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TNO report

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CRUISE Evaluation Report

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Contents

Appendices
A Experiment evaluation questionnaire

1 Scope

1.1 Scope and applicability

This document is the Final Evaluation Report of the CRUISE (Crew User Interface System Enhancement) project, defined by the Contract Change Notice Crusade-1 [CRU_CCN], ESA Contract number 18500/04/NL/VK. It describes the demonstration and test of two systems in supporting specific crew operations in the ISS: the Procedural Display (PD) and the voice Activated Procedure Viewer (vaPV).

1 vaPV: support the crew for hands-busy procedure execution through voice input technology.
2 PD: merging a procedure (ODF) operations product with real-time system data elements to support nominal ISS operations.

1.2 Document structure

This document has the following layout:

Chapter 1 presents the document scope and applicability of the study and provides the overall document structure.

Chapter 2 includes a list of terms and abbreviations.

Chapter 3 describes background information on the PD and vaPV and the test method and goals.

Chapter 4 describes the test plan for the evaluations.

Chapter 5 describes the results of the pre-mission, on-orbit and post-mission sessions.

Chapter 6 describes the experiment conclusion discussing the results in context of the hypotheses and claims.

Appendix A describes what questionnaires were used and lists the questionnaires in the following Appendices.

2   Terms and abbreviations

CRUISE	CRew User Interface System Enhancement
EAC	European Astronaut Centre
ISS	International Space Station
Lapap Mk II	LAPtop APlication Mark 2 (Graphical User Interface in Columbus)
MCC	Mission Control Centre
ODF	Operations Data File (Standard for ISS Crew Procedures)
PD	Procedural Displays
PDU	Power Distribution Unit
PI	Principal Investigator
RSME	Rating Scale Mental Effort
RGSH	Return Grid Sensor House
SA	Situation Awareness
SAM	Self-Assessment Manakin
sCE	situated Cognitive Engineering
vaPV	Voice Activated Procedure Viewer

3   Introduction

The CRUISE experiment focused on the comparison of Procedural Displays (PD) and Voice Activated Procedure Viewer (vaPV) extensions of the Lapap MK II software for supporting crew operations on-board. This experiment provides insight in the effects of the support functions under on-orbit conditions (e.g., microgravity and noise), on the user experience of the PD and vaPV (ESR, 2012). This document specifies the evaluation measures, methods, plans and evaluation findings.

3.1   Background

3.1.1   Procedural display

On-board, procedures are provided in electronic format with powerful tools supporting their on-line use, paper versions are primarily kept for backup. With the installation of LAPAP MK II on-board Columbus Operations Data File (ODF) procedure execution is supported and enables crew members to activate synoptic displays for carrying out command & control operations directly from within procedures while executing them (LAPAP_CRU, 2012).
The objective of the PD study (2008) was to take this approach significantly further by integrating command buttons and data fields directly with the procedural contents. This enables not only a more efficient use of screen real estate, but also supports a streamlined work flow, see Figure 1.
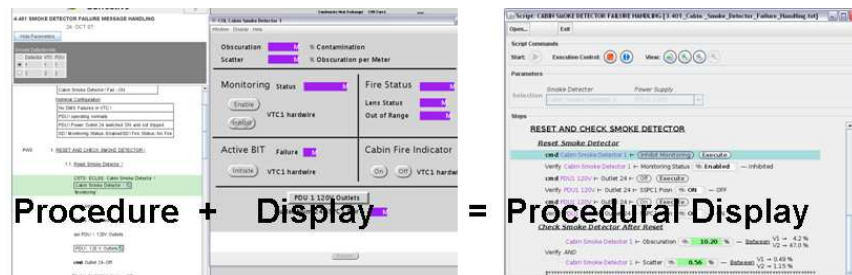

Figure 1   PD integrates two different displays (procedure + display) into one display (Procedural Display) (ESO-IT-RP-0668, 2013).

The PD software was also integrated into the user interface demonstrator for a future European crew transport system. Figure 2 depicts this demonstrator with the embedded PD component at the left side.
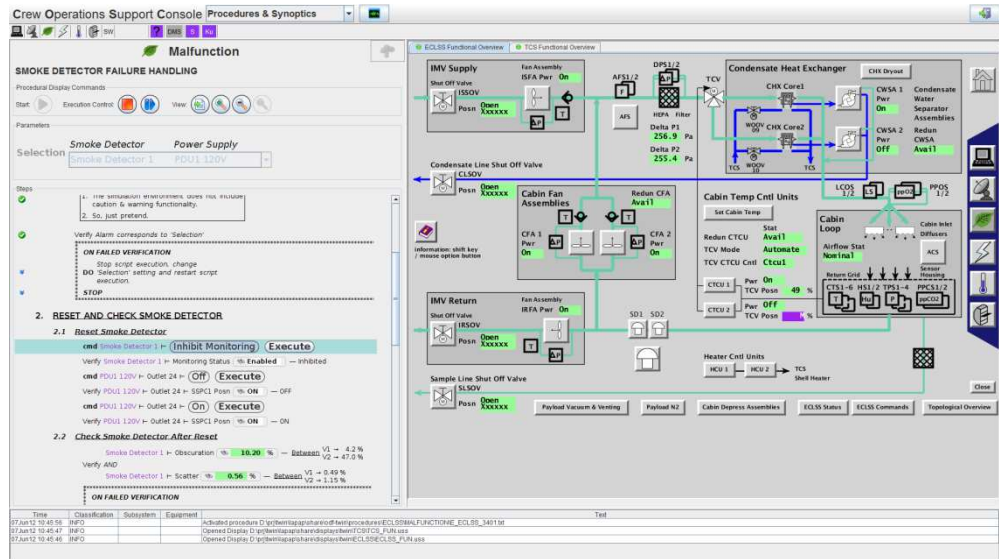
Figure 2   screenshot of the PD software integrated into the user interface demonstrator for a future European crew transport system (ESO-IT-RP-0668, 2013).

3.1.2   *Voice activated procedure viewer*

The initial vaPV (Voice Activated Procedure Viewer) study performed in 2008 and had the objective to provide two new modes of interaction with the crew laptop namely, voice commanding as an input mode, using speech recognition technology, and audio playback of information as an output mode, using Text-To-Speech Technology (vaPV_Report, 2008). These two modes aim to support crewmembers who find themselves in "hands-busy" or "eyes-busy" work situations.

The two new modes where implemented as additional functions in the ESA crew graphical user interface Lapap Mk II, see Figure 3.
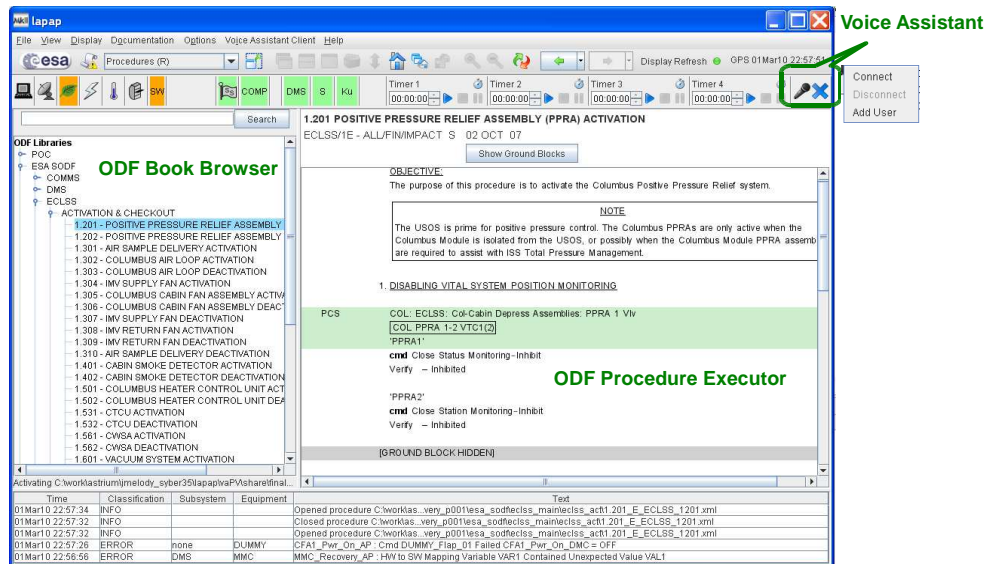

Figure 3   screenshot of Lapap MK II with the Voice Assistant integrated. The microphone icon in the top right corner, circled in green, indicates that the Voice Assistant plugin is loaded. (ESO-IT-RP-0668, 2013).

3.2 Description of test methods and goals

The CRUISE evaluation was not a controlled experiment with systematic manipulations of experimental conditions and a sufficient number of participants to apply inferential statistics. Consequently, we will not be able to draw conclusions about the population the data are thought to represent. It will be a qualitative assessment of the user experience in a real on-orbit environment, with actual end-users (i.e. astronauts) performing high-fidelity scenarios. The objective is to perform a first validation of the functions and claims and then be able to provide recommendations for improvement.

3.2.1 User Experience Measures
First of all, as prescribed in human factors engineering standards (ECSS- ST-10-11C, ISO 9241-210:2010), this assessment should comprise three types of usability measures: effectiveness, efficiency and satisfaction.

Effectiveness (accuracy and completeness).
- For the Crusade evaluation scenarios, a normative performance should be available: the actions to be completed.

Efficiency.
- Time per task should be measured.
- Corrections, repetitive acts and "navigation path": log file
- Rating Scale Mental Effort (RSME; Zijlstra, 1993)

Satisfaction.
- Questionnaire

In addition to complying with state-of-the-art usability standards, the CRUISE user interfaces intend to support astronauts' task performance on trust, situation awareness and context. Thus these measures are also taken into account.

Trust
- Questionnaire

User experience
- The general operational context: video recordings
- User state: questionnaire at start of experiment ("mood"). We will use the Self-Assessment Manakin (SAM; Morris, 1995) questionnaire to assess the participant's emotional state and how pleasant the participants are feeling.

Situation awareness
Unobtrusive measurement of situation awareness is complex. In order to prevent interference with the actual task execution, we chose for an indirect measure:
- a questionnaire at the end of the scenario, asking for which events appeared ("awareness" about what happened in the environment) and how these events were addressed ("awareness" about the performance).

3.2.2   *Core functions and claims explanation*
For the PD and vaPV, the core functions were identified with the corresponding claims using the situated Cognitve Engineering (sCE) method by Neerincx (2011). The core functions (high-level functional requirements) were derived from the scenarios test definitions. The claims specify the measures (data) to be collected during the evaluation and consist of upsides and downsides. The trade-off in design is that in general the upsides are higher than the downsides, this should be validated. A claim definition looks like:
- Claim (each variable should refer to definitions of measures!):
  - <objective> constrained and efficient interaction,
    - ↑ <upsides> adequate completeness of task performance (do not forget procedural step) less errors in parameter setting (e.g., temperature within set boundaries, outside boundaries is not possible, as prescribed in procedure?),
    - ↓<downsides> too much information presentation and superficial procedure execution results in errors.

3.2.3   *Core functions and claims for PD and vaPV*
This paragraph describes the core functions and claims for the PD and vaPV:
- Core function PD:
  - The integration of the synoptic displays with the procedure viewer, merging a procedure (ODF) operations product with real-time system data elements to support nominal ISS operations. (links to claim 1, 2, 3 and 4).
- Core function vaPV:
  - Support for hands-busy procedure execution through voice input technology. (links to claim 1, 4, 5 and 6).

- Claim 1
  - PD and vaPV will enhance effectiveness, because the user will be guided by the procedure viewer or voice activated procedure viewer.
    - ↑ Effectiveness will be more accurate and complete (compare to normative path).
    - ↓ Trust, the astronaut might not trust these applications (questionnaire).

- Claim 2
  - The PD's integrated display will increase efficiency.
    - ↑ Efficiency (time per task, RSME).

- Claim 3
  - The PD's integrated display will improve awareness of procedural state with relevant actions and corresponding conditions.
    - ↑ Better situation awareness (task specific SA questions).

- Claim 4
  - The PD and vaPV will have a general positive effect on user satisfaction.
    - ↑ Satisfaction (questionnaire).

- Claim 5
  – The vaPV's use of voice commands makes operation more efficient (simultaneous execution of task and going through procedures)
    – ↑ Efficiency (time per task, RSME).
    – ↓ Satisfaction, poor recognition of voice commands (e.g. when background noise is present) negatively influences the user satisfaction (questionnaire).

- Claim 6
  – The vaPV's option to repeat procedure steps by voice will increase awareness of procedural state with relevant and corresponding conditions.
    – ↑ Better situation awareness (task specific SA questions).
    – ↓ Satisfaction, recognition of voice commands is never 100%, this might influence the user satisfaction (questionnaire).

4   Test Plan

4.1   Test Procedure

Two astronauts conducted the (vaPV and PD) experiment one time on-orbit, and two times on ground (pre- and post-mission). The pre-mission and on-orbit session lasted approximately 45 (PD) and 65 (vaPV) minutes (experiment installation: 80 minutes, 1 astronaut).The post-mission session lasted two hours.

4.1.1   *Pre-mission and on-orbit session*

The pre-mission and on-orbit session had the same set-up. Except that the pre-mission session included a training to get acquainted with the PD and vaPV. Pre-mission, the PD and vaPV experiments were performed in the Columbus mock-up at EAC.

Table 1   outline of activities for pre-mission and on-orbit session

Activity	Session
Introduction and instruction	Pre-mission
Training session	Pre-mission
Experiment 'test' (PD and vaPV)	Pre-mission and on-orbit
Questionnaires	Pre-mission and on-orbit

Procedural display

Procedural Displays are displays with command and control capabilities.
They are displayed in the procedure execution area rather than in the synoptic display area of the Lapap application. By directly embedding display elements for data presentation and command execution they ensure a streamlined workflow and optimize the use of screen real estate. Figure 4 shows the three main areas of Procedural Displays:

1   Command and view control area.
>   contains buttons for starting and resetting a procedural display, for centering the active instruction vertically in the main contents area and for zooming.
2   Parameter selection area.
>   allows specifying parameter values for procedure execution, thereby enabling the use of a single procedural display for common tasks related to redundant, functionally identical pieces of equipment.
3   Main contents area.
>   This is where the actual procedural display is shown. In general the PD appearance very much resembles ODF checklist procedures. Command and control buttons and data fields are embedded within procedure instructions. Steps and instructions are situated in the center of the PD. At the right dedicated interaction buttons are displayed for the active instruction if applicable. The active instruction is highlighted with a light green bar similar to the one used for the ODF procedure viewer. This bar turns to light blue for system command instructions (before execution is initiated) and light orange for failed verifications or system commands. On the left side an icon gives feedback on status after an instruction was executed.
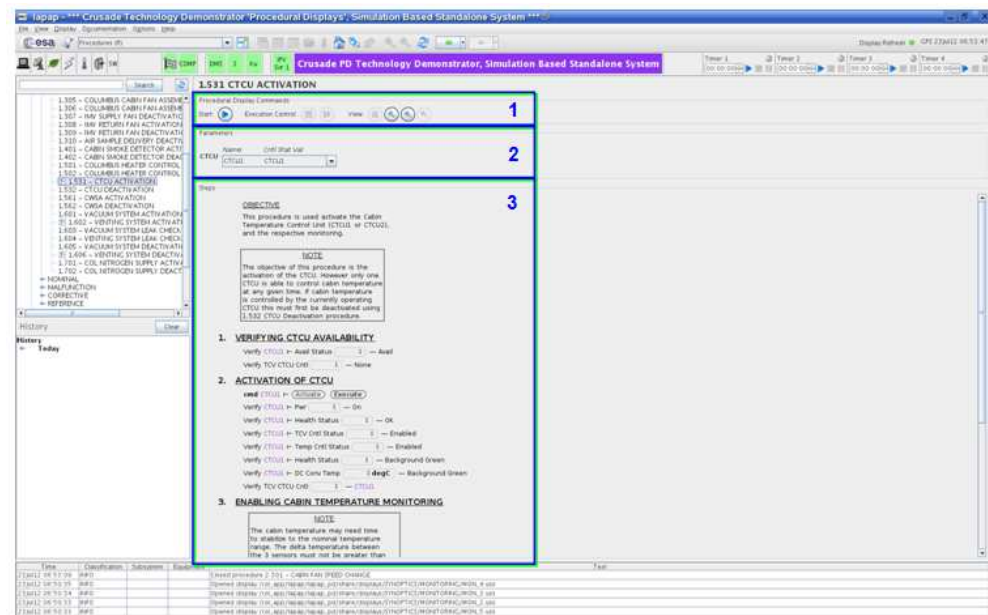
Figure 4: screenshot of PD application, with indication of main areas: 1) command and control view area, 2) Parameter selection area, 3) Main contents area (ESO-IT-RP-0668, 2013).

To demonstrate the specific capabilities of procedural displays, only procedures for command and control tasks rather than for genuinely manual activities were considered for selection. The selection was further restricted by excluding procedures involving vital command and control actions. During the execution the participant had to perform five checklist procedures:

- 1.531 – CTCU ACTIVATION: activation of the Cabin Temperature Control Unit
- 1.602 – VENTING SYSTEM ACTIVATION: This procedure is used to activate the Columbus Venting system.
- 1.606 – VENTING SYSTEM DEACTIVATION: This procedure is used to deactivate the Columbus Venting system.
- 2.301 – CABIN FAN SPEED CHANGE: this procedure is used to change the Cabin Fan Assembly Speed.
- 2.531 – CABIN TEMPERATURE SETTING: This procedure is used to change the cabin temperature set-point of the active Cabin Temperature Control Unit.

Voice activated Procedure Viewer

vaPV was performed following the PD experiment. In the pre-mission session the hands-on task was not performed, but the user walked through the procedures using vaPV. In the on-orbit session the procedure was executed, using vaPV.
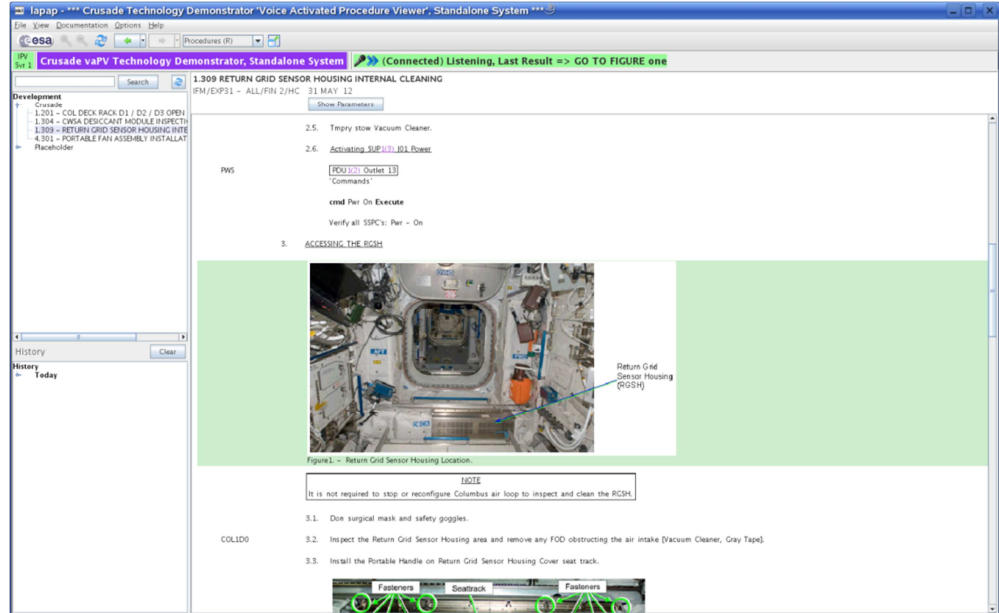

Figure 5: vaPV application (ESO-IT-RP-0668, 2013).

As hands busy scenario the participant performed maintenance activity Return Grid Sensor House cleaning procedure [ODF_RGSH].

- Return Grid Sensor House (RGSH) internal cleaning procedure consists of:
    (a) collecting tools (screw driver, vacuum cleaner and dusk mask, photo camera),
    (b) turn on PDU (Power Distribution Unit) a system activity usually performed by ground,
    (c) plug in the vacuum cleaner,
    (d) unscrew the return grid,
    (e) inspect and photo document the area,
    (f) vacuum clean the area,
    (g) photo document the area,
    (h) screw the return grid,
    (i) turn off the PDU, system activity performed by ground control,
    (j) and finally clean up all tools used.

The user could control vaPV using voice commands, a small sample of actions and associated voice commands is given below:

- *Action:* Navigate within the procedure without moving the green bar
  Possible voice commands:
    − PAGE DOWN, SCROLL DOWN, DOWN.
    − PAGE UP, SCROLL UP, UP.
    − PAGE LEFT, SCROLL LEFT.

- *Action:* Execute procedure by moving the green bar to the step indicated
  Possible voice commands:
  - NEXT, NEXT INSTRUCTION.
  - PREVIOUS, PREVIOUS INSTRUCTION

4.1.2 *Post-mission session*

In the post-mission session the participant went briefly through the Procedural Display (PD) and voice activated Procedure Viewer (vaPV). The objective of this session was to refresh the participant's memory how the PD and vaPV worked, and subsequently talk about the participant's findings and opinions through questionnaires and open discussion.

The participants were located in Houston Texas and were guided through the post-mission session by the test leader by phone. The principal Investigators (PI) team was present by phone as well. Also there was a local representative, that prepared the session and print-outs for the post-mission session.

During the post-mission session the participant only executed a reduced number of procedures with the PD. For the vaPV the participant did not perform procedures, but assignments aimed at using the voice navigation commands. During the usage and execution of the procedures or assignments, the participants were asked to provide running commentary at certain points.
This request was provided in the procedure or assignment.
Running commentary was necessary to let the PI team know what was going on and understand what the participant was doing since the PI team could not see the participant's laptop interaction.

Table 2   outline of activities for post-mission session

Activity	Time (minutes)
PD session and questionnaires	20
vaPV session and questionnaires	30
Break	10
Discussion session	40
End of session	10

4.2 Materials

Below are the material listed used during the sessions. For a detailed description of the materials used during the experiments, please have a look at the CRUISE final report (ESO-IT-RP-0668, 2013).
- CRUISE laptop (where they could run PD and vaPV)
- A headset when using the vaPV

4.3 Experimental design and participants

The experiment had a within-participant design. There were two participants, both astronauts. Both participant performed the PD and vaPV tasks.

5 Experiment results

First we will discuss the results from the pre-mission and on-orbit session. These sessions can be compared because they are similar in set-up and execution. At the end of the results section we will separately discuss the post mission session, that had a different set-up.

5.1 Results from pre-mission and on-orbit sessions

5.1.1 General feedback
In addition to the user experience measures, we asked the participants about their opinion of the PD and vaPV. We specifically asked them to list aspects that they found positive, negative and to add further remarks.

We first list the positive and negative feedback on the **PD**.
Positive:
- Check marks at successful completion.
- Action on same line as direction.
- Nice font.
- Intuitive to work with.

Negative
- Feedback on selection using 'white/gray' is ambiguous.
- Being forced to acknowledge notes.
- Repeated identical entries cannot be changed.
- Have to be read; would be nice to listen instead.

We asked the participants for other remarks and suggestions:
A fresh opening of a procedure should have a clean template

Here is a list of the positive and negative feedback on the **vaPV**.
Positive:
- Hands off of display, can have tools already in hand. (this comment was made by both participants).

Negative:
- Cannot return to a step you departed from.
- Beeps when the vaPV is asleep, should be disabled.
- Cannot have a conversation with MCC or another crewmate without feedback of vaPV.
- Fallible, requires repeats of commands.
- Cannot jump to a photo and back without having to remember specific step numbers.

We asked the participants for other remarks and suggestions:
- Participant A indicated that having a cord and headset is a drawback, and suggests a wireless headset. Maybe use different commands: participant once lost the whole procedure while saying 'back'.
- Participant B suggested to get rid of earpiece and microphone. Use natural words for commands (like asleep to turn off, wake up to turn on.

5.1.2 *User experience measures*
This paragraph describes the results of the user experience measures measured in the experiments. Both PD and vaPV results will be discussed.

5.1.2.1 *Effectiveness and efficiency*
Table 3 shows usage data of the PD on-orbit session. The number of interactions is exactly the same pre-mission as on-orbit. Differences can be seen in the time it took to go through the procedures.

Table 3   Data on usage of PD for both participants during pre-mission and on-orbit sessions, number of interactions (number of times participant clicked in PD screen) and time it took the participant to go through the procedure in minutes and seconds.

PD	Number interactions	Time (min:sec)
Participant 1 pre-mission	81	15:20
Participant 1 on-orbit	81	10:14
Participant 2 pre-mission	81	05:49
Participant 2 on-orbit	81	12:07

Table 4 shows the usage data for the vaPV pre-mission and on-orbit mission for both participants, where number of interactions means the number of times the participant clicked something in the PD screen. In the pre-mission session the participants did not actually perform the task, whereas in the on-orbit sessions they did. This is why the on-orbit sessions took longer than the pre-mission sessions. Recognition failures occurred when vaPV did not recognize the command spoken by the participant, or recognized it for a wrong command than was spoken.
The data in the table shows that the number of recognition failures is higher for both participants in the on-orbit session than in the pre-mission sessions.

Table 4   Data on usage of vaPV for both participants during pre-mission and on-orbit sessions.

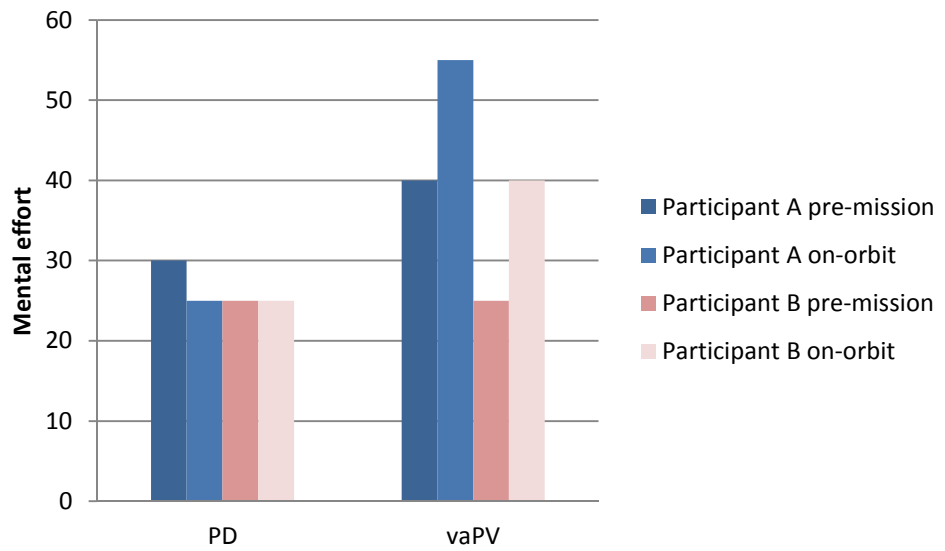| vaPV	Number interactions	Time (min:sec)	Number of recognition failures
Participant 1 pre-mission	65	29:38	2
Participant 1 on-orbit	63	47:11	9
Participant 2 pre-mission	44	12:34	0
Participant 2 on-orbit	31	66:03	7

Figure 6   graph showing mental effort of participants in different tests, where 0 = absolutely no
effort and 55 = rather much effort, (on-ground before, in space and on-ground after) for
the PD and vaPV.

The bar graph in Figure 6 shows the values that both participants filled in for their
mental effort. Where 25 means 'a little effort', 40 'some effort' and 55 'rather much
effort'. For both participants the vaPV cost more effort on-orbit than pre-mission.
The PD is is valued the same by participant B, but participant A found that the PD
took a bit less effort on-orbit than in the pre-mission session.

5.1.2.2 *Satisfaction and trust*
To get an indication of the user experience, satisfaction and trust, the participant
had to rate eight statements on a scale from 1 (totally disagree) to 5 (totally agree).
The statements were:
1   I found the program easy to use.
2   I trusted the information the program gave me.
3   I found the program pleasant to use.
4   I was satisfied with the way the program worked.
5   The program is truthful.
6   I found the program reliable.
7   I found the information offered by the program useful.
8   The information was offered at the right time.

Participant A rated the PD lower on ease of use on-orbit than in the pre-mission
session. Participant B rated the reliability of the PD lower on-orbit than in the pre-
mission session. Participant B rated the usefulness of information offered by the PD
and offered at the right time, higher on-orbit than in the pre-mission session.
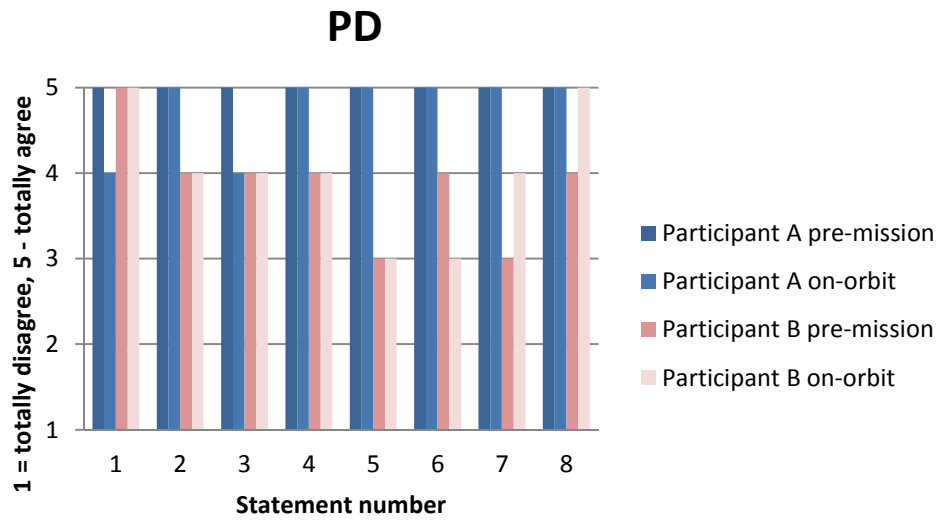
PD

Figure 7   answer to eight statements concerning user experience, satisfaction and trust for the
PD on a scale from 1 (totally disagree) to 5 (totally agree).

Participant A rated the information offered by the program (statement 7) higher on-orbit than pre-mission (see Figure 8). Participant B rated the vaPV on-orbit lower than in the pre-mission session. Ease of use, trust, pleasant to use, reliability and satisfaction (statement 1, 2, 3, 4 and 6) were all rated lower on-orbit.
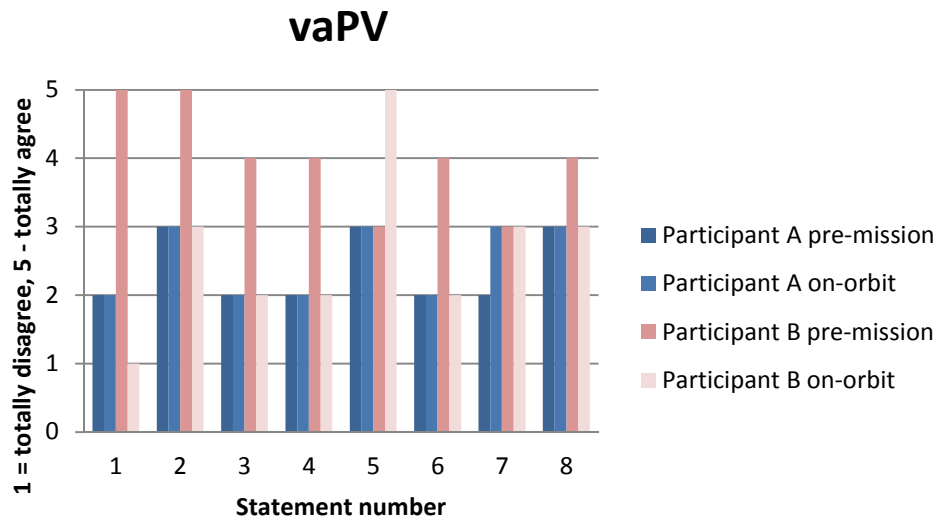
vaPV

Figure 8   answer to eight statements concerning user experience, satisfaction and trust for the
vaPV on a scale from 1 (totally disagree) to 5 (totally agree).

To get an indication of the user's trust in the PD and vaPV we asked them if they trusted the program. They answered the question on a 5-point Likert scale (1 = totally disagree and 5 = totally agree). The graph shows that the trust in the PD is higher for both participants than trust in the vaPV. The trust in the PD was higher on-orbit for participant B and lower on-orbit for participant A. Participant B had high trust in the vaPV pre-mission, it was lower on-orbit.
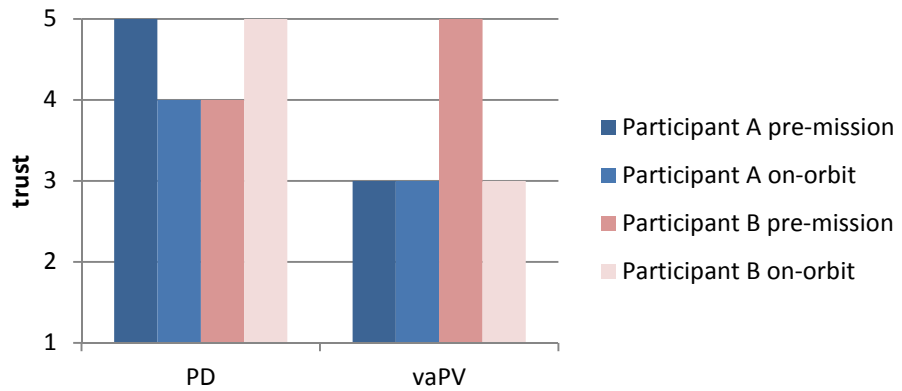
Figure 9: graph showing trust of participants A and B in different tests (on-ground and in space) for the PD and vaPV.

5.1.2.3 *Situation awareness*

Participants gave feedback on the situation awareness questions, they wrote that they are trained on very short term memories and focus only on what is in front of them at the time. The filled in questionnaires also support this view, they tried to answer the questions, but did not answer correct or complete. This questionnaire seems to have been more of a memory questionnaire.

5.1.2.4 *User experience*

The graphs below show the arousal of the participants before they started on the experiment.
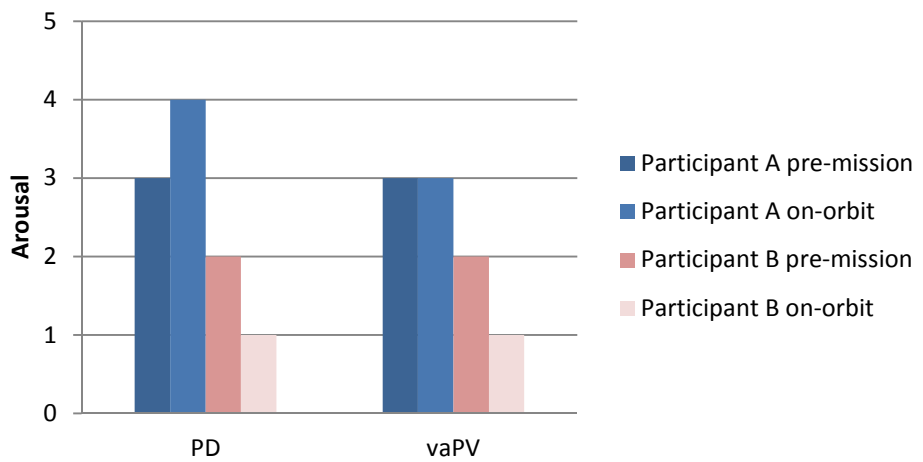

Figure 10   graph showing arousal of participants A and B in different tests (on-ground and in space) for the PD and vaPV (1 = calm or low emotional activity, 5 = excited or high emotional activity).
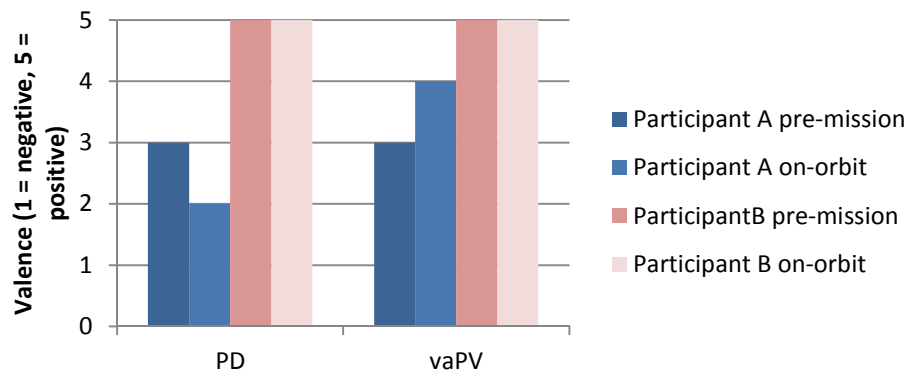
Figure 11   graph showing valence of participants A and B in different tests (on-ground and in space) for the PD and vaPV (1 = unpleasant, negative feeling, 5 = pleasant, positive feeling).

5.2 Post-mission session

Here the results from the post-mission session are reported.

5.2.1 General feedback
We asked the participants about their opinion of the PD and vaPV. We specifically asked them to list aspects that they found positive, negative and to add further remarks.

We first list the positive and negative feedback on the **PD**.
Positive:
- Overall simple interface (mentioned by both participants).
- One source for procedure control and relevant data.
- Fast.

Negative:
- If a mistake is made, the participants had no way of knowing where he was in the process and what the big picture is. The application is leading the participant by the hand so much he loses the big picture (mentioned by both participants).

We asked the participants for other remarks and suggestions:
- Have a display next to this one (for situation awareness).

Here is a list of the positive and negative feedback on the **vaPV**.
Positive:
- Hands free possibilities are excellent (mentioned by both participants).
- Relatively quick response to commands, and usually get correct results.
- Don't have to fiddle with zero G cursor control devices (there are no good zero-G cursor control devices).

Negative:
- Being attached by a headset to the laptop (mentioned by both participants).
- The feedback system (audio) could be in a different form instead of through the earpiece.

We asked the participants for other remarks and suggestions:
- Each time the participants wakes vaPV up, don't have vaPV say 'hello user'. Just make it simple, have the icon of vaPV turn green.
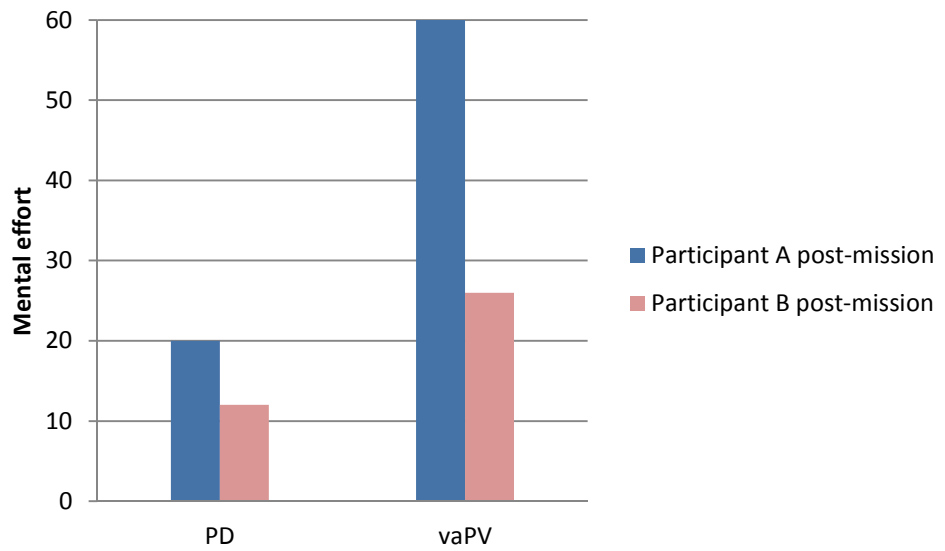
Figure 12   graph showing mental effort of participants in different tests, where 0 = absolutely no
            effort and 55 = rather much effort, (on-ground before, in space and on-ground after) for
            the PD and vaPV.

The bar graph in Figure 12 shows the values that both participants filled in for their
mental effort. Where 0 means 'absolutely no effort', 25 'a little effort' and 40 'some
effort'.

5.2.1.1   *Satisfaction and trust*

To get an indication of the user experience, satisfaction and trust, the participant
had to rate eight statements on a scale from 1 (totally disagree) to 5 (totally agree).
The statements were:
1   I found the program easy to use.
2   I trusted the information the program gave me.
3   I found the program pleasant to use.
4   I was satisfied with the way the program worked.
5   The program is truthful.
6   I found the program reliable.
7   I found the information offered by the program useful.
8   The information was offered at the right time.

PD

Figure 13   answer to eight statements concerning user experience, satisfaction and trust for the PD on a scale from 1 (totally disagree) to 5 (totally agree).
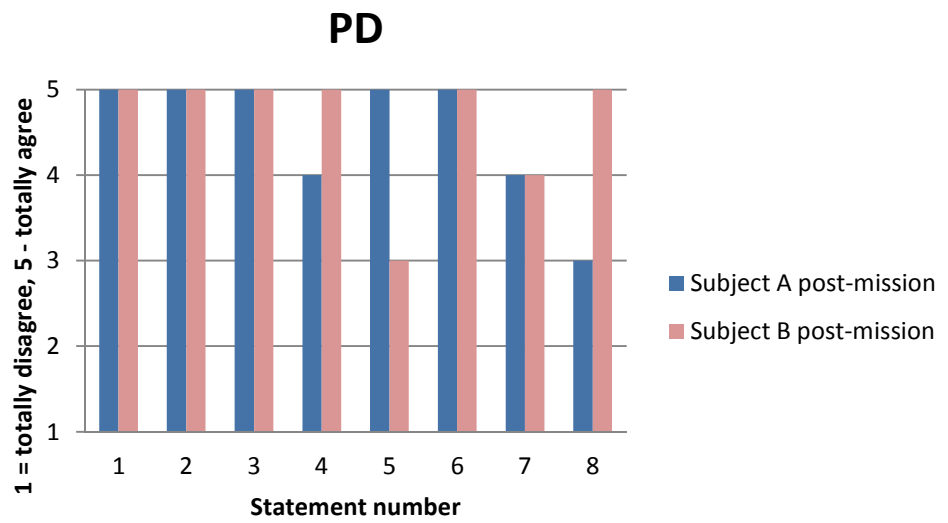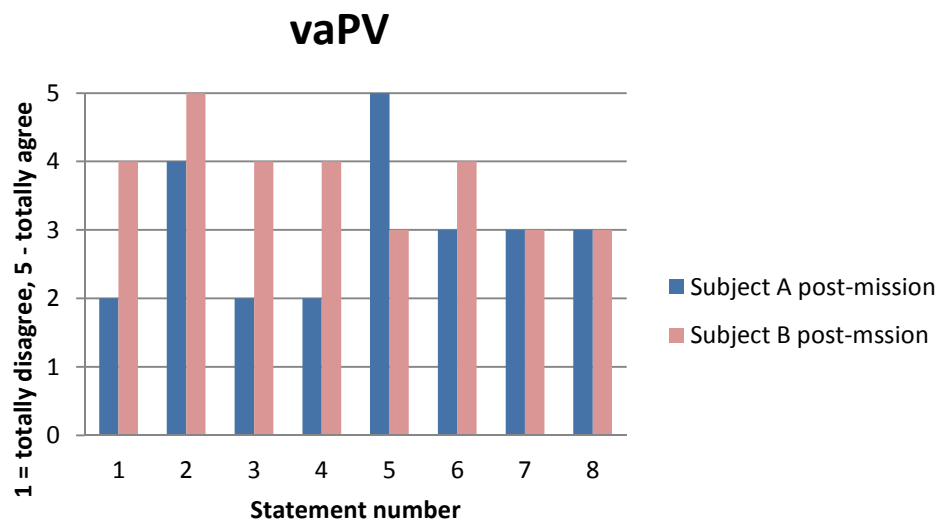
vaPV

Figure 14   answer to eight statements concerning user experience, satisfaction and trust for the vaPV on a scale from 1 (totally disagree) to 5 (totally agree).

6 Conclusion

6.1 Discussion of claims

First we will discuss the results with respect to the claims we formulated.
The mental effort when using vaPV increases for both participants when on-orbit as opposed to pre-mission values. Also the number of failures increase when using the vaPV on-orbit. The vaPV is thus not in a state that it possible to say anything about vaPV making operation more efficient or not (claim 5). Although a big advantage for efficiency, is that when doing a hands-on job, the tools can already be taken in hand while going to the procedure. This difference is not seen in the use of the PD.

The effectiveness and efficiency data for PD shows that both participants need to same number of interactions. There is some time differences between on-ground an on-orbit operation of the PD. It cannot be said with certainty that the PD enhances effectiveness and efficiency (claim 1 and 2).

In general the satisfaction and trust values are higher for PD than for vaPV. For the differences between sessions, nothing much can be said, because these satisfaction and trust measures, measure a moment in time and the differences are too small to draw conclusions. But it shows that the PD has a more positive effect on user satisfaction than vaPV (claim 4). This is also what is seen in the subjective feedback by the participants.

The feedback from the participants on PD show that the SA is actually worse (claim 3), they have no idea where they are operating in the bigger picture. Fearing that if something might go wrong with the application, they have no idea where they were or how to cope with it. This shows that the PD has to be improved to support SA, by perhaps adding an extra display as was suggested by the astronauts themselves.

The voice recognition on-orbit was poor. This was because of change of voice on-orbit due to constant congestion of sinuses and lack of gravity and feedback from vaPV when talking to crewmates. This made interaction difficult. An increase of awareness of procedural state and conditions was not seen (claim 6).

6.2 General conclusions

Upsides of the PD were that it is an overall simple interface, with one source for procedure control and relevant data and it is fast. Downside was found in the results on the situation awareness questions, they showed that if there is a situation where they have to get back to a previous task state, memory support is needed and an overview for possible deviations from the current procedure. This is also confirmed by the feedback in the post-mission session by the participants.

The biggest upside of the vaPV was the hands free possibility while executing hands-on procedures. One of the big downsides of the vaPV was having the crew member "tethered" to the laptop (especially on-board) in order to operate the vaPV system. Suggested improvements to the vaPV were to capture the audio and communicate to the system using wireless technology, either WiFi or Bluetooth.

Crew members also expressed a preference for systems that do not require them to wear an earpiece or in any case not to have both ears covered by a headset. Audio communications from the laptop to the crew member could be provided via the laptop speakers.

In general the PD is more appreciated than the vaPV. Upsides of the hands-free voice control were noted, but downsides of speech dialogue are still rather large. This was particularly shown on-orbit. These results show the importance of a test in a realistic and high-fidelity setting.

7   References

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A   Experiment evaluation questionnaire

Below in the table is described what questionnaires there are, when they should be distributed, how long they take and in which section they can be found.
The questionnaires have to be printed one-sided.

Section	Name	When?	Completion time (min.sec)
A.1	General questionnaire	On-ground	3.00
A.2	Emotional state (user state)	Before each test	0.20
A.3	Satisfaction & Trust	After each test One time for PD and one time for vaPV	2.00
A.4	Efficiency	After each test One time for PD and one time for vaPV	0.10
A.5.1	Situation awareness: PD	After on-ground PD test	2.00
A.5.2	Situation awareness: PD	Afert on-orbit PD test	2.00
A.5.3	Situation awareness: vaPV	After on-ground vaPV test	2.00
A.5.4	Situation awareness: vaPV	After on-orbit vaPV test	2.00
A.6.1	End questionnaire: PD	After each vaPV test	3.00
A.6.2	End questionnaire: vaPV	After each vaPV test	3.00

A.1 General questionnaire

Participant number:_____

Date: _____

Please fill in the short questionnaire below. If you have any questions for clarification, do not hesitate to ask them.

1. Age: _____

2. Sex: O Male   O Female

3. Do you have experience with *paper* procedural support in space?
   - ❑ Yes, extensive.
   - ❑ Yes, average.
   - ❑ Yes, limited.
   - ❑ No

4. Do you have knowledge on and/or experience with *voice controlled programs*, besides vaPV?
   - ❑ Yes, extensive.
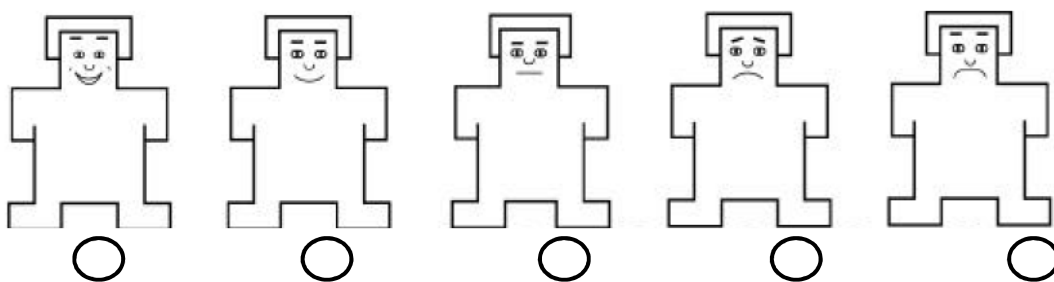   - ❑ Yes, average.
   - ❑ Yes, limited.
   - ❑ No
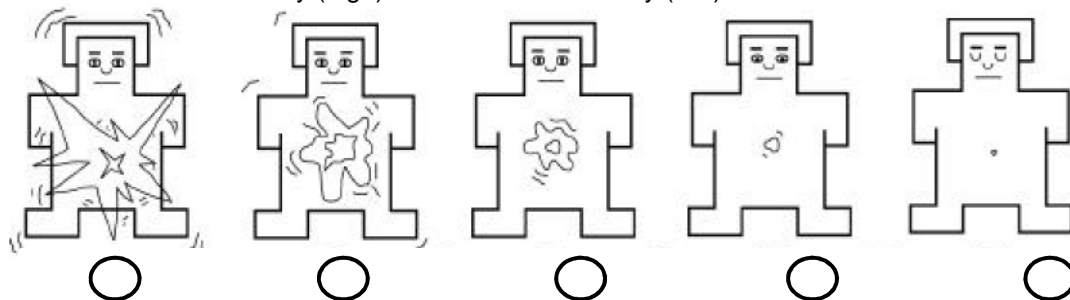
A.2 Emotional state

Participant number:_____

Date: _____

Please indicate your current emotional state. Cross the circle below the picture for valence and arousal.

Valence: pleasant (positive feeling) ←—→ unpleasant (negative feeling)

Arousal: emotional activity (high) ←—→ emotional activity (low)

A.3   Satisfaction & trust

Please, evaluate the program on the portable device (not the device itself) you used by encircling one of the numbers on a scale from 1 (totally disagree) to 5 (totally agree):

		Totally disagree	Disagree	Neither agree nor disagree	Agree	Totally agree
1	I found the program easy to use.	1	2	3	4	5
2	I trusted the information the program gave me.	1	2	3	4	5
3	I found the program pleasant to use.	1	2	3	4	5
4	I was satisfied with the way the program worked.	1	2	3	4	5
5	The program is truthful.	1	2	3	4	5
6	I found the program reliable.	1	2	3	4	5
7	I found the information offered by the program useful.	1	2	3	4	5
8	The information was offered at the right time.	1	2	3	4	5

Comments:

_____

_____

_____

_____

A.4   Efficiency

Rating Scale Mental Effort

Please indicate, by marking the vertical axis below, how
much effort it took for you to complete the task you've just finished

```
150 ─┐
     │
140 ─┤
     │
130 ─┤
     │
120 ─┤
     │
110 ─┼───────  EXTREME EFFORT
     │
100 ─┼───────  VERY GREAT EFFORT
     │
90  ─┤
     │
     ┼───────  GREAT EFFORT
80  ─┤
     │
70  ─┼───────  CONSIDERABLE EFFORT
     │
60  ─┤
     ┼───────  RATHER MUCH EFFORT
50  ─┤
     │
40  ─┼───────  SOME EFFORT
     │
30  ─┤
     ┼───────  A LITTLE EFFORT
20  ─┤
     │
10  ─┼───────  ALMOST NO EFFORT
     │
     ┼───────  ABSOLUTELY NO EFFORT
0   ─┘
```
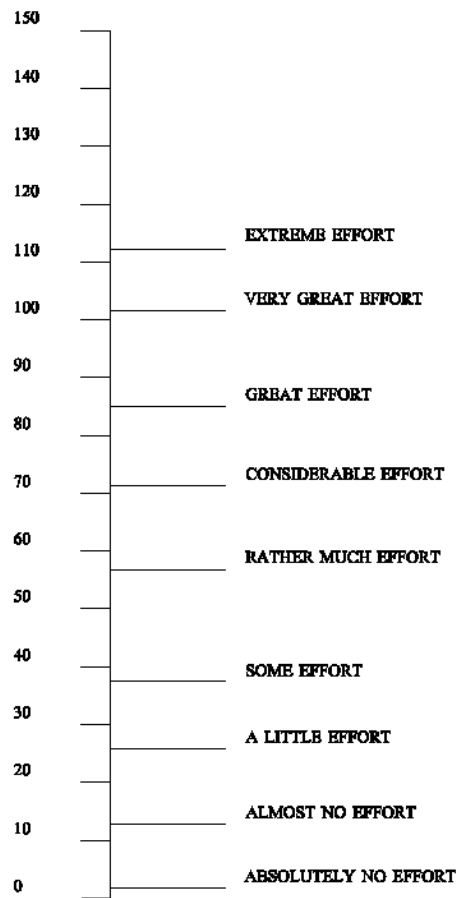
A.5   Situation awareness

A.5.1   PD on ground
The following question concern the **Procedural Display (PD).**

1. General question:
    Please provide the procedural steps for 'Cabin Temperature setting' that you
    executed and the conditions that affect this step.

_____

_____

_____

_____

_____

_____

(Please do not turn around page until question on this page has been answered)

2. Specific questions:
    What should you take into account when starting the CTCU activation procedure?

    Answer:
    The cabin temperature may need time to stabilize to the nominal temperature range. The delta temperature between the 3 sensors must not be greater than 1.5 degC. If the cabin temperature is out of the expected values, retry this step within one hour. Rational: for most cases one hour is sufficient for the CTCU to attain nominal operation temperature.

    What is the objective of the cabin temperature setting procedure?

    Answer:
    This procedure is used to change the cabin temperature set-point of the active Cabin
    Temperature Control Unit (CTCU). The set-point can be selected between 18 degC and 27
    degC.

A.5.2   Situation awareness: PD on-orbit
The following question concern the **Procedural Display (PD).**

1. General question:
    Please provide the procedural steps for 'Cabin Temperature setting' that you executed and the conditions that affect this step.

    _____

    _____

    _____

    _____

    _____

    _____

(Please do not turn around page until question on this page has been answered)

2. Specific questions:
   Under which conditions of the VEMRV and the V&V can the Venting System be activated?

   _____

   _____

   _____

   What should be taken into account before opening the VEDD valves to avoid unintended propulsive venting?

   _____

   _____

   _____

A.5.3   *Situation Awareness: vaPV on-ground*
The following question concern the **voice activated Procedure Viewer (vaPV).**

1. General question (first to be answered):
   Please provide the procedural steps that you executed and the conditions that affect this step.

Click here to enter text.

Do not proceed to next page until question on this page has been answered

2. Specific questions:

Below is a picture, please label the illustration correctly by providing the corresponding number in the table.

List	Corresponding number
(a) Cabin temperature sensor	*3*
(b) Air duct debris screen	*1*
(c) Horseshoe bracket	*2*

What caution do you have to take into account with the nozzle when using the vacuum cleaner?

Answer:
To prevent damage to the Cabin Temperature Sensors (CTS) probes, do not bring Vacuum Cleaner nozzle in direct contact with the CTS probes.

A.5.4 *Situation Aareness: vaPA on-orbit*

The following question concern the **voice activated Procedure Viewer (vaPV).**

3. General question (first to be answered):

Please provide the procedural steps that you executed and the conditions that affect this step.

_____

_____

_____

_____

(Please do not turn around page until question on this page has been answered)

4. Specific questions:
   Which warning should be taken into account during this specific procedure?

   _____

   _____

   _____

   Which conditions of the "Columbus air loop" have to be taken into account "to inspect and clean the RGSH"?

   _____

   _____

   _____

A.6   End questionnaire

A.6.1   PD

Participant number:_____
Date: _____

The following question concern the **Procedural Display (PD).**
   1. Please mention 2 aspects of PD that you find positive?

   1. _____

   2. _____

   2. Please mention 2 aspects of PD that you find negative?

   1. _____

   2. _____

   3. Do you have any remaining remarks or suggestions concerning the PD?

   _____

   _____

   _____

A.6.2   End questionnaire: vaPV

Participant number:_____

Date: _____

The following question concern the **voice activated Procedure Viewer (vaPV).**
    4. Please mention 2 aspects of vaPV that you find positive?

        1.   _____

        2.   _____

    5. Please mention 2 aspects of vaPV that you find negative?

        1.   _____

        2.   _____

    6. Do you have any remaining remarks or suggestions concerning the vaPV?
        _____

        _____

        _____