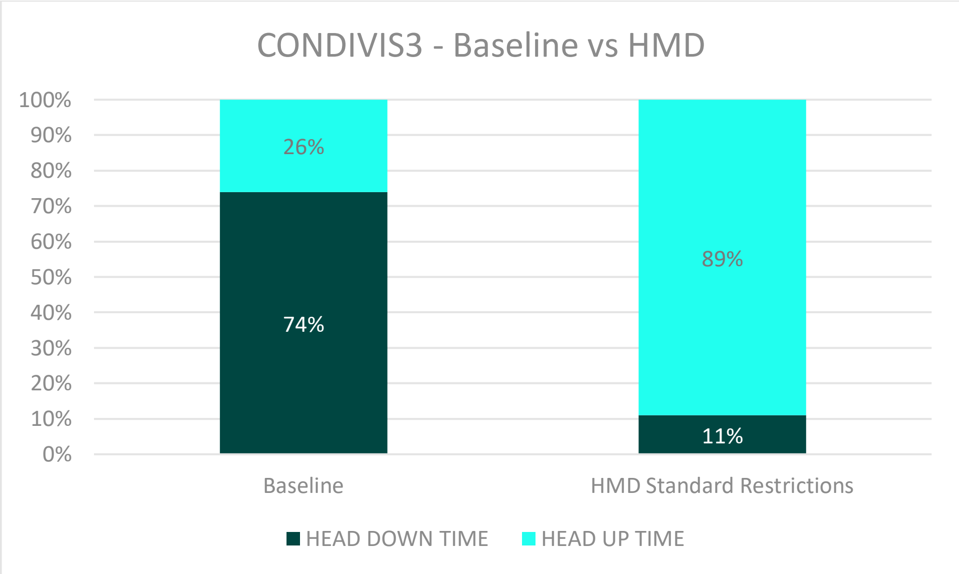


Figure 35 Share of time spent head up/head down by the user in CONDIVIS3 exercises. Baseline vs HMD. Average values on three subjects.

Fig. 35 shows that solution HMD reduces head down time in CONDIVIS3 by a factor of 6.5 compared to the baseline equipment. Baseline (74%) – HMD (11%). The results are **OK**.

Success Criterion 002: Solution HMD increases the accessibility of the information in CONDI VIS 3 (subjective assessment).

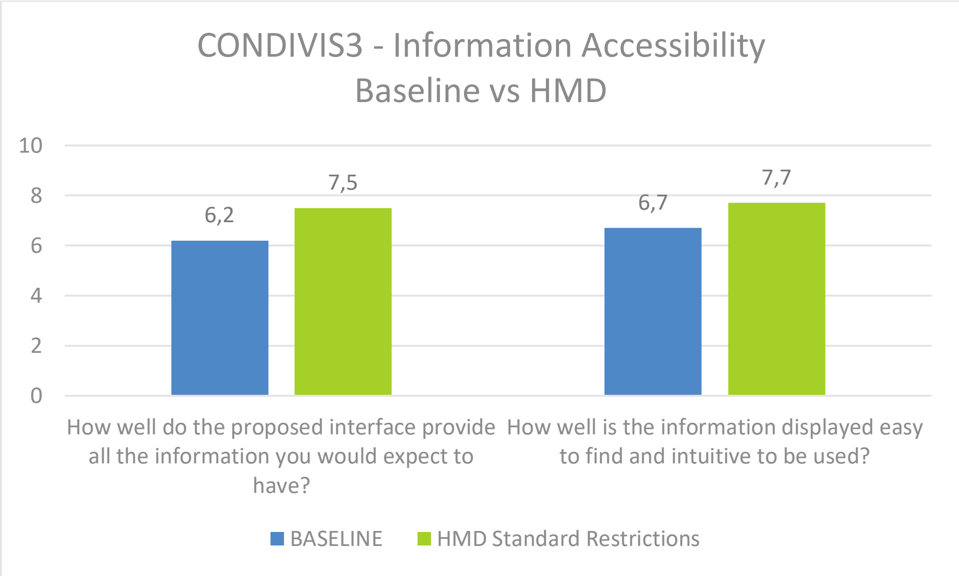


Figure 36 Information accessibility in CONDIVIS3. Baseline vs HMD. Average values on three subjects.

Fig.36 shows that subjective rates about information accessibility in CONDIVIS2 are higher when using the HMD solution (7,5 – 7,7) compared to the ones obtained with the baseline equipment (6,2 – 6,7).The results are **OK**.

<u>Success Criterion 003</u>: **Solution HMD reduces the number of switch head down/head up in CONDI VIS 3 (eye tracking).**

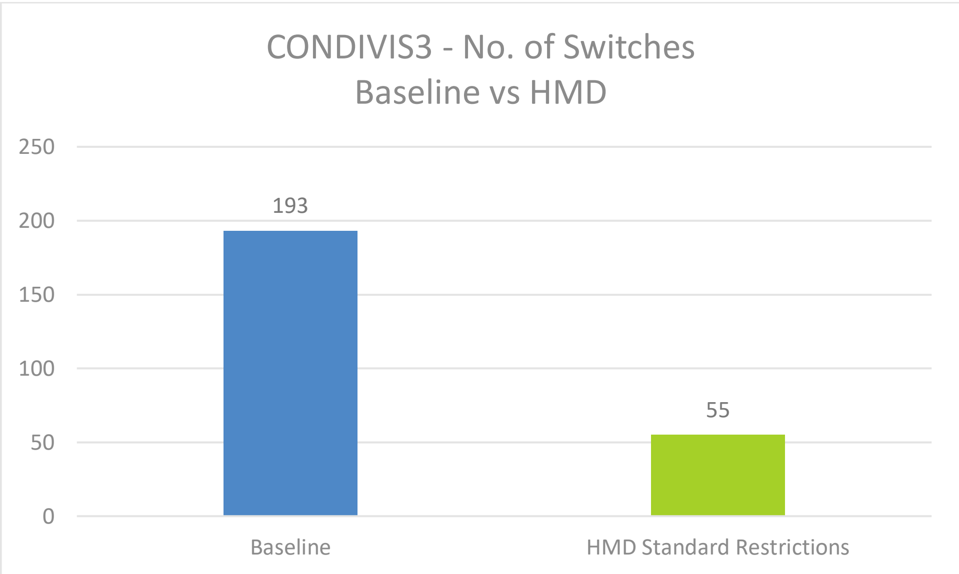


Figure 37 Number of switches between Head-Down/Head-Up Positions in CONDIVIS3 Exercises. Baseline vs HMD. Average values on three subjects.

Fig.37 shows that solution HMD reduces the number of switches between head down/head up in CONDIVIS3 by a factor of 3.5 compared to the baseline equipment. Baseline (193) – HMD (55). The results are **OK**.

Success Criterion 004: Solution HMD increases the capability of achieving the following tasks in CONDI VIS 3: rwy incursion detection (TWR), aircraft and vehicle identification on the manoeuvring area (GND), monitor of wind/QNH/visibility changes, monitor of incursion into closed/restricted taxiways

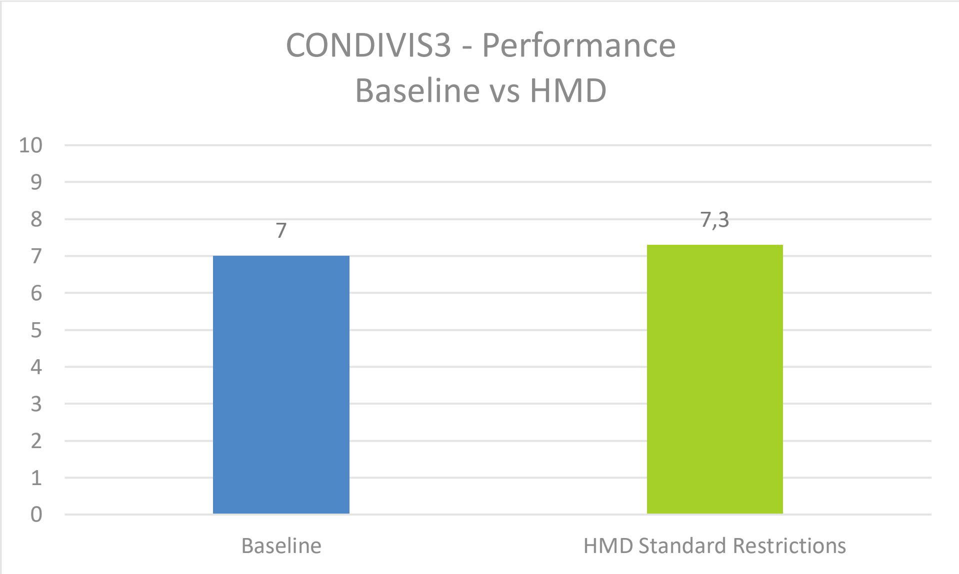


Figure 38 Results of subjective assessment about performance in CONDIVIS3. Baseline vs HMD. Average values on three subjects.

Fig. 38 shows that subjective assessment about performance (question number 4 in NASA TLX) in CONDIVIS3 provides higher rates when using the HMD solution compared to the ones obtained with baseline equipment. It is worth mentioning that question number 4 in NASA TLX was tailored to the tasks defined in the specific success Criterion, i.e. rwy incursion detection (TWR), aircraft and vehicle identification on the manoeuvring area (GND), monitor of wind/QNH/visibility changes, monitor of incursion into closed/restricted taxiways. The results are **OK**.

Success Criterion 005: Solution HMD reduces the workload (NASA TLX) in CONDI VIS 3

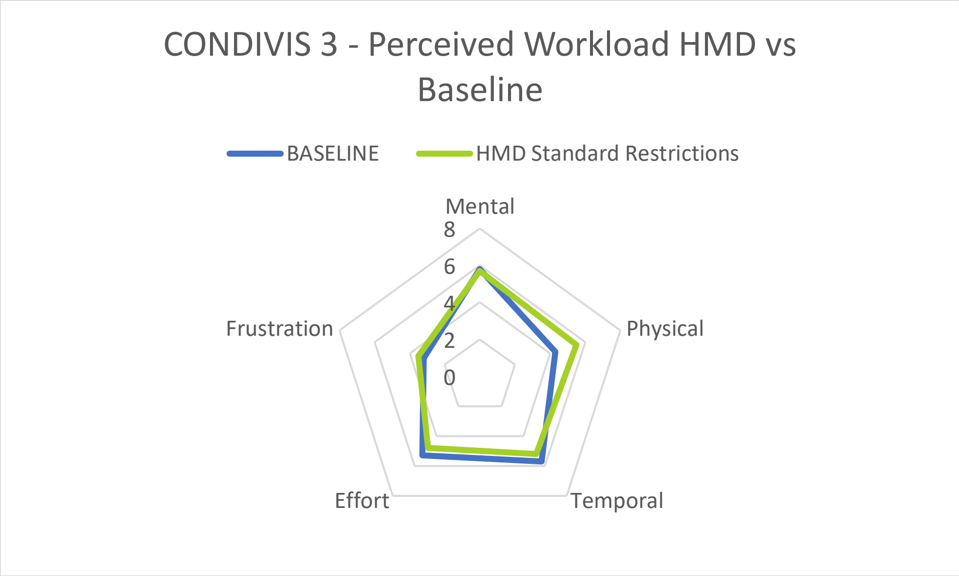


Figure 39 Radar chart of workload five components (as defined in NASA TLX questionnaire) for CONDIVIS3. Baseline vs HMD. Average values on three subjects.

Fig.39 shows that, when using HMD solution in CONDIVIS3, all workload components are reduced except Physical Workload and Frustration that are slightly increased compared to the ones obtained with baseline equipment. The results are **OK**.

3.2.4 OBJ-RETINA-VALP-HP-04 Results

<u>Success Criterion 001</u>: Solution SD reduces the head down time in normal visibility condition (eye tracking).

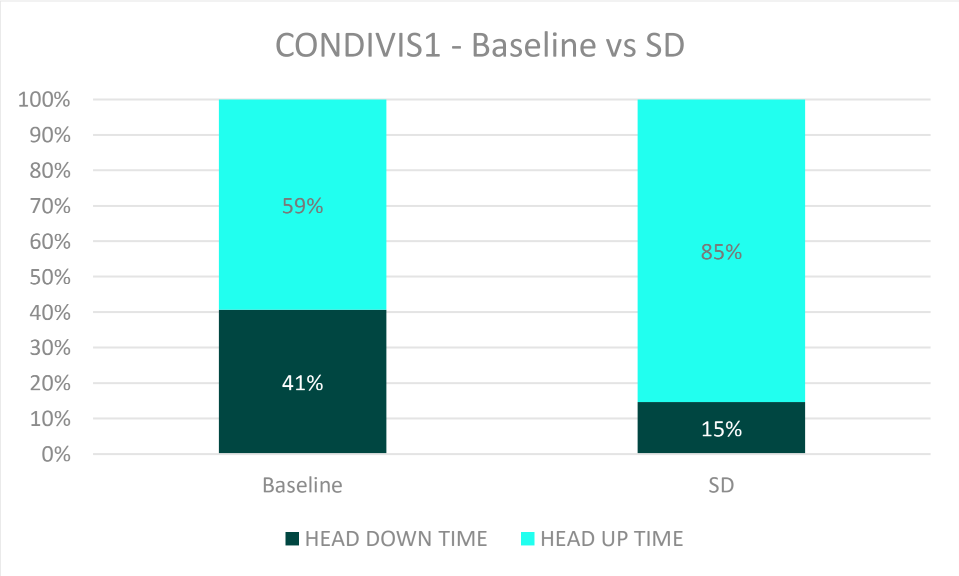


Figure 40 Share of time spent head up/head down by the user in CONDIVIS1 exercises. Baseline vs SD. Average values on three subjects.

Fig. 40 shows that solution SD reduces head down time in normal visibility conditions by a factor of 2.5 compared to the baseline equipment. Baseline (41%) – SD (15%). The results are **OK**.

<u>Success Criterion 002</u>: Solution SD increases the accessibility of the information in normal visibility condition (subjective assessment).

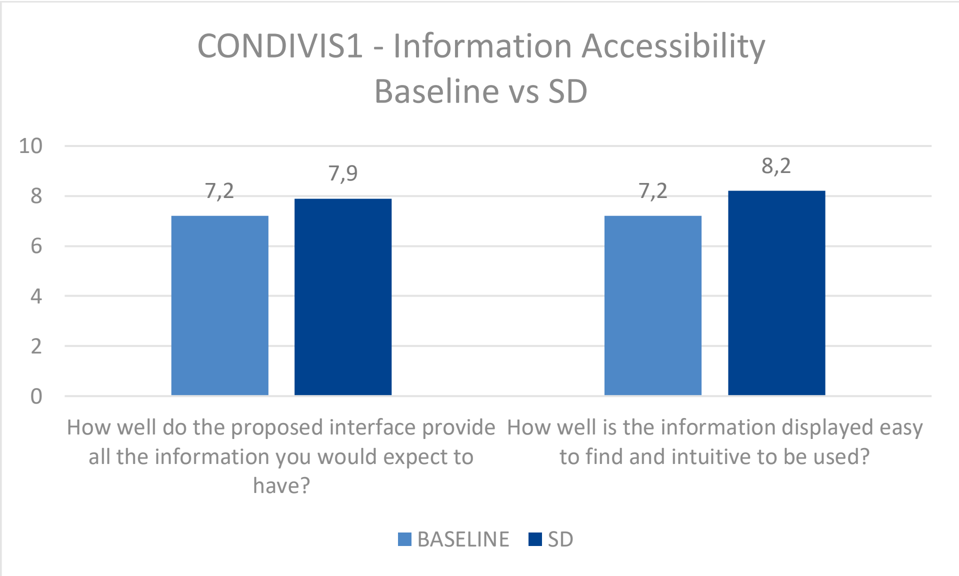


Figure 41 Information accessibility in CONDIVIS1. Baseline vs SD. Average values on three subjects.

Fig.41 shows that subjective rates about information accessibility in normal visibility conditions are higher when using SD solution (7,9 – 8,2) compared to the ones obtained with baseline equipment (7,2 – 7,2).The results are **OK**.

<u>Success Criterion 003</u>: Solution SD reduces the number of switch head down/head up in normal visibility condition (eye tracking).

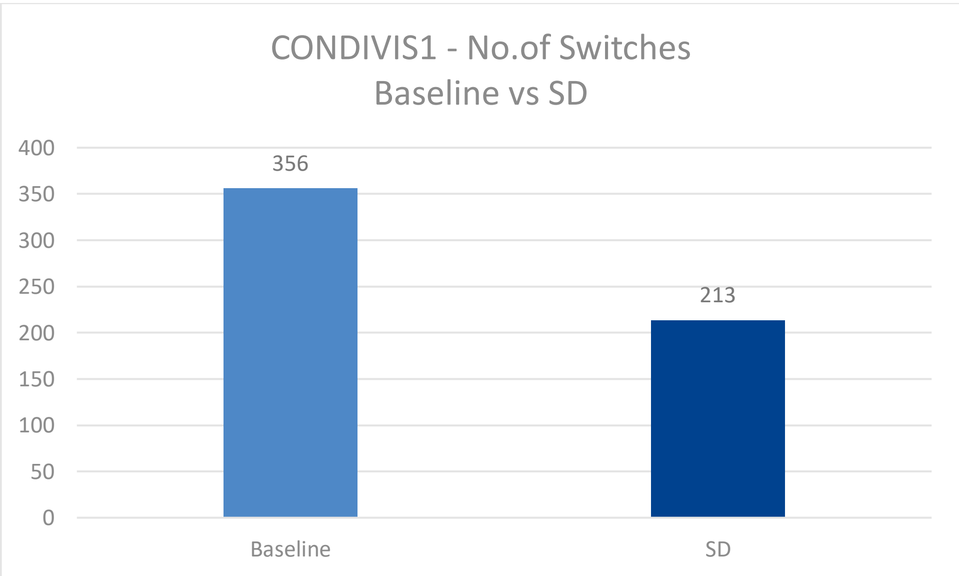


Figure 42 Number of switches between Head-Down/Head-Up Positions in CONDIVIS1 Exercises. Baseline vs SD. Average values on three subjects.

Fig.42 shows that solution SD reduces the number of switches head down/head up in normal visibility conditions by a factor of 1.5 compared to the baseline equipment. Baseline (356) – SD (213). The results are **OK**.

Success Criterion 004: Solution SD increases the capability of achieving the following tasks in normal visibility conditions: rwy incursion detection (TWR), aircraft and vehicle identification on the manoeuvring area (GND), monitor of wind/QNH/visibility changes, monitor of incursion into closed/restricted taxiways.

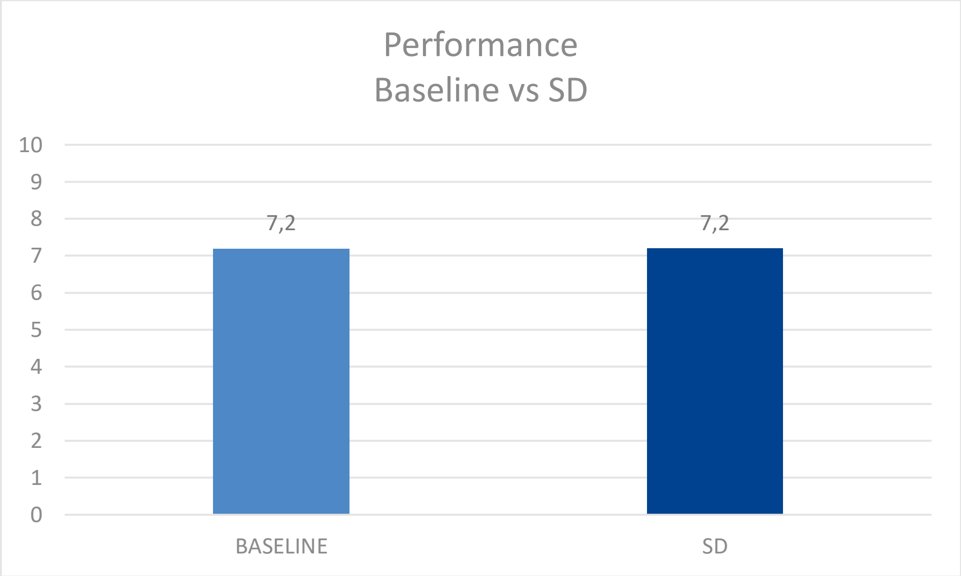


Figure 43 Results of subjective assessment about performance in CONDIVIS1. Baseline vs SD. Average values on three subjects.

Fig.43 shows that the subjective assessment about performance (question number 4 in NASA TLX) in normal visibility conditions provides equal rates when using the SD solution compared to the ones obtained with the baseline equipment. It is worth mentioning that question number 4 in NASA TLX was tailored to the tasks defined in the specific success Criterion, i.e. rwy incursion detection (TWR), aircraft and vehicle identification on the manoeuvring area (GND), monitor of wind/QNH/visibility changes, monitor of incursion into closed/restricted taxiways.

The results are **NOT OK**, since the capability is maintained but it is not increased. It is worth to notice that, since the capability is not decreased, this result does not affect the success of the validation.

Success Criterion 005: Solution SD reduces the workload in normal visibility condition (NASA TLX).

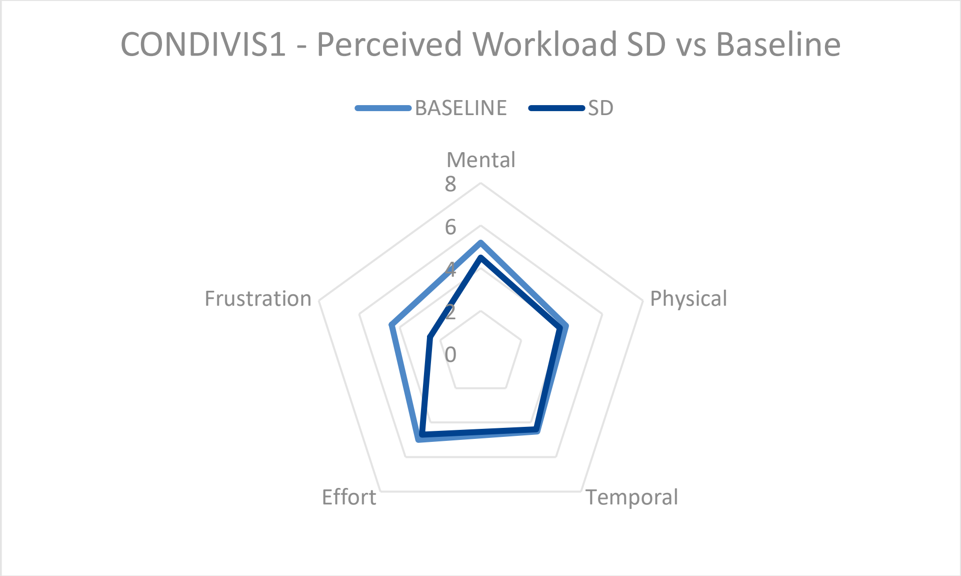


Figure 44 Radar chart of workload five components (as defined in NASA TLX questionnaire) for CONDIVIS1. Baseline vs SD. Average values on three subjects.

Fig.44 shows that, when using SD solution in normal visibility conditions, all workload components are reduced with respect to the ones obtained with baseline equipment.

The results are **OK**.

3.2.5 OBJ-RETINA-VALP-HP-05 Results

Success Criterion 001: Solution SD reduces the head down time in CONDI VIS 2 (eye tracking).

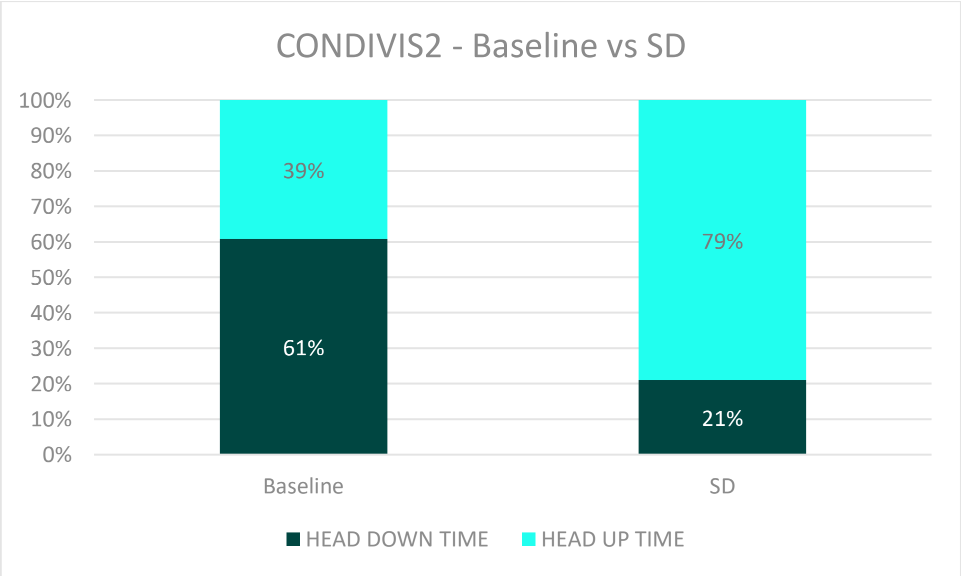


Figure 45 Share of time spent head up/head down by the user in CONDIVIS2 exercises. Baseline vs SD. Average values on three subjects.

Fig.45 shows that solution SD reduces head down time in normal visibility conditions by a factor of 3 compared to the baseline equipment. Baseline (61%) – SD (21%). The results are **OK**.

<u>Success Criterion 002</u>: Solution SD increases the accessibility of the information in CONDI VIS 2 (subjective assessment).

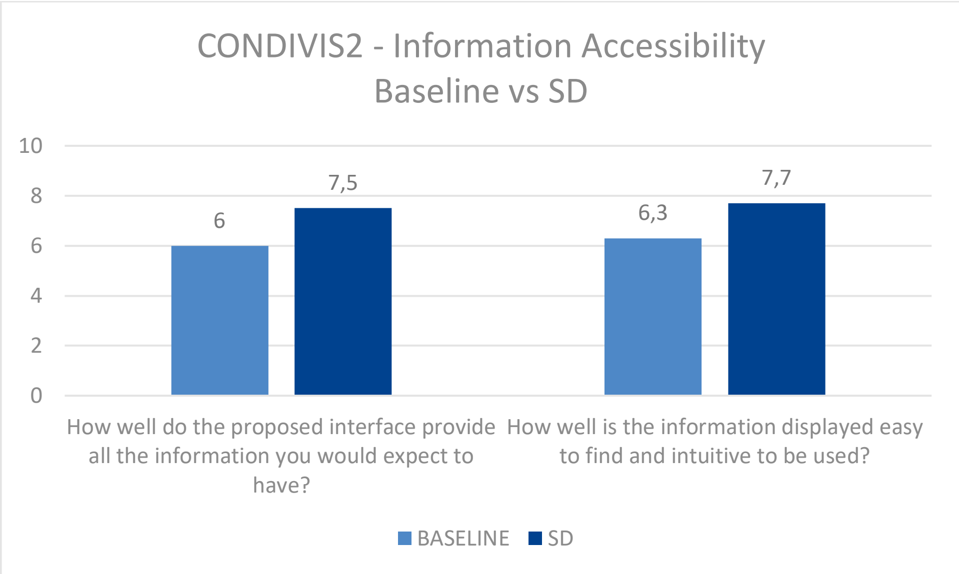


Figure 46 Information accessibility in CONDIVIS2. Baseline vs SD. Average values on three subjects.

Fig. 46 shows that subjective rates about information accessibility in normal visibility conditions are higher when using SD solution (7,5 – 7,7) compared to the ones obtained with baseline equipment (6,0 – 6,3).The results are **OK**.

<u>Success Criterion 003</u>:. Solution SD reduces the number of switch head down/head up in CONDI VIS 2 (eye tracking).

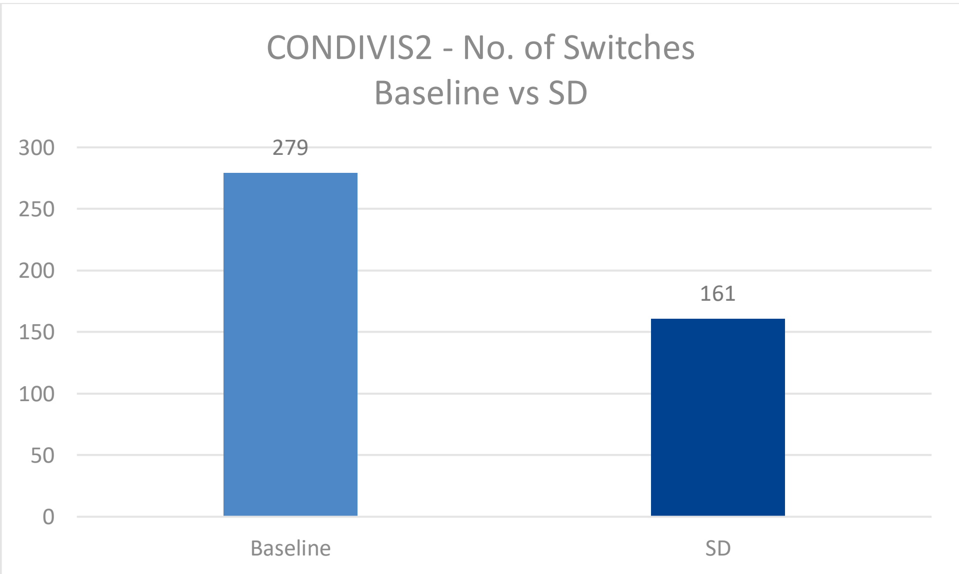


Figure 47 Number of switches between Head-Down/Head-Up Positions in CONDIVIS2 Exercises. Baseline vs SD. Average values on three subjects.

Fig. 47 shows that solution SD reduces the number of switches head down/head up in normal visibility conditions by a factor of 1.5 compared to the baseline equipment. Baseline (279) – SD (161). The results are **OK**.

<u>Success Criterion 004</u>: Solution SD increases the capability of achieving the following tasks in CONDI VIS 2: aircraft and vehicle identification on the manoeuvring area, rwy incursion detection (TWR) and monitor of wind/QNH/visibility changes.

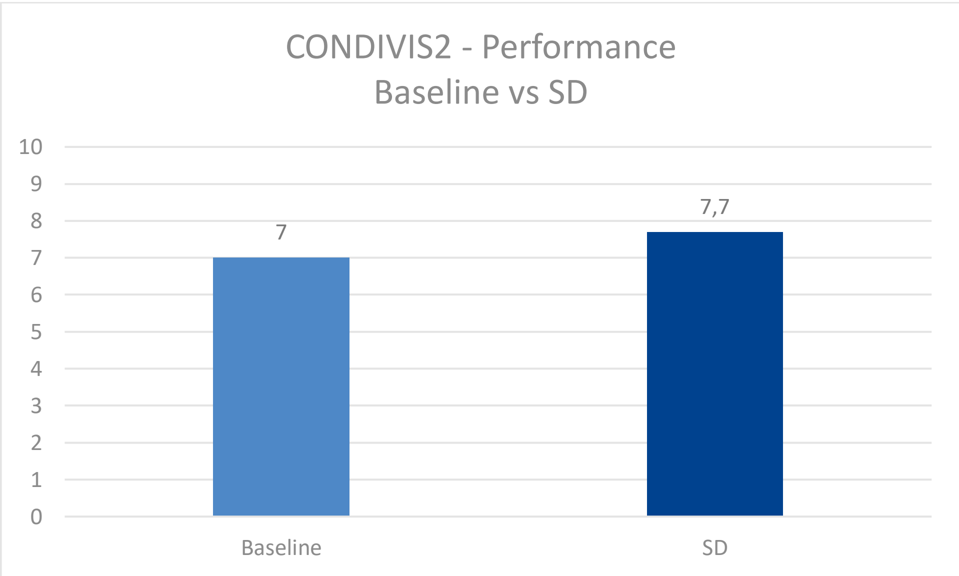


Figure 48 Results of subjective assessment about performance in CONDIVIS2. Baseline vs SD. Average values on three subjects.

Fig. 48 shows that the subjective assessment about performance (question number 4 in NASA TLX) in CONDIVIS2 provides higher rates when using the SD solution compared to the ones obtained with the baseline equipment. It is worth mentioning that question number 4 in NASA TLX was tailored to the tasks defined in the specific success Criterion, i.e. aircraft and vehicle identification on the manoeuvring area, rwy incursion detection (TWR) and monitor of wind/QNH/visibility changes. The results are **OK**.

<u>Success Criterion 005</u>: Solution SD reduces the workload in CONDI VIS 2 (NASA TLX).

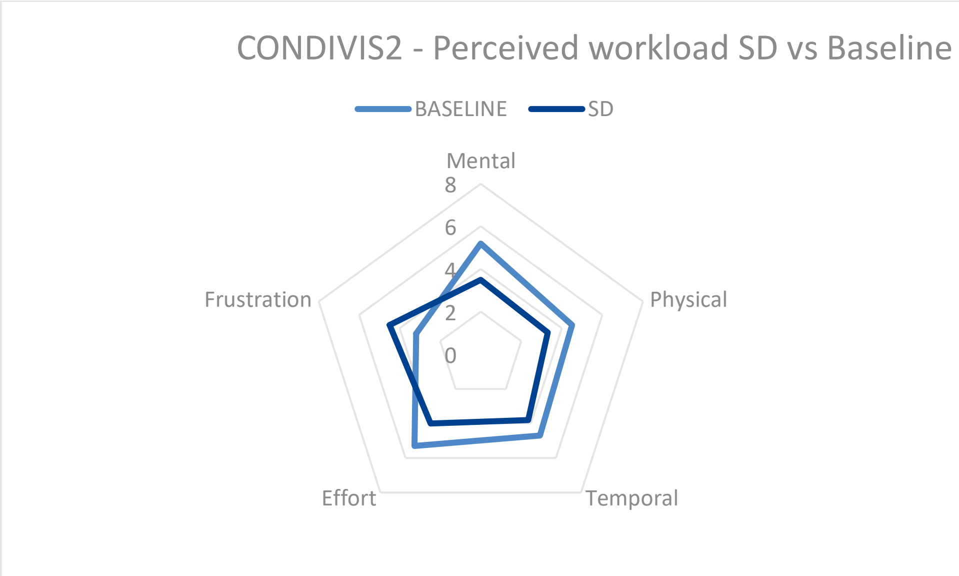


Figure 49 Radar chart of workload five components (as defined in NASA TLX questionnaire) for CONDIVIS2. Baseline vs SD. Average values on three subjects.

Fig.49 shows that, when using the SD solution in CONDI VIS 2, all workload components are reduced except Frustration, which is increased compared to the one obtained with the baseline equipment. This latter is an unexpected result, apparently not related to criticality of the specific condition, although it might be further investigated in subsequent studies. The results are **OK**.

3.2.6 OBJ-RETINA-VALP- EF-01Results

<u>Success Criterion 001</u>: Solution HMD increases the number of aircraft safely managed in CONDI VIS 2.

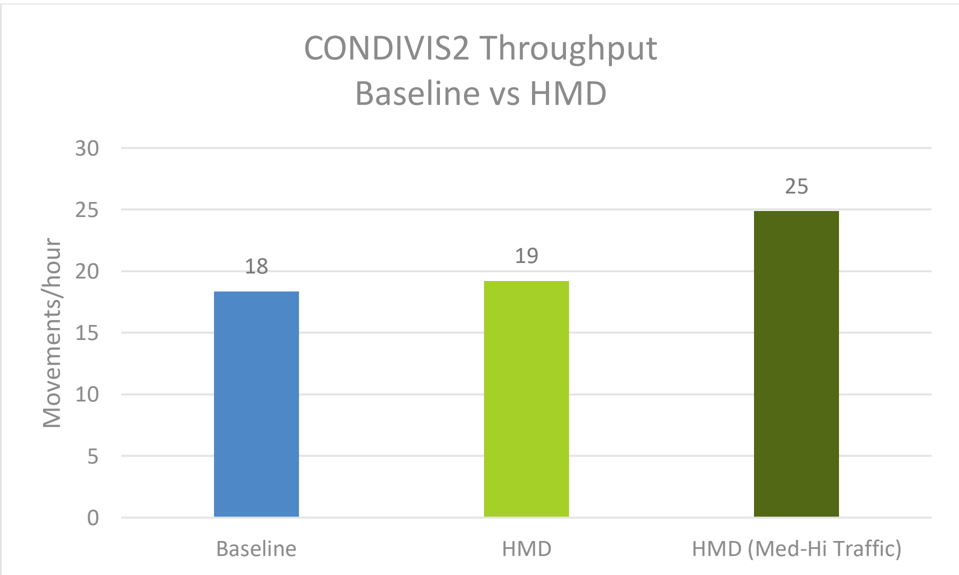


Figure 50 Throughput in CONDIVIS2 Exercises. Baseline vs HMD. Average values on three subjects.

Fig.50 shows that, in CONDIVIS2, the HMD provides an increase in the number of aircraft safely managed by the operator in the unit of time compared to the baseline equipment. The results confirm that the HMD solution is effective in achieving higher volumes of traffic. The results are **OK**.

<u>Success Criterion 002</u>: **Solution HMD provides acceptable levels of workload in CONDI VIS 2.**

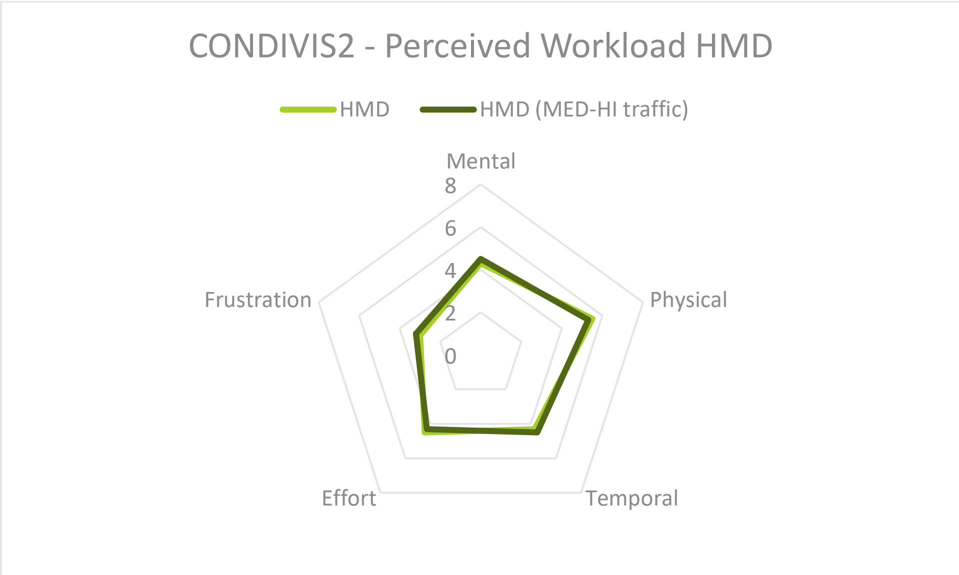


Figure 51 Radar chart of workload five components (as defined in NASA TLX questionnaire) for CONDIVIS2 with HMD equipment. Average values on three subjects.

Workload levels using the HMD in CONDIVIS2 are acceptable, even in medium-high traffic conditions. The results are **OK**.

3.2.7 OBJ-RETINA-VALP- EF-02 Results

<u>Success Criterion 001</u>: **Solution HMD increases the number of aircraft safely managed in CONDI VIS 3.**

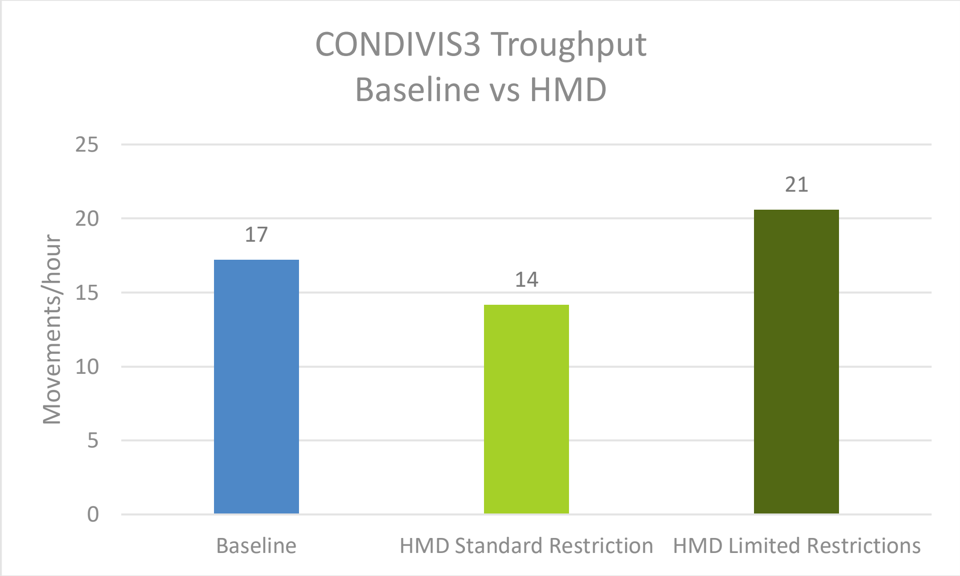


Figure 52 Throughput in CONDIVIS3 Exercises. Baseline vs HMD. Average values on three subjects.

Fig. 52 shows that, when restrictions apply, the throughput in CONDIVIS3 with the HMD solution is reduced compared to the baseline whilst, as expected, the introduction of the RETINA HMD solution makes it possible to test the removal of some restrictions. Thus, the results confirm that the HMD solution is effective in achieving higher volumes of traffic. The results are **OK**.

<u>Success Criterion 002</u>: Solution HMD provides acceptable levels of workload in CONDI VIS 3.

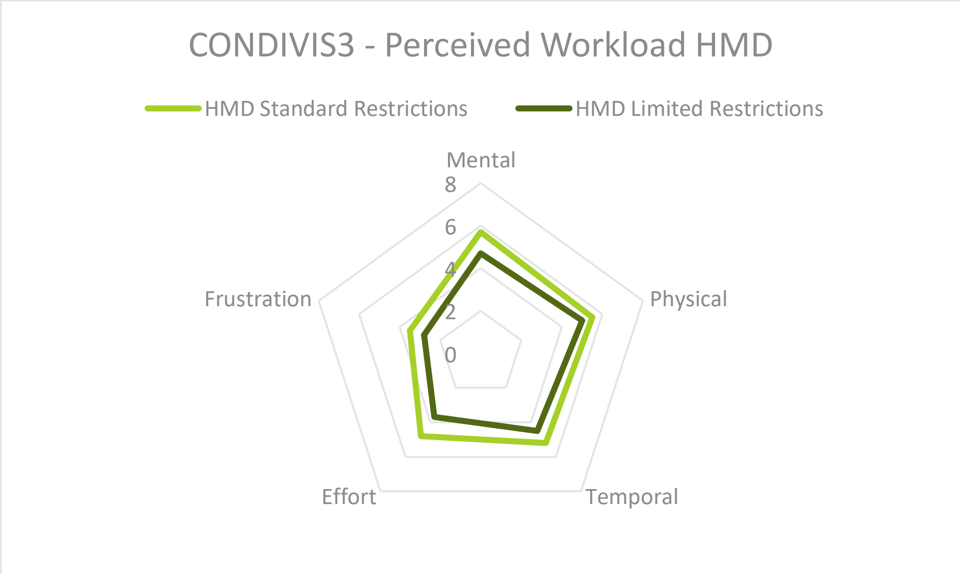


Figure 53 Radar chart of workload five components (as defined in NASA TLX questionnaire) for CONDIVIS3 with HMD equipment. Average values on three subjects.

Workload levels using the HMD in CONDIVIS3 are acceptable. When restrictions are removed, all workload components are slightly reduced. The results are **OK**.

3.2.8 OBJ-RETINA-VALP- SAF-01 Results

Success Criterion 001: Solution HMD preserves/increases the capability of achieving the following tasks in CONDI VIS 1: monitoring of holding points(GND).

Based on observations during the exercise, the capability of the user to monitor holding points is preserved using HMD in CONDIVIS1.

The results are **OK**.

Success Criterion 002: Solution SD preserves/increases the capability of achieving the following tasks in CONDI VIS 1: rwy incursion detection (TWR), ATCO to monitor the separation of traffic on final.

Based on observations during the exercise, the capability of the user to detect rwy incursions and monitor the separation of traffic on final is preserved using SD in CONDIVIS1.

The results are **OK**.

3.2.9 OBJ-RETINA-VALP- SAF-02 Results

Success Criterion 001: Solution HMD preserves/increases the capability of achieving the following tasks in CONDI VIS 2 : monitoring of holding point (GND).

Based on observations during the exercise, the capability of the user to monitor holding points is preserved using HMD in CONDIVIS2.

The results are **OK**.

Success Criterion 002: Solution SD preserves/increases the capability of achieving the following tasks in CONDI VIS 2: rwy incursion detection (TWR), monitor of the traffic separation on final.

Based on observations during the exercise, the capability of the user to detect rwy incursions and monitor the separation of traffic on final is preserved using SD in CONDIVIS2.

The results are **OK**.

Success Criterion 003: Solution HMD preserves/increases the capability of achieving the following tasks in CONDI VIS 2: rwy incursion detection (TWR), monitor of the traffic separation on final.

Based on observations during the exercise, the capability of the user to detect rwy incursions and monitor the separation of traffic on final is preserved using HMD in CONDIVIS2.

The results are **OK**.

3.2.10OBJ-RETINA-VALP- SAF-03 Results

<u>Success Criterion 001</u>: Solution HMD preserves/increases the capability of achieving the following tasks in CONDI VIS 3: detect deviation from taxi clearance (GND).

Based on observations during the exercise, the capability of the user to detect deviations from taxi clearance is preserved using HMD in CONDIVIS3.

The results are **OK**.

3.3 RTS 14 Results

The 29 questions from the questionnaire were broken down into the 8 Validation Objectives in the following manner. The questionnaire was included in the RETINA VALP [3][1].

OBJ-RETINA-HF-01 - Assess the readability and meaningfulness of textual information displayed by the information overlays with RETINA HMD solution.
Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8, Q9
OBJ-RETINA-HF-02 - Assess the readability and meaningfulness of graphical objects, symbols and representations in the information overlays with RETINA HMD solution
Q10, Q11,
OBJ-RETINA-HF-03 - Assess the consistency and completeness of the information displayed by the overlays with RETINA HMD solution
Q12, Q13, Q14, Q19,
OBJ-RETINA-HF-04 - Assess the timeliness and prioritization of the information displayed by the overlays with RETINA HMD solution
Q15, Q16, Q17, Q18; Q20
OBJ-RETINA-HF-05 - Assess the adequacy of information from the overlays with RETINA HMD solution
Q21, Q22, Q23
OBJ-RETINA-HF-06 - Assess the practicability and intuitiveness of commands on HMI objects, with RETINA HMD solution
Q24, Q25, Q26
OBJ-RETINA-HF-07 - Assess the adequacy of feedbacks of commands / actions on HMI objects, with RETINA HMD solution
Q27
OBJ-RETINA-HF-08 - Assess the impact that the information overlays have on supporting the controller in the decision making process with RETINA HMD solution
Q28

Table 6 Questionnaire responses related to each Validation Objective for RTS 14

If we look at the totality of the questions, it can be seen that in Fig.54 that no only were the majority of the responses above average, but the minimum response was quite often a 1.

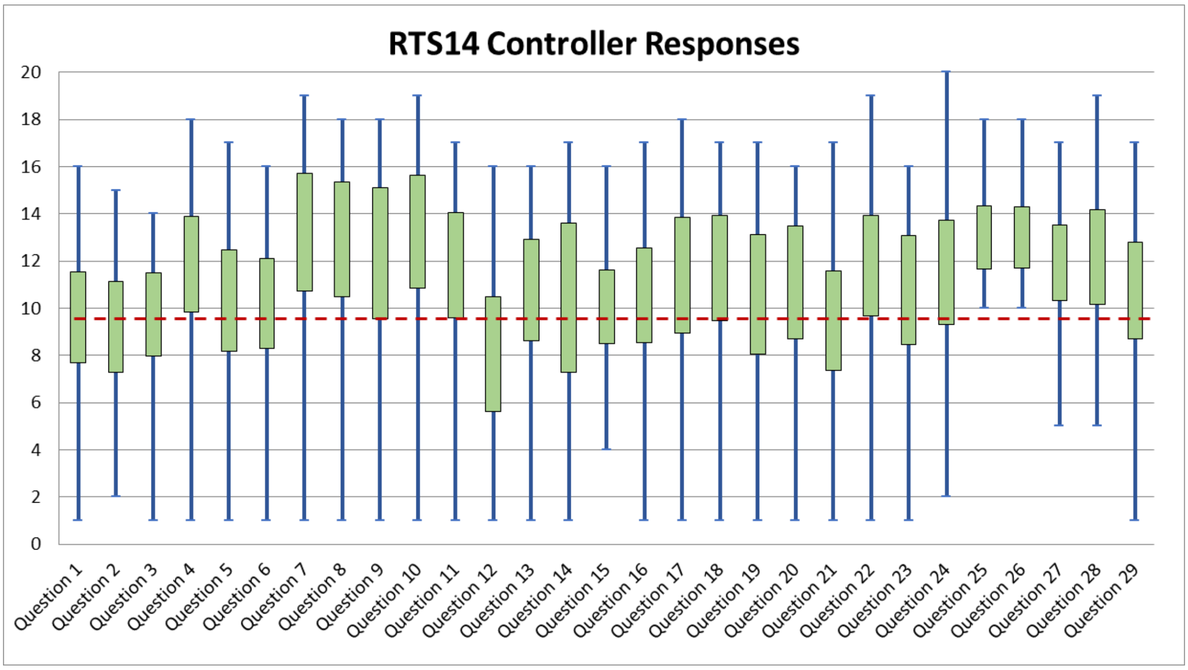


Figure 54 Averaged controller responses to each questionnaire question

Further analysis shown in Fig.55 makes it clear that these minimums were the responses of a single controller. The responses of value 0 were those where the controller did not respond and do not affect the score.

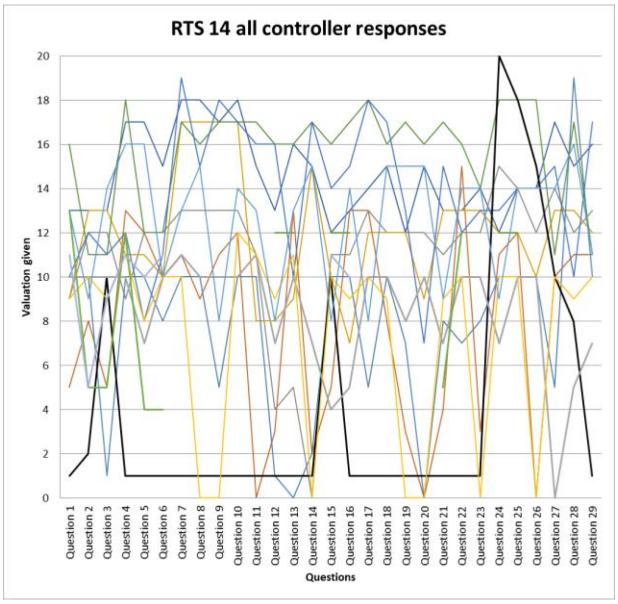


Figure 55 Individual controller responses to each questionnaire question

Because of this, it was decided to show the responses with all controllers included, as well as with this low-outlier removed, to see if it affected the success of the objective or not.

3.3.1 OBJ-RETINA-VALP-HF-01 Results

Success Criterion 001: Controllers appreciate meaning, fonts type, dimension, colour of the information displayed by the overlays.

Overall, the marks received were above average, and improved noticeably when the low-outlier was removed. The only below average response was related to question 2, which was about the dimensions of the static overlays.

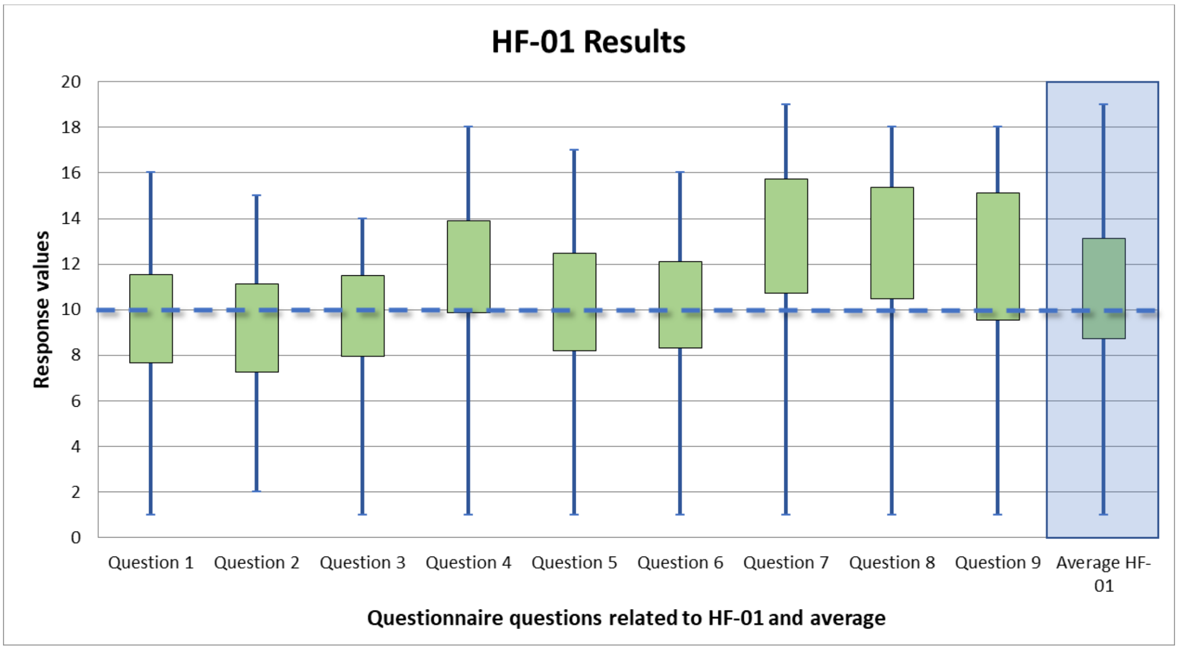


Figure 56 Controller appreciation of overlay font type, color, and dimension

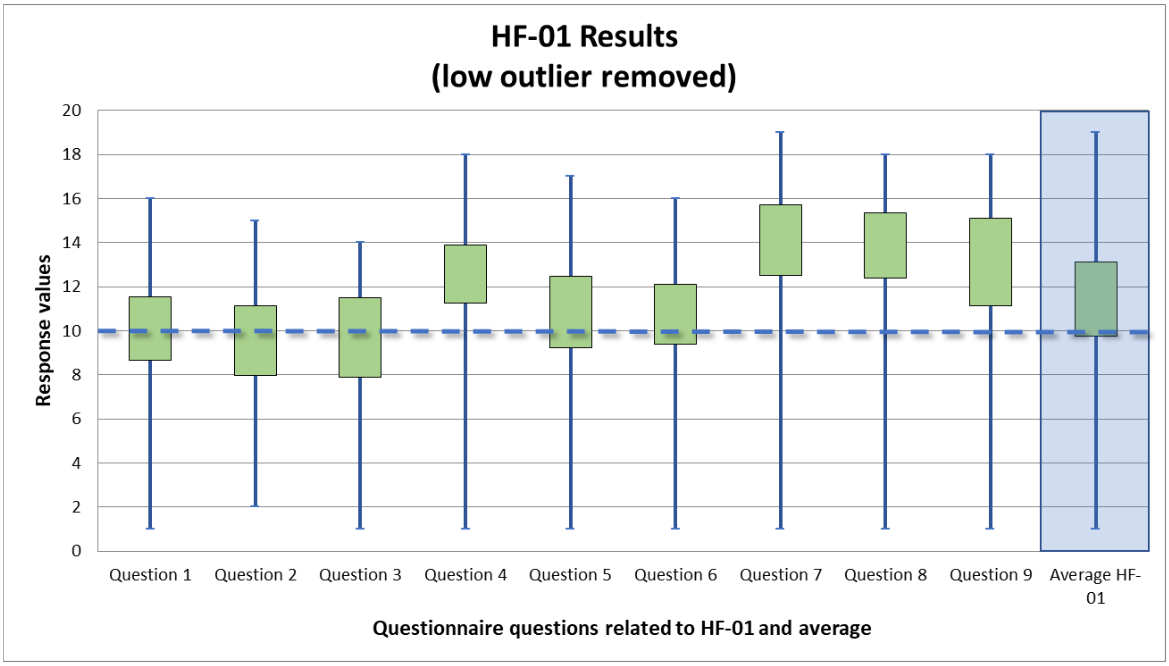


Figure 57 Controller appreciation of overlay font type, color, and dimension(low outlier removed

Analysing the textual responses in 9 questions from 15 controllers can be difficult without some automated tools. Determining the most often repeated words can help focus the analysis. Fig. 58 shows the search of the answers that the controllers gave for often repeated words.

Figure 58 Word cloud analysis of Controller comments regarding overlay font type, color, and dimension

When reading the comments, the most common one was that the flight tags were too big, but the METAR data was too small. The colours were also seen to be distracting and should be of a uniform colour. Red was suggested to be avoided except for warnings. Green like pilot HUDs was suggested. However, given the marks that the controllers gave the questions, these were seen as room for improvement and not something that prevented the success of this validation objective. **The results are OK.**

3.3.2 OBJ-RETINA-VALP- HF-02 Results

Success Criterion 001: Controllers appreciate symbols, objects and type of information displayed on the information overlays.

The results for HF-02 are also above average, however the removal of the low outlier didn't noticeably improve the results.

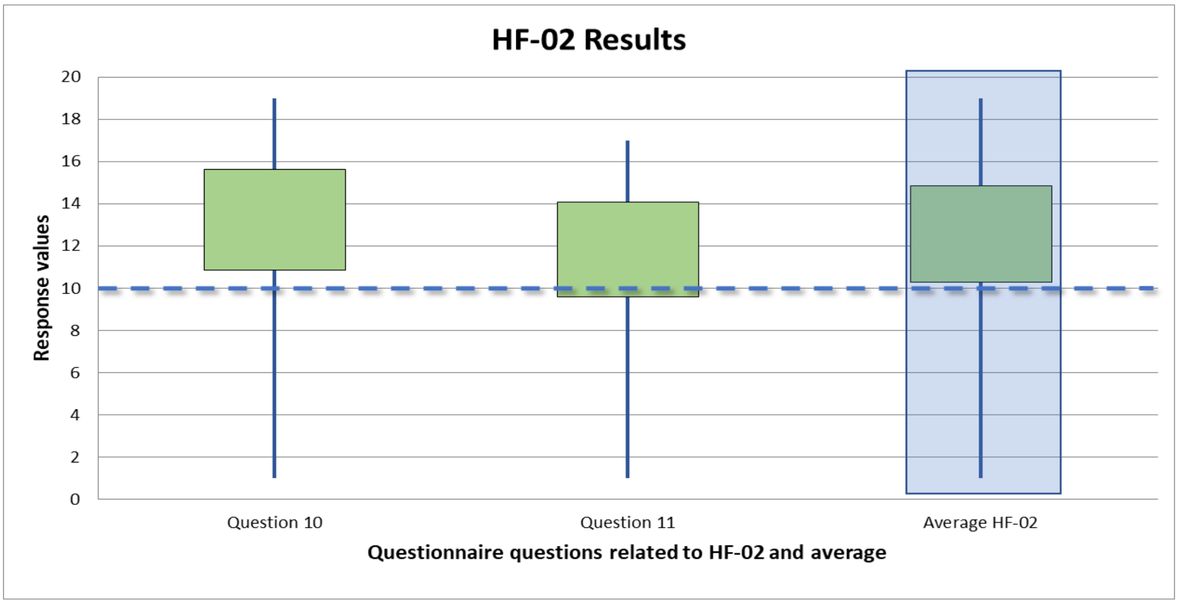


Figure 59 Controller appreciation of overlay symbols, objects and information type

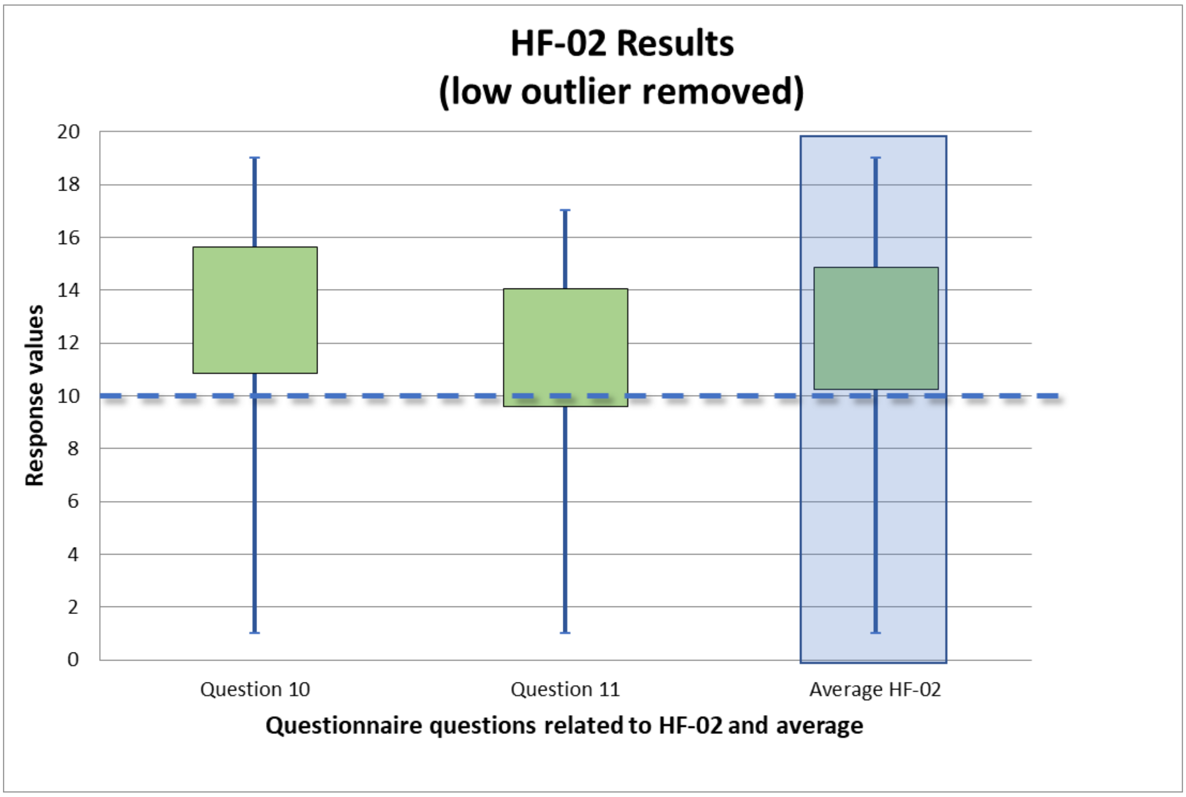


Figure 60 Controller appreciation of overlay symbols, objects and information type (low outlier removed)

Looking at the text responses the comments focused on the unreadability of the METAR info due to the symbols being too small to read. However, given the marks that the controllers gave the questions, these were seen as room for improvement and not something that prevented the success of this validation objective. **The results are OK**

3.3.3 OBJ-RETINA-VALP- HF-03 Results

<u>Success Criterion 001</u>: Controllers confirm that the displayed information is coherent and complete to manage the traffic in a safe manner.

The results for HF-03 are a bit mixed. The average response across the four questions is slightly below average, but slightly above average when the low-outlier is removed.

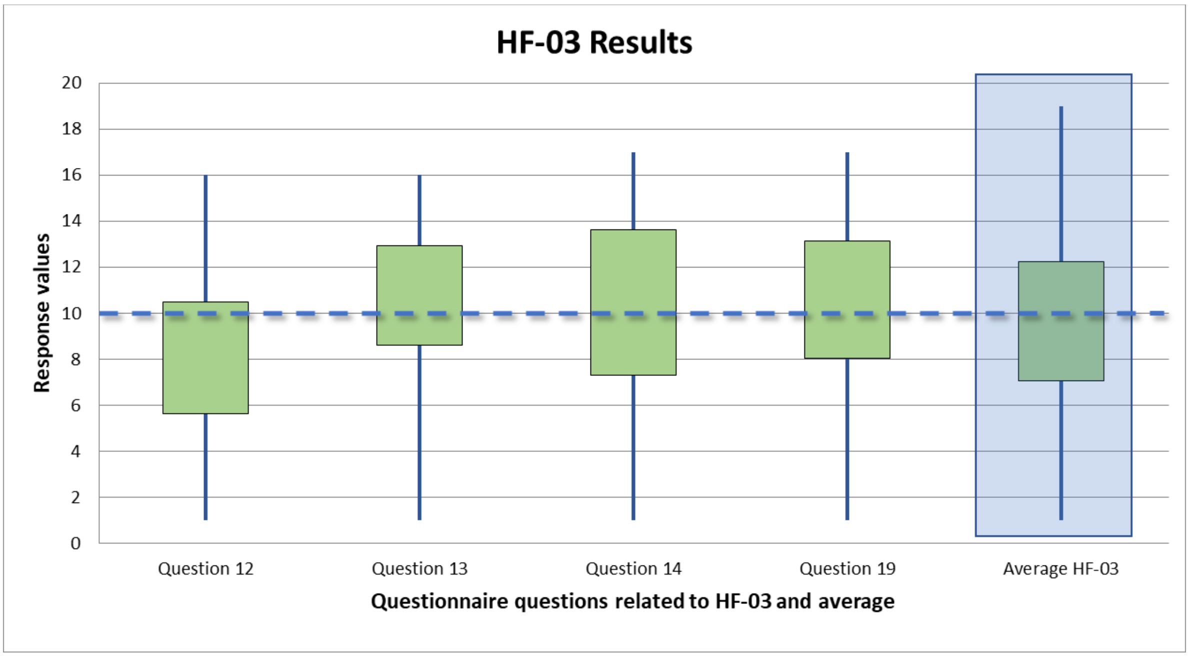


Figure 61 Controller appreciation of information coherence and completeness

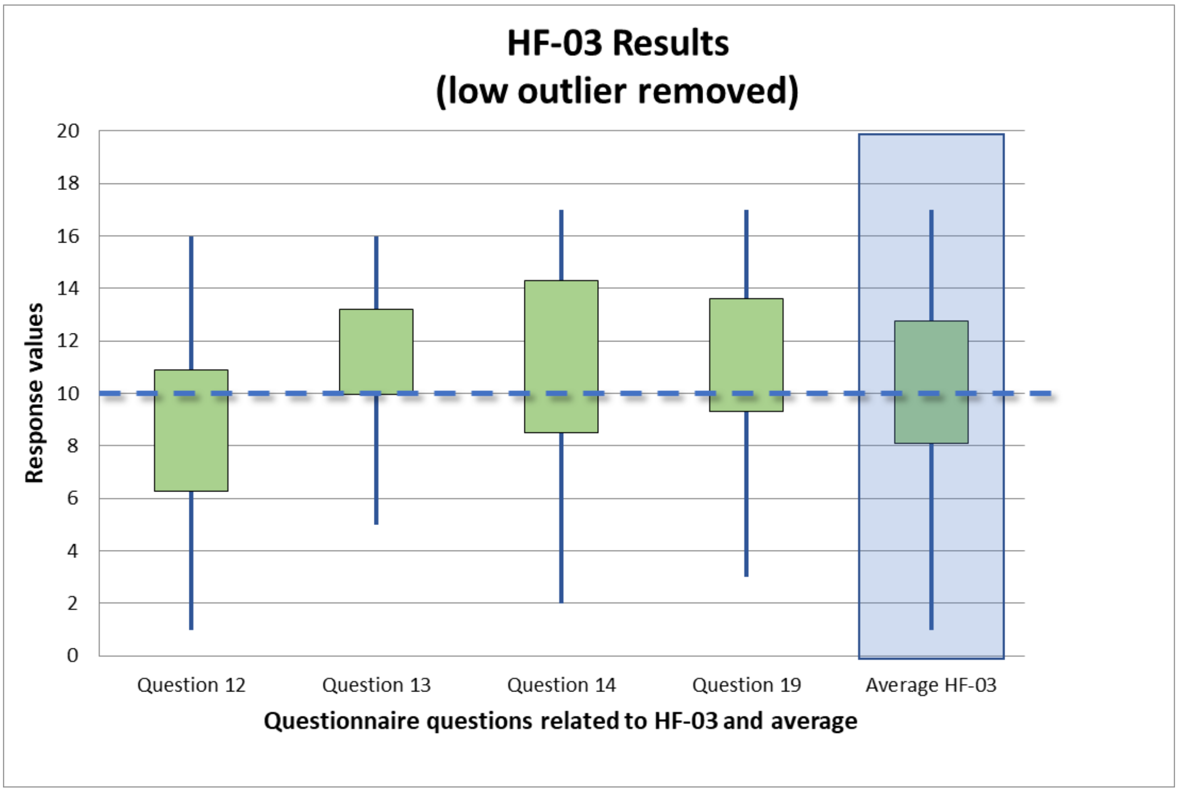


Figure 62 Controller appreciation of information coherence and completeness (low outlier removed)

The textual responses are also mixed. Some controllers said that there was too much information in the flight tags, while others said they needed to include things like the SID, Wake Category, etc. One possible resolution to this could be that the information would just show the flight ID by default, and then expand when the gaze was nearby. Also, with the introduction of RECAT EU pair-wise separations, including the Wake category will not be helpful as there are 96 categories. Given that the exclusion of the low-outlier raises the score, we consider that **the results are OK, but just slightly.**

3.3.4 OBJ-RETINA-VALP- HF-04 Results

Success Criterion 001: The displayed information is timely and correctly prioritised.

Again, the results for HF-04 are slightly above average, even with the low outlier removed.

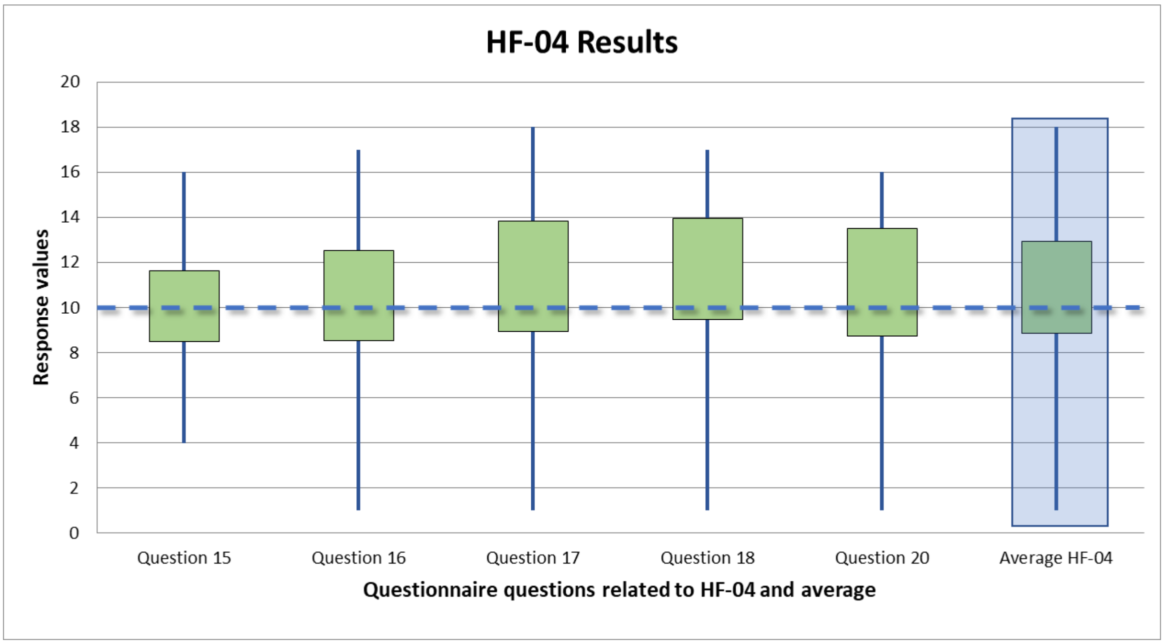


Figure 63 Controller appreciation of information timeliness and prioritization

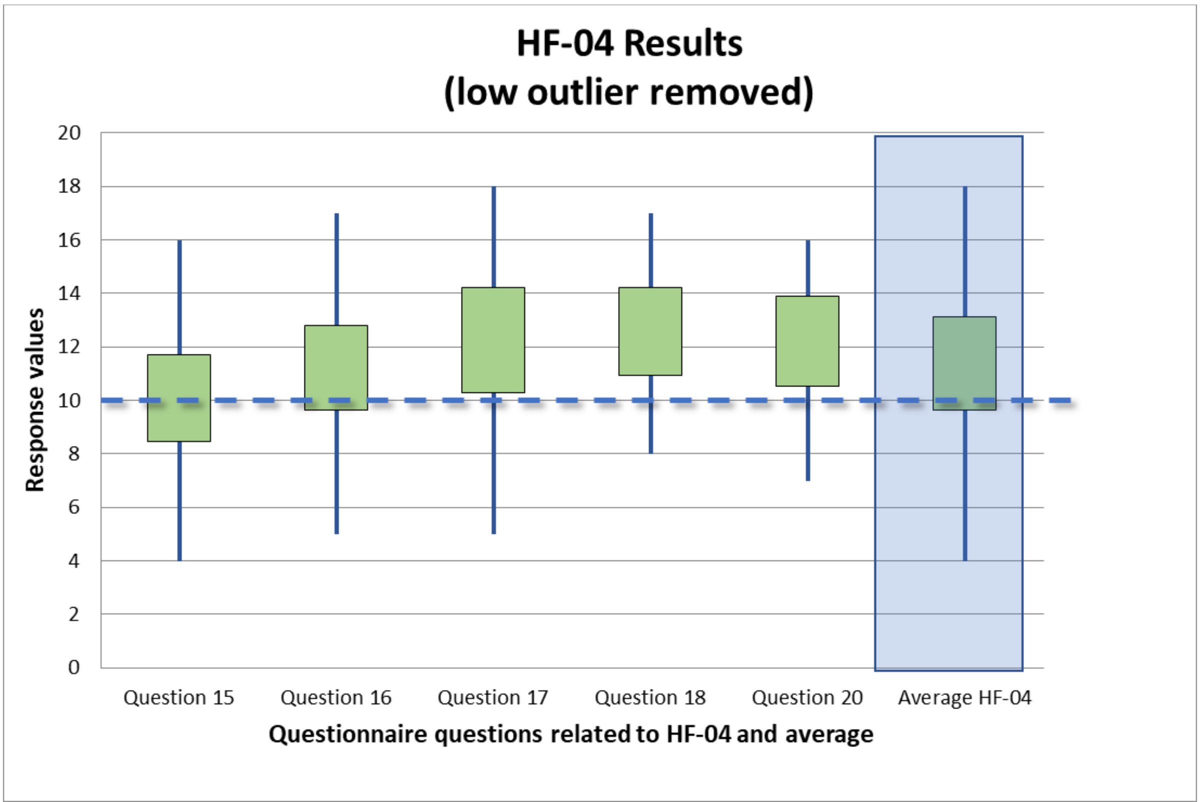


Figure 64 Controller appreciation of information timeliness and prioritization (low outlier removed)

The written responses stated that it was good that the flight tags appeared related to the closeness of EOBT and CTOT. However, when the tags were moved, sometimes they could get lost. This is due to the three-dimensional nature of the tags. They are currently constructed to be a certain height above the aircraft. So, when the aircraft is far away from the controller, the distance between the tag and the aircraft could be a few hundred meters relative to the size of the aircraft. So, when the aircraft gets close to the tower, the tag can be above where the controller is looking, since it maintains those hundred meters of vertical distance from the aircraft. This is something that should be investigate in further research. Also, many controllers mentioned that they did not like how the METAR information followed their gaze; that it was overpresent. Suggestions to pin it to a physical location, like the runway threshold, were voiced. Over all, **the timeliness and prioritization of the information was deemed to be OK.**

3.3.5 OBJ-RETINA-VALP- HF-05 Results

Success Criterion 001: Controllers consider the displayed information to be adequate to perform their tasks.

As with other objectives, HF-05 results became noticeably improved with the removal of the low outlier. Even with its inclusion, the results were above average.

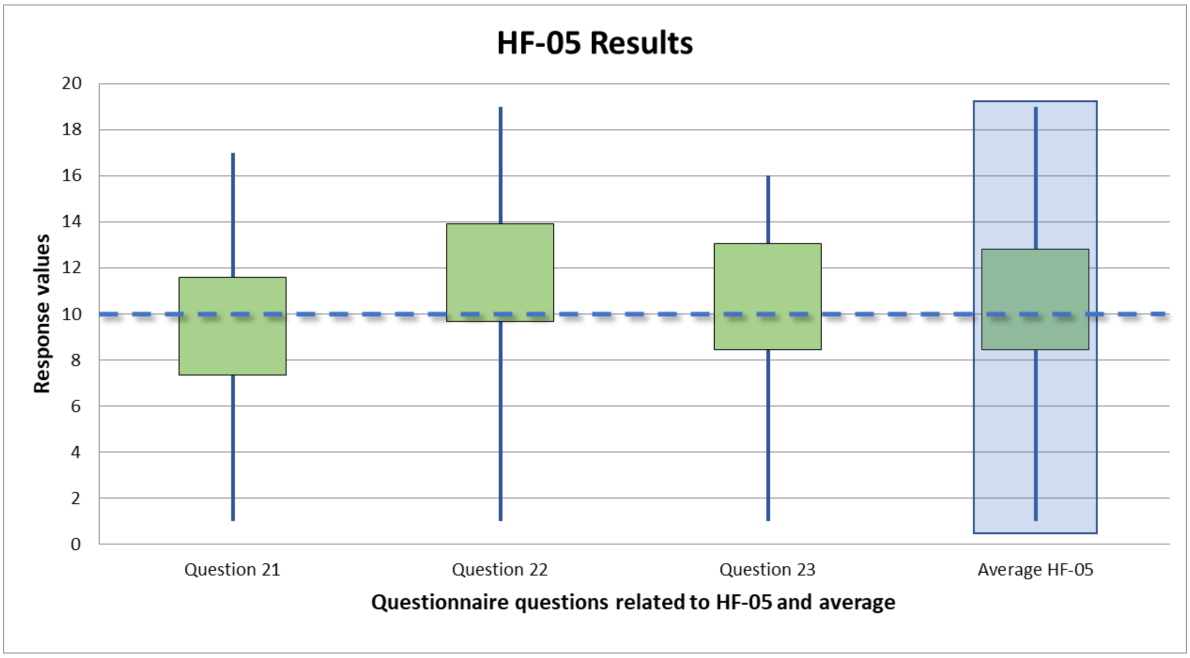


Figure 65 Controller appreciation of information adequacy for task performance

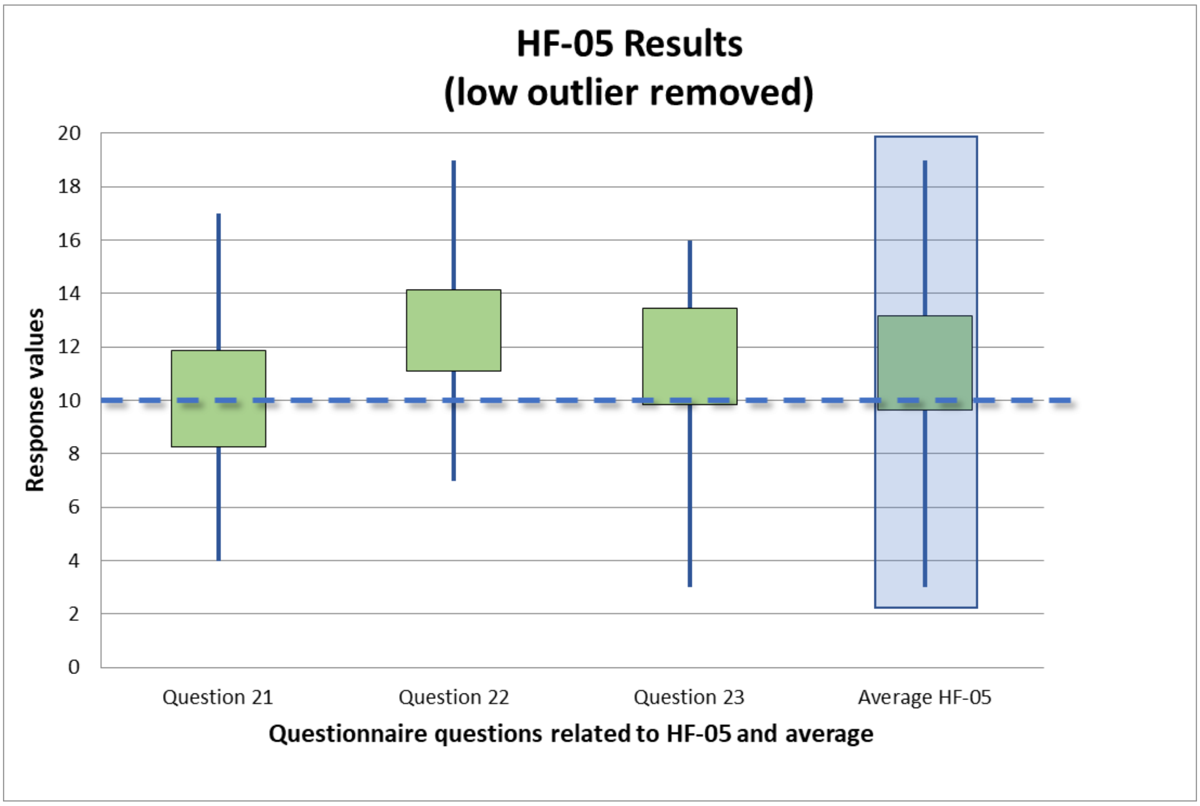


Figure 66 Controller appreciation of information adequacy for task performance (low outlier removed)

The text responses focused on desires that the flight tags functioned like the ones currently on their heads down displays. When flight tags came close to coming into conflict, one would move out of the way in order avoid overlapping. Other comments mentioned that the tilting of the tags with the head was bothersome and that they should stay fixed relative to the horizon. However, given the marks that the controllers gave the questions, these were seen as room for improvement and not something that prevented the success of this validation objective. **The results are OK**

3.3.6 OBJ-RETINA-VALP- HF-06 Results

Success Criterion 001: Controllers consider information finding and sorting quick, easy, practical and intuitive.

The results related to HF-06 were the best of all the objectives, with the average of the three questions clearly above average, even with the low outlier included.

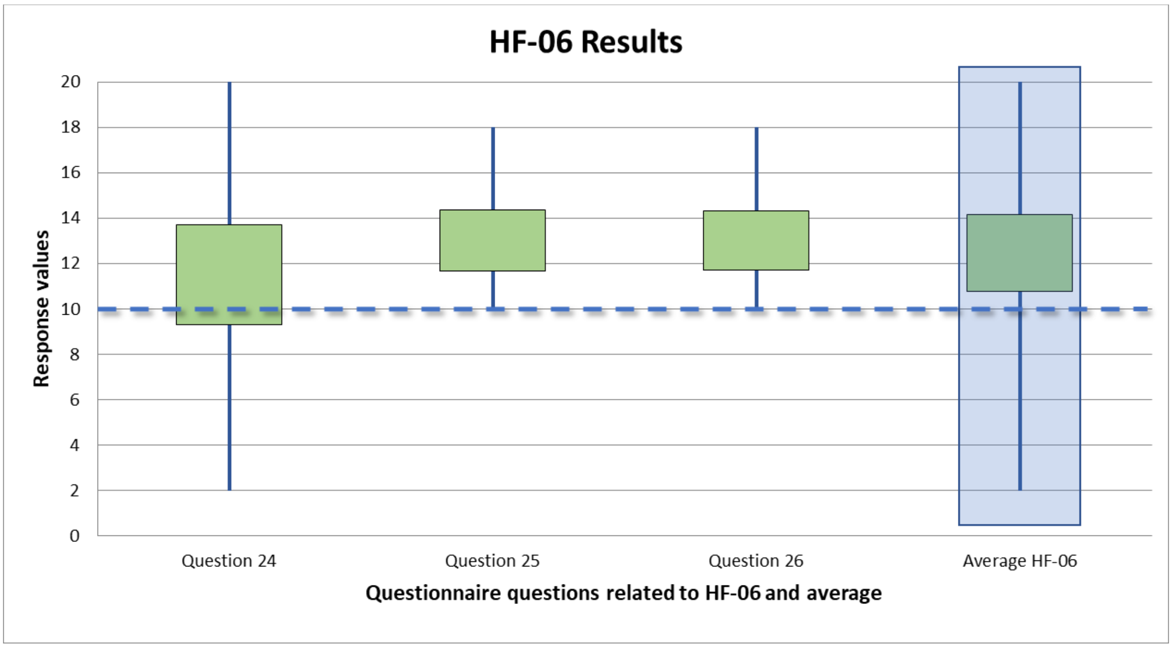


Figure 67 Controller appreciation of ease of finding and sorting information

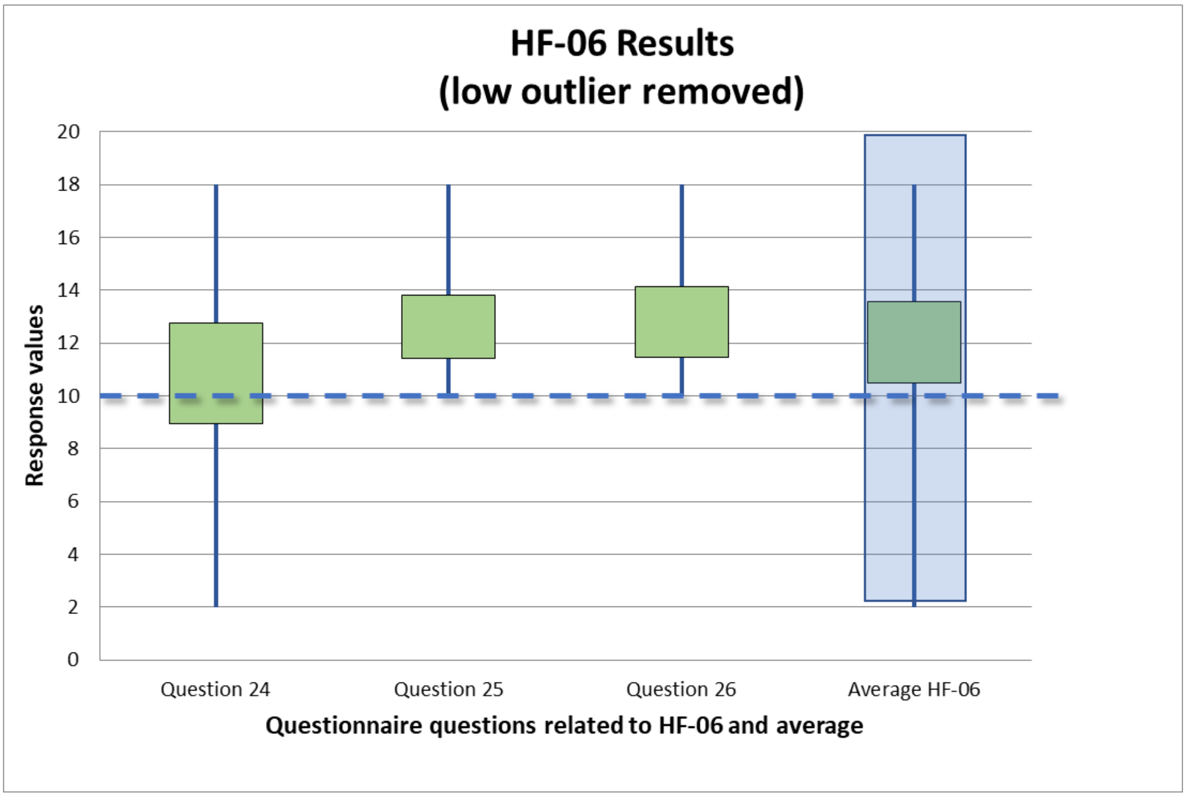


Figure 68 Controller appreciation of ease of finding and sorting information (low outlier removed)

The text responses were the same for HF-06 as they were for HF-05; the tags should not conflict or overlap, and they shouldn't tilt. **The results are OK.**

3.3.7 OBJ-RETINA-VALP- HF-07 Results

Success Criterion 001: HMI objects provide adequate feedbacks for each controller input

HF-07 results were also above average, even with the inclusion of the low outlier. As only one question was related to HF-07, no average was calculated.

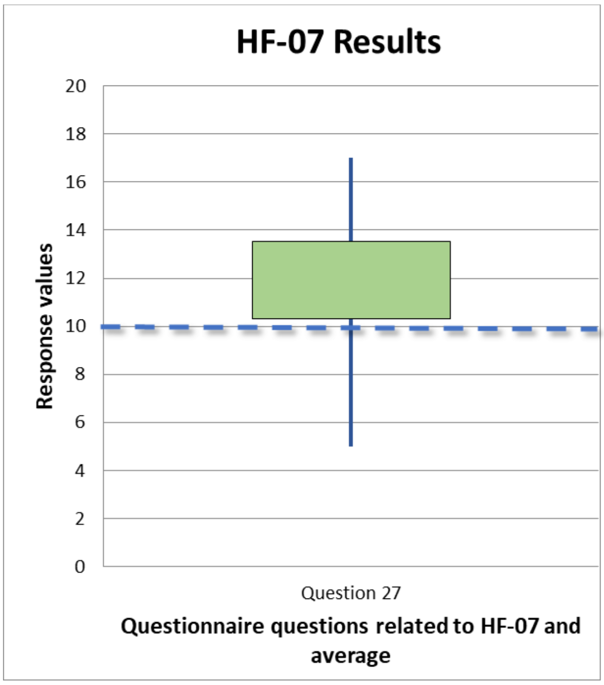


Figure 69 Controller appreciation of HMI feedback to input

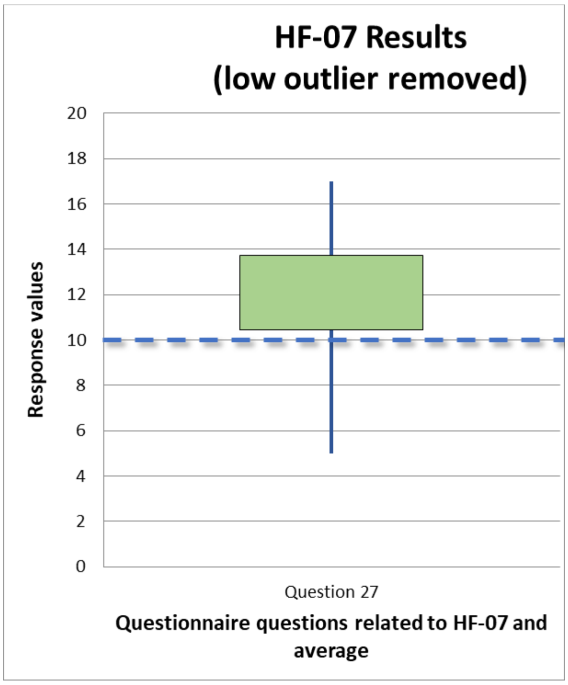


Figure 70 Controller appreciation of HMI feedback to input (low outlier removed)

There were not many comments regarding HF-07 worthy of note other than one that mentioned that the use of the HMD could be improved through the inclusion of a keyboard or joystick as a secondary input method. However, given the marks that the controllers gave the questions, these were seen as room for improvement and not something that prevented the success of this validation objective. **The results are OK**

3.3.8 OBJ-RETINA-VALP- HF-08 Results

Success Criterion 001: Controllers confirm that the outputs and triggers provided by the different tools and displayed on the HMI support them during the decision making process.

As with HF-07, HF -08 is related to only one question, so an average is not presented. The results were above an average score with the low outlier included.

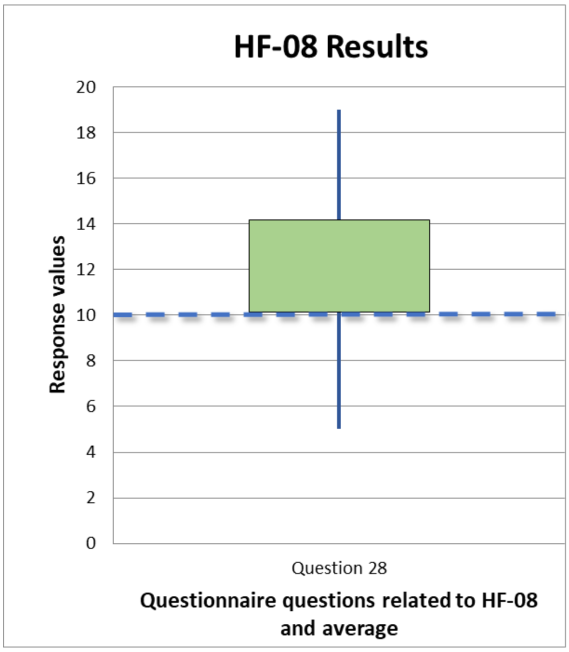


Figure 71 Controller appreciation of HMI output and trigger support to decision making

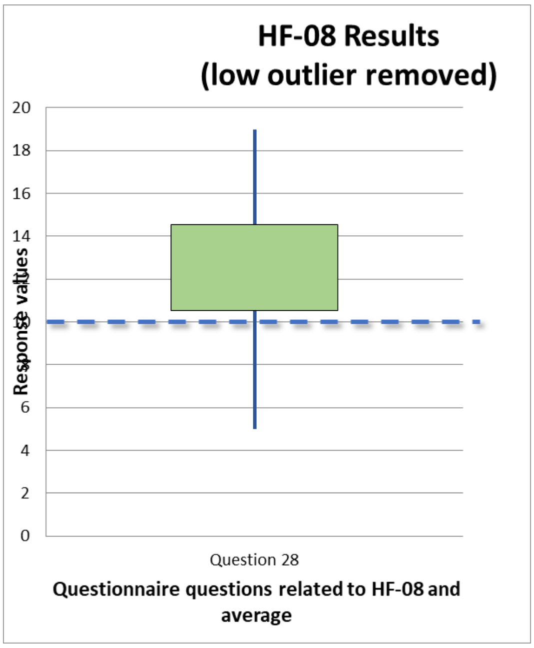


Figure 72 Controller appreciation of HMI output and trigger support to decision making (low outlier removed)

The only comment of note was a request for the inclusion of conflict alerts. As this was not part of the validated information being shown, but is foreseen to be included in further development, this is not seen as detrimental against the validation objective. Therefore, the results are **OK.**

3.4 High Level arguments for Human performance analysis

The SESAR methodology for transversal area assessment is considered as the reference for the validation approach [5][6][7][8]The RETINA Consortium assumes that the maturity level of the project (i.e. exploratory research targeting V1) justifies a partial application of the SESAR methodology for transversal area assessment.

Specifically, at this stage, the validation aims to define the impact of the RETINA concept on the high level arguments for Human Performance listed in table 7.

Arg. 1: The role of the human is consistent with human capabilities and limitations	
Arg. 1.1 Roles and responsibilities of human actors are clear and exhaustive.	*Role and responsibilities of human actors in the RETINA concept are the same as in the current practice.*
Arg. 1.2: Operating methods (procedures) are exhaustive and support human performance.	*The procedures in use support human performances as demonstrated in par.*
Arg. 1.3: Human actors can achieve their tasks (in normal & abnormal conditions of the operational environment and degraded modes of operation).	*The ATCO can achieve his/her tasks as demonstrated in par.*
Arg. 2: Technical systems support the human actors in performing their tasks.	
Arg. 2.1: There is an appropriate allocation of tasks between the human and machine (i.e. level of automation).	*The level of automation is the same as the current practice.*
Arg. 2.2: The performance of the technical system supports the human in carrying out their task.	*Technical systems used to test the RETINA concept present information in a head-up conformal view in order to support the ATCO in carrying out his/her task.*
Arg. 2.3: The design of the human-machine interface supports the human in carrying out their tasks.	*The design of the human-machine interface supports the ATCO in carrying out his/her task. Nevertheless the HMI should be improved based on the feedback collected in EXE11.*
Arg. 3: Team structures and team communication support the human actors in performing their tasks.	
Arg. 3.1: Effects on team composition are identified.	*At this stage, the concept is not affecting team composition.*
Arg. 3.2: The allocation of tasks between human actors supports human performance.	*At this stage, the allocation of task between human actors is the same as in the current practice.*
Arg. 4: Human Performance related transition factors are considered	
Arg. 4.1: The proposed solution is acceptable to affected human actors.	*The ATCOs involved in the validation provided very good feedback about acceptability of both solutions.*
Arg. 4.2: Changes in competence requirements are analysed.	*At this stage, the proposed concept does not call for any change in competence requirements.*
Arg. 4.3: Changes in staffing requirements and staffing levels are identified.	*At this stage, the proposed concept does not call for any change in competence requirements.*

Table 7 Impact of the RETINA concept on the high level arguments for Human Performance

4 Conclusions and recommendations

4.1 Conclusions

This section gives a summary of the conclusions raised by the synthesis of the different Experimental exercises analysis. It prepares the recommendations.

Conclusions are divided in operational benefits and technical feasibility.

4.1.1 Conclusions on operational benefits

This section captures the main conclusions related to the added value of using the RETINA concept in comparison with current tower operations:

- the RETINA concept has a clear effect in stimulating the ATCO to work in a head-up position more than in a head-down position.
- The ATCO is provided with a unique conformal representation of all the needed information that is currently provided by means of several visual inputs.
- When low visibility conditions apply, the use of RETINA tools provides the ATCO with a head up conformal view of all needed information, leading to the reduction of current restrictions due to LVP, with consequent increased throughput.
- The proposed solutions provide quantified benefits in terms of mental workload, temporal workload, performance, effort, frustration, information accessibility, and head-down time.
- The operational benefits provided by the two conceptual solutions explored, namely HMD and SD, are comparable.
- RETINA tools proved to preserve safety. Moreover they lead to safety improvement as they enhance situational awareness.
- In the usability test performed on HMD the controllers were quite optimistic about the operational benefits regarding the use of this solution. One of the controllers in RTS11 wrote "At the cognitive level, the sense of workload was reduced (IMHO) because I did not have to take a look at my flight strips or the distance radar to check who an aircraft was." Another wrote regarding the use in LVC, "That would be, in fact, the perfect fit for a first application, and with a significant reduction of workload."

4.1.2 Conclusions on technical feasibility

This section captures the main conclusions related to the technical feasibility of the RETINA concept:

The implementation in a laboratory environment of both conceptual solutions served as proof of concept.

The following technical issues were achieved with the current validation:

- Compatibility of the technology used with the current data provision format;
- Capability of tracking the user position;
- capability of providing the user with a conformal head-up view of synthetic information overlapped to the out-of the tower view.

As far as the SD solution is concerned, it is worth remembering that the Augmented Reality technology for this solution is not yet available, thus this solution achieves TRL2.

On the other hand, since the HMD Augmented Reality technology is more mature, its application does achieve TRL3. However, since this technology is not yet mature enough for full deployment in a safety critical environment, further research is required to demonstrate it in a real environment.

4.2 Recommendations

This section captures the main recommendations to improve the technical feasibility of the process and potential applications:

- Perform an update of the operational concept described in [2] and report it in a dedicated document. This document should include a revision of the RETINA ConOps for both conceptual solutions taking into account the validation results;
- Test the most mature solution, i.e. Head Mounted Display, in a real control tower under real operative and visibility conditions. This would improve the maturity of the solution, validating it in a real environment in order to achieve TRL5-6 (V2);
- Continue testing the less mature solution in a simulated environment, i.e. Spatial Display, considering different evolution scenarios for this technology, and including multi-user operations.
- Study the option to have the flight tags avoid each other so that they do not overlap at any time and they do not obstruct any relevant point in the airport. Consider billboard's transparency as an option;
- Refine the size of the flight tags. Make the tags expand to show the useful information when requested, but just the flight ID otherwise. Customize the flight tags information based on the phase of flight;
- In the Head Mounted Display solution, change the METAR display to make the wind direction more readable, and make it fixable to a location in the scene.
- Change the colours so that there is a more uniform colour, but still differentiate between arrivals and departures. Remove the red and only use it in cases of warnings.

- For the most mature solution, i.e. Head Mounted Display, analyse safety requirements for the introduction of the technology in the airport control tower, including the availability of safety-critical graphical libraries, safety-critical devices, redundancy of information and systems;

Although several benefits were observed/recorded or inferred by the simulation activities, a few ‘issues’ were also noted, which, if the concept were to be developed, would need to be addressed.

These include but are not limited to:

- In its present version, the Head Mounted Display used for the validation should not be used continuously for a long time. Further study should investigate what time limit, if any, should apply for the continuous use of such a device in the control tower.
- The AR technology for Spatial Display is not yet mature. The main limitations for this technology are screen size, costs, and the possibility to provide AR holograms to multiple users looking at the same device. While the first two issues will be likely overcome in the next decade, the latter might take more time to get over. This being said, further testing of the concept should continue in a simulated environment to further develop the concept.

5 References

[1] D1.1 RETINA, State of Art and Initial Concept Requirements, Ref. Ares(2016)5158626, Edition 00.01.00, 10/09/2016

[2] D2.1 RETINA, Operational Concepts Description, Ref. Ares(2017)1073072, Edition 00.02.00, 28/02/2017

[3] D4.1 RETINA, Validation Plan, Ref. Ares(2017)4837437, Edition 00.01.00, 04/10/2017

[4] D7.1 RETINA, H-Requirement n.2, Ref. Ares(2016)6986318, Edition 00.02.00, 15/12/2016

[5] Project 16.04.01 D10 - Human Performance Assessment Process V1 to V3, Edition: 00.02.00, 16/12/2013

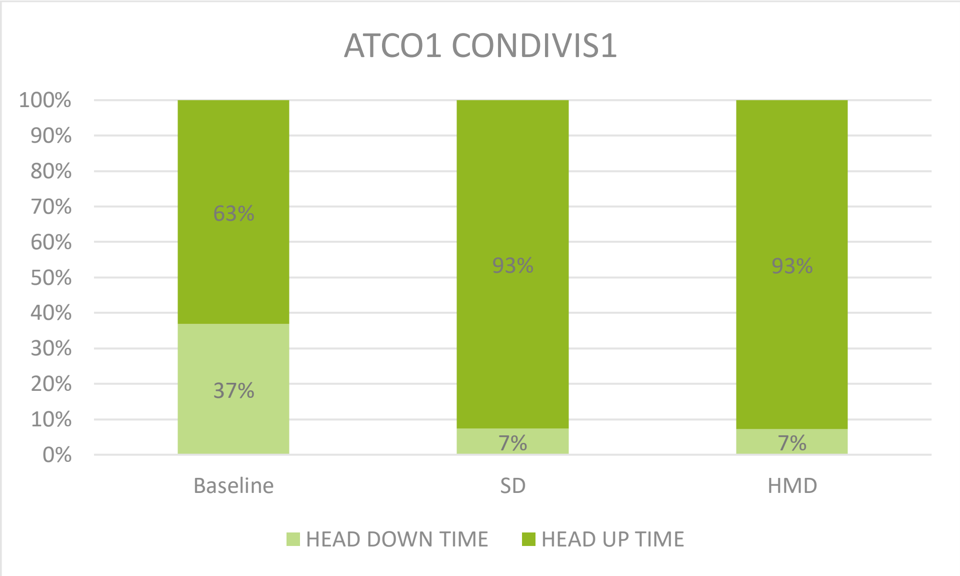
[6] Project 16.06.05, D26 - SESAR Human Performance Reference Material - Guidance Edition 00.01.01

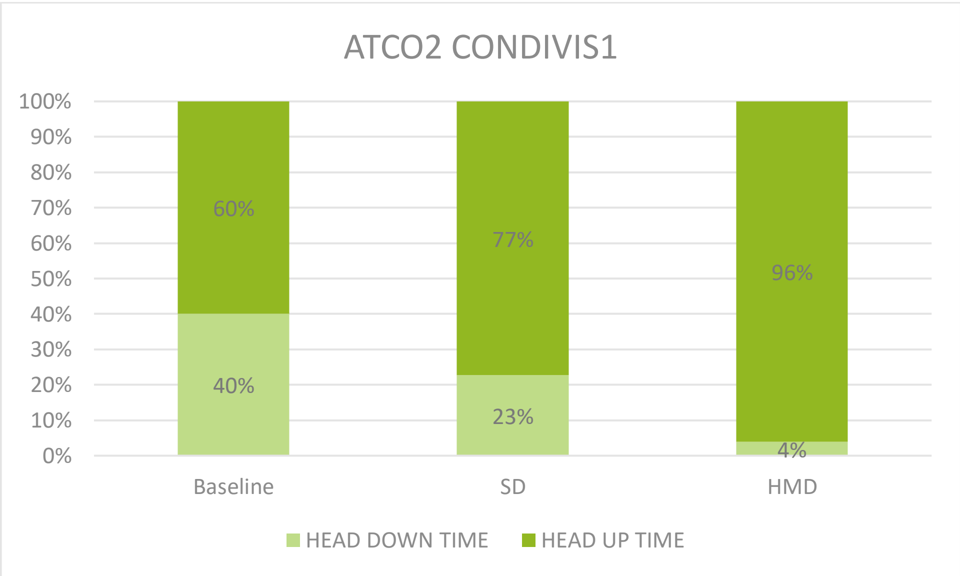
[7] Project 16.06.01, D27 - SESAR Safety Reference Material, Edition 00.04.00

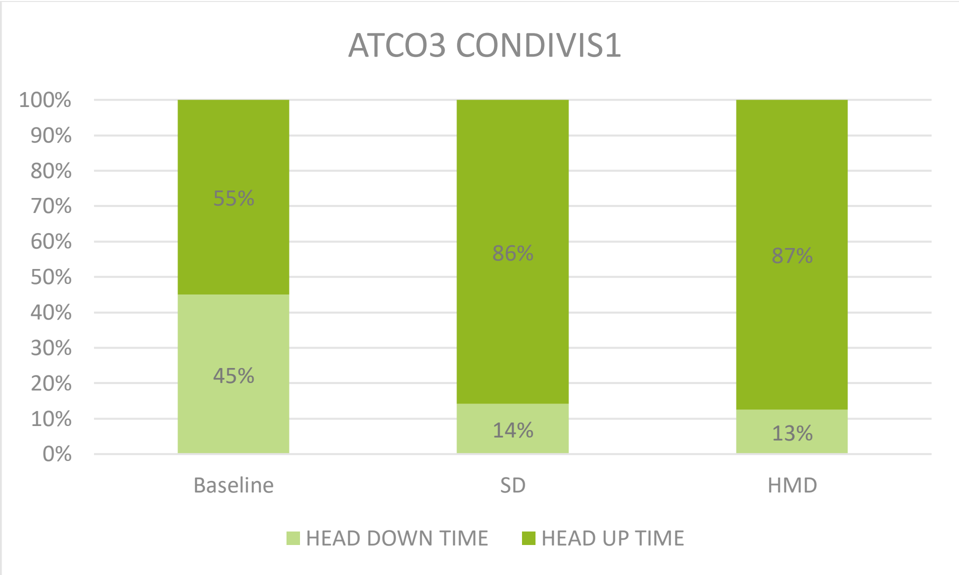
[8] D27 - Guidance to Apply the SESAR Safety Reference Material, Edition 00.03.00

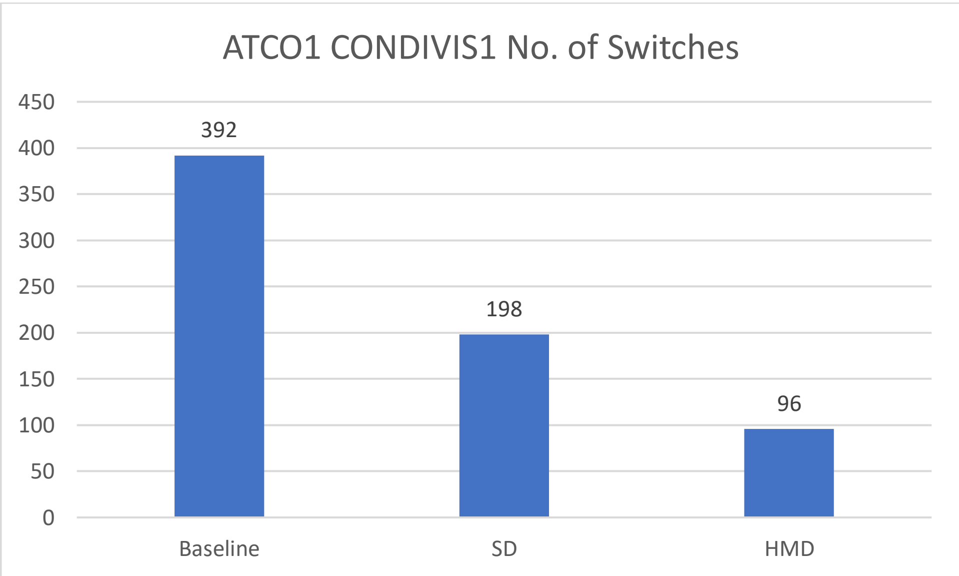
Appendix A Results for exercises 1-10

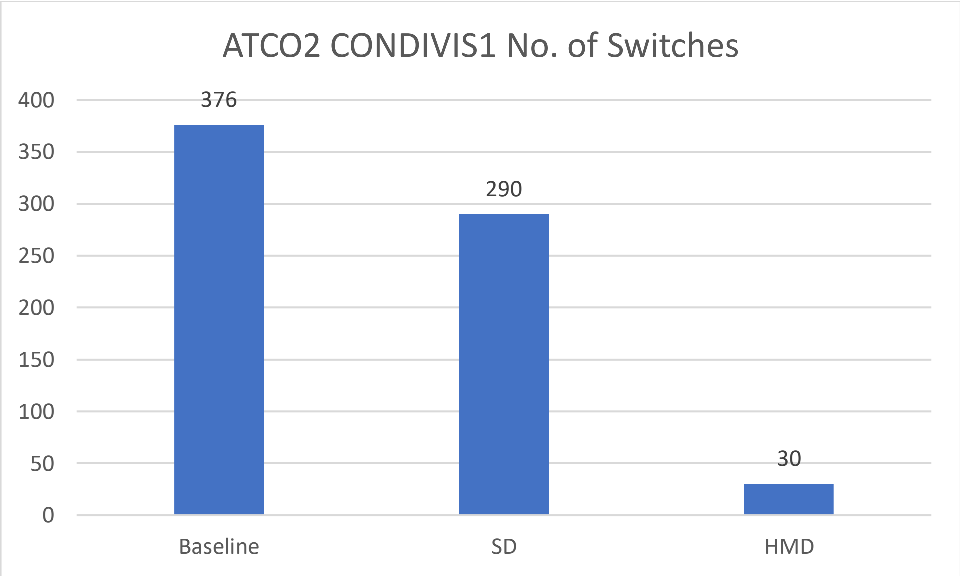
CONDIVIS 1: results for ATCO 1, ATCO2 and ATCO3

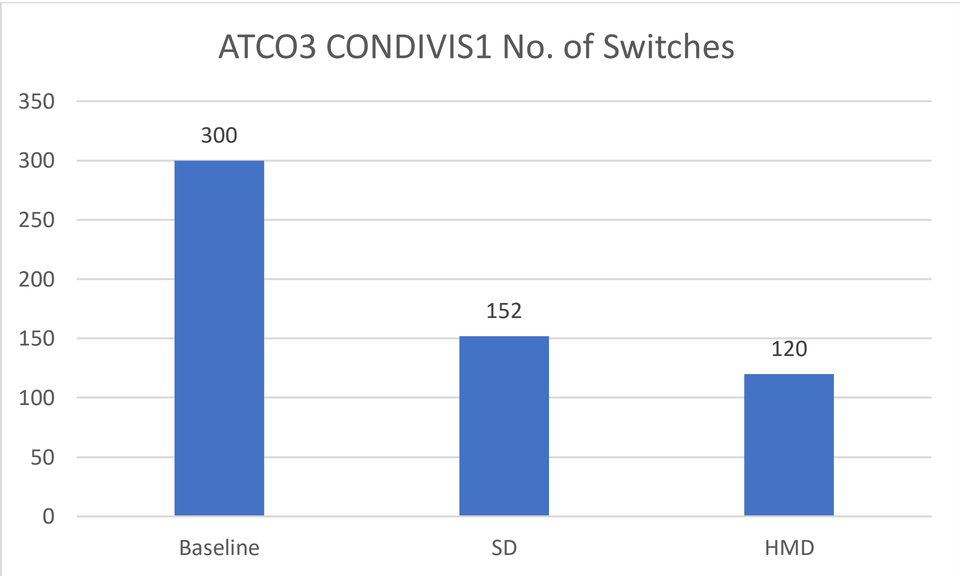


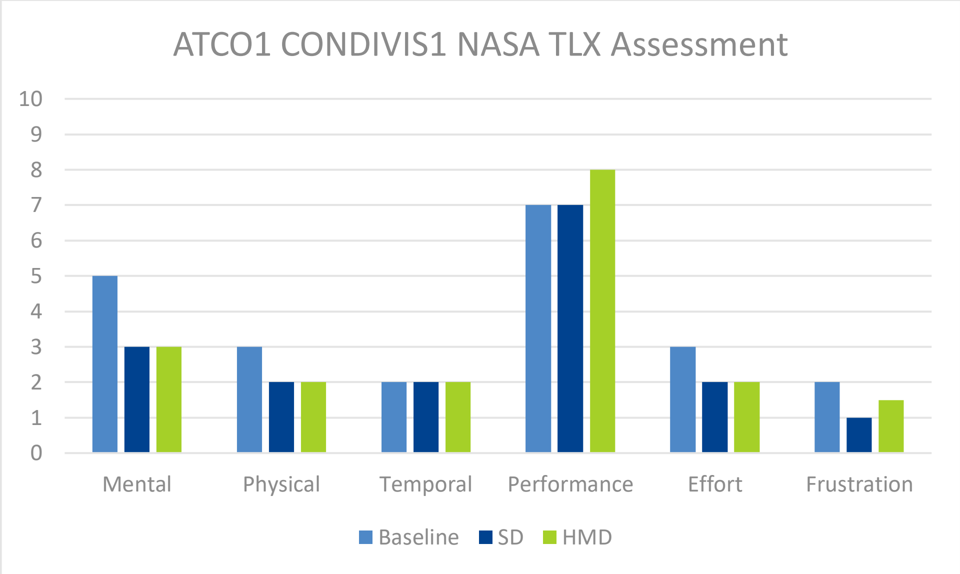


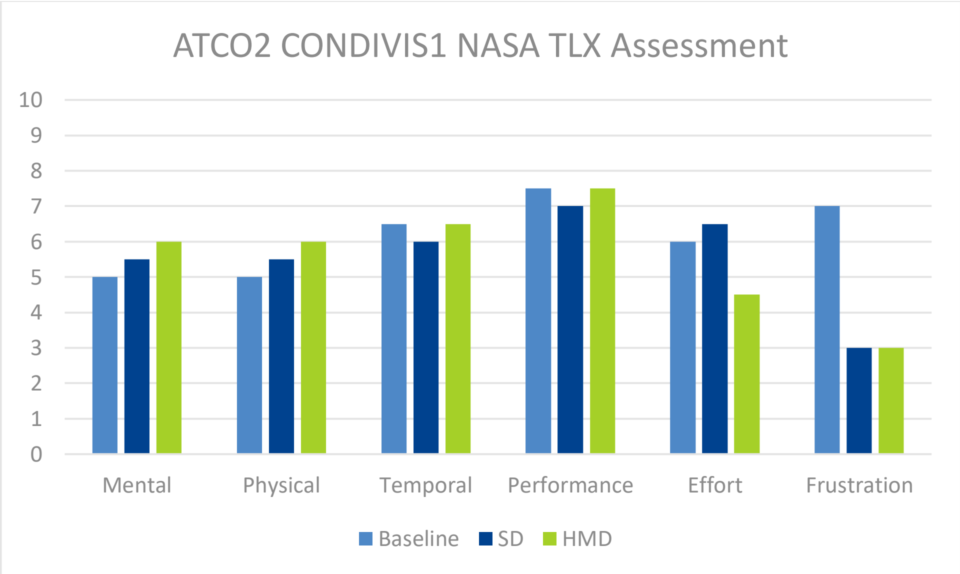

ATCO3 CONDIVIS1
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
55%
45%
86%
14%
87%
13%
Baseline
SD
HMD
HEAD DOWN TIME
HEAD UP TIME

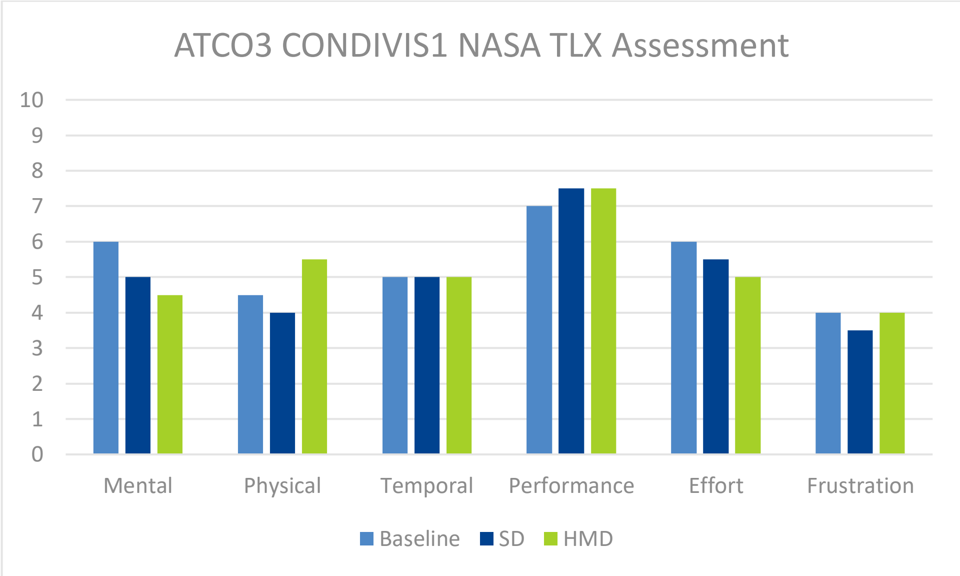

ATCO1 CONDIVIS1 No. of Switches
450
400
350
300
250
200
150
100
50
0
392
198
96
Baseline
SD
HMD

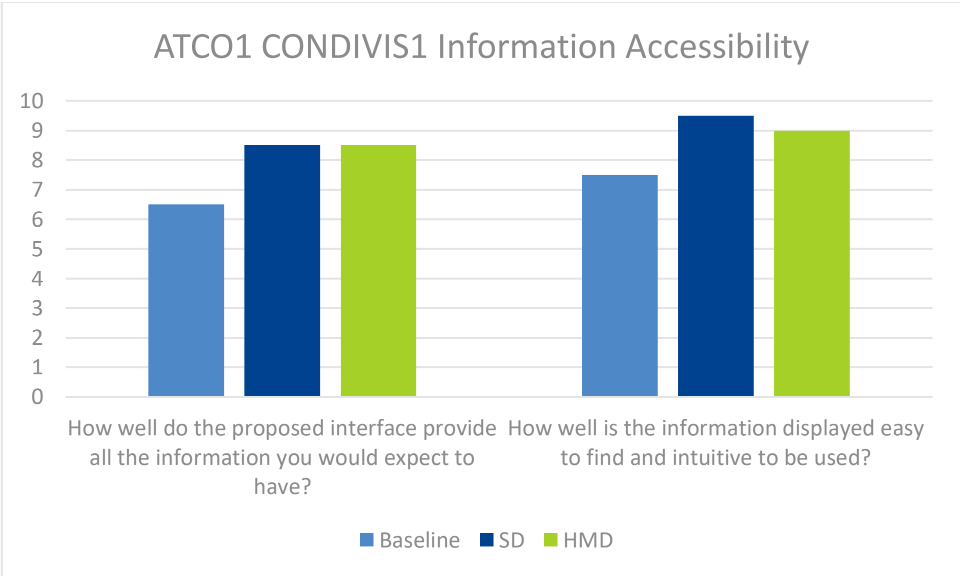

ATCO2 CONDIVIS1 No. of Switches
400
350
300
250
200
150
100
50
0
376
290
30
Baseline
SD
HMD

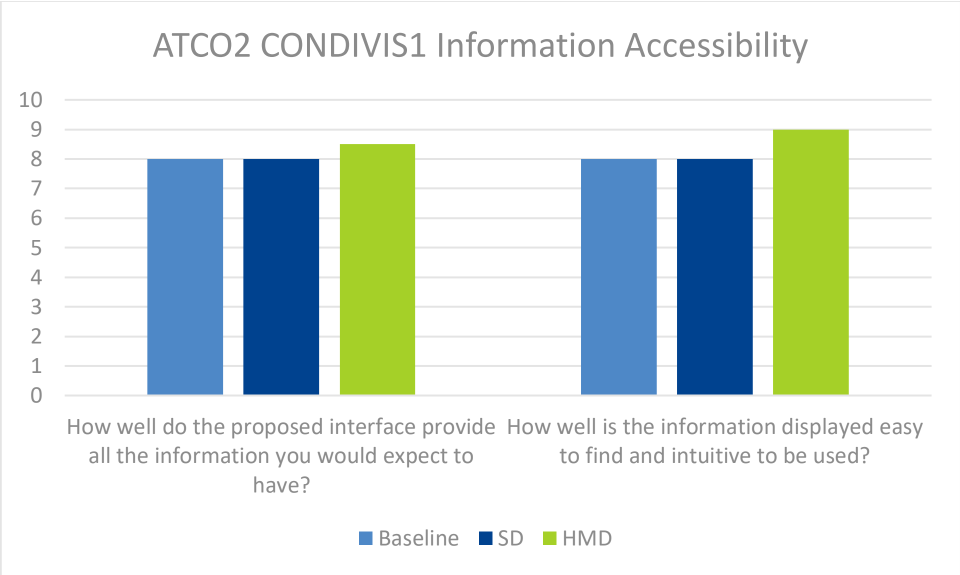

ATCO3 CONDIVIS1 No. of Switches
350
300
250
200
150
100
50
0
300
152
120
Baseline
SD
HMD

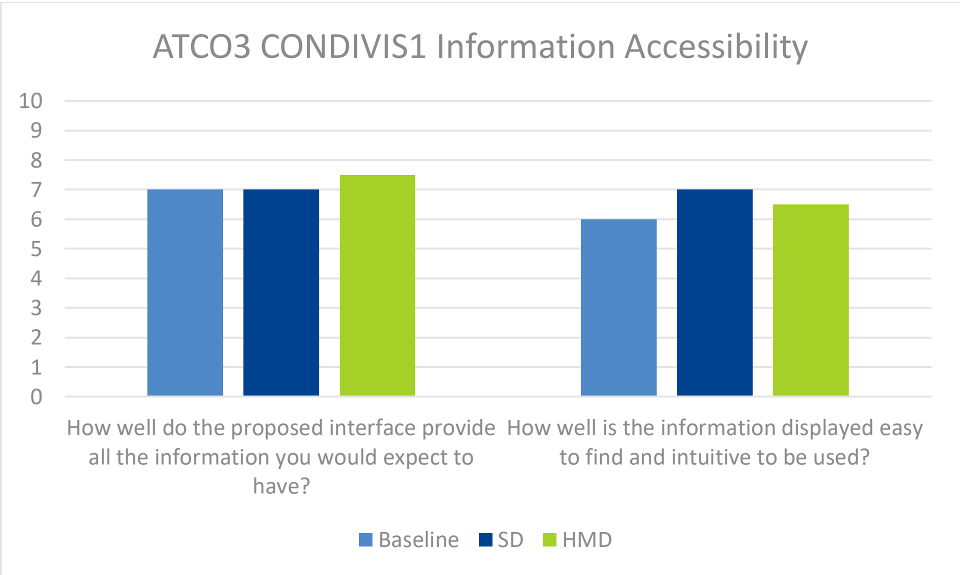

ATCO1 CONDIVIS1 NASA TLX Assessment
10
9
8
7
6
5
4
3
2
1
0
Mental
Physical
Temporal
Performance
Effort
Frustration
Baseline
SD
HMD

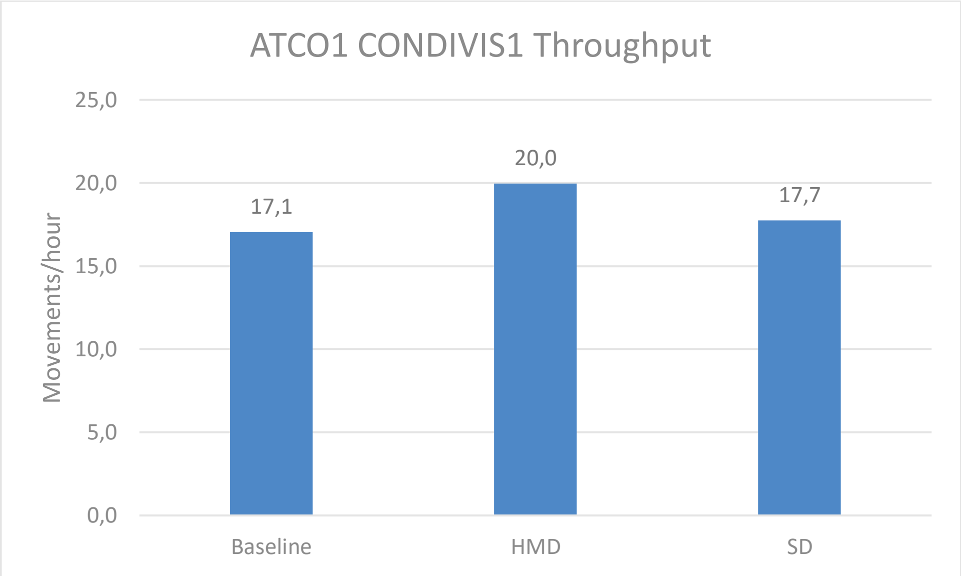

ATCO2 CONDIVIS1 NASA TLX Assessment
10
9
8
7
6
5
4
3
2
1
0
Mental
Physical
Temporal
Performance
Effort
Frustration
Baseline
SD
HMD

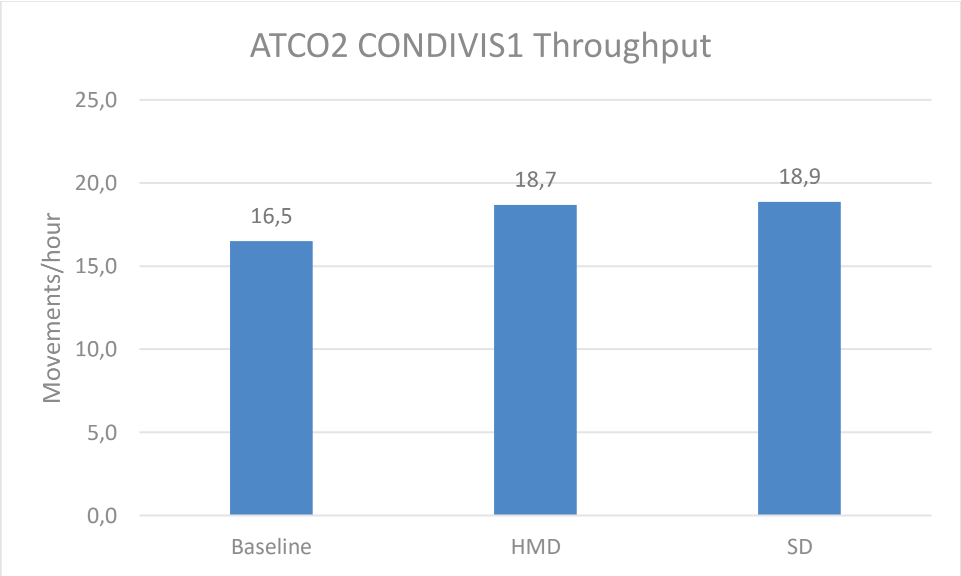

ATCO3 CONDIVIS1 NASA TLX Assessment
10
9
8
7
6
5
4
3
2
1
0
Mental
Physical
Temporal
Performance
Effort
Frustration
Baseline
SD
HMD

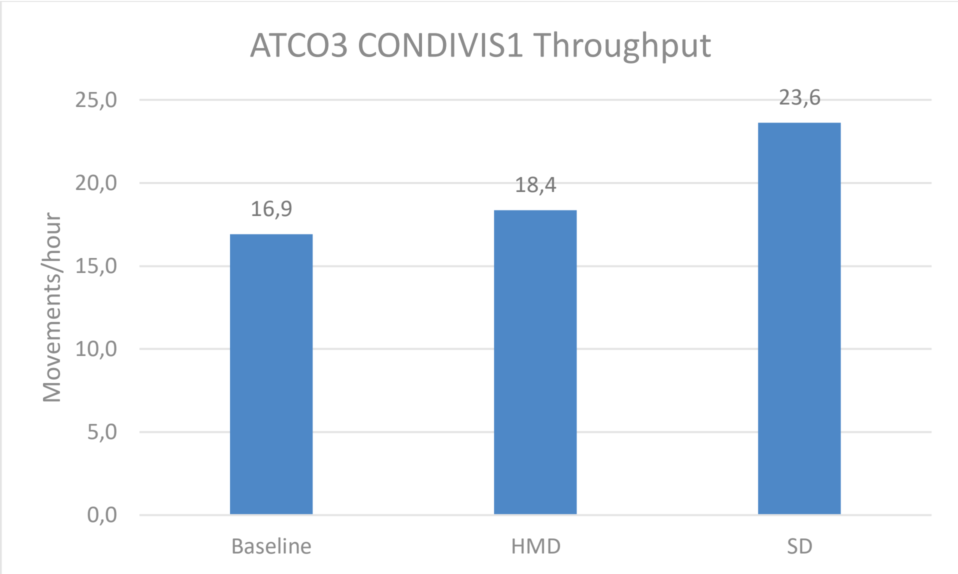

ATCO1 CONDIVIS1 Information Accessibility
10
9
8
7
6
5
4
3
2
1
0
How well do the proposed interface provide all the information you would expect to have?
How well is the information displayed easy to find and intuitive to be used?
Baseline
SD
HMD


ATCO2 CONDIVIS1 Information Accessibility
10
9
8
7
6
5
4
3
2
1
0
How well do the proposed interface provide all the information you would expect to have?
How well is the information displayed easy to find and intuitive to be used?
Baseline
SD
HMD

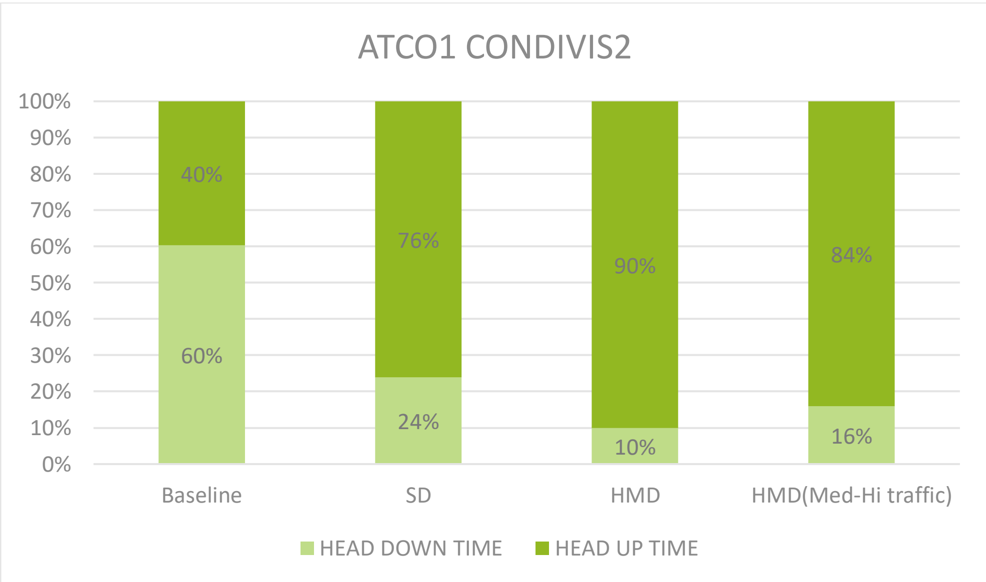

ATCO3 CONDIVIS1 Information Accessibility
10
9
8
7
6
5
4
3
2
1
0
How well do the proposed interface provide all the information you would expect to have?
How well is the information displayed easy to find and intuitive to be used?
Baseline
SD
HMD

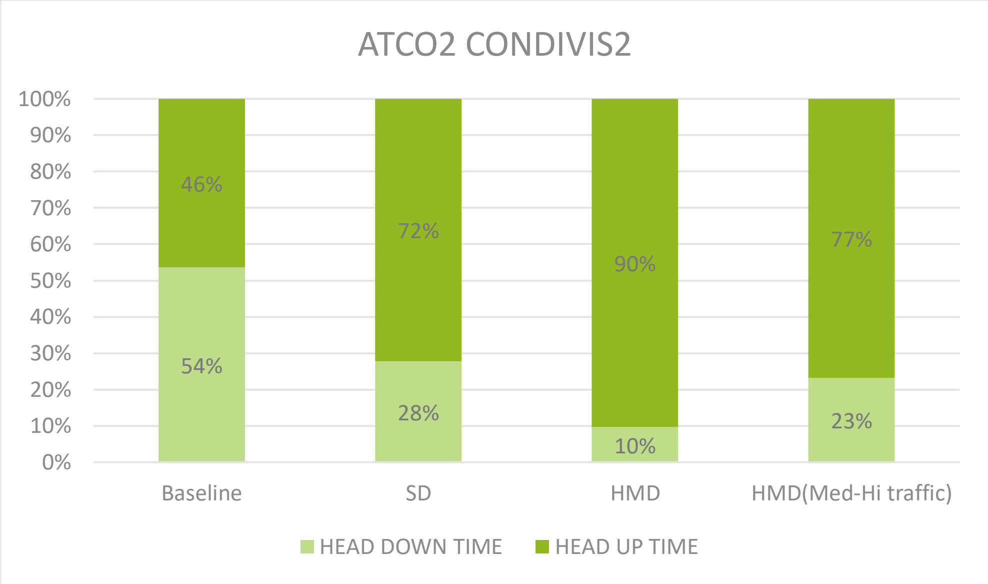

ATCO1 CONDIVIS1 Throughput
Movements/hour
25,0
20,0
15,0
10,0
5,0
0,0
17,1
20,0
17,7
Baseline
HMD
SD

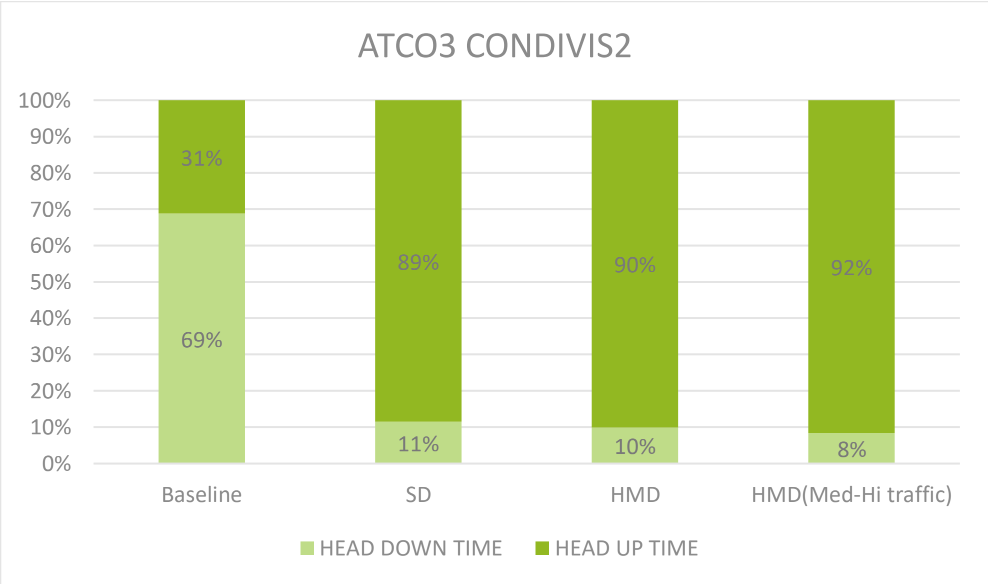

ATCO2 CONDIVIS1 Throughput
Movements/hour
25,0
20,0
15,0
10,0
5,0
0,0
16,5
18,7
18,9
Baseline
HMD
SD

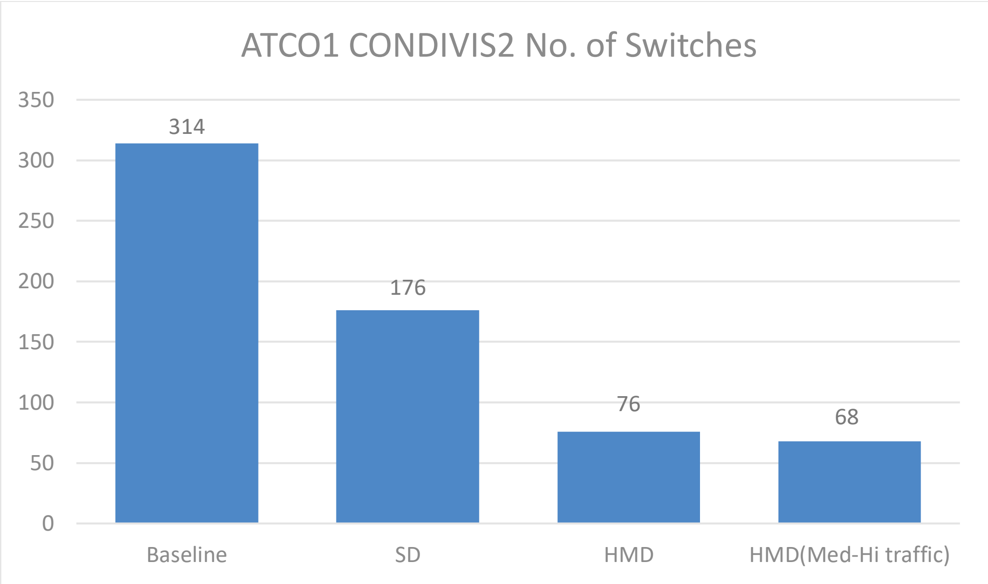


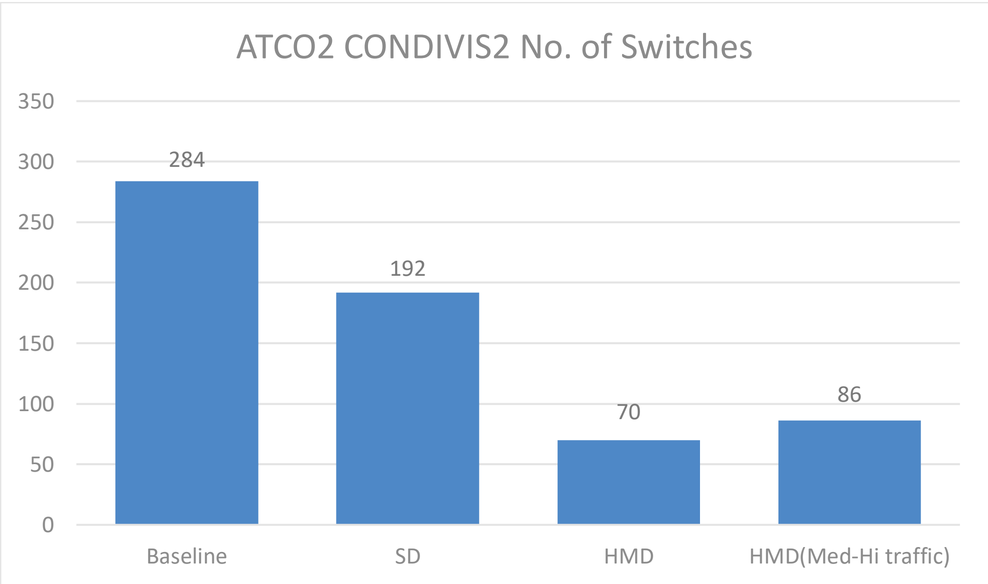
CONDIVIS 2: results for ATCO1, ATCO2 and ATCO3

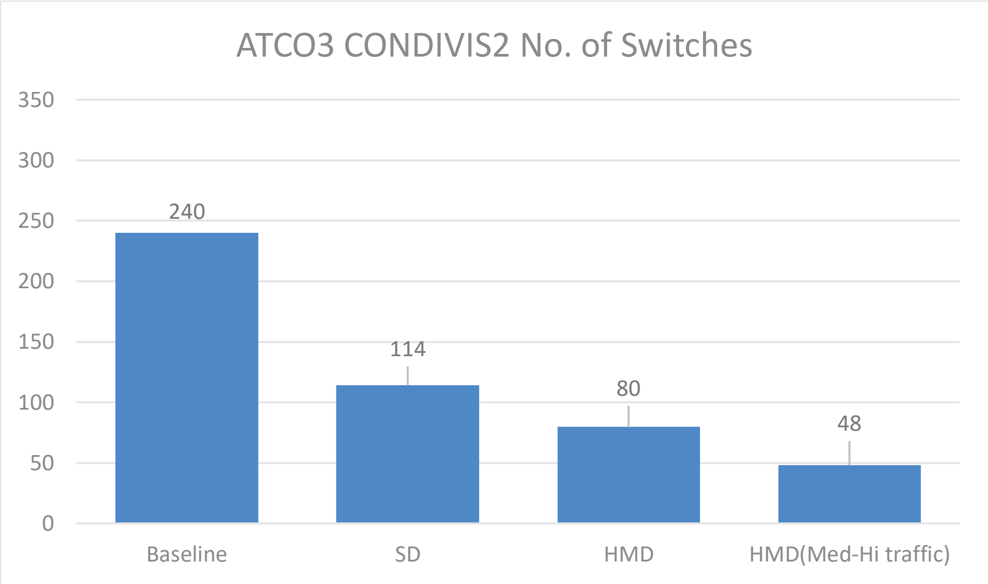


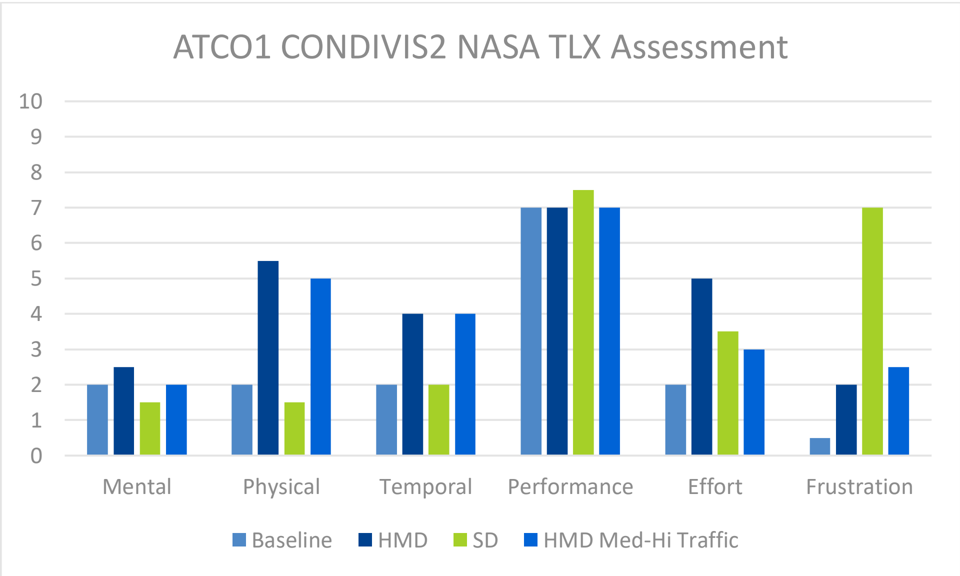

ATCO2 CONDIVIS2
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
46%
54%
72%
28%
90%
10%
77%
23%
Baseline
SD
HMD
HMD(Med-Hi traffic)
HEAD DOWN TIME
HEAD UP TIME

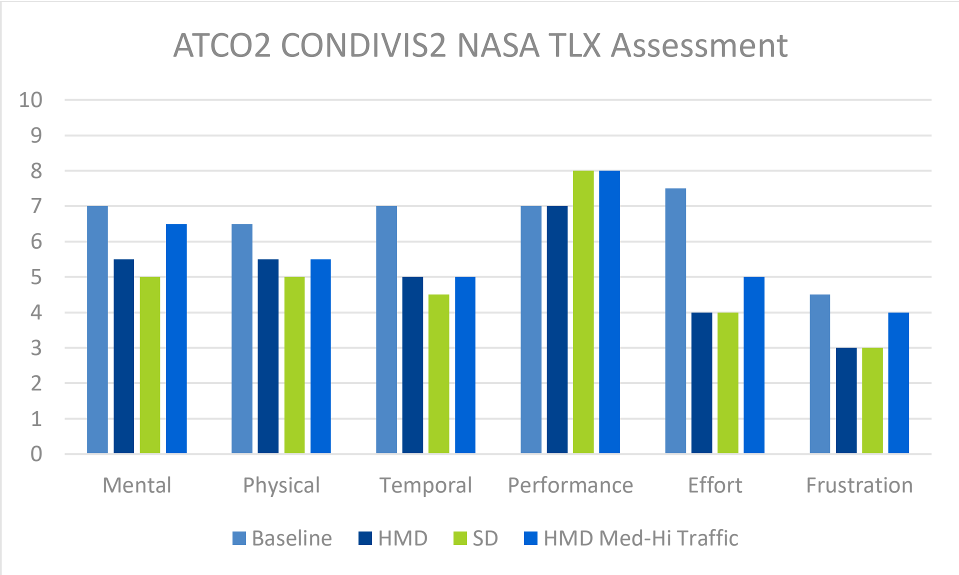

ATCO3 CONDIVIS2
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
31%
69%
89%
11%
90%
10%
92%
8%
Baseline
SD
HMD
HMD(Med-Hi traffic)
HEAD DOWN TIME
HEAD UP TIME

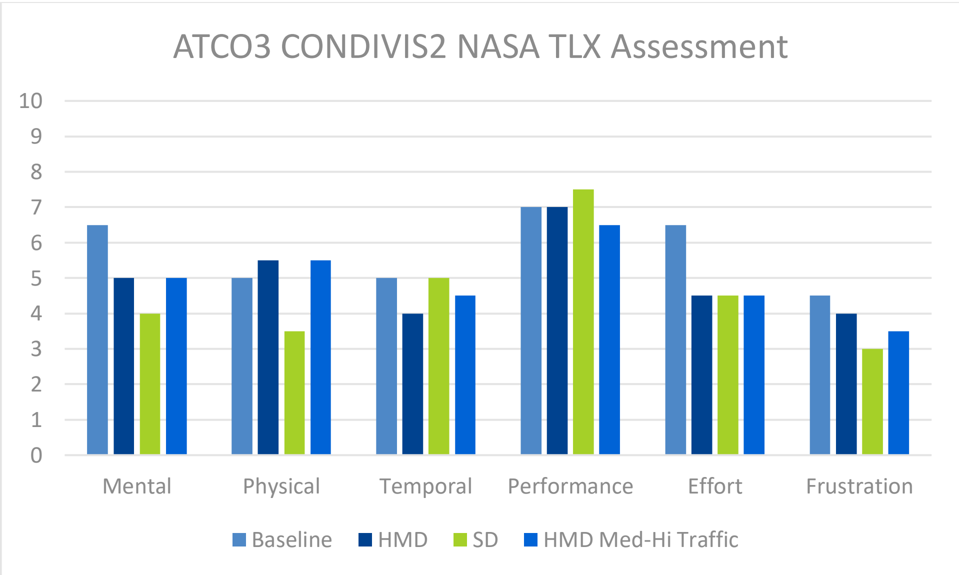

ATCO1 CONDIVIS2 No. of Switches
350
300
250
200
150
100
50
0
314
176
76
68
Baseline
SD
HMD
HMD(Med-Hi traffic)

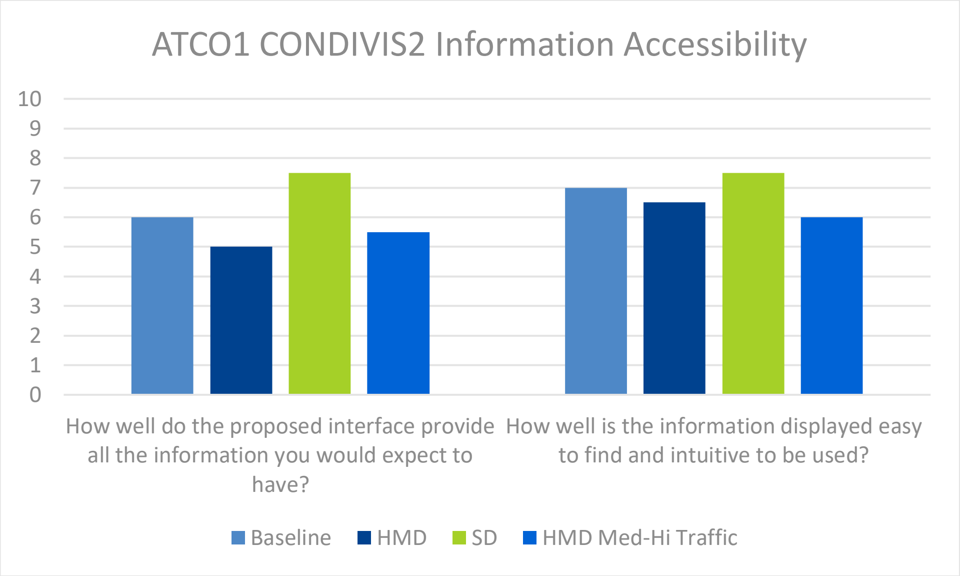

ATCO2 CONDIVIS2 No. of Switches
350
300
250
200
150
100
50
0
284
192
70
86
Baseline
SD
HMD
HMD(Med-Hi traffic)

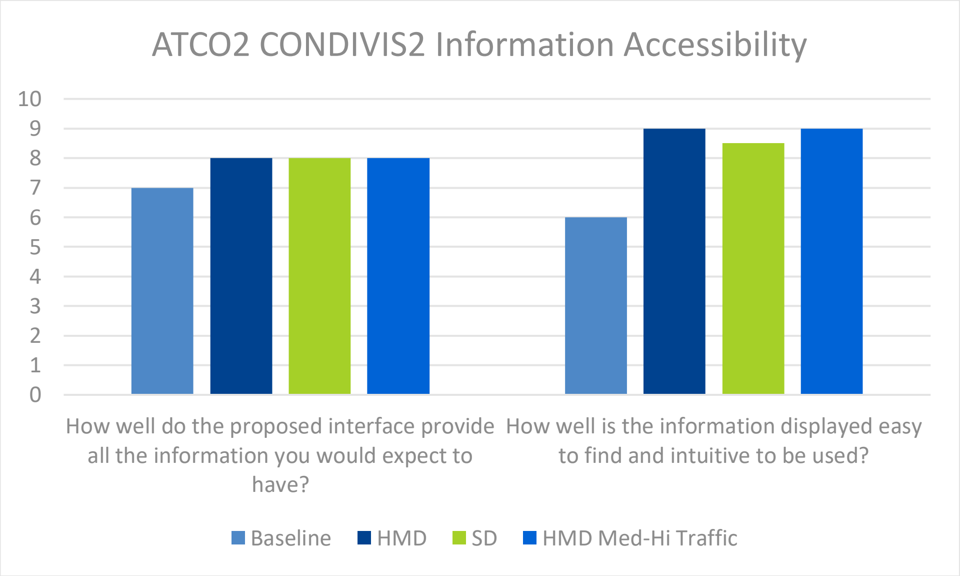

ATCO3 CONDIVIS2 No. of Switches
350
300
250
200
150
100
50
0
240
114
80
48
Baseline
SD
HMD
HMD(Med-Hi traffic)

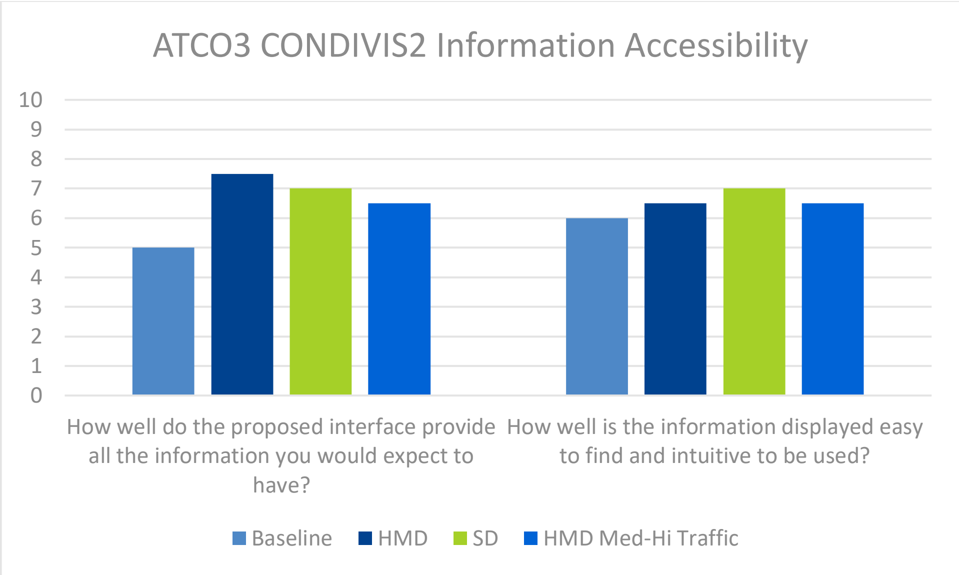

ATCO1 CONDIVIS2 NASA TLX Assessment
10
9
8
7
6
5
4
3
2
1
0
Mental
Physical
Temporal
Performance
Effort
Frustration
Baseline
HMD
SD
HMD Med-Hi Traffic

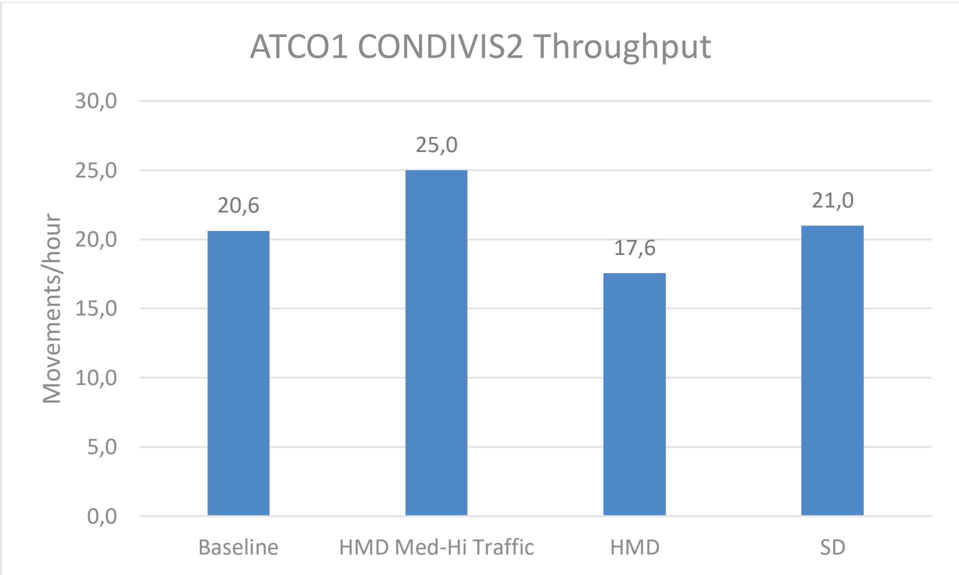

ATCO2 CONDIVIS2 NASA TLX Assessment
10
9
8
7
6
5
4
3
2
1
0
Mental
Physical
Temporal
Performance
Effort
Frustration
Baseline
HMD
SD
HMD Med-Hi Traffic


ATCO3 CONDIVIS2 NASA TLX Assessment
10
9
8
7
6
5
4
3
2
1
0
Mental
Physical
Temporal
Performance
Effort
Frustration
Baseline
HMD
SD
HMD Med-Hi Traffic

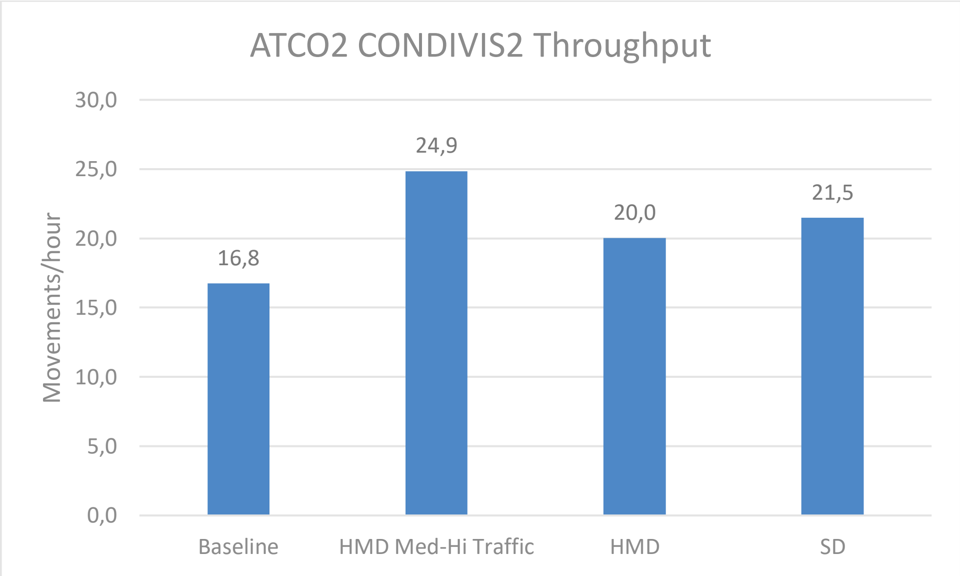

ATCO1 CONDIVIS2 Information Accessibility
10
9
8
7
6
5
4
3
2
1
0
How well do the proposed interface provide all the information you would expect to have?
How well is the information displayed easy to find and intuitive to be used?
Baseline
HMD
SD
HMD Med-Hi Traffic

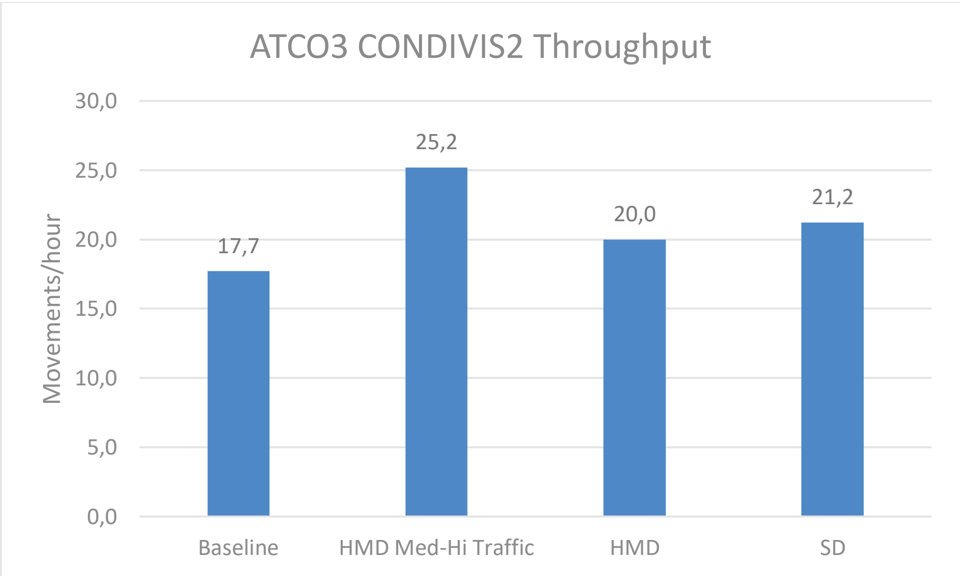

ATCO2 CONDIVIS2 Information Accessibility
10
9
8
7
6
5
4
3
2
1
0
How well do the proposed interface provide all the information you would expect to have?
How well is the information displayed easy to find and intuitive to be used?
Baseline
HMD
SD
HMD Med-Hi Traffic





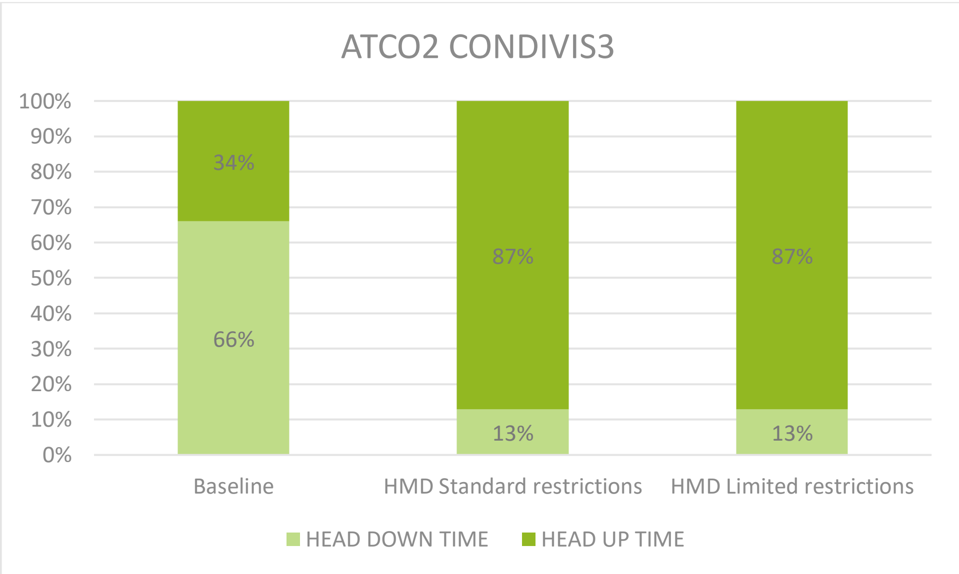
Founding Members

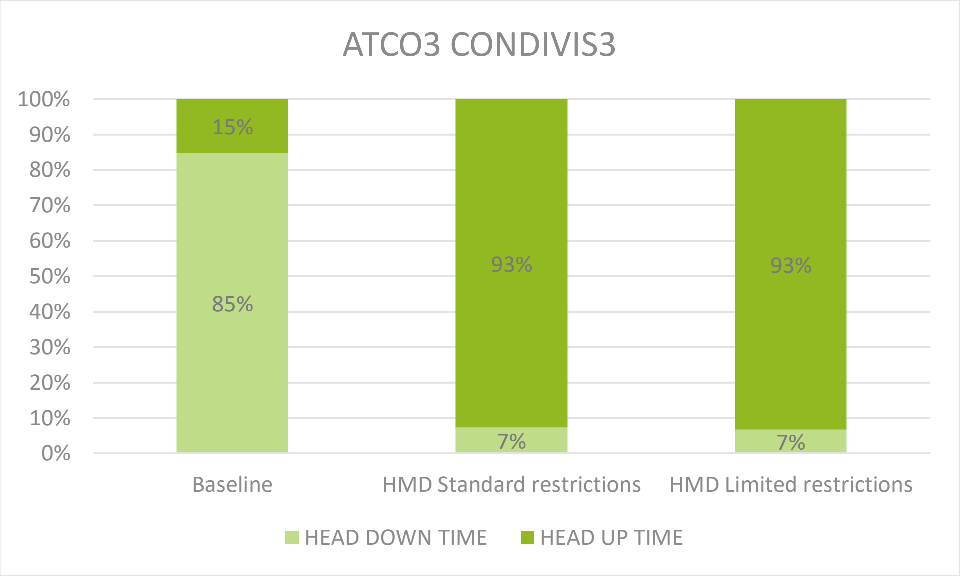


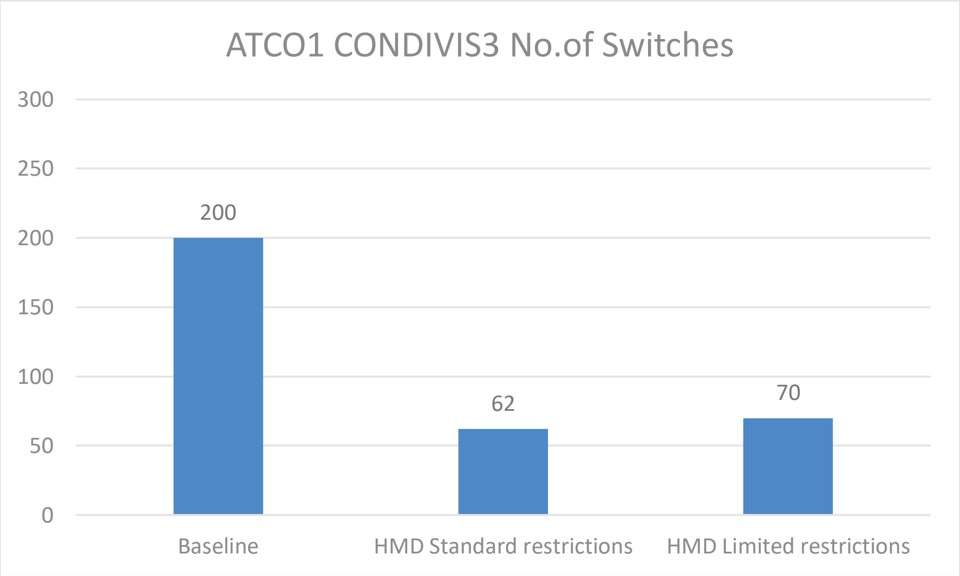


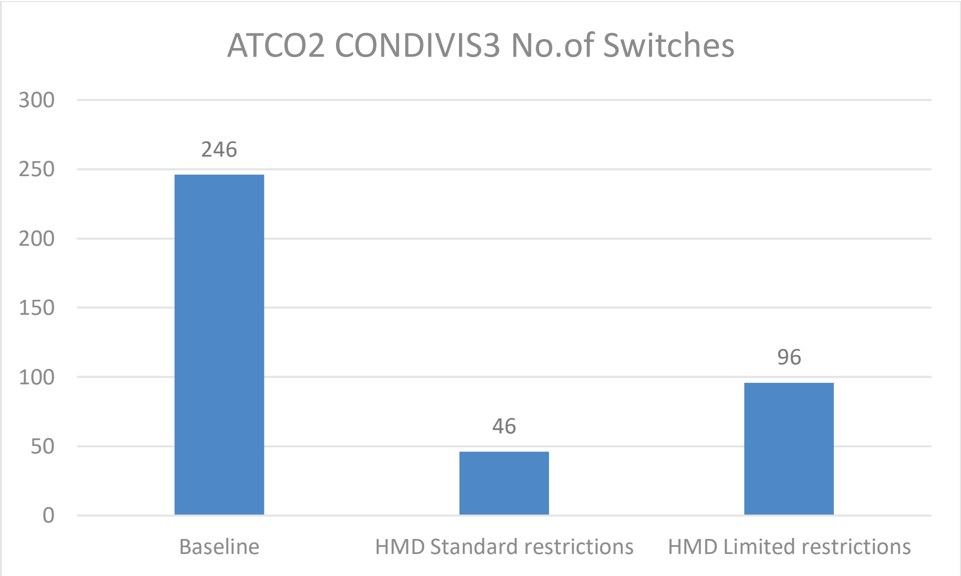
CONDIVIS 3: results for ATCO1, ATCO2 and ATCO3

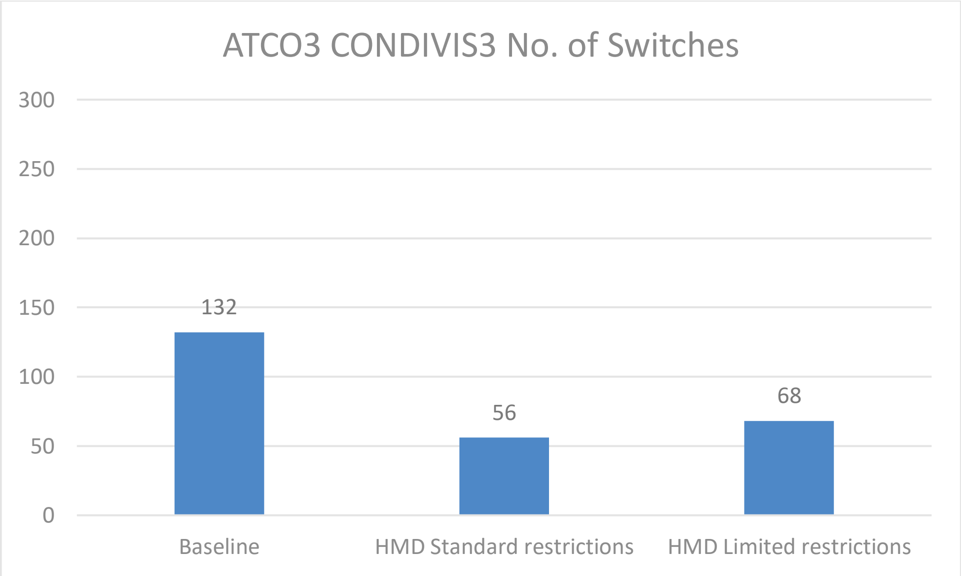

ATCO1 CONDIVIS3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
28%
72%
87%
13%
92%
8%
Baseline
HMD Standard restrictions
HMD Limited restrictions
HEAD DOWN TIME
HEAD UP TIME

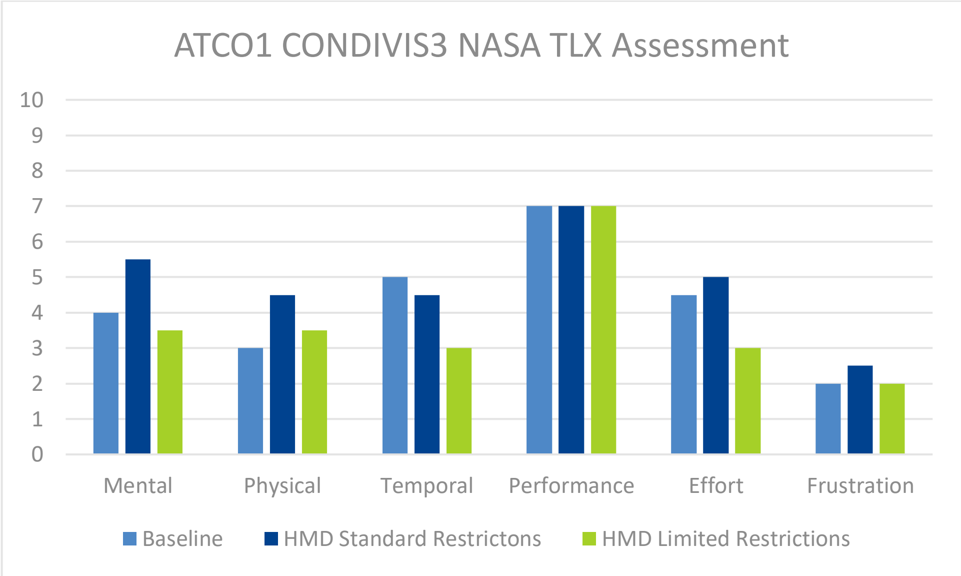

ATCO2 CONDIVIS3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
34%
66%
87%
13%
87%
13%
Baseline
HMD Standard restrictions
HMD Limited restrictions
HEAD DOWN TIME
HEAD UP TIME

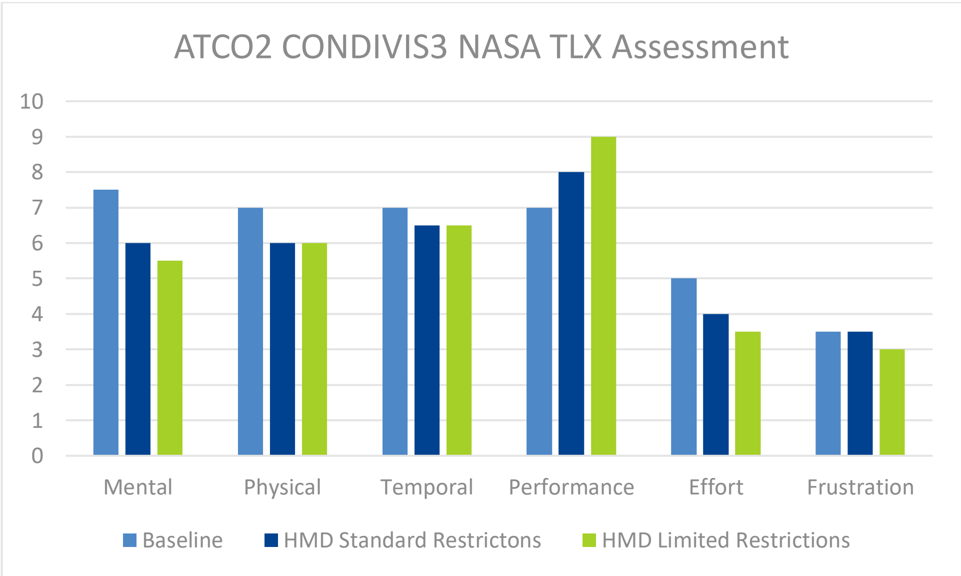

ATCO3 CONDIVIS3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
15%
85%
93%
7%
93%
7%
Baseline
HMD Standard restrictions
HMD Limited restrictions
HEAD DOWN TIME
HEAD UP TIME

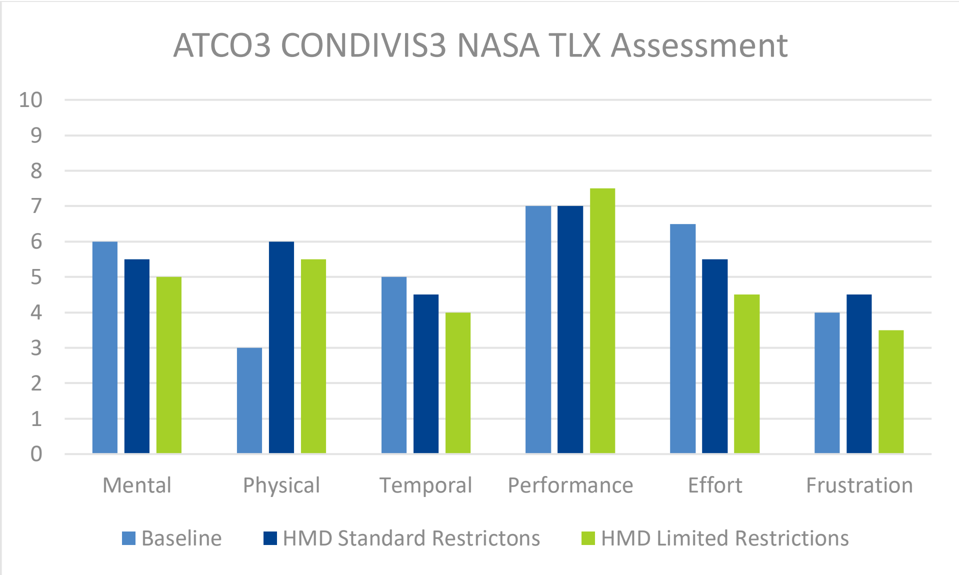

ATCO1 CONDIVIS3 No.of Switches
300
250
200
150
100
50
0
200
62
70
Baseline
HMD Standard restrictions
HMD Limited restrictions

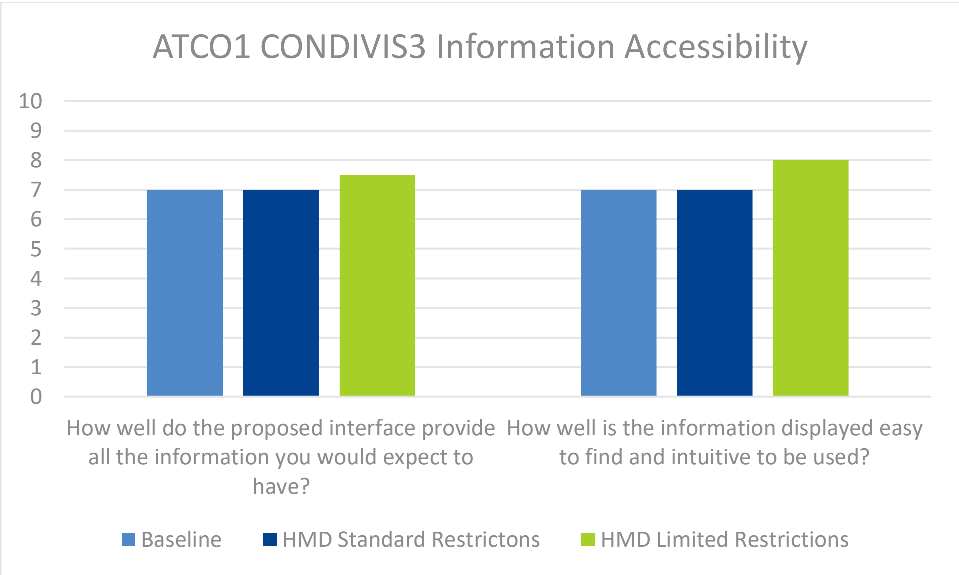

ATCO2 CONDIVIS3 No.of Switches
300
250
200
150
100
50
0
246
46
96
Baseline
HMD Standard restrictions
HMD Limited restrictions

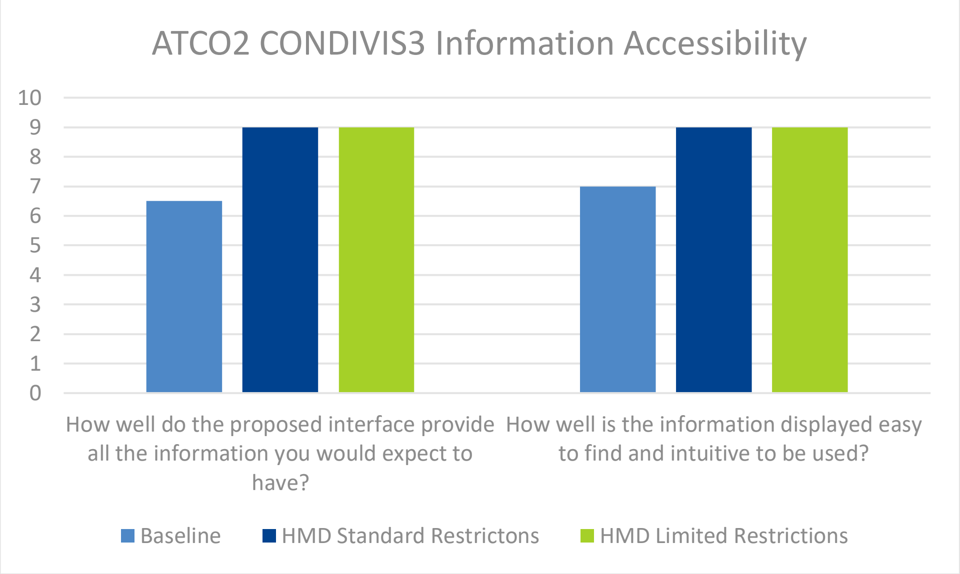

ATCO3 CONDIVIS3 No. of Switches
300
250
200
150
100
50
0
132
56
68
Baseline
HMD Standard restrictions
HMD Limited restrictions

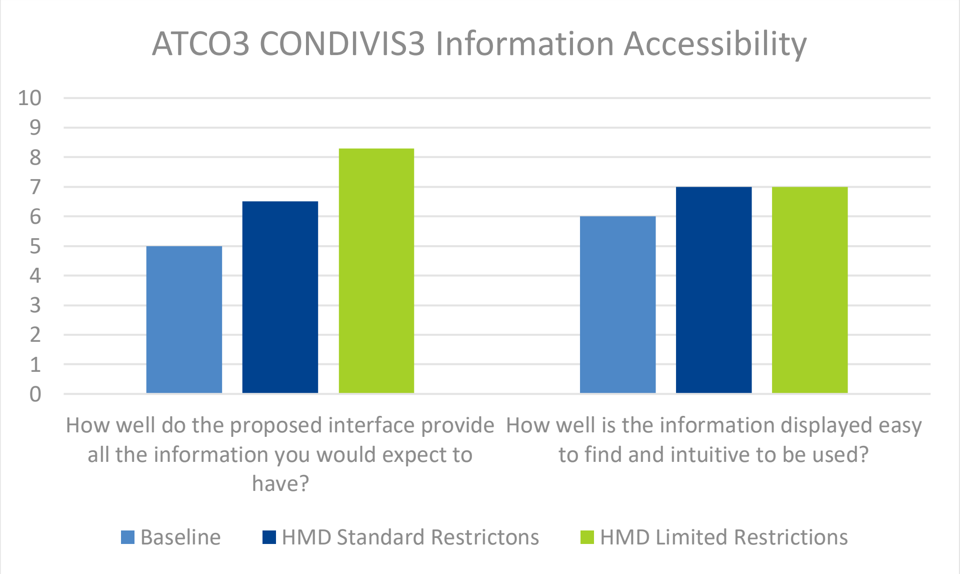

ATCO1 CONDIVIS3 NASA TLX Assessment
10
9
8
7
6
5
4
3
2
1
0
Mental
Physical
Temporal
Performance
Effort
Frustration
Baseline
HMD Standard Restrictons
HMD Limited Restrictions

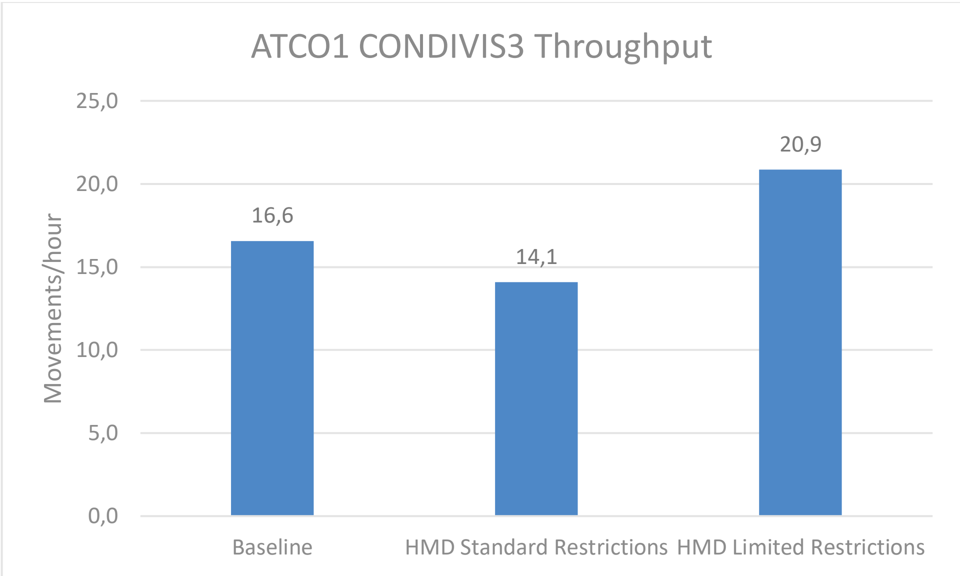

ATCO2 CONDIVIS3 NASA TLX Assessment
10
9
8
7
6
5
4
3
2
1
0
Mental
Physical
Temporal
Performance
Effort
Frustration
Baseline
HMD Standard Restrictons
HMD Limited Restrictions

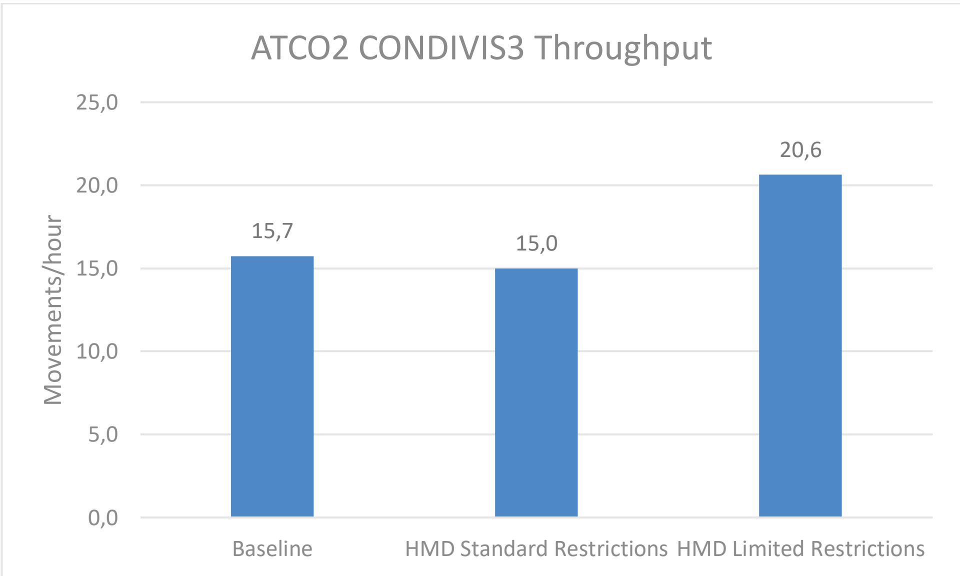

ATCO3 CONDIVIS3 NASA TLX Assessment
10
9
8
7
6
5
4
3
2
1
0
Mental
Physical
Temporal
Performance
Effort
Frustration
Baseline
HMD Standard Restrictons
HMD Limited Restrictions

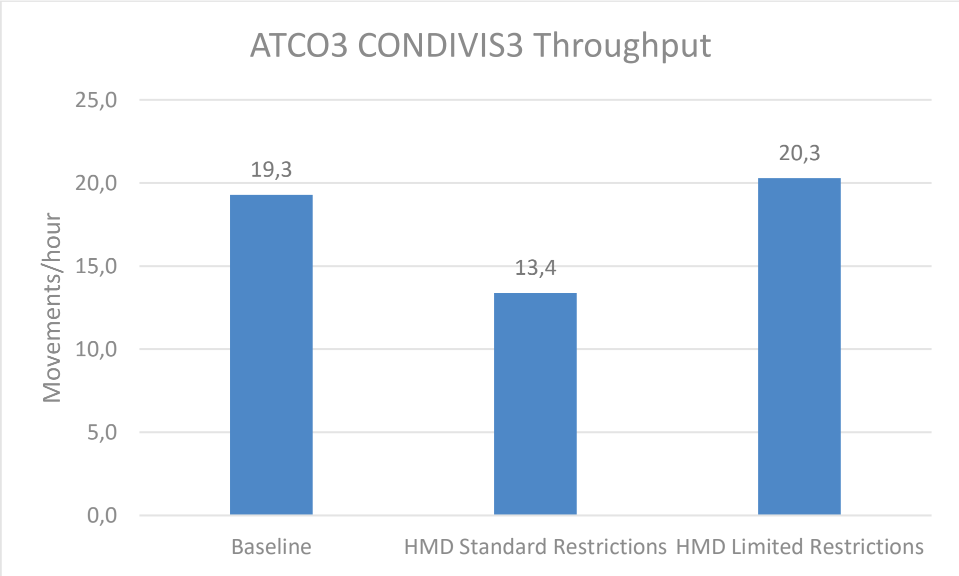

ATCO1 CONDIVIS3 Information Accessibility
10
9
8
7
6
5
4
3
2
1
0
How well do the proposed interface provide all the information you would expect to have?
How well is the information displayed easy to find and intuitive to be used?
Baseline
HMD Standard Restrictons
HMD Limited Restrictions


ATCO2 CONDIVIS3 Information Accessibility
10
9
8
7
6
5
4
3
2
1
0
How well do the proposed interface provide all the information you would expect to have?
How well is the information displayed easy to find and intuitive to be used?
Baseline
HMD Standard Restrictons
HMD Limited Restrictions


ATCO3 CONDIVIS3 Information Accessibility
10
9
8
7
6
5
4
3
2
1
0
How well do the proposed interface provide all the information you would expect to have?
How well is the information displayed easy to find and intuitive to be used?
Baseline
HMD Standard Restrictons
HMD Limited Restrictions


ATCO1 CONDIVIS3 Throughput
Movements/hour
25,0
20,0
15,0
10,0
5,0
0,0
16,6
14,1
20,9
Baseline
HMD Standard Restrictions
HMD Limited Restrictions


ATCO2 CONDIVIS3 Throughput
Movements/hour
25,0
20,0
15,0
10,0
5,0
0,0
15,7
15,0
20,6
Baseline
HMD Standard Restrictions
HMD Limited Restrictions


ATCO3 CONDIVIS3 Throughput
Movements/hour
25,0
20,0
15,0
10,0
5,0
0,0
19,3
13,4
20,3
Baseline
HMD Standard Restrictions
HMD Limited Restrictions

Appendix B Responses to EXE 11

Questions	Cont 1	Cont 2	Cont 3	Cont 4	Cont 5	Cont 6	Cont 7	Cont 8
Question 1		It's hard to read because it's in the corner. To judge the font I would have to be able to compare it to others		METAR info not necessary in the display	To much information on each label	Wind display was confusing. I was unable to read the wind direction and intensity. Font a bit bigger will be ok		
Question 2		it should be higher		It adds to much noise to the display				Maybe too big. In my opinion should be smaller

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Question 3				Red and green colors are very aggressive and don't provide further information. No need for those colors for the basic information.	in my opinion, the background should be clearer, almost transparent
Question 4		Big font for a busy airport			
Question 5					should be smaller
Question 6	Wake Turbulence Tag should be in a different color (H)		tags overlap, translucent would be helpful	I would prefer more transparency in the presentation of the tags	should be clearer, almost transparent
Question 7					
Question 8					Although it is too big

Question 9		Red is very aggressive. Maybe for the firefighter patrol on mission, but not for a runway revision
Question 10		
Question 11	wind information wasn't easy to read. Meteo info is on top, not really comfortable to look up and right for every plane	

Question 12	Copy information from SACTA labels, many fields are missing	I couldn't see wind information. As an idea it would be good that the text blink when it changes (i.e. QWH)		Not needed in display. Wind info in a strange format	To much information. Only Call sign Other info on demand		We don't need red runway to know it's busy. Same thing for the taxiway. It's obvious. Maybe in the parking would be useful.	Taxiways should be red only in the part ahead of the plane. Runways should turn red when the arrival is cleared to land
Question 13	fields from SACTA labels are missing, E.G. SID, Wake Type, etc.			C mode not needed in display	Much of the information should only be on demand	too much information. no need to know altitude of ground planes	This point should be evaluated in further stage of development now is not the point	
Question 14				No information displayed			I miss the clearance association for the vehicle tag	Short information but we don't need more
Question 15						wind info is basic		
Question 16						clear wind direction and speed		

			needed. Increase font a bit	
Question 17	when moved, labels may get lost or out of scope			The information doesn't match with the routine controller orders
Question 18		Shouldn't overlap		
Question 19				I miss information about the route of the vehicle
Question 20	hard to tell with just one vehicle		I didn't clear the vehicle. I only saw its tag	

Question 21	Shouldn't be displayed	I need intelligent tags that avoid conflict of position and also I need to be able to fix the position of the tag referring to dry land or referring to a position on the airport. We don't need the tilting of the tags when you tilt your head. it can make you dizzy	
Question 22			
Question 23	not displayed		we don't need more. It's enough

Question 24	Labels sometimes get lost or unaccessible			wind info not easy to read				
Question 25	Sometimes cannot be found and difficult when aircraft cross							
Question 26						I didn't use the vehicle tag		
Question 27							Its paramount to combine this device with a keyboard or joystick for command selection	Two flight were unable to be cleared
Question 28								

Question 29	Difficult to follow aircraft, maybe impossible in other configurations							Runway information should depend on the holding point you are looking at. We'd need visibility as well as RWR or the possibility to select one of them.
Free Comments				Arrivals are difficult to find			HMD device should be combined with a hand device to perform the main functions without worrying moving head. We have to combine both devices to get an optimum	

						performance. The head leads to observe and the hands "over the table" or "over the keyboard_" has to select. Hands in the air to select can lead to user fatigue.	

Questions	Cont 9	Cont 10	Cont 11	Cont 12	Cont 13	Cont 14	Cont 15
Question 1	antialiasing is needed, but I think the defects are somehow related to the glasses themselves	the info is not clear. The movement of the info overlays makes it difficult to read		although it is easy to read, there are problems when the aircraft are close to one another			

Question 2		too big and not static			dimensions were Ok, however I found it annoying that it remains "static" moving around and blinking. It was hard to move my eyes up to the corner.	the anemometer is small and I think it shouldn't be presented. It should be fixed in the periphery.	In my case they were too small to have to possibility to verify them.
Question 3	high contrast, like the black on yellow improves readability but attracts too much attention in spite of departures. A more neutral color combination should ne used for arrivals.			lack of confirmation on cleared to land. Too many colors must be avoided		There a quite a few colors	
Question 4		too big and too much info					

Question 5	tags are too big and present an interline space that's too big	too big. Unable to read the info if there is much traffic	overlap for traffic that is far away	confusion and anxiety when several tags arise together	dimensions made it easy to read and understand and click. However, they seem a bit big if there was more traffic.	The tags are quite large
Question 6	see Q3	not easy to differentiate departures from arrivals		demo fails when actions are selected	Departure color OK, Arrivals color was too bright yellow	There might be too many colors
Question 7		too big		did not come out in the demo		
Question 8		too big				
Question 9		red means warning or danger			The red color is too alarming. Should use a softer tone.	
Question 10		similar info/ color between arrival/departure				

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Question 11		not easy to differentiate			generally OK. However, wind info is unreadable
Question 12		wind is not easy to see	it is uncomfortable to have static info that moves with the head motion, unlike the tags which are attached to "reality"	the particular case of the weather info could be improved	I would prefer no static info. Show on click only at a fixed location. (e.g. when click on nothing in particular show info, again to remove)
Question 13	On request, other pieces of information such as SID, distance or WTC of previous departure could be very useful	sometimes too much, sometimes lack of info			arrival traffic should also show minutes to runway threshold (as the radar screens do)
Question 14		poor info (the request of the marshal)	don't know intentions		
Question 15			This should not be shown all the time		wind not good, and I didn't like it moving

					around. See Q2 and Q12
Question 16		allows double clearance (take off and landing) at the same time	This should not be shown all the time	in the demo it works properly but not sure with a high amount of traffic	
Question 17	timely display of callsigns according to EOBT and CTOT is very useful				Info was OK. Some more clearances could be available (e.g. take-off clearance may be given while taxi)
Question 18				needs to be improved with more feedback	
Question 19	it would be very useful to give a chance to the ATCO to fill-in some details like intentions				

	or clearances given					
Question 20	not much information is being shown					
Question 21	the possibilities based on contextual means are endless	same info during all phases of the departure	better to just be shown when you ask for it.	being a new tool in my case generated anxiety if selecting the wrong tag	wind unreadable	The information is not realized in an adequate manner.
Question 22				could be useful in airports with low traffic in the first stage	missing just minutes to land	
Question 23		no info about the request of the vehicle				
Question 24					see Q2, 12, and 15	

Question 25				flight tags + vehicle tags should remain horizontal not incline left or right with the head movement.
Question 26				
Question 27				
Question 28	Conflict alerts, etc. should be implemented (i.e. departure of a M traffic behind H traffic where 2NM WTC separation applies or conflicting SIDS, low performance AC, etc.)	must improve for more traffic	demo failed sometimes	

Question 29	that would be, in fact, the perfect fit for a first application, and with a significant reduction of workload.		only reflects the real position, not the clearance position	could be useful in LVP			
	At the cognitive level, the sense of workload was reduced (IMHO) because I did not have to take a look at my flight strips or the distance radar to check who an aircraft was. In terms of ergonomics, a cable for RTFT charging of the Hololens should be implemented to reduce the weight of the whole system.	Uncomfortable to use if wearing glasses. They left a mark. The tags are large and contain too much information that do not aide in the control of the aircraft. You cannot distinguish between arrivals and departures.	Need more feedback for accepted clearances. Don't change the angle of tags when head moves. METAR should not move with the vision. Time is not needed. Ability to clear landing aircraft while looking at the departing aircraft at the other end of the runway. keep the tag moving with the aircraft, even if moved.	As a new tool it is very interesting and challenging. I'm not aware of how this will work in high density aerodromes with lots of tags at the same time. Maybe the HMD could be improved. Maybe two buttons one could be to desect the METAR. The tool must be as simple as possible, use of colors,		The glasses have a limited visual field and the ergonomics aren't very well developed.	The field of view is limited and the glasses weight is high.

	anything that moves with the head is bothersome. text and tags should be like the HUDs in fighters (green and transparent). Runway should show "occupied" when any related clearance is given (land, take-off, cross, etc.)	movement, otherwise may generate stress. In my opinion tags should be static, not changing the angle when you move your head. blind parking zones should be taken into account like LVP.	

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	The car with a red tag calls your attention too much for the importance it has. Red should be used only for warning or danger and is always something urgent. It's not adequate that it calls my attention all the time.	