A Virtual Environment Task Analysis Workbook for the Creation and Evaluation of Virtual Art Exhibits

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Abstract

This document introduces a Virtual Task Analysis Tool (VETAT) for the creation and evaluation of virtual art exhibits. VETAT was developed to provide structure and guidance to the needs analysis process essential to the successful development of life-like virtual exhibits. The first part of the workbook draws a general profile of the target application. It introduces organizational, user and task related factors typically collected when designing or modifying computer-based systems. The second section presents the user and task requirements unique to the creation of a virtual environment. Task requirements are collected within storyboards and organized according to an appropriate architecture. Storyboards identify the images, sounds, sensations and scents found in individual galleries. The architecture establishes a sensible order in which the galleries may be accessed. User requirements determine the human sensory, cognitive and ergonomic needs relevant to the key activities museum visitors are expected to perform. Activities include visualization and inspection, exploration and the manipulation of virtual artifacts. Eight goal-categories define user requirements. Visual, auditory and haptic needs are determined by human sensory issues. Features relevant to memory capacity, information load and mental models are the result of cognitive issues. Physical and physiological considerations are determined by human ergonomics. The last section of the workbook identifies usability issues, measures of achieved performance and/or competence. Four subjective measures are suggested to evaluate the success of the system and identify critical issues. One questionnaire investigates user satisfaction with regard to the activities performed within the environment. A second targets health issues and a third the participants' reported sense of presence and realism. A fourth questionnaire collects information relevant to various image properties of specific interest to art specialists. It is hoped that this document provides a useful basis for the successful creation and evaluation of life-like virtual exhibits. Comments and suggestions for future improvements are invited.

Résumé

Ce document présente un ensemble d'outils reliés à la création et à l'évaluation d'expositions d'arts virtuelles. Il propose une structure permettant l'analyse des besoins que nous présumons essentiels à la réalisation d'expositions virtuelles naturelles. La première section du document établie le profil général de l'application cible. Elle présente les attributs propres à l'organisation, aux utilisateurs et aux fonctions typiquement recueillis lors du développement ou la modification d'un système informatique. La deuxième section du document identifie les besoins uniques à la création d'un environnement virtuel. Les premiers relèvent du contenu des galeries. Les seconds relèvent des tâches effectuées par les visiteurs de l'exposition, soit la visualisation, l'inspection et la manipulation des objets d'art. Le contenu des galeries est décrit à l'aide de maquettes organisées selon une architecture pertinente. Les maquettes décrivent les images, sons, sensations et senteurs rattachés à chacune des galeries. L'architecture définie l'ordre selon laquelle l'exploration de celles-ci peut être effectuée. Les besoins reliés aux tâches identifient les paramètres d'ordre sensoriels, cognitifs et ergonomiques humains auxquels elles font appel. Les paramètres reliés aux mécanismes perceptuels, auditifs et haptiques répondent aux besoins d'ordre sensoriel. Les paramètres portant sur la mémoire, le traitement de l'information et les modèles mentaux résultent de besoins d'ordre cognitif. Les principes reliés aux contraintes physiques et physiologiques du corps humain respectent des besoins d'ordre ergonomique. La dernière section du document propose des mesures permettant d'évaluer les bénéfices et limites du système. Quatre questionnaires sont présentés. L'un détermine la satisfaction des visiteurs de l'exposition. Un deuxième cible les effets de l'environnement sur la santé des participants et un troisième relève les sentiments de présence et de réalisme suscités. Le quatrième questionnaire recueille une évaluation des propriétés des images virtuelles d'intérêt spécifique aux spécialistes de l'art. Nous espérons que ce document offre un ensemble d'outils utiles à la création et à l'évaluation d'expositions d'arts virtuelles naturelles. Afin d'améliorer une version ultérieure de ce document le lecteur/la lectrice est invité(e) à nous faire parvenir ses commentaires et suggestions.

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1. INTRODUCTION

The Virtual Environment Task Analysis Tools (VETAT) was developed to provide structure and guidance to the needs analysis process essential to the creation of life-like virtual exhibits. The design of a virtual environment rests on an analysis of the user and task requirements of a given application. An understanding of the target application is critical to user satisfaction and to the successful development of the system. Pragmatic methods are currently needed to identify the specific needs of life-like virtual environments and capture them within clear requirements documentation (Rory, 1996). This workbook hopes to help close the gap between users and developers, ensuring that applications products and services meet user expectations. The more informed our analyses, the better our design choices are likely to be.

In order to support the analysis and design of a virtual art exhibit this workbook offers a set of tools identifying the various requirements assumed essential to the development of the system. The first part of the document draws a general profile of the target application. It introduces organizational, user and task related factors typically collected when designing or modifying computer-based systems. The second section presents the requirements unique to a virtual environment. Task requirements are collected within storyboards and organized according to a convenient architecture. Storyboards identify the images, sounds, sensations and scents to be found in individual galleries. The architecture establishes a sensible order in which the galleries may be accessed. User requirements define human sensory, cognitive and ergonomic needs relevant to the key activities museum visitors are expected to perform. Activities include visualization and inspection, exploration and the manipulation of virtual artifacts. Eight goal-categories are identified. Visual, auditory and haptic needs identify sensory requirements. Features relevant to memory capacity, information load and mental models identify cognitive requirements. Physical and physiological considerations determine ergonomic requirements. A survey of design requirements can be found in Parent (1998a). The last section of the workbook identifies usability issues, measures of achieved performance and/or competence. Four subjective measures are suggested to evaluate the success of the system and identify critical issues. One questionnaire investigates user satisfaction with regard to the activities performed within the environment. A second targets health issues and a third the participants reported sense of presence and realism. A fourth questionnaire collects information relevant to various image properties of particular interest to art specialists.

It is hoped that this workbook provides a useful basis for the successful creation and evaluation of life-like virtual exhibits. Comments and suggestions for future improvements are invited.

2. PART I - ORGANIZATIONAL, USER AND TASK PROFILES

The needs analysis process begins with the collection of organisational, user and task related facts. Given the relative familiarity of most system designers with the nature of this data, only a brief description of the items is offered. The items presented are assumed to be relevant to most applications. Of course, one may wish to collect additional facts when pertinent to a particular context.

2.1. Organizational Profile

This section identifies the attributes of the organization within which the virtual environment will exist. Organizational factors of possible relevance to system designers include relevant constraints and company culture toward new technologies. Constraints may refer to maintenance resources, development deadlines, database compatibilities or other limitations likely to affect the development of the environment. Company doctrines may be positive, negative or neutral. Doctrines may, for example, suggest that more or less introductory material should be provided.

1. Name	
2. Opportunity	
3. Justification	
4. Key Constraints a. resources b. deadlines c. compatibility d. other	
5. Doctrine a. positive b. neutral c. negative	

2.2. User Profile

A profile of each user-type should be drawn. User-types are defined as groups of users with similar backgrounds and prerequisite knowledge of the technology. A user profile identifies the attributes of the user group which may influence exploration and interaction modes within the virtual environment. Groups with high and low computer literacy may indicate a need for naive and expert interaction modes or a trade-off choice. Attributes of potential interest include a user's occupation, literacy level, knowledge of similar technologies, language, physical and psychological constraints.

USER ATTRIBUTES	RECOMMENDATIONS
1. Knowledge, Skills, Experience	
a. Occupation	
i. student	
ii. unrelated discipline	
iii. related discipline	
iv. specialist	
b. Computer Literacy	
i. high	
ii. moderate	
iii. low	
c. Similar Applications	
i. none	
ii. one	

iii. some	
d. Language	
i. French	
ii. English	
iii. Other	
2. Physical Constraints	
a. Color-blindness	
b. Handicaps	
3. Psychological Constraints	
a. Motivation	
i. high	
ii. moderate	
iii. low	
4. Reservations	
I. high	
ii. moderate	
iii. low	

2.3. Task Profile

2.3.1. Task Attributes

A profile of each of the tasks the users will be expected to perform should also be drawn. Task attributes describe the mandatory or discretionary nature of the activities, frequency of use, task importance, training needs and turnover rates of each of the user groups the system is designed to service. This data may inform of particular design requirements such as special connections to various databases and needed safeguards. The task profile identifies the characteristics of the task that will guide hardware (e.g. devices) choices and image content. This section identifies the general attributes of an art exhibit. A virtual environment who's use is mandatory, for example, should be designed to allow for particular user needs (e.g. color-blindness).

TASK ATTRIBUTES	RECOMMENDATIONS
1. VE Use	
a. mandatory	
b. discretionary	
2. Frequency of use	
a. high	
b. medium	
c. low	
3. Task Importance	
a. high	
b. medium	
c. low	
4. Training	
a. none	
b. manual only	
c. elective formal	
d. mandatory formal	
5. Turnover rate	
a. high	
b. moderate	
c. low	

6. Other tools used (computers, electronic games)	

2.3.2. Task Analysis

This section defines the functional goals and success criteria of the virtual environment.

1. Rationale for the VE i. improve performance ii. reduce costs iii. increase accessibility iv. other	Increase accessibility; improve performance of the museum by communicating more information concurrently; Increase time accessibility; decrease storage requirements; Avoid damage due to air and direct sunlight; Avoid theft and vandalism; provide access to greater levels of artistic detail with regard to brush strokes, chisel shape and more.
2. Goals of the task	
3. Expected activities	
4. Workspace requirements (for reading, writing and equipment use e.g. telephone)	
5. Storage and Filing requirements	
6. Space for others (visitors, customers, co-workers)	
7. Privacy requirements	
8. Functions to delight	
9. Task inputs (from related systems)	
10. Critical success factors	Increased museum attendance; Increased opportunities to learn about masterpieces, their creators and times.

3. PART II - DESIGN REQUIREMENTS AND RECOMMENDATIONS

This part of the workbook identifies the task requirements of the application through storyboards and the elaboration of the exhibit architecture. User requirements and design recommendations follow.

3.1. Task Requirements

3.1.1. Storyboards

Storyboards are series of panels depicting the important changes of scene and action in a planned film, television show or act. They may include images, sounds, sensations, scents, text and animation.

3.1.1.1. Images

Table 1: Objects

Table 2: Video

Table 3: Text

3.1.1.2. Sounds

Table 4: Music

Table 5: Noise

3.1.1.3. Sensations

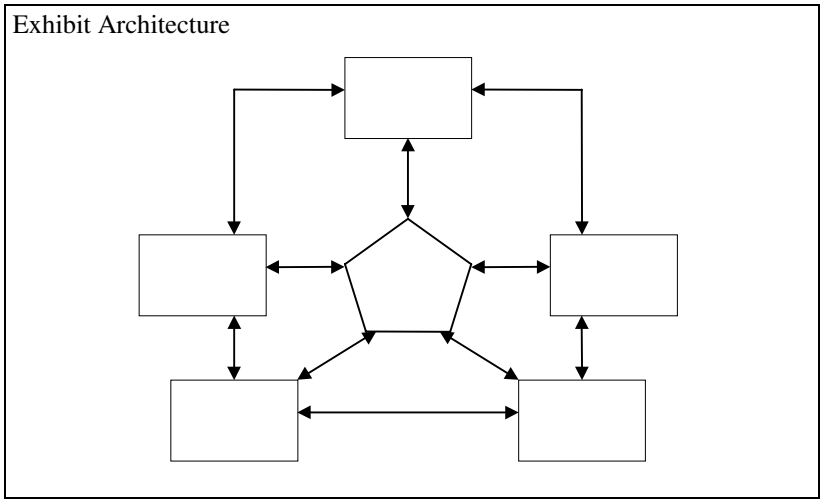
Table 6: Sensations

3.1.1.4. Scents

Table 7: Odors

3.1.2. Architecture

The exhibit architecture is a plan showing available pathways to the different galleries. Of course, each gallery may contain one or many rooms.



3.2. User Requirements

This section identifies the sensory, cognitive and ergonomic requirements of the key activities the museum visitors will perform, the visualization and manipulation of paintings, sculptures and various artifacts, and the exploration the virtual galleries. It is unlikely that the application will require that the virtual environment simulate the physical world in all of its detail and complexity (and perhaps impossible). It is therefore important to carefully identify the issues that are essential to the efficient and effective performance of the key activities. A more detailed description of user requirements can be found in Parent (1998a).

3.2.1. Sensory Requirements

Sensory requirements define the parameters of human sensations and perception. An important goal of the virtual environment is to provide appropriate visual, auditory, haptic and olfactory cues. Visual fidelity defines the degree of coherence between human visual mechanisms and the display of system images. Auditory requirements describe the sounds produced in the virtual environment. Haptic requirements define the parameters of human tactile, kinesthetic, proprioceptic and vestibular sensations. Olfactory requirements are included for completeness but this technology is not expected to be available in the next few years (Youngblut et al. 1996).

3.2.1.1. Visual Requirements

REQUIREMENTS	RANK	RECOMMENDATIONS
1. Eye Geometry		
a. field of view Head-Mounted Display (HMD) Spatially Immersive Display (SID) Head-Coupled System (HCS) Virtual Model Display (VMD)		
b. interpupillary distance (HMD)		
2 Perception of colour (hue, saturation and brightness)		
a. color palette		
i.chromaticity values		
• chromatic color attributes (hue, saturation)		
• achromatic attributes		
(brightness level)		
ii. luminance steps		
3. Perception of contrast and detail		
a. luminance,		
b. contrast ratio		
c. spatial resolution		
4. Foveal vs peripheral perception		
5. Depth perception		
a. Binocular cue (stereopsis)		
b. Static monocular cues		
i. relative size and height		
ii. linear perspective		
iii. foreshortening		
iv. interposition		
v. gradient of object		
vi. textural gradient		
i. relative brightness		
viii. light and shadow effects		
• light sources		
-number		
-position		
-color		
-type (specular ambient, diffuse)		
-texture		

REQUIREMENTS	RANK	RECOMMENDATIONS
ix. atmospheric effects		
• sky & ground color		
• fog (color, type, range)		
x. levels of detail		
c. Dynamic monocular cue (motion parallax)		
6. Motion perception		
a. Object motion cues		
i. angular size		
ii. texture density		
iii. lateral speed of detail		
b. Self-motion cues		
i. motion parallax (for estimating speed)		
ii optic flow (for estimating direction)		

3.2.1.2. Auditory Requirements

REQUIREMENTS	RANK	RECOMMENDATIONS
1. Foreground		
a. number		
b. patterning		
i. pitch		
ii. loudness		
iii. timbre		
iv. spatial display		
2. Background		
a. number		
b. patterning		
i. pitch		
ii. loudness		
iii. timbre		
iv. spatial display		
3. Collision(s)		
a. number		
b. patterning		
i. pitch		
ii. loudness		
iii. timbre		
iv. spatial display		

3.2.1.3. Haptic Requirements

REQUIREMENTS	RANK	RECOMMENDATIONS
1. Tactile		
a. temperature		
b. texture		

2. Kinesthetic pressure on muscles, joints and tendons		
3. Proprioceptic (limb/torso position)		
4. Vestibular (balance)		
a. functions to avoid sickness		
i. control-display gain		
• x, y, z, pitch, roll, yaw		
ii. control order		
• x, y, z, pitch, roll, yaw		
iii. time delay		

3.2.1.4. Olfactory Requirements

REQUIREMENTS	RANK	RECOMMENDATIONS
Scents		
a. nature		
b. origin		

3.2.2. Cognitive Requirements

Cognitive requirements define the parameters of human information processing. Fidelity to one's models of interaction refers to the consistency between the users actions and their expected effects on the system (Sheridan, 1992). Cognitive fidelity also defines the coherence between the laws of the physical world and those of the virtual world (Barfield & Weghorst, 1993; Barfield et.al.1995). Memory requirements aim to insure that ease of learnability of the interactive modes and procedures is considered given a particular group of users. Information load considerations insure that the quantity of information displayed on the screen or required to accomplish a specific activity is within limits available to a wide range of user groups.

3.2.2.1. Mental Models

REQUIREMENTS	RANK	RECOMMENDATIONS
1. Environmental		
a. degree of scene complexity		
b. object constancy		
c. object consistency		
d. object geometry		
e. number of sensory output		
f. range of sensory output		
g. intermodal consistency		
2. Physical and social interaction		
a. conformity to expectation of various scenarios		
i. collision		
ii effect		
• sound		
• text		
• image		

REQUIREMENTS	RANK	RECOMMENDATIONS
b. range of control behaviors		
Inspection		
i. scaling (object)		
• center of scaling		
• scaling factor		
ii. devices		
• mouse		
• wand		
• spaceball		
• menus		
- physical		
- virtual		
iii. actions		
• select/release		
• zoom in/zoom out		
• magnification level(s)		
Exploration		
i. modes		
• hand directed		
- pointing mode		
- cross-hairs		
- dynamic scaling		
• gaze-directed & orbital		
ii. speed		
• constant speed (units)		
• constant acceleration		
• degrees of freedom		
- x,y,z, pitch, roll, yaw		
• direction		
- forward/ backward		
- up/down		
iii. scaling (user)		
• center of scaling		
• scaling factor		
iv. devices		
• mouse		
• wand		
• spaceball		
• menus		
- physical		
- virtual		
• direct user motion		
• object driven		
• goal driven		
v. actions		
• start/stop		
• accelerate		
• decelerate		
Object Manipulation		
i. modes		
• local		
• action-at -a distance		
• gaze directed		
• voice input		

REQUIREMENTS	RANK	RECOMMENDATIONS
• list selection		
iii. devices		
• sensing glove		
• wand		
• mouse		
• menus		
- physical		
- virtual		
• direct user interaction		
iv. actions		
• select/release		
• open/close		
• push/ pull		
c . temporal predictability		
i. update frequency		
ii. refresh rate		
iii. image delay		
e. spatial predictability		

3.2.2.2. Memory

REQUIREMENTS	RANK	RECOMMENDATIONS
Learnability		
a. inspection options		
b. exploration options		
c. manipulation options		

3.2.2.3. Information Load

REQUIREMENTS	RANK	RECOMMENDATIONS
1. Required concentration		
a. low		
b. medium		
c. high		
2. Monotony		
3. Information displayed		
a. variety		
b. amount		

3.2.3. Ergonomic Requirements

Ergonomic requirements insure that the physical expectations placed on the human body and its movement are appropriate. Ergonomic requirements are satisfied when the position of the user is efficient and comfortable and the interactive devices provided conform to human physiology.

REQUIREMENTS	RANK	RECOMMENDATIONS

1. Position		
a. standing		
b. sitting		
d. bending		
e. crouching		
i. stooping		
2. Hand/fingers		
a. pointing		
b. grasping		
c. pressing		
3. Arm movements		
a. reaching		
b. stretching		

4. PART III - USABILITY TESTING

Usability testing evaluates the success with which the virtual environment satisfies its goals. Critical success factors defined within the task analysis are here re-visited.

4.1. Usability Issues

Usability issues address the ease with which museum visitors interact with the virtual environment. Usability issues include discoverability, efficiency, learnability, feedback, recoverability and likeability (Neilsen, 1993). Discoverability is the ease with which the user can guess how the system operates, the transparency of inspection, exploration and manipulation procedures. Efficiency describes how well the user achieves his/her goals. Learnability refers to the ease with which a user learns how to perform various activities. Feedback issues identify how well the user can follow the system's reactions. Recoverability defines the ease of reversing an error. Likeability determines how pleasing the virtual exhibit is judged by its visitors. In order to gain an appreciation of the environment's usability, four questionnaires appended to the workbook are proposed.

4.1.1. A Virtual Exhibit Usability Questionnaire

The Virtual Exhibit Usability Questionnaire investigates user satisfaction with regard to visual clarity, compatibility, user control and system feedback, error correction, functionality, general usability and ergonomics. It is introduced in Appendix I.

4.1.2. A Simulator Sickness Questionnaire

This questionnaire is used to assess the virtual environment's effects on an individual's health, specifically nausea, oculomotor discomfort and disorientation. Items are based on studies conducted by Kennedy et al. (1993). It is introduced in Appendix II.

4.1.3. Presence and Realism

The sense of presence and realism generated by the environment is assessed by this questionnaire. It is presented in Appendix III.

4.1.4. Image Property Ratings

This questionnaire was developed to determine an art specialist's satisfaction with regard to specific properties of the images displayed. The questionnaire is presented in Appendix IV.

4.2. Performance Measures

Performance measures determine the efficiency of the virtual exhibit. They may compare natural and virtual exhibit attendance given baseline figures or similar circumstances. Studies may determine better displays, better devices, better and most cost effective approaches to visualization, exploration and the manipulation of virtual objects.

4.3. Competence Measures

Competence measures determine the effectiveness of the galleries as learning environments. Pre and post-test scores may be obtained from various groups of users invited to participate in the studies. Insights potentially gained by specialists may also be investigated.

5. CONCLUSION

The Virtual Environment Task Analysis Tools (VETAT) was developed to provide structure and guidance to the needs analysis process essential to the successful development of life-like virtual exhibits. Pragmatic methods are currently needed to identify the specific needs of life-like virtual environments and capture them within clear requirements documentation (Rory, 1996). This workbook hopes to help close the gap between users and developers, ensuring that applications products and services meet user expectations.

In order to support the analysis and design of a virtual exhibit the VETAT workbook offers a set of tools identifying the various requirements assumed essential to the development of life-like virtual exhibits. The first part of the document draws a general profile of the target application. It introduces organizational, user and task related factors typically collected when designing or modifying computer-based systems. The second section presents the requirements unique to a virtual environment. Task requirements are collected within storyboards and organized according to a convenient architecture. Storyboards identify the images, sounds, sensations and scents to be found in individual galleries. The architecture establishes a sensible order in which the galleries may be accessed. User requirements define human sensory, cognitive and ergonomic needs relevant to the key activities museum visitors are expected to perform. Activities include visualization and inspection, exploration and the manipulation of virtual artifacts. Eight goal-categories are identified. Visual, auditory and haptic needs identify sensory requirements. Features relevant to memory capacity, information load and mental models identify cognitive requirements. Physical and physiological considerations determine ergonomic requirements. The last section of the workbook identifies usability issues, measures of achieved performance and/or domain competence. Four subjective measures are suggested to evaluate the success of the system and identify critical issues. One questionnaire investigates user satisfaction with regard to the activities performed within the environment. A second targets health issues and a third the participants' reported sense of presence and realism. A fourth questionnaire collects information relevant to various image properties of particular interest to art specialists.

It is hoped that this workbook provides a useful basis for the successful creation and evaluation of life-like virtual exhibits.

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GLOSSARY

Control-display Gain
Effort and displacement required to obtain a change in the display.

Control order
Rate of change in display state that results from a change of position.

Foreshortening
Compression of an image seen sideways.

Gradient of Object
At greater distances there are more objects and details in the same angular area.

Haptic
Sensations of touch; include: tactile, kinesthetic, proprioceptic and vestibular.

Image Delay
Sampling time of trackers + time for calculating a change in viewpoint position.

Kinesthetic
Force sensed by muscles, joints and tendons.

Optic Flow
Pattern of objects approaching (e.g. expanding) or moving away.

Proprioceptic
Sense of limb/torso positions.

Refresh Rate
Speed with which a whole frame of the display is written.

Textural Gradient
Texture is more apparent as the object is closer to the observer.

Time Delay
Time required to display a new image content.

Vestibular
Sense of balance; inner ear's sensing of linear and angular accelerations of the head.

Update Frequency
Frequency with which a totally new image content is generated.

APPENDIX I

A Virtual Exhibit Usability Questionnaire

The following checklists define a set of criteria to evaluate the success of a virtual exhibit and help identify areas in need of improvement. The questionnaire is designed to explore 1) visual clarity, 2) compatibility with same or similar technologies, 3) the appropriateness of user controls and system feedback, 4) ease of error correction, 5) functionality effectiveness, 6) general usability, 7) general ergonomics and overall user satisfaction.

A. Physiological Conditions

1. Visual Clarity

The quality of the images displayed in the environment should be good and their presentation should be clear, well-organized and unambiguous.

Visualization and inspection

ISSUES	1 Totally Agree	2	3	4	5 Totally Disagree
1. The field of view is adequate.					
2. The detail of the virtual image is easy to read.					
3. Overall, the perception of depth when viewing the virtual image is adequate; specifically with regard to:					
a. relative size					
b. relative height					
c. linear perspective					
d. texture					
e. relative brightness					
f. stereo vision					
g. resolution according to distance					
h. bumpiness of the surface					
4. In general, colour discrimination is clear and easy when viewing the virtual image; specifically with regard to:					
a. scene lighting level					
b. luminance contrast between object and background					
c. number of colors					
d. shading					
e. reflections from different points of view					
5. Finding the required objects in the environment is easy.					

Are there any comments (good or bad) you wish to add regarding the above issues?

Overall, how would you rate this activity in terms of visual clarity?

Very satisfactory	Moderately satisfactory	Neutral	Moderately unsatisfactory	Very unsatisfactory

Exploration

ISSUES	1 Totally Agree	2	3	4	5 Totally Disagree
1. The field of view is adequate.					
2. Overall, the perception of depth when viewing the virtual image is adequate; specifically with regard to:					
a. relative size					
b. relative height					
c. linear perspective					
d. texture					
e. relative brightness					
f. stereo vision					
g. resolution according to distance					
3. In general, colour discrimination is clear and easy when viewing the virtual image; specifically with regard to:					
a. scene lighting level					
b. luminance contrast between object and background					
c. number of colors					
d. shading					
e. reflections from different points of view					
4. Finding the required objects in the environment is easy.					

Are there any comments (good or bad) you wish to add regarding the above issues?

Overall, how would you rate this activity in terms of visual clarity?

Very satisfactory	Moderately satisfactory	Neutral	Moderately unsatisfactory	Very unsatisfactory

Object manipulation

ISSUES	1 Totally Agree	2	3	4	5 Totally Disagree
1. The field of view is adequate.					
2. Overall, the perception of depth when viewing the virtual image is adequate; specifically with regard to:					
a. relative size					
b. relative height					
c. linear perspective					
d. texture					
e. relative brightness					
f. stereo vision					
g. resolution according to distance					

ISSUES	1 Totally Agree	2	3	4	5 Totally Disagree
3. In general, colour discrimination is clear and easy when viewing the virtual image; specifically with regard to:					
a. scene lighting level					
b. luminance contrast between object and background					
c. number of colors					
d. shading					
e. reflections from different points of view.					
4. Finding the required objects in the environment is easy.					

Are there any comments (good or bad) you wish to add regarding the above issues?

Overall, how would you rate this activity in terms of visual clarity?

Very satisfactory	Moderately satisfactory	Neutral	Moderately unsatisfactory	Very unsatisfactory

B. Psychological Conditions

2. Compatibility

The way the system looks and works should be compatible with user conventions and expectations.

ISSUES	1 Totally Agree	2	3	4	5 Totally Disagree
1. The colors of the images are realistic.					
2. Control actions are compatible with other systems with which I interact or feel natural.					
3. The geometry of the images feels natural.					
4. The control procedures work as expected (e.g. to explore or manipulate an object)					
5. The system works the way I expect it to work.					

Are there any comments (good or bad) you wish to add regarding the above issues?

Overall, how would you rate the system in terms of consistency with your expectations?

Very satisfactory	Moderately satisfactory	Neutral	Moderately unsatisfactory	Very unsatisfactory

3. Control and Feedback

Users should feel in control of the system. They should be given clear, informative feedback on where they are in the environment, what actions they have taken and whether these actions have been successful.

ISSUES	1 Totally Agree	2	3	4	5 Totally Disagree
1. The system reactions to my actions are obvious; specifically with regard to:					
a. head orientation					
b. inspection					
c. exploration					
b. object manipulation					
2. The actions needed to achieve a result are clear.					

Are there any comments (good or bad) you wish to add regarding the above issues?

Overall, how would you rate the system in terms of control and feedback?

Very satisfactory	Moderately satisfactory	Neutral	Moderately unsatisfactory	Very unsatisfactory

4. Error Correction

The environment should be designed to minimize the possibility of user error, with in-built facilities for detecting and handling those which do occur.

ISSUES	1 Totally Agree	2	3	4	5 Totally Disagree
1. Errors are easy to correct.					
2. Inspection errors are due to the magnification procedure.					
3. Exploration errors are due to motion procedures					
4, Interaction errors are due to device procedures					
5. Errors are due to action-effect latencies					
6. Errors are due to sensor inaccuracies (e.g. measurement errors)					
7. Errors are due to object translations					
8. Errors are due to object rotations					
9. Errors are due to limited sensor range					
10. Difficult actions can be tried without the system causing problems					
11. In general, the environment is free of errors and malfunctions.					

Are there any comments (good or bad) you wish to add regarding the above issues?

Overall, how would you rate this activity in terms of error correction?

Very satisfactory	Moderately satisfactory	Neutral	Moderately unsatisfactory	Very unsatisfactory

5. Appropriate Functionality

The environment should meet the needs and requirements of users activities.

ISSUES	1 Totally Agree	2	3	4	5 Totally Disagree
1. The devices are appropriate to the activities carried out.					
2. The information provided is appropriate to the needs.					
3. The information provided is complete.					
4. All options necessary to an activity are appropriate.					
5 Options necessary to an activity are easily accessible.					
6. Information relevant to a need is always accessible.					
7. I would like the option to define some preferences.					

Are there any comments (good or bad) you wish to add regarding the above issues?

Overall, how would you rate this activity in terms of functionality?

Very satisfactory	Moderately satisfactory	Neutral	Moderately unsatisfactory	Very unsatisfactory

6. General Usability

When using the system, how adequate are the following points:

ISSUES	1 Totally Agree	2	3	4	5 Totally Disagree
1. Learning to use the environment is easy.					
2. Understanding the procedures to inspect, explore and interact with objects is easy					
3. Understanding how my actions relate to the display of information is easy.					
4. Finding needed information is easy.					

ISSUES	1 Totally Agree	2	3	4	5 Totally Disagree
5. Colors are easy to view (no eye fatigue).					
6. The structure of the environment is flexible.					
7. Unexpected reactions of the system are rare.					
8. Devices are generally easy to use; specifically,					
a. physical controls					
b. virtual controls					
c. menus					
8. In general, system response times were too slow; specifically with regard to,					
a. head movements					
b. inspection activities					
c. exploration					
d. object manipulation					
i. touching					
ii. grasping					
iii lifting					
iv turning					
v. dropping					
8. In general, system response times were too fast; specifically with regard to,					
a. head movements					
b. inspection activities					
c. exploration					
d. object manipulation					
i. touching					
ii. grasping					
iii lifting					
iv turning					
v. dropping					

13. Are there any comments (good or bad) you wish to add regarding the above issues?

Overall, how would you rate the system in terms of general usability?

Very satisfactory	Moderately satisfactory	Neutral	Moderately unsatisfactory	Very unsatisfactory

C. Ergonomic Conditions

7. General ergonomics

The system should be designed for user comfort.

ISSUES	1 Totally Agree	2	3	4	5 Totally Disagree

ISSUES	1 Totally Agree	2	3	4	5 Totally Disagree
1. My posture is uncomfortable. (sitting or standing)					
2. The 3-D glasses are too tight/large.					
3. The 3-D glasses are too heavy.					
4. The head sensor are cumbersome.					
5. The motion sensor are cumbersome.					
6. Hand-held devices are cumbersome					
7. The sensing glove is uncomfortable.					

Are there any comments (good or bad) you wish to add regarding the above issues?

Overall, how would you rate the ergonomics of the system?

Very satisfactory	Moderately satisfactory	Neutral	Moderately unsatisfactory	Very unsatisfactory

General Questions

1. What are the best aspects of the environment?

2. What are the worst aspects of the environment?

3. What are the most common mistakes you made when using the system?

4. What changes would you make to the system to make it better?

5. How does the system compare to other virtual environments you have experienced?

References

Ravden S.J. & Johnson G.I. (1989). *Evaluating Usability of Human-Computer Interfaces*, G. Johnson & S. Ravden (eds), Ellis Horwood Limited

Aldridge, R.J. Carr, K. England R. Meech J.F. Solomonides, T. (1996). Getting a grasp on virtual reality, *Proceedings of Computer Human Interaction* (CHI) 96, April 13-18, pp. 229-30.

APPENDIX II

A Simulator Sickness Questionnaire

The following questionnaire measures the effects of a virtual environment on an individual's health. The ratings form the basis of 3 subscale scores; Nausea, Oculomotor Discomfort, and Disorientation. Items are based on Kennedy et al. (1993).

Please rate the following symptoms for each activity performed in the virtual environment.

Inspection

ISSUES	0 Absent	1 Slight	2 Moderate	3 Severe
1. General discomfort				
2. Fatigue				
3. Headache				
4. Eyestrain				
5. Difficulty focusing				
6. Increased salivation				
7. Sweating				
8. Nausea				
9. Difficulty concentration				
10. Fullness of head				
11. Blurred vision				
12. Dizzy (eyes open)				
13 Dizzy (eyes closed)				
14. Vertigo				
15. Stomach awareness				
16. Indigestion				

Are there any comments you wish to add regarding the above issues?

Exploration

ISSUES	0 Absent	1 Slight	2 Moderate	3 Severe
1. General discomfort				
2. Fatigue				
3. Headache				
4. Eyestrain				
5. Difficulty focusing				
6. Increased salivation				
7. Sweating				
8. Nausea				
9. Difficulty concentration				
10. Fullness of head				
11. Blurred vision				
12. Dizzy (eyes open)				
13 Dizzy (eyes closed)				
14. Vertigo				
15. Stomach awareness				

ISSUES	0 Absent	1 Slight	2 Moderate	3 Severe
16. Indigestion				

Are there any comments you wish to add regarding the above issues?

Object Manipulation

ISSUES	0 Absent	1 Slight	2 Moderate	3 Severe
1. General discomfort				
2. Fatigue				
3. Headache				
4. Eyestrain				
5. Difficulty focusing				
6. Increased salivation				
7. Sweating				
8. Nausea				
9. Difficulty concentration				
10. Fullness of head				
11. Blurred vision				
12. Dizzy (eyes open)				
13 Dizzy (eyes closed)				
14. Vertigo				
15. Stomach awareness				
16. Indigestion				

Are there any comments you wish to add regarding the above issues?

References

Kennedy, R.S., Lane, N.E., Berbaum, K.S. & Lilienthal (1993) A simulator sickness questionnaire (SSQ): A method for quantifying simulator sickness. *International Journal of Aviation Psychology*, 3 (3) 203-220.

Kennedy, R.S. and Stanney, K.M. (1996) Postural instability induced by virtual reality exposure: development of a certification protocol, *International Journal of Human-Computer Interaction.* Jan.-March 8(1); 25-47.

Lampton,D.R., Kolasinski E.M. Knerr, B.W. Bliss J.P. Bailey, J.H. Witmer, B.G. (1994) Side effects and after effects of immersion in virtual reality environments, *Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting*, 1154-1157

APPENDIX III

Questionnaire on Presence and Realism

This questionnaire rates the sense of presence and degree of realism felt in the virtual environment. Items are based on Hendrix & Barfield (1996).

Please rate the following aspects of the environment.

Presence and Realism

ISSUES	0 None	1 2-50%	2 50-75%	3 75-100%
1. If one's level of presence in the real world is 100%, rate your level of presence in this virtual world.				
2. How strong was your sense of presence?				
3. Did you feel you could reach into the virtual environment and grasp an object?				
4.How realistic did the virtual world appear?				
5. How realistic were depth and volume?				
6. How realistic were the virtual world's reactions to your actions?				
7. When exploring the virtual space, did the objects appear too compressed or too magnified?				
8. Did the virtual objects appear geometrically correct, did they seem to have the right size and distance in relation to yourself and other objects?				

Overall, how would you rate the sense of presence generated by the environment?

Very satisfactory	Moderately satisfactory	Neutral	Moderately unsatisfactory	Very unsatisfactory

Overall, how would you rate the degree of realism achieved by the virtual environment?

Very satisfactory	Moderately satisfactory	Neutral	Moderately unsatisfactory	Very unsatisfactory

References

Hendrix & Barfield (1996). Presence within Virtual Environments as a function of visual display parameters. *Presence, Telepresence and Virtual Environments*, Volume 5, Number 3, p. 281.

APPENDIX IV

Image Property Rating Questionnaire

This questionnaire rates user satisfaction with regard to the following image properties. The importance of the properties will vary according to the nature of the art work displayed.

PROPERTIES	1 Totally Agree	2 Agree	3 Neutral	4 Disagree	5 Totally Disagree
1. Image transparency is realistic.					
2. The glossiness of the virtual artifacts is realistic.					
3. The finish of the virtual artifacts is realistic.					
4. General lighting conditions are appropriate; specifically with regard to:					
a. source					
b. nature					
c. color					
5. Object colors are natural; specifically with regard to:					
a. hue					
b. saturation					
c. brightness					
6. The color palette is appropriate.					
7. The shape of artifacts is accurately displayed.					
8. The size of artifacts is accurately displayed.					
9. The proportions of the artifacts are accurately displayed.					
10.Textures are accurately displayed.					
11. Image resolution is adequate, given one's distance.					

Overall, how would you rate the quality of the virtual images?

Very satisfactory	Moderately satisfactory	Neutral	Moderately unsatisfactory	Very unsatisfactory