Appendix 1

Experimental protocol, Information sheet, and Consent form

A1.1 EXPERIMENTAL PROTOCOL

Human Navigation Performance Using 6DOF Dynamic Viewpoint Tethering in Virtual Environments

Investigators: Wenbi Wang and Paul Milgram

This research project is part of the Ph.D. programme of Wenbi Wang, in the Department of Mechanical and Industrial Engineering at the University of Toronto, and is under the direct supervision of Professor Paul Milgram.

Background, purpose, and justification

Navigation, in real or virtual worlds, can be described as a process of gathering information, forming or revising a mental representation, and using that representation for route planning and moving about. Failure in any part of this process will cause disorientation problems. Such problems are experienced by a large number of people in different situations. The key to solving these problems is to identify navigational requirements and develop appropriate navigational aids.

There are generally two goals when people travel in space: 1) to understand the spatial structure of the space, and 2) to arrive successfully at the destination. These two goals reflect the two sub-tasks involved in navigation: *global awareness* (tasks involving understanding) and *local guidance* (tasks involving control). In this study, local guidance is defined as the largely motor task of manoeuvring along a route in the presence of nearby objects, while global awareness is defined as the comprehending of one's position relative to the world at large. The same terms can be used with respect to the task of controlling a separate object, or *avatar,* from the perspective of a *virtual camera,* defined relative to that object/avatar.

A large amount of literature has shown that these two classes of sub-tasks are supported by knowledge of different frames of reference. To be more specific, local guidance tasks are supported by knowledge of egocentric frames of reference, whereas global awareness tasks are supported by knowledge of exocentric frames of reference. The conventional first-person "out-the-window" display and "bird's eye view" map displays are examples in which respectively egocentric and exocentric knowledge are presented. In situations where both sub-tasks are required at the same time, information about both egocentric and exocentric frames of reference should be provided to the human operator.

Viewpoint tethering, a newly developed viewpoint definition concept, is designed to integrate advantages of both conventional formats (first-person displays and map-displays) by attaching the virtual camera to the nominal viewpoint on the avatar through a *virtual tether*. However, problems associated with tethered displays, such as incompatible control and displayed motions, prevent the concept from being used in many application areas.

In this research, our aim is to address those problems experienced with conventional tethered displays by modelling the virtual tether as a six degree of freedom mass-spring-damper system – i.e. a *dynamic tether*. Analogous to a frequency-separated display, the dynamic tether display presumably should solve some of the major problems with the conventional tethered display, and thus improve subjects' performance accordingly.

The primary goal of this study is to identify human users' navigation performance differences in both local control and global awareness tasks between dynamic tether displays and other conventional display formats. This should confirm or disconfirm our hypotheses about the fundamental effectiveness of dynamic viewpoint tethering.

Two sets of experiment will be carried out in this study. The first is a base-line experiment in which users' navigation performance using a dynamically tethered display will be compared with conventional viewpoint display performance (i.e., egocentric, exocentric, and rigidly tethered displays). The main objective of the second set of experiment is to investigate the effect of different values of dynamic tether parameters on users' navigational performance.

The same software platform, running on a SGI O2 graphic workstation, will be used in both sets of experiments. It consists of a virtual environment, developed using OpenGL, representing a cubic space traversed by a virtual winding tunnel. whose centre line is indicated by a red line (see Figure 1). A Spaceball^{TM} will be used as the control device. The Spaceball, together with mouse and joystick, is one of the standard input devices used with SGI workstations and has been widely used in multi-degree of freedom manipulation tasks for more than 10 years. No adverse effects on human users have previously been reported. During the experiment, the subjects will be required to view the experiment on a standard Silicon Graphics monitor, while wearing stereoscopic shuttering glasses, in order to provide maximal depth cues. IMAX stereo goggles and emitter, operating in synchrony with the O2 workstation, will be used to present the

stereo images. The battery powered shuttering glasses are manufactured by Imax Corporation, and constitute a standard piece of laboratory equipment, essentially equivalent to those worn by members of the public in Imax 3D theatres.

Based on the results of the experiments, we expect to obtain a better idea of requirements for the design of synthetic environments whose use encompasses a large navigational component. By better defining the parameter of an optimal display viewpoint, the proposed solution has potential applications in such areas as teleoperation, endoscopic surgery, CAD design and gaming.

Research procedure

The experimental task will require the participant to control the avatar, represented by an aircraft symbol, flying along the centre of the virtual tunnel, while mentally keeping track of the home base (starting position of the tunnel) at the same time. A Spaceball^{TM} will be used to control the three rotational dofs of the aircraft (i.e. pitch, yaw and roll). (Forward motion of the aircraft will be controlled by the software itself; that is, the aircraft will automatically fly forward at a constant speed.) RMS tracking error will be used to measure performance on the local guidance subtask. For any particular trial the program will automatically stop when the end of the tunnel has been reached. In this manner, a complex 3D path will be traversed through the space volume.

After completion of each navigation trial, the program will present a front view of the whole cubic environment without showing the tunnel. The end position of the tunnel will be explained to the participants and they will be asked to make a precise relative judgement of the home base location within the cubic space. The accuracy of the judgement (i.e., the distance between the actual home base and judged home base) will be taken as an indication of the quality of the cognitive map developed by the participants during the experiment, and thus will be used as a measure of global awareness performance.

Qualified participants will be tested individually during a six-day period, comprising six 40-minute sessions.

During the first session, which will be used for training, participants will receive both written and oral instructions describing the experimental platform and the tasks. (See Appendix 1.) Based on the experimenter's explanation, a consent form will be signed. (See Appendix 2.) The experimenter will remain in the room and answer questions at all times. Participants will then be required to fill out a questionnaire. (See Appendix 3.) Finally, one training trial on each display condition will be performed.

In the ensuing four sessions, the participants will complete four blocks of trials (one for each display). The order of display presentation will be counterbalanced across

participants and sessions. Within each block there are eight experimental trials, each consisting of a different tunnel trajectory, and each lasting up to 5 minutes.

The sixth session will be a review session, in which participants will first review the four displays they have worked with and then perform a comparative subjective evaluation of the conditions by, filling out a questionnaire. (See Appendix 4.)

The procedure for the second set of experiments will be exactly the same as the first, except that the display conditions will be changed to dynamically tethered displays, comprising different dynamic filtering parameters.

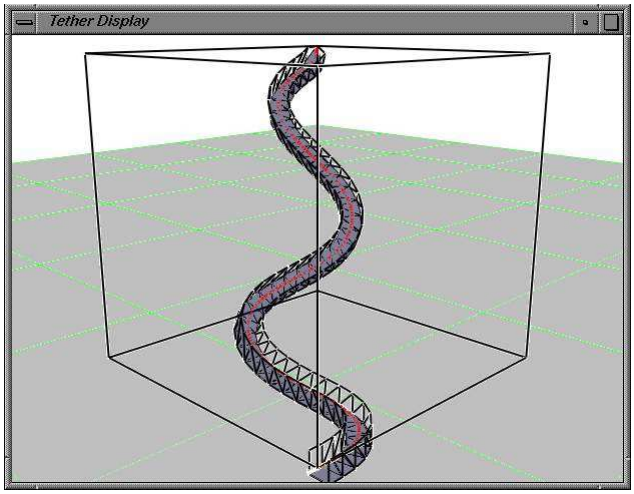


Figure 1. Virtual environment used in the experiment.

Participants

For both sets of experiments, 24 subjects will be recruited from among graduate and undergraduate students at the University of Toronto. To qualify, a subject will have to demonstrate that he/she has adequate stereo-acuity (see Recruitment). Gender, ethnic background and experience in working with stereoscopic display systems will not be considered as part of the selection criteria.

Recruitment

Participation in this study will be strictly voluntary. Recruiting flyers will be posted in both the Mechanical building (MC) and the Rosebrugh building (RS). (See Appendix 5.)

A Randot Stereotest will be performed to test participants' stereo acuity. It is a standard test, designed by Stereo Optical Co. Inc. The participants will view 22 figures by wearing a pair of polarising glasses and make ground-figure judgements. To qualify, a subject will have to demonstrate that he/she has a stereo-acuity of 20 min of arc or better at a distance of 400mm.

Risk/Benefit

No possible risks to the subjects or adverse effects are foreseen through the use of the laboratory equipment described, or through the conducting of the experiment.

Privacy and confidentiality

Participants' privacy and identity will be carefully protected in this study. A code will be assigned to each participant and used throughout the experiment to ensure anonymity. The participants have the right to withdrawn from the experiment at any point without any penalty, to request that his/her data be destroyed, and to be remunerated for the time spent to date.

Compensation

Each subject will be paid $60 for his or her time and participation in the whole experiment.

Conflicts of interest

No possible conflicts of interest are foreseen in the experiments.

Informed consent

After the Randot Stereotests, qualified participants will receive both written and oral instructions describing the experimental platform and the tasks. The experimenter will explain the participants' right and answer their questions. After all the questions have been answered to the participants' satisfaction, they will be given a consent form to sign. (See Appendix 2.)

Scholarly review
n/a

Additional ethics reviews
n/a

Contracts
n/a

Clinical Trials
n/a

A1.2 INFORMATION SHEET

Information Sheet for Participants in Research Project
"Human Navigation Performance Using 6DOF Dynamic Viewpoint Tethering in Virtual Environments"

Investigators: Wenbi Wang and Paul Milgram
Department of Mechanical and Industrial Engineering
University of Toronto

This research project is part of the Ph.D. programme of Wenbi Wang in the Department of Mechanical and Industrial Engineering at the University of Toronto, and is under the direct supervision of Professor Paul Milgram.

The purpose of this experiment is to evaluate navigational performance using dynamic tethered displays in large-scale virtual environments. The experiment will investigate the effects of different parametric values in dynamically tethered displays on navigational performance in a variety of tasks. The test environment for this study is a SGI graphic workstation.

The study comprises six 1-hour sessions and will require you to perform repeated trials of a navigational procedure on various dynamically tethered displays. During each trial, you will be asked to control a Spaceball and manipulate an aircraft symbol flying along a virtual tunnel. Two spatial ability tests (Guilford-Zimmerman spatial orientation and visualization tests) and a questionnaire will also be filled out during the experiments. Results from this experiment will help us determine the optimal parametric values of dynamic tethered displays in supporting navigation in complex virtual environments.

Participation in this study is strictly voluntary. After completing all sessions, you will be paid $70 for your time and participation. You may choose to withdraw from the study at any time. In that case, the compensation will be calculated based on a rate of $10 per hour and the actual time you will have spent in the study. Results of this study will be published as part of a Ph.D. dissertation, and may be presented at conferences or in scientific journals. No reference to the identity of the participants will be possible through publication of the results of this study, thereby ensuring that all participants in this study will remain anonymous.

Thank you for your participation.

Wenbi Wang

A1.3 CONSENT FORM

"Human Navigation Performance Using 6DOF Dynamic Viewpoint Tethering in Virtual Environments"

I hereby consent to participate in the research project entitled "Human Navigation Performance Using 6DOF Dynamic Viewpoint Tethering in Virtual Environments", which is being carried out to understand and enhance human navigational performance in virtual environments.

I understand that participation in the study involves:

- Testing my stereoscopic visual acuity;
- Testing my spatial ability;
- Filling out a questionnaire before testing;
- Performing a series of control and judgement tasks, which have been explained to me;
- Some of the testing trials may be video-taped.

I understand that the experiment will include six separate sessions of about 1-hour each and which will be scheduled to occur at a convenient time for me.

I understand that any questions that I have asked have been answered to my satisfaction and that I may ask now, or in the future, any questions I have about the study or the research procedures.

I understand that I have the right to withdraw from this experiment at any point without any penalty, and to request that my data be destroyed. I understand that my name will not appear on the questionnaires and that my performance data will remain confidential. I understand that I will not be identified in any report or presentation which may arise from the study.

I understand that, whereas I may not benefit directly from the study, the information gained may provide a better understanding of human users' navigational behaviour in large-scale virtual environments.

I have been given a copy of this consent form.

I understand what this study involves and agree to participate.

Participant's Name: _____ Signature: _____

Date: _____

The person who may be contacted about this research is: Wenbi Wang (416-978-3776)

Appendix 2

Questionnaires

A2.1 DEMOGRAPHIC QUESTIONNAIRE USED IN THREE EXPERIMENTS

For participation in the experiment "Human Navigational Performance Using 6DOF Dynamic Viewpoint Tethering in Virtual Environments"

Subject No.: Date:

1. **Gender** Male Female

2. **Age** <20 20-29 30-39 40-49 ≥50

3. **Do you ordinarily wear corrective lenses of any kind?** Yes No

If Yes, are you wearing your prescribed lenses right now? Yes No

4. **Are you predominantly left or right handed?** Left Right

Which hand do you prefer to use in manual tasks, e.g., using a mouse? Left Right

5. **Have you had any prior experience viewing any stereoscopic system?** Yes No

If yes, please describe and indicate hours involved below

_____ <5 hours 5-10 hours >10 hours

6. **Have you had any prior experience using a Spaceball?** Yes No

If yes, please describe and indicate hours involved below

_____ <5 hours 5-10 hours >10 hours

7. **Have you ever played any kind of first-person or third-person video game (e.g. DOOM, Quake, Tomb Raider, etc.)?**

Yes No

If yes, please describe and indicate hours involved below (please circle one):

_____ <5 hours 5-10 hours >10 hours

8. **Do you have any experience of flying an aircraft?**

Yes No

If yes, do you have a pilot license?

Yes No

9. **Have you ever played any kind of flight simulation game (e.g. Flight Simulator, Combat flight simulator, etc.)?**

Yes No

If yes, please describe and indicate hours involved below:

_____ <5 hours 5-10 hours >10 hours

A2.2 POST-TRIAL QUESTIONNAIRE USED IN EXPERIMENT 1

Subject No.: Date:

Part 1. Rating Scales

Instructions: You are about to be presented with the four displays you have used in this experiment. After each presentation, please rate each by placing a mark in an appropriate position on the three scales below.

(1) Egocentric display

Understandability: Confusing Simple
I----------I----------I----------I----------I----------I

Ease of use: Difficult Easy
I----------I----------I----------I----------I----------I

Intuitiveness: Low High
I----------I----------I----------I----------I----------I

Frustration: Low High
I----------I----------I----------I----------I----------I

Mental effort Low High
I----------I----------I----------I----------I----------I

(2) Rigidly tethered display

Understandability: Confusing Simple
I----------I----------I----------I----------I----------I

Ease of use: Difficult Easy
I----------I----------I----------I----------I----------I

Intuitiveness: Low High
I----------I----------I----------I----------I----------I

Frustration: Low High
I----------I----------I----------I----------I----------I

Mental effort Low High
I----------I----------I----------I----------I----------I

(3) Dynamically tethered display

Understandability:	Confusing	Simple
	I----------I----------I----------I----------I	
Ease of use:	Difficult	Easy
	I----------I----------I----------I----------I	
Intuitiveness:	Low	High
	I----------I----------I----------I----------I	
Frustration:	Low	High
	I----------I----------I----------I----------I	
Mental effort	Low	High
	I----------I----------I----------I----------I	

(4) Exocentric display

Understandability:	Confusing	Simple
	I----------I----------I----------I----------I	
Ease of use:	Difficult	Easy
	I----------I----------I----------I----------I	
Intuitiveness:	Low	High
	I----------I----------I----------I----------I	
Frustration:	Low	High
	I----------I----------I----------I----------I	
Mental effort	Low	High
	I----------I----------I----------I----------I	

Part 2. Pair-wise Preference Comparison

Instruction: Select the display condition in each pair that you prefer or feel comfortable to work on. Circle your choice in each pair.

Egocentric / Exocentric	Rigid tethered / Exocentric
Dynamic tethered / Exocentric	Egocentric / Rigid tethered
Egocentric / Dynamic tethered	Rigid tethered / Dynamic tethered

Appendix 3

Statistical Outputs (Descriptive Statistics and ANOVA Results)

A3.1 EXPERIMENT 1

A3.1.1 Local Guidance (Overall RMS error)

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		384	0.0432	0.0342	0.0017

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
1		48	0.0321	0.0300	0.0043
2		48	0.0352	0.0222	0.0032
3		48	0.0411	0.0410	0.0059
4		48	0.0412	0.0373	0.0054
5		48	0.0361	0.0312	0.0045
6		48	0.0510	0.0367	0.0053
7		48	0.0428	0.0181	0.0026
8		48	0.0663	0.0397	0.0057

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	1	96	0.0426	0.0286	0.0029
	2	96	0.0656	0.0449	0.0046
	3	96	0.0303	0.0235	0.0024
	4	96	0.0344	0.0241	0.0025

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
1	1	12	0.0464	0.0494	0.0143
1	2	12	0.0339	0.0195	0.0056
1	3	12	0.0201	0.0059	0.0017
1	4	12	0.0281	0.0243	0.0070
2	1	12	0.0358	0.0201	0.0058
2	2	12	0.0528	0.0273	0.0079
2	3	12	0.0238	0.0113	0.0032
2	4	12	0.0284	0.0171	0.0049
3	1	12	0.0343	0.0191	0.0055
3	2	12	0.0828	0.0547	0.0158
3	3	12	0.0204	0.0126	0.0036
3	4	12	0.0267	0.0319	0.0092
4	1	12	0.0435	0.0372	0.0107
4	2	12	0.0756	0.0438	0.0127
4	3	12	0.0183	0.0069	0.0020

```
4       4          12      0.0273      0.0230      0.0066
5       1          12      0.0309      0.0154      0.0044
5       2          12      0.0586      0.0547      0.0158
5       3          12      0.0253      0.0061      0.0017
5       4          12      0.0297      0.0118      0.0034
6       1          12      0.0438      0.0212      0.0061
6       2          12      0.0836      0.0540      0.0156
6       3          12      0.0351      0.0114      0.0033
6       4          12      0.0415      0.0260      0.0075
7       1          12      0.0438      0.0132      0.0038
7       2          12      0.0471      0.0321      0.0093
7       3          12      0.0369      0.0033      0.0009
7       4          12      0.0435      0.0110      0.0032

8       1          12      0.0626      0.0299      0.0086
8       2          12      0.0904      0.0355      0.0103
8       3          12      0.0624      0.0508      0.0147
8       4          12      0.0498      0.0320      0.0092

FACTOR  :   subjects     tunnel    display        rms
LEVELS  :         12          8          4        384
TYPE    :     RANDOM     WITHIN     WITHIN       DATA

SOURCE                 SS     df             MS         F      p
============================================================
mean             0.7173      1          0.7173   142.989  0.000 ***
s/               0.0552     11          0.0050

tunnel           0.0403      7          0.0058     6.391  0.000 ***
ts/              0.0693     77          0.0009

display          0.0717      3          0.0239    18.944  0.000 ***
ds/              0.0416     33          0.0013

td               0.0275     21          0.0013     2.119  0.004 **
tds/             0.1429    231          0.0006
```

Tukey pair-wise comparison ($\alpha = 0.05$).

Displays(Viewpoints)	*Egocentric*	*Rigidly tethered*	*Dynamically tethered*
Rigidly tethered	0.00067 *		
	0.02401		
Dynamically tethered	-0.00342	-0.01576	
	0.01991	0.00757	
Exocentric	-0.03464 *	-0.02365 *	-0.01955 *
	-0.01131	-0.04698	-0.04289

A3.1.2 Global Awareness (Tunnel shape recognition score)

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		384	0.5729	0.4953	0.0253

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
1		48	0.5208	0.5049	0.0729
2		48	0.5417	0.5035	0.0727
3		48	0.3750	0.4892	0.0706
4		48	0.4375	0.5013	0.0724
5		48	0.7500	0.4376	0.0632
6		48	0.7500	0.4376	0.0632
7		48	0.5417	0.5035	0.0727
8		48	0.6667	0.4764	0.0688

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	1	96	0.5938	0.4937	0.0504
	2	96	0.6771	0.4700	0.0480
	3	96	0.4688	0.5016	0.0512
	4	96	0.5521	0.4999	0.0510

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
1	1	12	0.5833	0.5149	0.1486
1	2	12	0.6667	0.4924	0.1421
1	3	12	0.3333	0.4924	0.1421
1	4	12	0.5000	0.5222	0.1508
2	1	12	0.6667	0.4924	0.1421
2	2	12	0.7500	0.4523	0.1306
2	3	12	0.3333	0.4924	0.1421
2	4	12	0.4167	0.5149	0.1486
3	1	12	0.5833	0.5149	0.1486
3	2	12	0.4167	0.5149	0.1486
3	3	12	0.1667	0.3892	0.1124
3	4	12	0.3333	0.4924	0.1421
4	1	12	0.5000	0.5222	0.1508
4	2	12	0.5000	0.5222	0.1508
4	3	12	0.1667	0.3892	0.1124
4	4	12	0.5833	0.5149	0.1486
5	1	12	0.5833	0.5149	0.1486
5	2	12	0.8333	0.3892	0.1124
5	3	12	0.8333	0.3892	0.1124
5	4	12	0.7500	0.4523	0.1306
6	1	12	0.5000	0.5222	0.1508
6	2	12	0.8333	0.3892	0.1124
6	3	12	0.8333	0.3892	0.1124
6	4	12	0.8333	0.3892	0.1124
7	1	12	0.5833	0.5149	0.1486
7	2	12	0.6667	0.4924	0.1421
7	3	12	0.4167	0.5149	0.1486
7	4	12	0.5000	0.5222	0.1508
8	1	12	0.7500	0.4523	0.1306
8	2	12	0.7500	0.4523	0.1306

```
8       3         12     0.6667     0.4924     0.1421
8       4         12     0.5000     0.5222     0.1508

FACTOR  :   subjects     tunnel    display  judgement
LEVELS  :         12          8          4        384
TYPE    :     RANDOM     WITHIN     WITHIN       DATA

SOURCE                SS     df             MS         F      p
============================================================
mean           126.0417      1       126.0417    95.481  0.000 ***
s/              14.5208     11         1.3201

tunnel           6.4167      7         0.9167     4.147  0.001 ***
ts/             17.0208     77         0.2210

display          2.1667      3         0.7222     1.866  0.155
ds/             12.7708     33         0.3870

td               4.7083     21         0.2242     1.425  0.108
tds/            36.3542    231         0.1574
```

A3.1.3 Subjective Evaluation on 5 Usability Factors

1. Understandability

```
SOURCE: grand mean
display    N       MEAN         SD         SE
          48     2.5312     1.0984     0.1585

SOURCE: display
display    N       MEAN         SD         SE
1         12     1.6250     1.1894     0.3434
2         12     2.6667     1.0299     0.2973
3         12     3.0417     0.6895     0.1990
4         12     2.7917     0.9643     0.2784

FACTOR  :   subjects    display understand
LEVELS  :         12          4         48
TYPE    :     RANDOM     WITHIN       DATA

SOURCE                SS     df             MS         F      p
============================================================
mean           307.5469      1       307.5469   442.767  0.000 ***
s/               7.6406     11         0.6946

display         14.0156      3         4.6719     4.399  0.010 *
ds/             35.0469     33         1.0620
```

2. Ease of Use

```
SOURCE: grand mean
display    N       MEAN         SD         SE
          48     2.2083     1.1478     0.1657

SOURCE: display
display    N       MEAN         SD         SE
1         12     1.0833     0.8483     0.2449
2         12     2.4167     1.1645     0.3362
3         12     2.8333     0.7785     0.2247
4         12     2.5000     1.0000     0.2887

FACTOR  :   subjects    display easy_of_us
LEVELS  :         12          4         48
TYPE    :     RANDOM     WITHIN       DATA

SOURCE                SS     df             MS         F      p
============================================================
mean           234.0833      1       234.0833   305.931  0.000 ***
s/               8.4167     11         0.7652

display         21.4167      3         7.1389     7.343  0.001 ***
ds/             32.0833     33         0.9722
```

3. Intuitiveness

```
SOURCE: grand mean
display    N       MEAN         SD         SE
          48     2.5729     1.1204     0.1617

SOURCE: display
display    N       MEAN         SD         SE
1         12     2.3750     1.1506     0.3321
2         12     2.5000     1.2613     0.3641
3         12     2.5833     1.2029     0.3472
4         12     2.8333     0.9374     0.2706

FACTOR  :   subjects    display intuitiven
LEVELS  :         12          4         48
TYPE    :     RANDOM     WITHIN       DATA

SOURCE                SS     df             MS         F      p
============================================================
mean           317.7552      1       317.7552   292.928  0.000 ***
s/              11.9323     11         1.0848

display          1.3490      3         0.4497     0.325  0.808
ds/             45.7135     33         1.3853
```

4. Mental Effort

```
SOURCE: grand mean
display    N       MEAN         SD         SE
          48     1.9167     1.2175     0.1757

SOURCE: display
display    N       MEAN         SD         SE
1         12     3.1250     0.7111     0.2053
2         12     1.0000     1.1677     0.3371
3         12     1.5833     0.7930     0.2289
4         12     1.9583     1.0967     0.3166

FACTOR  :   subjects    display mental_eff
LEVELS  :         12          4         48
TYPE    :     RANDOM     WITHIN       DATA

SOURCE                SS     df             MS         F      p
============================================================
mean           176.3333      1       176.3333   350.015  0.000 ***
s/               5.5417     11         0.5038

display         28.9583      3         9.6528     9.058  0.000 ***
ds/             35.1667     33         1.0657
```

5. Frustration

```
SOURCE: grand mean
display    N       MEAN         SD         SE
          48     1.8021     1.1096     0.1602

SOURCE: display
display    N       MEAN         SD         SE
1         12     2.8750     0.8292     0.2394
2         12     1.2917     0.9643     0.2784
3         12     1.5833     1.0188     0.2941
4         12     1.4583     0.9405     0.2715

FACTOR  :   subjects    display frustratio
LEVELS  :         12          4         48
TYPE    :     RANDOM     WITHIN       DATA

SOURCE                SS     df             MS         F      p
============================================================
mean           155.8802      1       155.8802   356.684  0.000 ***
s/               4.8073     11         0.4370

display         18.9323      3         6.3108     6.102  0.002 **
ds/             34.1302     33         1.0342
```

A3.2 EXPERIMENT 2

A3.2.1 Local guidance, Display group A, Active flying task, High + low frequency condition

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		720	1.6302	2.1708	0.0809

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
0		120	0.9771	1.5743	0.1437
1		120	1.3226	1.5630	0.1427
2		120	1.3567	1.8188	0.1660
3		120	1.7935	2.3483	0.2144
4		120	1.5329	1.9416	0.1772
5		120	2.7981	2.9909	0.2730

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	10	144	2.1498	2.4340	0.2028
	20	144	1.6166	2.2064	0.1839
	40	144	1.2315	1.6430	0.1369
	80	144	1.3850	1.7177	0.1431
	160	144	1.7681	2.5960	0.2163

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
0	10	24	0.9695	1.4826	0.3026
0	20	24	0.6042	0.5631	0.1149
0	40	24	0.9606	1.3753	0.2807
0	80	24	1.3078	2.2428	0.4578
0	160	24	1.0433	1.7671	0.3607
1	10	24	1.4607	1.5394	0.3142
1	20	24	1.5896	2.2257	0.4543
1	40	24	0.8990	0.9060	0.1849
1	80	24	1.2459	1.1509	0.2349
1	160	24	1.4176	1.6954	0.3461
2	10	24	2.0848	2.4894	0.5082
2	20	24	1.4136	2.0850	0.4256
2	40	24	0.8983	1.0207	0.2083
2	80	24	1.4042	1.8891	0.3856
2	160	24	0.9829	1.0181	0.2078
3	10	24	1.8376	1.8790	0.3836
3	20	24	2.4385	3.0727	0.6272
3	40	24	1.1119	0.9888	0.2018
3	80	24	1.4557	2.1984	0.4487
3	160	24	2.1240	2.9317	0.5984
4	10	24	2.3491	2.4627	0.5027
4	20	24	1.1351	1.3351	0.2725
4	40	24	1.6381	2.8480	0.5814
4	80	24	1.2426	1.0043	0.2050
4	160	24	1.2997	1.2336	0.2518
5	10	24	4.1971	3.1629	0.6456
5	20	24	2.5183	2.5531	0.5212

5	40	24	1.8808	1.7338	0.3539
5	80	24	1.6536	1.5656	0.3196
5	160	24	1.7410	4.3599	0.8900

FACTOR	:	subjects	tunnel	display	rms
LEVELS	:	12	6	5	720
TYPE	:	RANDOM	WITHIN	WITHIN	DATA

SOURCE	SS	df	MS	F	p	
mean	1913.3674	1	1913.3674	28.423	0.000	***
s/	740.4972	11	67.3179			
tunnel	239.5432	5	47.9086	13.114	0.000	***
ts/	200.9276	55	3.6532			
display	73.1978	4	18.2994	6.130	0.001	***
ds/	131.3595	44	2.9854			
td	132.7000	20	6.6350	2.087	0.005	**
tds/	699.2988	220	3.1786			

Tukey pair-wise comparison ($\alpha = 0.05$).

	A1	A2	A3	A4
A2	-0.159			
	1.226			
A3	0.226 *	-0.308		
	1.611	1.078		
A4	0.073 *	-0.461	-0.846	
	1.458	0.924	0.539	
A5	-0.311	-0.844	-1.229	-1.076
	1.075	0.541	0.156	0.310

A3.2.2 Local guidance, Display group A, Active flying task, High frequency condition

```
SOURCE: grand mean
tunnel  display     N       MEAN         SD         SE
                  360     2.0415     2.5182     0.1327

SOURCE: tunnel
tunnel  display     N       MEAN         SD         SE
3                 120     1.7935     2.3483     0.2144
4                 120     1.5329     1.9416     0.1772
5                 120     2.7981     2.9909     0.2730

SOURCE: display
tunnel  display     N       MEAN         SD         SE
        10         72     2.7946     2.7186     0.3204
        20         72     2.0307     2.4810     0.2924
        40         72     1.5436     2.0056     0.2364
        80         72     1.4506     1.6477     0.1942
        160        72     2.3882     3.2369     0.3815

SOURCE: tunnel display
tunnel  display     N       MEAN         SD         SE
3       10         24     1.8376     1.8790     0.3836
3       20         24     2.4385     3.0727     0.6272
3       40         24     1.1119     0.9888     0.2018
3       80         24     1.4557     2.1984     0.4487
3       160        24     2.1240     2.9317     0.5984
4       10         24     2.3491     2.4627     0.5027
4       20         24     1.1351     1.3351     0.2725
4       40         24     1.6381     2.8480     0.5814
4       80         24     1.2426     1.0043     0.2050
4       160        24     1.2997     1.2336     0.2518
5       10         24     4.1971     3.1629     0.6456
5       20         24     2.5183     2.5531     0.5212
5       40         24     1.8808     1.7338     0.3539
5       80         24     1.6536     1.5656     0.3196
5       160        24     3.7410     4.3599     0.8900

FACTOR  :   subjects     tunnel    display        rms
LEVELS  :         12          3          5        360
TYPE    :     RANDOM     WITHIN     WITHIN       DATA

SOURCE                SS     df             MS          F      p
============================================================
mean          1500.4339      1      1500.4339    34.164  0.000 ***
s/             483.1045     11        43.9186

tunnel         107.1187      2        53.5593    17.696  0.000 ***
ts/             66.5873     22         3.0267

display         92.4825      4        23.1206     5.254  0.002 **
ds/            193.6161     44         4.4004

td              79.2537      8         9.9067     2.068  0.047 *
tds/           421.5471     88         4.7903
```

Tukey pair-wise comparison ($\alpha = 0.05$).

	A1	A2	A3	A4
A2	-0.364 1.892			
A3	0.123 * 2.379	-0.641 1.615		
A4	0.216 * 2.472	-0.548 1.708	-1.035 1.221	
A5	-0.722 1.535	-1.486 0.771	-1.973 0.284	-2.066 0.191

A3.2.3 Local Guidance, Display group A, Active flying task, Low frequency condition

```
SOURCE: grand mean
tunnel  display    N       MEAN         SD         SE
                360     1.2188     1.6606     0.0875

SOURCE: tunnel
tunnel  display    N       MEAN         SD         SE
0               120     0.9771     1.5743     0.1437
1               120     1.3226     1.5630     0.1427
2               120     1.3567     1.8188     0.1660

SOURCE: display
tunnel  display    N       MEAN         SD         SE
        10          72     1.5050     1.9232     0.2266
        20          72     1.2025     1.8173     0.2142
        40          72     0.9193     1.1032     0.1300
        80          72     1.3193     1.7941     0.2114
        160         72     1.1479     1.5218     0.1794

SOURCE: tunnel display
tunnel  display    N       MEAN         SD         SE
0       10          24     0.9695     1.4826     0.3026
0       20          24     0.6042     0.5631     0.1149
0       40          24     0.9606     1.3753     0.2807
0       80          24     1.3078     2.2428     0.4578
0       160         24     1.0433     1.7671     0.3607
1       10          24     1.4607     1.5394     0.3142
1       20          24     1.5896     2.2257     0.4543
1       40          24     0.8990     0.9060     0.1849
1       80          24     1.2459     1.1509     0.2349
1       160         24     1.4176     1.6954     0.3461
2       10          24     2.0848     2.4894     0.5082
2       20          24     1.4136     2.0850     0.4256
2       40          24     0.8983     1.0207     0.2083
2       80          24     1.4042     1.8891     0.3856
2       160         24     0.9829     1.0181     0.2078

FACTOR  :   subjects     tunnel    display        rms
LEVELS  :         12          3          5        360
TYPE    :     RANDOM     WITHIN     WITHIN       DATA

SOURCE                 SS     df             MS          F      p
============================================================
mean           534.7736      1       534.7736    17.830  0.001 **
s/             329.9164     11        29.9924

tunnel          10.5843      2         5.2922     1.883  0.176
ts/             61.8165     22         2.8098

display         13.4641      4         3.3660     2.016  0.109
ds/             73.4735     44         1.6699

td              20.6976      8         2.5872     1.603  0.135
tds/           142.0215     88         1.6139
```

A3.2.4 Global Awareness, Display group A, Active flying task, High frequency condition

```
SOURCE: grand mean
tunnel  display    N       MEAN         SD         SE
                 360     0.8139     0.3897     0.0205

SOURCE: tunnel
tunnel  display    N       MEAN         SD         SE
3                120     0.6917     0.4637     0.0423
4                120     0.9250     0.2645     0.0241
5                120     0.8250     0.3816     0.0348

SOURCE: display
tunnel  display    N       MEAN         SD         SE
        b1          72     0.7917     0.4090     0.0482
        b2          72     0.8333     0.3753     0.0442
        b3          72     0.8194     0.3873     0.0456
        b4          72     0.8333     0.3753     0.0442
        b5          72     0.7917     0.4090     0.0482

SOURCE: tunnel display
tunnel  display    N       MEAN         SD         SE
3       b1          24     0.6667     0.4815     0.0983
3       b2          24     0.6667     0.4815     0.0983
3       b3          24     0.7500     0.4423     0.0903
3       b4          24     0.7500     0.4423     0.0903
3       b5          24     0.6250     0.4945     0.1009
4       b1          24     0.9167     0.2823     0.0576
4       b2          24     0.9167     0.2823     0.0576
4       b3          24     0.9167     0.2823     0.0576
4       b4          24     0.8750     0.3378     0.0690
4       b5          24     1.0000     0.0000     0.0000
5       b1          24     0.7917     0.4149     0.0847
5       b2          24     0.9167     0.2823     0.0576
5       b3          24     0.7917     0.4149     0.0847
5       b4          24     0.8750     0.3378     0.0690
5       b5          24     0.7500     0.4423     0.0903

FACTOR  :   subjects     tunnel    display     global
LEVELS  :         12          3          5        360
TYPE    :     RANDOM     WITHIN     WITHIN       DATA

SOURCE                SS     df             MS         F      p
============================================================
mean          238.4694      1       238.4694   232.195  0.000 ***
s/             11.2972     11         1.0270

tunnel          3.2889      2         1.6444     7.789  0.003 **
ts/             4.6444     22         0.2111

display         0.1278      4         0.0319     0.267  0.898
ds/             5.2722     44         0.1198

td              0.8222      8         0.1028     0.944  0.485
tds/            9.5778     88         0.1088
```

A3.2.5 Global Awareness, Display group A, Active flying task, Low frequency condition

```
SOURCE: grand mean
tunnel  display     N       MEAN         SD         SE
                  360     0.7306     0.5301     0.0279

SOURCE: tunnel
tunnel  display     N       MEAN         SD         SE
0                 120     0.6333     0.6973     0.0637
1                 120     0.8167     0.3886     0.0355
2                 120     0.7417     0.4396     0.0401

SOURCE: display
tunnel  display     N       MEAN         SD         SE
        b1         72     0.6806     0.4695     0.0553
        b2         72     0.7500     0.4361     0.0514
        b3         72     0.6806     0.4695     0.0553
        b4         72     0.7500     0.4361     0.0514
        b5         72     0.7917     0.7680     0.0905

SOURCE: tunnel display
tunnel  display     N       MEAN         SD         SE
0       b1         24     0.5417     0.5090     0.1039
0       b2         24     0.6250     0.4945     0.1009
0       b3         24     0.5417     0.5090     0.1039
0       b4         24     0.6250     0.4945     0.1009
0       b5         24     0.8333     1.2039     0.2457
1       b1         24     0.7917     0.4149     0.0847
1       b2         24     0.7917     0.4149     0.0847
1       b3         24     0.8750     0.3378     0.0690
1       b4         24     0.8750     0.3378     0.0690
1       b5         24     0.7500     0.4423     0.0903
2       b1         24     0.7083     0.4643     0.0948
2       b2         24     0.8333     0.3807     0.0777
2       b3         24     0.6250     0.4945     0.1009
2       b4         24     0.7500     0.4423     0.0903
2       b5         24     0.7917     0.4149     0.0847

FACTOR  :   subjects     tunnel    display     global
LEVELS  :         12          3          5        360
TYPE    :     RANDOM     WITHIN     WITHIN       DATA

SOURCE                SS     df             MS         F      p
============================================================
mean          192.1361      1       192.1361   138.767  0.000 ***
s/             15.2306     11         1.3846

tunnel          2.0389      2         1.0194     2.466  0.108
ts/             9.0944     22         0.4134

display         0.6833      4         0.1708     0.676  0.612
ds/            11.1167     44         0.2527

td              1.6000      8         0.2000     0.815  0.591
tds/           21.6000     88         0.2455
```

A3.2.6 Local Guidance, Display group B, Active flying task, High + low frequency condition

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		864	1.4250	1.8778	0.0639

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
0		144	0.9858	1.7400	0.1450
1		144	1.1427	1.4817	0.1235
2		144	1.2314	1.9315	0.1610
3		144	1.8662	2.5592	0.2133
4		144	1.4603	1.6370	0.1364
5		144	1.8637	1.5474	0.1290

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	B1	144	2.0203	2.2930	0.1911
	B6	144	1.6413	2.2752	0.1896
	B2	144	1.4193	1.7422	0.1452
	B5	144	1.2729	1.8679	0.1557
	B4	144	0.9649	0.9720	0.0810
	B3	144	1.2315	1.6430	0.1369

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
0	B1	24	1.0207	1.0701	0.2184
0	B6	24	0.9395	1.2896	0.2632
0	B2	24	1.1443	2.0373	0.4159
0	B5	24	1.0948	2.9039	0.5928
0	B4	24	0.7546	1.2006	0.2451
0	B3	24	0.9606	1.3753	0.2807
1	B1	24	1.7148	2.0387	0.4161
1	B6	24	1.0818	1.5043	0.3071
1	B2	24	1.2923	1.5698	0.3204
1	B5	24	1.0132	1.6718	0.3413
1	B4	24	0.8548	0.7843	0.1601
1	B3	24	0.8990	0.9060	0.1849
2	B1	24	1.6550	1.8778	0.3833
2	B6	24	1.6804	3.4418	0.7026
2	B2	24	1.2446	1.3112	0.2676
2	B5	24	1.2177	1.8864	0.3850
2	B4	24	0.6923	0.8288	0.1692
2	B3	24	0.8983	1.0207	0.2083
3	B1	24	2.9459	3.9143	0.7990
3	B6	24	3.3185	3.1949	0.6521
3	B2	24	1.6308	2.4909	0.5085
3	B5	24	1.1612	1.2193	0.2489
3	B4	24	1.0290	1.0976	0.2240
3	B3	24	1.1119	0.9888	0.2018
4	B1	24	1.7180	1.5157	0.3094
4	B6	24	1.3713	1.2521	0.2556
4	B2	24	1.3371	0.9934	0.2028
4	B5	24	1.5780	1.7618	0.3596
4	B4	24	1.1195	0.5763	0.1176

```
4       B3        24     1.6381     2.8480     0.5814
5       B1        24     3.0672     1.6824     0.3434
5       B6        24     1.4561     0.8655     0.1767
5       B2        24     1.8666     1.7189     0.3509
5       B5        24     1.5726     1.4159     0.2890
5       B4        24     1.3389     1.1321     0.2311
5       B3        24     1.8808     1.7338     0.3539

FACTOR  :   subjects     tunnel    display        rms
LEVELS  :         12          6          6        864
TYPE    :     RANDOM     WITHIN     WITHIN       DATA

SOURCE                SS     df             MS         F      p
============================================================
mean          1754.4794      1      1754.4794    31.182  0.000 ***
s/             618.9171     11        56.2652

tunnel         100.5844      5        20.1169     6.344  0.000 ***
ts/            174.4123     55         3.1711

display         96.9785      5        19.3957     7.702  0.000 ***
ds/            138.4976     55         2.5181

td             112.1374     25         4.4855     1.842   0.01 **
tds/           669.6542    275         2.4351
```

Tukey pair-wise comparison ($\alpha = 0.05$).

	B1	B2	B3	B4	B5
B2	-0.021				
	1.223				
B3	0.167 *	-0.434			
	1.411	0.810			
B4	0.433 *	-0.168	-0.355		
	1.677	1.076	0.889		
B5	0.125 *	-0.476	-0.663	-0.930	
	1.369	0.768	0.581	0.314	
B6	-0.246	-0.847	-1.035	-1.301 *	-0.993
	0.996	0.395	0.207	-0.059	0.249

A3.2.7 Local Guidance, Display group B, Active flying task, High frequency condition

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		432	1.7301	1.9731	0.0949

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
3		144	1.8662	2.5592	0.2133
4		144	1.4603	1.6370	0.1364
5		144	1.8637	1.5474	0.1290

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	B1	72	2.5770	2.6460	0.3118
	B6	72	2.0486	2.2081	0.2602
	B2	72	1.6115	1.8260	0.2152
	B5	72	1.4373	1.4749	0.1738
	B4	72	1.1625	0.9645	0.1137
	B3	72	1.5436	2.0056	0.2364

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
3	B1	24	2.9459	3.9143	0.7990
3	B6	24	3.3185	3.1949	0.6521
3	B2	24	1.6308	2.4909	0.5085
3	B5	24	1.1612	1.2193	0.2489
3	B4	24	1.0290	1.0976	0.2240
3	B3	24	1.1119	0.9888	0.2018
4	B1	24	1.7180	1.5157	0.3094
4	B6	24	1.3713	1.2521	0.2556
4	B2	24	1.3371	0.9934	0.2028
4	B5	24	1.5780	1.7618	0.3596
4	B4	24	1.1195	0.5763	0.1176
4	B3	24	1.6381	2.8480	0.5814
5	B1	24	3.0672	1.6824	0.3434
5	B6	24	1.4561	0.8655	0.1767
5	B2	24	1.8666	1.7189	0.3509
5	B5	24	1.5726	1.4159	0.2890
5	B4	24	1.3389	1.1321	0.2311
5	B3	24	1.8808	1.7338	0.3539

FACTOR	:	subjects	tunnel	display	rms
LEVELS	:	12	3	6	432
TYPE	:	RANDOM	WITHIN	WITHIN	DATA

SOURCE	SS	df	MS	F	p	
mean	1293.0522	1	1293.0522	49.912	0.000	***
s/	284.9728	11	25.9066			
tunnel	15.7176	2	7.8588	1.740	0.199	
ts/	99.3836	22	4.5174			
display	91.8398	5	18.3680	6.198	0.000	***
ds/	162.9994	55	2.9636			
td	83.9201	10	8.3920	2.678	0.006	**
tds/	344.7094	110	3.1337			

Tukey pair-wise comparison ($\alpha = 0.05$).

	B1	B2	B3	B4	B5
B2	0.049 *				
	1.882				
B3	0.117 *	-0.849			
	1.950	0.984			
B4	0.498 *	-0.467	-0.535		
	2.331	1.365	1.298		
B5	0.223 *	-0.742	-0.810	-1.191	
	2.056	1.091	1.023	0.642	
B6	-0.388	-1.354	-1.421	-1.803	-1.528
	1.445	0.479	0.411	0.030	0.305

A3.2.8 Local Guidance, Display group B, Active flying task, Low frequency condition

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		432	1.1199	1.7266	0.0831

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
0		144	0.9858	1.7400	0.1450
1		144	1.1427	1.4817	0.1235
2		144	1.2314	1.9315	0.1610

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	2	72	1.4635	1.7204	0.2027
	6	72	1.2339	2.2834	0.2691
	20	72	1.2270	1.6443	0.1938
	40	72	0.9193	1.1032	0.1300
	60	72	0.7673	0.9451	0.1114
	80	72	1.1086	2.1902	0.2581

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
0	2	24	1.0207	1.0701	0.2184
0	6	24	0.9395	1.2896	0.2632
0	20	24	1.1443	2.0373	0.4159
0	40	24	0.9606	1.3753	0.2807
0	60	24	0.7546	1.2006	0.2451
0	80	24	1.0948	2.9039	0.5928
1	2	24	1.7148	2.0387	0.4161
1	6	24	1.0818	1.5043	0.3071
1	20	24	1.2923	1.5698	0.3204
1	40	24	0.8990	0.9060	0.1849
1	60	24	0.8548	0.7843	0.1601
1	80	24	1.0132	1.6718	0.3413
2	2	24	1.6550	1.8778	0.3833
2	6	24	1.6804	3.4418	0.7026
2	20	24	1.2446	1.3112	0.2676
2	40	24	0.8983	1.0207	0.2083
2	60	24	0.6923	0.8288	0.1692
2	80	24	1.2177	1.8864	0.3850

FACTOR	:	subjects	tunnel	display	rms
LEVELS	:	12	3	6	432
TYPE	:	RANDOM	WITHIN	WITHIN	DATA

SOURCE	SS	df	MS	F	p
mean	541.8388	1	541.8388	16.960	0.002 **
s/	351.4310	11	31.9483		
tunnel	4.4552	2	2.2276	0.852	0.440
ts/	57.5420	22	2.6155		
display	22.1229	5	4.4246	1.791	0.130
ds/	135.8962	55	2.4708		
td	11.2331	10	1.1233	0.751	0.675
tds/	164.5468	110	1.4959		

A3.2.9 Global awareness, Display group B, Active flying task, High frequency condition

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		432	0.8287	0.3772	0.0181

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
3		144	0.7222	0.4495	0.0375
4		144	0.8889	0.3154	0.0263
5		144	0.8750	0.3319	0.0277

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	a1	72	0.8194	0.3873	0.0456
	a2	72	0.8194	0.3873	0.0456
	a3	72	0.8333	0.3753	0.0442
	a4	72	0.8611	0.3483	0.0410
	a5	72	0.8194	0.3873	0.0456
	b3	72	0.8194	0.3873	0.0456

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
3	a1	24	0.7083	0.4643	0.0948
3	a2	24	0.7500	0.4423	0.0903
3	a3	24	0.7500	0.4423	0.0903
3	a4	24	0.7500	0.4423	0.0903
3	a5	24	0.6250	0.4945	0.1009
3	b3	24	0.7500	0.4423	0.0903
4	a1	24	0.7917	0.4149	0.0847
4	a2	24	0.8333	0.3807	0.0777
4	a3	24	0.9167	0.2823	0.0576
4	a4	24	0.9167	0.2823	0.0576
4	a5	24	0.9583	0.2041	0.0417
4	b3	24	0.9167	0.2823	0.0576
5	a1	24	0.9583	0.2041	0.0417
5	a2	24	0.8750	0.3378	0.0690
5	a3	24	0.8333	0.3807	0.0777
5	a4	24	0.9167	0.2823	0.0576
5	a5	24	0.8750	0.3378	0.0690
5	b3	24	0.7917	0.4149	0.0847

FACTOR	:	subjects	tunnel	display	global
LEVELS	:	12	3	6	432
TYPE	:	RANDOM	WITHIN	WITHIN	DATA

SOURCE	SS	df	MS	F	p	
mean	296.6759	1	296.6759	356.371	0.000	***
s/	9.1574	11	0.8325			
tunnel	2.4630	2	1.2315	4.041	0.032	*
ts/	6.7037	22	0.3047			
display	0.1019	5	0.0204	0.208	0.958	
ds/	5.3981	55	0.0981			
td	1.0926	10	0.1093	1.054	0.404	
tds/	11.4074	110	0.1037			

A3.2.10 Global awareness, Display group B, Active flying task, Low frequency condition

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		432	0.6968	0.4602	0.0221

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
0		144	0.6181	0.4876	0.0406
1		144	0.7917	0.4075	0.0340
2		144	0.6806	0.4679	0.0390

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	b1	72	0.5972	0.4939	0.0582
	b2	72	0.5972	0.4939	0.0582
	b4	72	0.7778	0.4187	0.0493
	b5	72	0.7778	0.4187	0.0493
	b6	72	0.7500	0.4361	0.0514
	b3	72	0.6806	0.4695	0.0553

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
0	b1	24	0.4583	0.5090	0.1039
0	b2	24	0.6250	0.4945	0.1009
0	b4	24	0.6667	0.4815	0.0983
0	b5	24	0.7083	0.4643	0.0948
0	b6	24	0.7083	0.4643	0.0948
0	b3	24	0.5417	0.5090	0.1039
1	b1	24	0.6667	0.4815	0.0983
1	b2	24	0.5833	0.5036	0.1028
1	b4	24	0.8750	0.3378	0.0690
1	b5	24	0.8750	0.3378	0.0690
1	b6	24	0.8750	0.3378	0.0690
1	b3	24	0.8750	0.3378	0.0690
2	b1	24	0.6667	0.4815	0.0983
2	b2	24	0.5833	0.5036	0.1028
2	b4	24	0.7917	0.4149	0.0847
2	b5	24	0.7500	0.4423	0.0903
2	b6	24	0.6667	0.4815	0.0983
2	b3	24	0.6250	0.4945	0.1009

FACTOR	:	subjects	tunnel	display	global
LEVELS	:	12	3	6	432
TYPE	:	RANDOM	WITHIN	WITHIN	DATA

SOURCE	SS	df	MS	F	p	
mean	209.7245	1	209.7245	148.593	0.000	***
s/	15.5255	11	1.4114			
tunnel	2.2269	2	1.1134	2.424	0.112	
ts/	10.1065	22	0.4594			
display	2.5949	5	0.5190	5.047	0.001	***
ds/	5.6551	55	0.1028			
td	1.4120	10	0.1412	0.900	0.536	
tds/	17.2546	110	0.1569			

Tukey pair-wise comparison ($\alpha = 0.05$).

	b1	b2	b3	b4	b5
b2	-0.2167				
	0.2167				
b3	-0.3000	-0.3000			
	0.1334	0.1334			
b4	-0.3973	-0.3973	-0.3139		
	0.0361	0.0361	0.1195		
b5	-0.3973	-0.3973	-0.3139	-0.2167	
	0.0361	0.0361	0.1195	0.2167	
b6	-0.3695	-0.3695	-0.2861	-0.1889	-0.1889
	0.0639	0.0639	0.1473	0.2445	0.2445

A3.2.11 Local Guidance, Display group A, Passive flying task, High frequency condition

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		180	85.9611	10.8125	0.8059

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
3		60	84.1833	10.3686	1.3386
4		60	90.1667	8.5135	1.0991
5		60	83.5333	12.1453	1.5679

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	a1	36	78.5556	10.6702	1.7784
	a2	36	86.8889	11.7151	1.9525
	a3	36	87.2500	9.8194	1.6366
	a4	36	88.4444	9.7642	1.6274
	a5	36	88.6667	9.0648	1.5108

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
3	a1	12	78.4167	9.7743	2.8216
3	a2	12	84.4167	13.1941	3.8088
3	a3	12	86.5833	9.2191	2.6613
3	a4	12	86.3333	10.0755	2.9085
3	a5	12	85.1667	8.4728	2.4459
4	a1	12	81.0000	7.3361	2.1177
4	a2	12	92.6667	6.3150	1.8230
4	a3	12	91.3333	6.8402	1.9746
4	a4	12	93.2500	6.6623	1.9232
4	a5	12	92.5833	9.3367	2.6953
5	a1	12	76.2500	14.1622	4.0883
5	a2	12	83.5833	12.9507	3.7385
5	a3	12	83.8333	11.9836	3.4594
5	a4	12	85.7500	10.9306	3.1554
5	a5	12	88.2500	8.4973	2.4530

```
FACTOR  :   subjects     tunnel    display evaluation
LEVELS  :         12          3          5        180
TYPE    :     RANDOM     WITHIN     WITHIN       DATA

SOURCE                 SS     df             MS         F      p
============================================================
mean      1330076.2722      1   1330076.2722  2360.551  0.000 ***
s/           6198.0611     11       563.4601

tunnel       1604.4778      2       802.2389     8.213  0.002 **
ts/          2148.9889     22        97.6813

display      2550.6444      4       637.6611     7.104  0.000 ***
ds/          3949.3556     44        89.7581

td            232.6889      8        29.0861     0.603  0.773
tds/         4242.5111     88        48.2104
```

Tukey pair-wise comparison ($\alpha = 0.05$).

	a1	a2	a3	a4
a2	-14.99 -1.67			
a3	-15.36 -2.03	-7.02 6.30		
a4	-16.55 -3.23	-8.22 5.11	-7.86 5.47	
a5	-16.77 -3.45	-8.44 4.88	-8.08 5.24	-6.88 6.44

A3.2.12 Local Guidance, Display group A, Passive flying task, Low frequency condition

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		180	92.5333	7.0911	0.5285

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
0		60	92.2333	7.0624	0.9117
1		60	92.6333	7.4810	0.9658
2		60	92.7333	6.8243	0.8810

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	a1	36	87.6944	7.4213	1.2369
	a2	36	93.5556	6.9053	1.1509
	a3	36	93.2222	6.7448	1.1241
	a4	36	94.5278	5.9449	0.9908
	a5	36	93.6667	6.5203	1.0867

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
0	a1	12	86.9167	6.5012	1.8767
0	a2	12	93.6667	6.1840	1.7852
0	a3	12	94.4167	6.7751	1.9558
0	a4	12	94.0833	7.1790	2.0724
0	a5	12	92.0833	6.8948	1.9903
1	a1	12	88.0000	6.6606	1.9228
1	a2	12	93.0000	9.3905	2.7108
1	a3	12	92.7500	7.0598	2.0380
1	a4	12	95.5833	6.0672	1.7514
1	a5	12	93.8333	6.8069	1.9650
2	a1	12	88.1667	9.3598	2.7019
2	a2	12	94.0000	4.9727	1.4355
2	a3	12	92.5000	6.8291	1.9714
2	a4	12	93.9167	4.7186	1.3621
2	a5	12	95.0833	6.0371	1.7428

FACTOR	:	subjects	tunnel	display	evaluation
LEVELS	:	12	3	5	180
TYPE	:	RANDOM	WITHIN	WITHIN	DATA

SOURCE	SS	df	MS	F	p
mean	1541235.2000	1	1541235.2000	5530.989	0.000 ***
s/	3065.2000	11	278.6545		
tunnel	8.4000	2	4.2000	0.102	0.903
ts/	902.4000	22	41.0182		
display	1087.0778	4	271.7694	7.116	0.000 ***
ds/	1680.5222	44	38.1937		
td	109.6556	8	13.7069	0.562	0.806
tds/	2147.5444	88	24.4039		

Tukey pair-wise comparison ($\alpha = 0.05$).

	a1	a2	a3	a4
a2	-10.232			
	-1.490			
a3	-9.899	-4.038		
	-1.157	4.704		
a4	-11.204	-5.343	-5.677	
	-2.462	3.399	3.065	
a5	-10.343	-4.482	-4.815	-3.510
	-1.601	4.260	3.927	5.232

A3.2.13 Local Guidance, Display group B, Passive flying task, High frequency condition

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		216	87.6759	10.0194	0.6817

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
3		72	88.5000	8.9175	1.0509
4		72	92.0139	8.0325	0.9466
5		72	82.5139	10.6374	1.2536

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	b1	36	88.1111	9.3832	1.5639
	b2	36	87.1111	10.8753	1.8126
	b4	36	87.0833	9.9610	1.6602
	b5	36	88.8056	9.2885	1.5481
	b6	36	87.6944	11.2271	1.8712
	b3	36	87.2500	9.8194	1.6366

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
3	b1	12	88.7500	10.1992	2.9442
3	b2	12	87.6667	8.9171	2.5742
3	b4	12	87.5000	8.6603	2.5000
3	b5	12	89.3333	7.7967	2.2507
3	b6	12	91.1667	9.7219	2.8065
3	b3	12	86.5833	9.2191	2.6613
4	b1	12	91.0000	10.7111	3.0920
4	b2	12	90.5000	9.4532	2.7289
4	b4	12	91.3333	5.8517	1.6892
4	b5	12	94.9167	6.6805	1.9285
4	b6	12	93.0000	8.4746	2.4464
4	b3	12	91.3333	6.8402	1.9746
5	b1	12	84.5833	6.1859	1.7857
5	b2	12	83.1667	13.3269	3.8471
5	b4	12	82.4167	12.7597	3.6834
5	b5	12	82.1667	8.9426	2.5815
5	b6	12	78.9167	10.3349	2.9834
5	b3	12	83.8333	11.9836	3.4594

```
FACTOR  :   subjects     tunnel    display evaluation
LEVELS  :         12          3          6        216
TYPE    :     RANDOM     WITHIN     WITHIN       DATA

SOURCE                 SS     df             MS         F      p
============================================================
mean      1660406.6852      1   1660406.6852  2706.345  0.000 ***
s/           6748.7593     11       613.5236

tunnel       3322.3426      2      1661.1713    10.944  0.001 ***
ts/          3339.2130     22       151.7824

display        83.4259      5        16.6852     0.359  0.874
ds/          2558.4630     55        46.5175

td            473.3796     10        47.3380     1.030  0.424
tds/         5057.7315    110        45.9794
```

A3.2.14 Local Guidance, Display group B, Passive flying task, Low frequency condition

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		216	93.9306	6.0900	0.4144

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
0		72	93.7778	6.5568	0.7727
1		72	94.3333	6.1667	0.7268
2		72	93.6806	5.5711	0.6566

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	b1	36	93.5278	7.2525	1.2088
	b2	36	94.1944	5.7710	0.9618
	b4	36	94.5278	4.4239	0.7373
	b5	36	93.8889	5.6809	0.9468
	b6	36	94.2222	6.5862	1.0977
	b3	36	93.2222	6.7448	1.1241

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
0	b1	12	90.8333	9.2524	2.6709
0	b2	12	93.7500	5.5942	1.6149
0	b4	12	94.8333	4.5092	1.3017
0	b5	12	93.4167	6.5430	1.8888
0	b6	12	95.4167	6.1120	1.7644
0	b3	12	94.4167	6.7751	1.9558
1	b1	12	96.5833	4.8140	1.3897
1	b2	12	95.0833	6.4025	1.8483
1	b4	12	94.3333	4.3135	1.2452
1	b5	12	94.6667	4.9970	1.4425
1	b6	12	92.5833	8.6913	2.5089
1	b3	12	92.7500	7.0598	2.0380
2	b1	12	93.1667	6.3509	1.8333
2	b2	12	93.7500	5.6909	1.6428
2	b4	12	94.4167	4.8140	1.3897
2	b5	12	93.5833	5.8225	1.6808
2	b6	12	94.6667	4.5193	1.3046
2	b3	12	92.5000	6.8291	1.9714

```
FACTOR  :   subjects     tunnel    display evaluation
LEVELS  :         12          3          6        216
TYPE    :     RANDOM     WITHIN     WITHIN       DATA

SOURCE                 SS     df             MS         F      p
============================================================
mean      1905757.0417      1   1905757.0417  5898.678  0.000 ***
s/           3553.9028     11       323.0821

tunnel         17.8611      2         8.9306     0.198  0.822
ts/           991.6944     22        45.0770

display        42.3750      5         8.4750     0.403  0.844
ds/          1155.6806     55        21.0124

td            287.6389     10        28.7639     1.644  0.104
tds/         1924.8056    110        17.4982
```

A3.2.15 Global awareness, Display group A, Passive flying task, High frequency condition

```
SOURCE: grand mean
tunnel  display    N       MEAN         SD         SE
                 180     0.9389     0.2402     0.0179

SOURCE: tunnel
tunnel  display    N       MEAN         SD         SE
3                 60     0.8500     0.3601     0.0465
4                 60     0.9833     0.1291     0.0167
5                 60     0.9833     0.1291     0.0167

SOURCE: display
tunnel  display    N       MEAN         SD         SE
        a1        36     0.9167     0.2803     0.0467
        a2        36     0.8889     0.3187     0.0531
        a3        36     0.9722     0.1667     0.0278
        a4        36     0.9722     0.1667     0.0278
        a5        36     0.9444     0.2323     0.0387

SOURCE: tunnel display
tunnel  display    N       MEAN         SD         SE
3       a1        12     0.8333     0.3892     0.1124
3       a2        12     0.6667     0.4924     0.1421
3       a3        12     0.9167     0.2887     0.0833
3       a4        12     0.9167     0.2887     0.0833
3       a5        12     0.9167     0.2887     0.0833
4       a1        12     1.0000     0.0000     0.0000
4       a2        12     1.0000     0.0000     0.0000
4       a3        12     1.0000     0.0000     0.0000
4       a4        12     1.0000     0.0000     0.0000
4       a5        12     0.9167     0.2887     0.0833
5       a1        12     0.9167     0.2887     0.0833
5       a2        12     1.0000     0.0000     0.0000
5       a3        12     1.0000     0.0000     0.0000
5       a4        12     1.0000     0.0000     0.0000
5       a5        12     1.0000     0.0000     0.0000

FACTOR  :   subjects     tunnel    display recognitio
LEVELS  :         12          3          5        180
TYPE    :     RANDOM     WITHIN     WITHIN       DATA

SOURCE                SS     df             MS         F      p
============================================================
mean          158.6722      1       158.6722  1251.677  0.000 ***
s/              1.3944     11         0.1268

tunnel          0.7111      2         0.3556     2.286  0.125
ts/             3.4222     22         0.1556

display         0.1889      4         0.0472     1.472  0.227
ds/             1.4111     44         0.0321

td              0.5111      8         0.0639     2.091  0.045 *
tds/            2.6889     88         0.0306
```

A3.2.16 Global awareness, Display group A, Passive flying task, Low frequency condition

```
SOURCE: grand mean
tunnel  display    N       MEAN         SD         SE
                 180     0.7167     0.4519     0.0337

SOURCE: tunnel
tunnel  display    N       MEAN         SD         SE
0                 60     0.7833     0.4155     0.0536
1                 60     0.9000     0.3025     0.0391
2                 60     0.4667     0.5031     0.0649

SOURCE: display
tunnel  display    N       MEAN         SD         SE
        a1        36     0.7778     0.4216     0.0703
        a2        36     0.6667     0.4781     0.0797
        a3        36     0.7222     0.4543     0.0757
        a4        36     0.8056     0.4014     0.0669
        a5        36     0.6111     0.4944     0.0824

SOURCE: tunnel display
tunnel  display    N       MEAN         SD         SE
0       a1        12     0.7500     0.4523     0.1306
0       a2        12     0.7500     0.4523     0.1306
0       a3        12     0.7500     0.4523     0.1306
0       a4        12     1.0000     0.0000     0.0000
0       a5        12     0.6667     0.4924     0.1421
1       a1        12     1.0000     0.0000     0.0000
1       a2        12     0.8333     0.3892     0.1124
1       a3        12     0.8333     0.3892     0.1124
1       a4        12     1.0000     0.0000     0.0000
1       a5        12     0.8333     0.3892     0.1124
2       a1        12     0.5833     0.5149     0.1486
2       a2        12     0.4167     0.5149     0.1486
2       a3        12     0.5833     0.5149     0.1486
2       a4        12     0.4167     0.5149     0.1486
2       a5        12     0.3333     0.4924     0.1421

FACTOR  :   subjects     tunnel    display recognitio
LEVELS  :         12          3          5        180
TYPE    :     RANDOM     WITHIN     WITHIN       DATA

SOURCE                 SS     df             MS         F      p
============================================================
mean            92.4500      1        92.4500   344.729  0.000 ***
s/               2.9500     11         0.2682

tunnel           6.0333      2         3.0167     6.937  0.005 **
ts/              9.5667     22         0.4348

display          0.9111      4         0.2278     2.137  0.092
ds/              4.6889     44         0.1066

td               0.8556      8         0.1069     0.815  0.591
tds/            11.5444     88         0.1312
```

A3.2.17 Global awareness, Display group B, Passive flying task, High frequency condition

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		216	0.9398	0.2384	0.0162

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
3		72	0.8333	0.3753	0.0442
4		72	0.9861	0.1179	0.0139
5		72	1.0000	0.0000	0.0000

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	b1	36	0.9444	0.2323	0.0387
	b2	36	0.9167	0.2803	0.0467
	b4	36	0.9167	0.2803	0.0467
	b5	36	0.9444	0.2323	0.0387
	b6	36	0.9444	0.2323	0.0387
	b3	36	0.9722	0.1667	0.0278

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
3	b1	12	0.8333	0.3892	0.1124
3	b2	12	0.8333	0.3892	0.1124
3	b4	12	0.7500	0.4523	0.1306
3	b5	12	0.8333	0.3892	0.1124
3	b6	12	0.8333	0.3892	0.1124
3	b3	12	0.9167	0.2887	0.0833
4	b1	12	1.0000	0.0000	0.0000
4	b2	12	0.9167	0.2887	0.0833
4	b4	12	1.0000	0.0000	0.0000
4	b5	12	1.0000	0.0000	0.0000
4	b6	12	1.0000	0.0000	0.0000
4	b3	12	1.0000	0.0000	0.0000
5	b1	12	1.0000	0.0000	0.0000
5	b2	12	1.0000	0.0000	0.0000
5	b4	12	1.0000	0.0000	0.0000
5	b5	12	1.0000	0.0000	0.0000
5	b6	12	1.0000	0.0000	0.0000
5	b3	12	1.0000	0.0000	0.0000

```
FACTOR  :   subjects     tunnel    display recognitio
LEVELS  :         12          3          6        216
TYPE    :     RANDOM     WITHIN     WITHIN       DATA

SOURCE                 SS     df             MS         F      p
============================================================
mean           190.7824      1       190.7824  1081.859  0.000 ***
s/               1.9398     11         0.1763

tunnel           1.2315      2         0.6157     3.492  0.048 *
ts/              3.8796     22         0.1763

display          0.0787      5         0.0157     0.565  0.726
ds/              1.5324     55         0.0279

td               0.1574     10         0.0157     0.510  0.880
tds/             3.3981    110         0.0309
```

A3.2.18 Global awareness, Display group B, Passive flying task, Low frequency condition

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		216	0.7176	0.4512	0.0307

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
0		72	0.8056	0.3985	0.0470
1		72	0.9028	0.2983	0.0352
2		72	0.4444	0.5004	0.0590

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	b1	36	0.7222	0.4543	0.0757
	b2	36	0.7778	0.4216	0.0703
	b4	36	0.6944	0.4672	0.0779
	b5	36	0.6389	0.4871	0.0812
	b6	36	0.7500	0.4392	0.0732
	b3	36	0.7222	0.4543	0.0757

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
0	b1	12	0.7500	0.4523	0.1306
0	b2	12	0.7500	0.4523	0.1306
0	b4	12	0.8333	0.3892	0.1124
0	b5	12	0.8333	0.3892	0.1124
0	b6	12	0.9167	0.2887	0.0833
0	b3	12	0.7500	0.4523	0.1306
1	b1	12	1.0000	0.0000	0.0000
1	b2	12	0.9167	0.2887	0.0833
1	b4	12	1.0000	0.0000	0.0000
1	b5	12	0.7500	0.4523	0.1306
1	b6	12	0.9167	0.2887	0.0833
1	b3	12	0.8333	0.3892	0.1124
2	b1	12	0.4167	0.5149	0.1486
2	b2	12	0.6667	0.4924	0.1421
2	b4	12	0.2500	0.4523	0.1306
2	b5	12	0.3333	0.4924	0.1421
2	b6	12	0.4167	0.5149	0.1486
2	b3	12	0.5833	0.5149	0.1486

```
FACTOR  :   subjects     tunnel    display recognitio
LEVELS  :         12          3          6        216
TYPE    :     RANDOM     WITHIN     WITHIN       DATA

SOURCE                 SS     df             MS         F      p
============================================================
mean           111.2269      1       111.2269   265.603  0.000 ***
s/               4.6065     11         0.4188

tunnel           8.3981      2         4.1991    12.710  0.000 ***
ts/              7.2685     22         0.3304

display          0.4120      5         0.0824     0.671  0.647
ds/              6.7546     55         0.1228

td               1.8796     10         0.1880     1.430  0.176
tds/            14.4537    110         0.1314
```

A3.3 EXPERIMENT 3

A3.3.1 Local guidance (Overall RMS error)

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		1152	0.2893	0.6099	0.0180

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
1		144	0.2782	0.5249	0.0437
2		144	0.2064	0.2627	0.0219
3		144	0.2483	0.3924	0.0327
4		144	0.2075	0.4179	0.0348
5		144	0.3109	0.6603	0.0550
6		144	0.4381	1.2035	0.1003
7		144	0.3433	0.5274	0.0440
8		144	0.2818	0.3419	0.0285

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	D1	192	0.2986	0.5572	0.0402
	D2	192	0.2316	0.3594	0.0259
	D3	192	0.1505	0.1294	0.0093
	D4	192	0.1961	0.1841	0.0133
	D5	192	0.3339	0.4197	0.0303
	D6	192	0.5252	1.2189	0.0880

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
1	D1	24	0.4342	1.0132	0.2068
1	D2	24	0.3166	0.5812	0.1186
1	D3	24	0.1890	0.1855	0.0379
1	D4	24	0.1792	0.1677	0.0342
1	D5	24	0.2750	0.3336	0.0681
1	D6	24	0.2754	0.3599	0.0735
2	D1	24	0.1930	0.1532	0.0313
2	D2	24	0.1661	0.1142	0.0233
2	D3	24	0.1165	0.0699	0.0143
2	D4	24	0.1600	0.1429	0.0292
2	D5	24	0.3551	0.5356	0.1093
2	D6	24	0.2477	0.2073	0.0423
3	D1	24	0.2931	0.3743	0.0764
3	D2	24	0.3204	0.6237	0.1273
3	D3	24	0.1404	0.1226	0.0250
3	D4	24	0.1489	0.0848	0.0173
3	D5	24	0.3000	0.2883	0.0588
3	D6	24	0.2868	0.5374	0.1097
4	D1	24	0.4545	0.9617	0.1963
4	D2	24	0.1264	0.0746	0.0152
4	D3	24	0.1588	0.1755	0.0358
4	D4	24	0.1648	0.0899	0.0184
4	D5	24	0.1666	0.1317	0.0269
4	D6	24	0.1736	0.1454	0.0297
5	D1	24	0.2434	0.1951	0.0398
5	D2	24	0.1556	0.1398	0.0285
5	D3	24	0.0993	0.0917	0.0187

5	D4	24	0.1795	0.1366	0.0279
5	D5	24	0.3674	0.3540	0.0723
5	D6	24	0.8205	1.4602	0.2981
6	D1	24	0.2993	0.4919	0.1004
6	D2	24	0.2698	0.3426	0.0699
6	D3	24	0.1560	0.0837	0.0171
6	D4	24	0.2332	0.1617	0.0330
6	D5	24	0.3309	0.3856	0.0787
6	D6	24	1.3398	2.7253	0.5563
7	D1	24	0.2722	0.2290	0.0467
7	D2	24	0.2722	0.2881	0.0588
7	D3	24	0.1954	0.1056	0.0215
7	D4	24	0.2649	0.3367	0.0687
7	D5	24	0.4742	0.6494	0.1326
7	D6	24	0.5809	0.9651	0.1970
8	D1	24	0.1989	0.2462	0.0503
8	D2	24	0.2259	0.2572	0.0525
8	D3	24	0.1487	0.1398	0.0285
8	D4	24	0.2385	0.2144	0.0438
8	D5	24	0.4019	0.4553	0.0929
8	D6	24	0.4772	0.4913	0.1003

FACTOR	:	subjects	tunnel	display	rms
LEVELS	:	12	8	6	1152
TYPE	:	RANDOM	WITHIN	WITHIN	DATA

SOURCE	SS	df	MS	F	p	
mean	96.4305	1	96.4305	109.603	0.000	***
s/	9.6780	11	0.8798			
tunnel	5.9003	7	0.8429	2.563	0.020	*
ts/	25.3247	77	0.3289			
display	17.0892	5	3.4178	8.484	0.000	***
ds/	22.1561	55	0.4028			
td	24.3866	35	0.6968	2.093	0.000	***
tds/	128.1481	385	0.3329			

Tukey pair-wise comparison ($\alpha = 0.05$).

	D1	D2	D3	D4	D5
D2	-0.0530				
	0.1869				
D3	0.0281 *	-0.0388			
	0.2680	0.2010			
D4	-0.0175	-0.0844	-0.1655		
	0.2224	0.1554	0.0743		
D5	-0.1552	-0.2222	-0.3033 *	-0.2577 *	
	0.0846	0.0177	-0.0634	-0.0178	
D6	-0.3466 *	-0.4135 *	-0.4946 *	-0.4490 *	-0.3113 *
	-0.1067	-0.1737	-0.2548	-0.2092	-0.0714

A3.3.2 Global awareness (Tunnel shape recognition score)

SOURCE: grand mean

tunnel	display	N	MEAN	SD	SE
		1152	0.6840	0.4651	0.0137

SOURCE: tunnel

tunnel	display	N	MEAN	SD	SE
1		144	0.7639	0.4262	0.0355
2		144	0.7778	0.4172	0.0348
3		144	0.7014	0.4592	0.0383
4		144	0.5903	0.4935	0.0411
5		144	0.5417	0.5000	0.0417
6		144	0.7014	0.4592	0.0383
7		144	0.6597	0.4755	0.0396
8		144	0.7361	0.4423	0.0369

SOURCE: display

tunnel	display	N	MEAN	SD	SE
	D1	192	0.5469	0.4991	0.0360
	D2	192	0.5521	0.4986	0.0360
	D3	192	0.6927	0.4626	0.0334
	D4	192	0.6979	0.4604	0.0332
	D5	192	0.7865	0.4109	0.0297
	D6	192	0.8281	0.3783	0.0273

SOURCE: tunnel display

tunnel	display	N	MEAN	SD	SE
1	D1	24	0.7917	0.4149	0.0847
1	D2	24	0.7917	0.4149	0.0847
1	D3	24	0.7917	0.4149	0.0847
1	D4	24	0.7917	0.4149	0.0847
1	D5	24	0.6667	0.4815	0.0983
1	D6	24	0.7500	0.4423	0.0903
2	D1	24	0.6250	0.4945	0.1009
2	D2	24	0.6250	0.4945	0.1009
2	D3	24	0.9167	0.2823	0.0576
2	D4	24	0.8750	0.3378	0.0690
2	D5	24	0.7917	0.4149	0.0847
2	D6	24	0.8333	0.3807	0.0777
3	D1	24	0.5833	0.5036	0.1028
3	D2	24	0.5417	0.5090	0.1039
3	D3	24	0.5417	0.5090	0.1039
3	D4	24	0.7083	0.4643	0.0948
3	D5	24	0.8750	0.3378	0.0690
3	D6	24	0.9583	0.2041	0.0417
4	D1	24	0.3750	0.4945	0.1009
4	D2	24	0.6250	0.4945	0.1009
4	D3	24	0.5417	0.5090	0.1039
4	D4	24	0.4167	0.5036	0.1028
4	D5	24	0.7917	0.4149	0.0847
4	D6	24	0.7917	0.4149	0.0847
5	D1	24	0.2917	0.4643	0.0948
5	D2	24	0.2917	0.4643	0.0948
5	D3	24	0.5417	0.5090	0.1039
5	D4	24	0.5833	0.5036	0.1028

5	D5	24	0.7917	0.4149	0.0847
5	D6	24	0.7500	0.4423	0.0903
6	D1	24	0.6667	0.4815	0.0983
6	D2	24	0.5833	0.5036	0.1028
6	D3	24	0.8333	0.3807	0.0777
6	D4	24	0.6250	0.4945	0.1009
6	D5	24	0.7083	0.4643	0.0948
6	D6	24	0.7917	0.4149	0.0847
7	D1	24	0.4167	0.5036	0.1028
7	D2	24	0.3750	0.4945	0.1009
7	D3	24	0.7083	0.4643	0.0948
7	D4	24	0.7500	0.4423	0.0903
7	D5	24	0.8750	0.3378	0.0690
7	D6	24	0.8333	0.3807	0.0777
8	D1	24	0.6250	0.4945	0.1009
8	D2	24	0.5833	0.5036	0.1028
8	D3	24	0.6667	0.4815	0.0983
8	D4	24	0.8333	0.3807	0.0777
8	D5	24	0.7917	0.4149	0.0847
8	D6	24	0.9167	0.2823	0.0576

FACTOR	:	subjects	tunnel	display	global
LEVELS	:	12	8	6	1152
TYPE	:	RANDOM	WITHIN	WITHIN	DATA

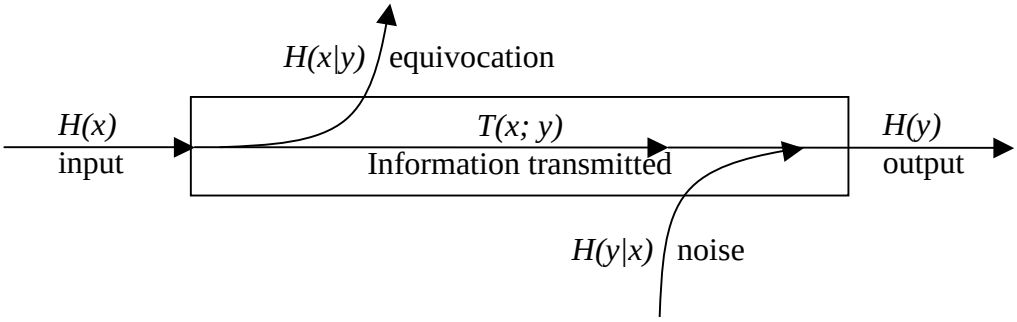
SOURCE	SS	df	MS	F	p	
mean	539.0139	1	539.0139	266.645	0.000	***
s/	22.2361	11	2.0215			
tunnel	6.9306	7	0.9901	3.662	0.002	**
ts/	20.8194	77	0.2704			
display	13.0069	5	2.6014	15.479	0.000	***
ds/	9.2431	55	0.1681			
td	11.1319	35	0.3181	1.759	0.006	**
tds/	69.6181	385	0.1808			

Tukey pair-wise comparison ($\alpha = 0.05$).

	D1	D2	D3	D4	D5
D2	-0.1372				
	0.1268				
D3	-0.2778 *	-0.2726 *			
	-0.0139	-0.0086			
D4	-0.2830 *	-0.2778 *	-0.1372		
	-0.0191	-0.0139	0.1268		
D5	-0.3716 *	-0.3664 *	-0.2257	-0.2205	
	-0.1076	-0.1024	0.0382	0.0434	
D6	-0.4132 *	-0.4080 *	-0.2674 *	-0.2622	-0.1736
	-0.1493	-0.1441	-0.0034	0.0018	0.0903

Appendix 4

Contingency Tables



Information measures associated with a channel.
(Adapted from Sheridan & Farrell, 1974)

$$H(x) = \sum_i p(x_i) \log_2 \frac{1}{p(x_i)}$$

$$H(y) = \sum_i p(y_i) \log_2 \frac{1}{p(y_i)}$$

$$T(x;y) = H(x) + H(y) - H(x,y)$$

$$= \sum_i p(x_i) \log_2 \frac{1}{p(x_i)} + \sum_i p(y_i) \log_2 \frac{1}{p(y_i)} - \sum_{ij} p(x_i, y_j) \log_2 \frac{1}{p(x_i, y_j)}$$

$$H(x \mid y) = H(x) - T(x;y) = \sum_{ij} p(x_i, y_j) \log_2 \frac{1}{p(x_i \mid y_j)}$$

$$H(y \mid x) = H(y) - T(x;y) = \sum_{ij} p(x_i, y_j) \log_2 \frac{1}{p(y_i \mid x_j)}$$

A4.1 Display D1 (*l*=0.5)

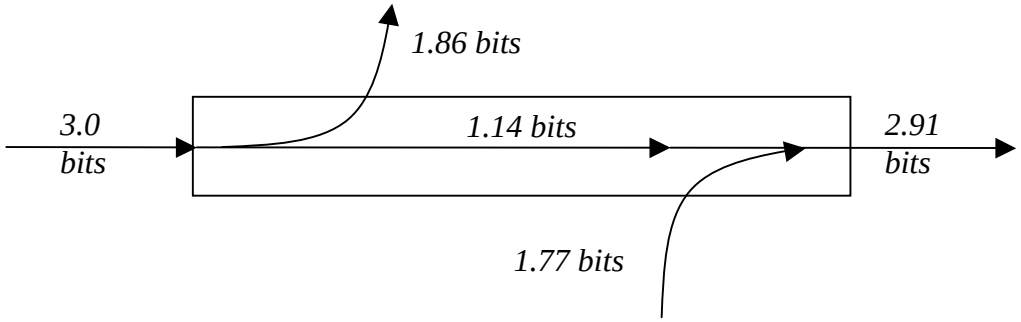
1. Summary of participants' tunnel shape recognition judgment (raw data).

D1		response							
		1	2	3	4	5	6	7	8
Path	1	13	3	1	1	1			
	2	5	17	1	3		1		
	3	5	5	8	4	2		1	
	4		2	1	14		1		1
	5	1	2	2		15	2	1	1
	6		6	3	3	6	14		2
	7		1	7		1		8	1
	8	1	3		8				14

2 The contingency table.

D1		response								
		1	2	3	4	5	6	7	8	total
path	1	0.085526	0.019737	0.006579	0.006579	0.006579	0	0	0	0.125
	2	0.023148	0.078704	0.00463	0.013889	0	0.00463	0	0	0.125
	3	0.025	0.025	0.04	0.02	0.01	0	0.005	0	0.125
	4	0	0.013158	0.006579	0.092105	0	0.006579	0	0.006579	0.125
	5	0.005208	0.010417	0.010417	0	0.078125	0.010417	0.005208	0.005208	0.125
	6	0	0.022059	0.011029	0.011029	0.022059	0.051471	0	0.007353	0.125
	7	0	0.006944	0.048611	0	0.006944	0	0.055556	0.006944	0.125
	8	0.004808	0.014423	0	0.038462	0	0	0	0.067308	0.125
	total	0.14369	0.190441	0.127845	0.182064	0.123707	0.073096	0.065764	0.093392	1

3. Graphical summary of information calculated for display D1.



A4.2 Display D2 (*l*=1)

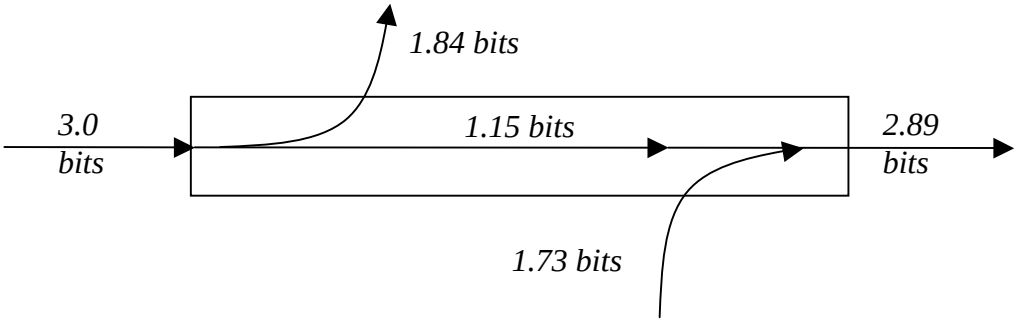
1. Summary of participants' tunnel shape recognition judgment (raw data).

D2		response							
		1	2	3	4	5	6	7	8
	1	20	9	2					
	2	1	14	1	2		3	1	
	3	2	3	5	6	1	1		
path	4	1	3		17				1
	5	2	3		1	13	1	1	
	6	1	4		2		17		2
	7	1	1	6	4	3		9	
	8		1	2	6	1	2	1	15

2 The contingency table.

D2		response								
		1	2	3	4	5	6	7	8	
	1	0.080645	0.03629	0.008065	0	0	0	0	0	0.125
	2	0.005682	0.079545	0.005682	0.011364	0	0.017045	0.005682	0	0.125
	3	0.013889	0.020833	0.034722	0.041667	0.006944	0.006944	0	0	0.125
path	4	0.005682	0.017045	0	0.096591	0	0	0	0.005682	0.125
	5	0.011905	0.017857	0	0.005952	0.077381	0.005952	0.005952	0	0.125
	6	0.004808	0.019231	0	0.009615	0	0.081731	0	0.009615	0.125
	7	0.005208	0.005208	0.03125	0.020833	0.015625	0	0.046875	0	0.125
	8	0	0.004464	0.008929	0.026786	0.004464	0.008929	0.004464	0.066964	0.125
	total	0.127818	0.200475	0.088647	0.212808	0.104415	0.120602	0.062973	0.082261	1

3. Graphical summary of information calculated for display D2.



A4.3 Display D3 (*l*=2)

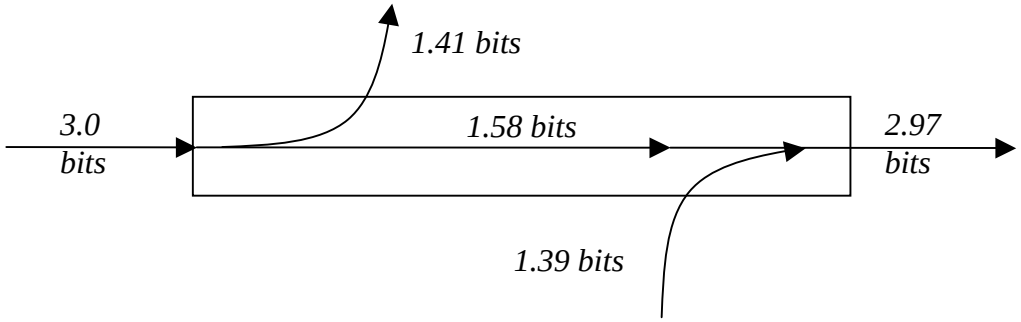
1. Summary of participants' tunnel shape recognition judgment (raw data).

D3		response							
		1	2	3	4	5	6	7	8
	1	21	3			1			
	2	1	17	1					
	3	1	1	9	2	1		2	
path	4		1	1	25			1	2
	5	2	2			16	1	3	
	6		3		1	2	16	1	4
	7			4	1	1		16	1
	8		2	2	4		3	2	15

2 The contingency table.

D3		response								
		1	2	3	4	5	6	7	8	
	1	0.105	0.015	0	0	0.005	0	0	0	0.125
	2	0.006579	0.111842	0.006579	0	0	0	0	0	0.125
	3	0.007813	0.007813	0.070313	0.015625	0.007813	0	0.015625	0	0.125
path	4	0	0.004167	0.004167	0.104167	0	0	0.004167	0.008333	0.125
	5	0.010417	0.010417	0	0	0.083333	0.005208	0.015625	0	0.125
	6	0	0.013889	0	0.00463	0.009259	0.074074	0.00463	0.018519	0.125
	7	0	0	0.021739	0.005435	0.005435	0	0.086957	0.005435	0.125
	8	0	0.008929	0.008929	0.017857	0	0.013393	0.008929	0.066964	0.125
	total	0.129808	0.172055	0.111726	0.147713	0.11084	0.092675	0.135931	0.099251	1

3. Graphical summary of information calculated for display D3.



A4.4 Display D4 (*l*=4)

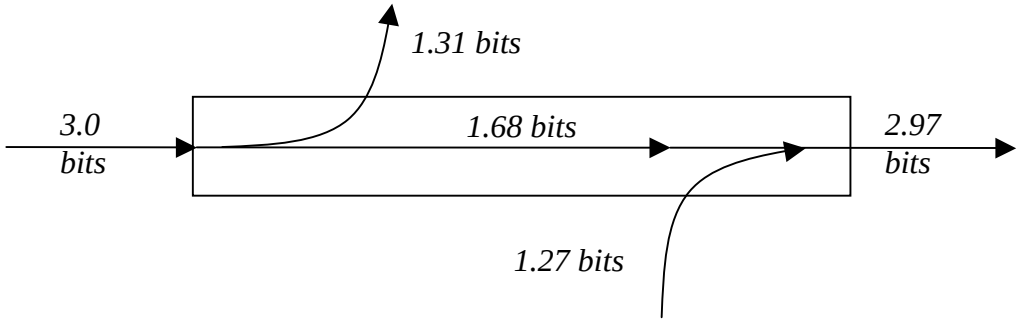
1. Summary of participants' tunnel shape recognition judgment (raw data).

D4		response							
		1	2	3	4	5	6	7	8
	1	21	3			1		1	
	2		23		1		1		1
	3	2	2	20	5		1	2	
path	4		4		23				1
	5	4	1			21	1		
	6		2	2	1	1	6		3
	7			1		2		12	1
	8	1			1		2	3	15

2 The contingency table.

D4		response								
		1	2	3	4	5	6	7	8	
	1	0.100962	0.014423	0	0	0.004808	0	0.004808	0	0.125
	2	0	0.110577	0	0.004808	0	0.004808	0	0.004808	0.125
	3	0.007813	0.007813	0.078125	0.019531	0	0.003906	0.007813	0	0.125
path	4	0	0.017857	0	0.102679	0	0	0	0.004464	0.125
	5	0.018519	0.00463	0	0	0.097222	0.00463	0	0	0.125
	6	0	0.016667	0.016667	0.008333	0.008333	0.05	0	0.025	0.125
	7	0	0	0.007813	0	0.015625	0	0.09375	0.007813	0.125
	8	0.005682	0	0	0.005682	0	0.011364	0.017045	0.085227	0.125
	total	0.132974	0.171966	0.102604	0.141033	0.125988	0.074707	0.123416	0.127312	1

3. Graphical summary of information calculated for display D4.



A4.5 Display D5 (*l*=8)

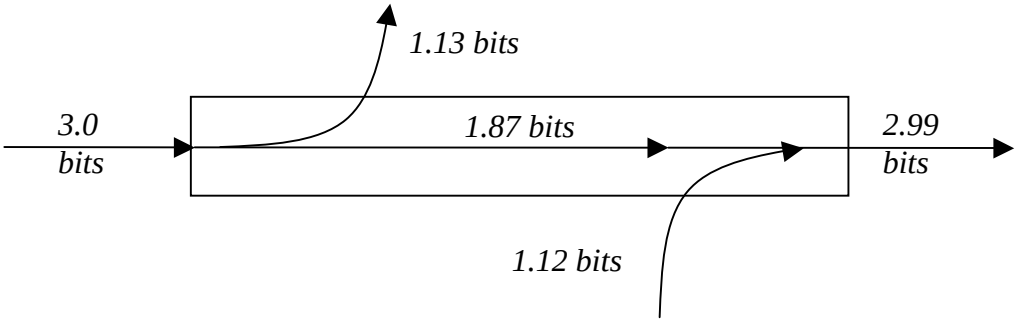
1. Summary of participants' tunnel shape recognition judgment (raw data).

D5		response							
		1	2	3	4	5	6	7	8
	1	14	2	2		2			1
	2	2	18		2				1
	3	5		19	1				
path	4	2	1	2	14	1	1	1	
	5			1	1	26	3		
	6	1				1	14		1
	7	3		2		1		26	
	8				2			1	18

2 The contingency table.

D5		response								
		1	2	3	4	5	6	7	8	
	1	0.083333	0.011905	0.011905	0	0.011905	0	0	0.005952	0.125
	2	0.01087	0.097826	0	0.01087	0	0	0	0.005435	0.125
	3	0.025	0	0.095	0.005	0	0	0	0	0.125
path	4	0.011364	0.005682	0.011364	0.079545	0.005682	0.005682	0.005682	0	0.125
	5	0	0	0.004032	0.004032	0.104839	0.012097	0	0	0.125
	6	0.007353	0	0	0	0.007353	0.102941	0	0.007353	0.125
	7	0.011719	0	0.007813	0	0.003906	0	0.101563	0	0.125
	8	0	0	0	0.011905	0	0	0.005952	0.107143	0.125
	total	0.149638	0.115413	0.130113	0.111352	0.133684	0.12072	0.113197	0.125883	1

3. Graphical summary of information calculated for display D5.



A4.6 Display D6 (*l*=12)

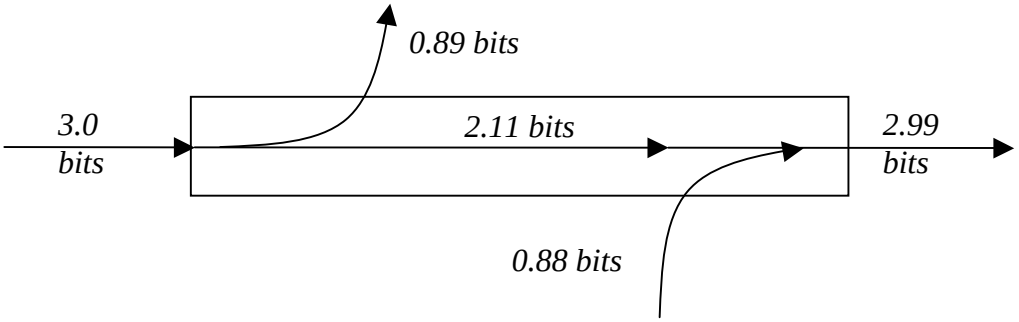
1. Summary of participants' tunnel shape recognition judgment (raw data).

D6		response							
		1	2	3	4	5	6	7	8
	1	17	1		2	2			
	2	1	22		3	1			
	3	1		22	3			2	
path	4		1	4	18				
	5					15	1	1	
	6		1			2	20		2
	7			1	1	3		25	1
	8							1	18

2 The contingency table.

D6		response								
		1	2	3	4	5	6	7	8	
	1	0.096591	0.005682	0	0.011364	0.011364	0	0	0	0.125
	2	0.00463	0.101852	0	0.013889	0.00463	0	0	0	0.125
	3	0.004464	0	0.098214	0.013393	0	0	0.008929	0	0.125
path	4	0	0.005435	0.021739	0.097826	0	0	0	0	0.125
	5	0	0	0	0	0.110294	0.007353	0.007353	0	0.125
	6	0	0.005	0	0	0.01	0.1	0	0.01	0.125
	7	0	0	0.004032	0.004032	0.012097	0	0.100806	0.004032	0.125
	8	0	0	0	0	0	0	0.006579	0.118421	0.125
	total	0.105685	0.117968	0.123986	0.140504	0.148384	0.107353	0.123667	0.132453	1

3. Graphical summary of information calculated for display D6.



Appendix 5

Regression Analysis from in Experiment 3

1 Predictor: spatial orientation score
Response: global awareness (tunnel shape recognition) score

The regression equation is
global mean = 0.794 - 0.00469 orientation

Predictor	Coef	StDev	T	P
Constant	0.7939	0.1604	4.95	0.001
orientat	-0.004685	0.006569	-0.71	0.492

S = 0.1935 R-Sq = 4.8% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.01905	0.01905	0.51	0.492
Residual Error	10	0.37450	0.03745		
Total	11	0.39355			

2. Predictor: spatial visualization score
Response: global awareness (tunnel shape recognition) score

The regression equation is
global mean = 0.537 + 0.0078 visualization

Predictor	Coef	StDev	T	P
Constant	0.5365	0.3289	1.63	0.134
visualiz	0.00778	0.01679	0.46	0.653

S = 0.1963 R-Sq = 2.1% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.00827	0.00827	0.21	0.653
Residual Error	10	0.38528	0.03853		
Total	11	0.39355			

3. Predictor: spatial orientation score
Response: local guidance (RMS error) score

The regression equation is
RMS mean = 0.415 - 0.00544 orientation

Predictor	Coef	StDev	T	P
Constant	0.4154	0.1101	3.77	0.004
orientat	-0.005439	0.004510	-1.21	0.256

S = 0.1329 R-Sq = 12.7% R-Sq(adj) = 4.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.02568	0.02568	1.45	0.256
Residual Error	10	0.17652	0.01765		
Total	11	0.20219			

4. Predictor: spatial visualization score
Response: local guidance (RMS error)score

The regression equation is
RMS mean = 0.428 - 0.0071 visualization

Predictor	Coef	StDev	T	P
Constant	0.4283	0.2341	1.83	0.097
visualiz	-0.00712	0.01196	-0.60	0.565

S = 0.1397 R-Sq = 3.4% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.00693	0.00693	0.35	0.565
Residual Error	10	0.19526	0.01953		
Total	11	0.20219			

Appendix 6

RMS error and its calculation

Root Mean Square (RMS) error is used in this study to measure participants' local guidance performance. The lower the RMS error, the better their guidance performance. Mathematically, a RMS error score is calculated using the following equation.

$$RMS\_Error = \sqrt{\frac{\sum_{i=1}^{N} Error_i^2}{N}}$$

Depending on the application, the error term is calculated in different ways. For example, in a 2D tracking task where a user manipulates a curser to follow a target on a 2D plane, the error corresponds to the absolute distance between the curser location and the target location. Figure A6.1 illustrates how such an error value is calculated.

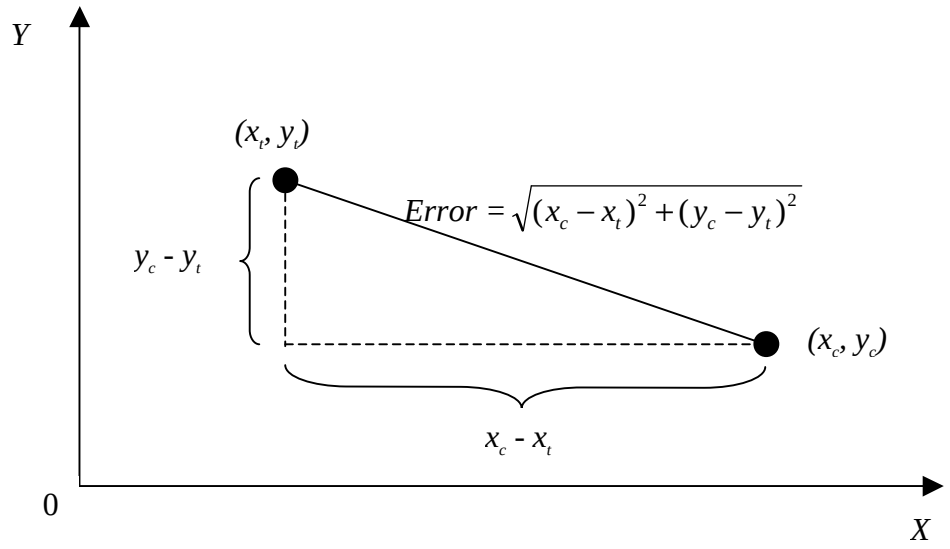


Figure A6.1. Error term calculation in a 2D tracking task.

The calculation becomes slightly more complicated when the tracking task is carried out in a three dimensional space, as in the case of current study. Besides positional displacements, orientational mismatches between the cursor and the target shall also be considered as errors.

The navigational task used in this project involved the flying of an airplane in a winding tunnel-like environment. Since participants were instructed to fly the airplane along the

centre of the tunnel which was depicted as a red line on the display. Therefore, the momentary ideal position and orientation of the airplane are uniquely determined. After a test trial is initiated, the software (DTS) is able to keep track of the airplane's location and orientation in the 3D space. Positional and orientational errors are obtained separately by computing the mismatch between the airplane's momentary position and orientation to its ideal position and orientation. By default, DTS thinks the point that is closest (in absolute distance) to the airplane on the tunnel's centre line is the one that the airplane is currently tracking.

Two local coordinates are involved in calculating the errors. Firstly, there is an airplane (avatar) local coordinate, $(XYZ)_a$, whose origin is the gravity centre of the airplane. Due to the simplicity of the airplane model used in this study, the centre point on the airplane body axis is defined to be its gravity centre. The Z_a axis starts from the origin and extends along the airplane's body axis, pointing forward. The Y_a axis is perpendicular to the main body axis and pointing upward. The X_a axis is perpendicular to the $(X\text{-}Z)_a$ plane, extending along the direction of the left wing. (see Figure A6.1a) Secondly, there is a momentary tunnel local coordinate, $(XYZ)_t$. The origin of this coordinate is the point on the tunnel centre line which the airplane is momentarily tracking with. During an experimental trial, the origin of the coordinate moves from the starting point to the end point along the tunnel centre line. The Z_t axis starts from the origin and extend along the tangent direction of the tunnel, pointing toward to the tunnel's end. The Y_t axis is perpendicular to the tunnel floor and pointing up toward the open ceiling of the tunnel. The X_t axis, again, is perpendicular to the $(Y\text{-}Z)_t$ plane, completing a right-hand orthogonal system by pointing leftward. (see Figure A6.1b)

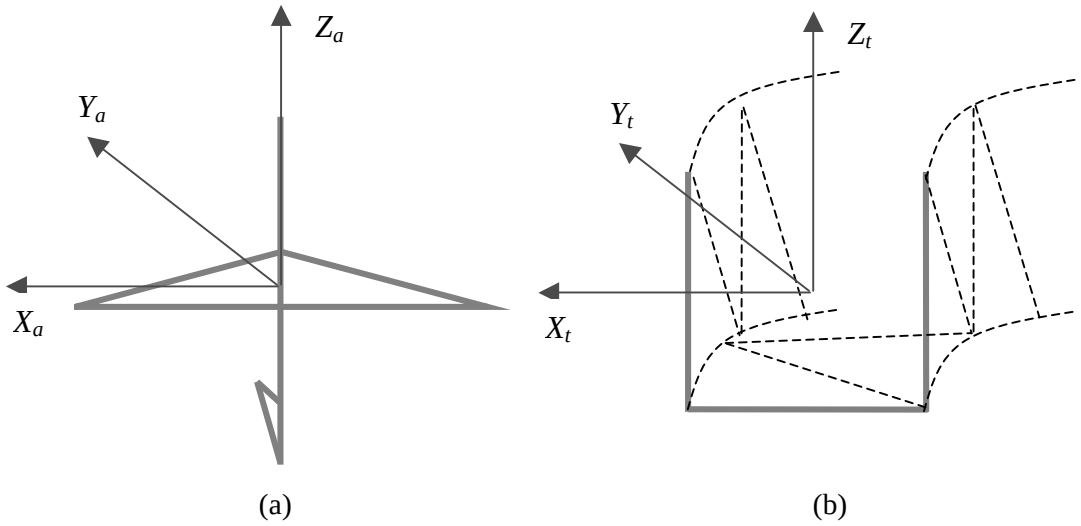


Figure A6.1 The definition of the local airplane coordinate system (a) and the momentary tunnel local coordinate system (b).

The calculation of RMS errors involves comparing the two local coordinate systems. See Figure A6.2, the positional error is obtained by calculating the distance between the

origins of the two coordinates. The orientational error, on the other hand, is computed from the angular displacement between the two coordinates.

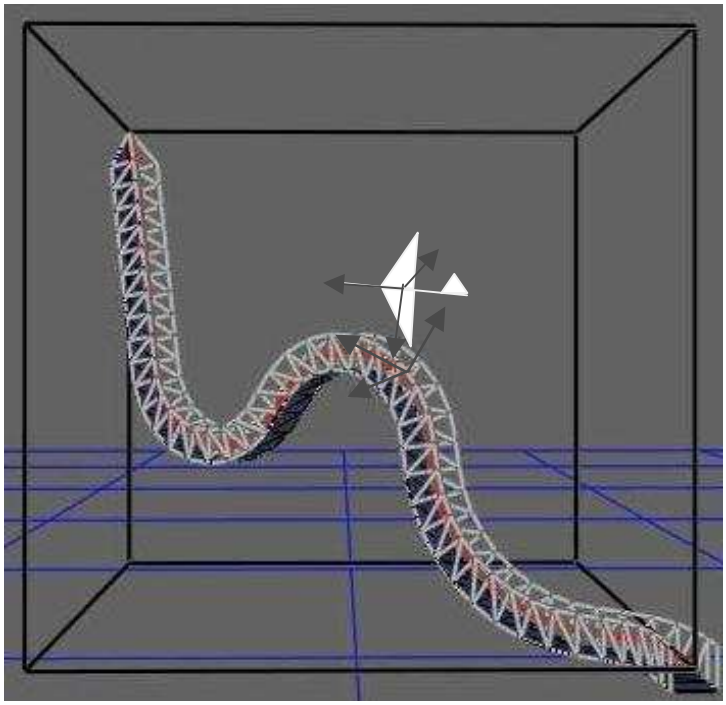


Figure A6.2 Calculating the errors by comparing the airplane local coordinate with the tunnel coordinate.

Mathematical equations for calculating the RMS error can be summarised as:

$$Positional\_RMS\_Error = \sqrt{\frac{\sum_{i=1}^{N}[(x_{ai}-x_{ti})^2+(y_{ai}-y_{ti})^2+(z_{ai}-z_{ti})^2]}{N}}$$

$$Orientational\_RMS\_Error = \sqrt{\frac{\sum_{i=1}^{N}[(\alpha_{ai}-\alpha_{ti})^2+(\beta_{ai}-\beta_{ti})^2+(\delta_{ai}-\delta_{ti})^2]}{N}}$$

where
x_{ai}, y_{ai}, z_{ai} are the avatar position;
x_{ti}, y_{ti}, z_{ti} are the target position;
$\alpha_{ai}, \beta_{ai}, \delta_{ai}$ are the avatar orientation (expressed in Euler angles);
$\alpha_{ti}, \beta_{ti}, \delta_{ti}$ are the target orientation (expressed in Euler engles).

In order to obtain a comprehensive measure of a participant's local guidance performance, an overall RMS error is calculated by adding together the positional and the orientational RMS errors. The overall RMS error has been throughout this study.