Schlußbericht zum DLR Vorhaben:WB 0429

EVALUIERUNG DER ORIENTIERUNG DER LISTING'SCHEN EBENE UNTER VERÄNDERTEN SCHWERKRAFTBEDINGUNGEN

Zuwendungsempfänger: **Prof. Dr.-Ing. A.H. Clarke**	Förderkennzeichen: **50 WB 0429**

Laufzeit des Vorhabens:

Mai 2004 – Mai 2007

Ausführende Stelle:

Labor für experimentelle Gleichgewichtsforschung
der Hals- Nasen- Ohrenklinik
Campus Benjamin Franklin
Charité Universitätsmedizin Berlin

INHALTSVERZEICHNIS

PRÄAMBEL

Als Fortsetzung des vorangegangenen Projektes WB 0023 diente das jetzige Vorhaben in erster Linie der Durchführung der begonnenen Experimente an Bord der Internationalen Raumstation (ISS). Es wurden Messungen während der von der ESA organisierten kurzzeitigen Missionen sowie der sechsmonatigen ISS Inkrementen von den Crew-Mitgliedern durchgeführt.

Desweiteren wurden Kontrolluntersuchungen im terrestrischen Labor sowie bei verschiedenen Parabelflugkampagnen durchgeführt.

PERSONAL

Die bewilligte 1/1 BAT IIa Stelle wurde weiterhin mit Herrn Dr. rer. nat. K. Drüen (3/4-Stelle) besetzt. Die restliche ¼ BAT II Stelle wurde weiterhin von Herrn Dipl.-Ing. W. Krzok besetzt.

Die studentische Hilfskraftstelle wurde vom Januar 2005 bis Dezember 2005 von Herrn Kand. Dipl.Ing. M. Röcker besetzt.

WISSENSCHAFTLICHE ZIELE

Teil 1:

Die Orientierung der Listing'schen Ebene unter veränderten Schwerkraftbedingungen

Dieser erste Teil des Vorhabens wird bei den laufenden Arbeiten - Vorbereitung, Training, Preflight- und Postflight-Basisdatenerhebung sowie die Auswertung der Meßdaten - für die ISS Missionen (Astrolab, Increment 13) fortgesetzt. Im Rahmen der ESA/russischen Kooperation wurde die ETD Anlage im russischen Sektor der ISS akkommodiert und das Experiment weitgehend von den russischen Crew-Mitgliedern durchgeführt.

Teil 2.

Co-Investigator bei der IBMP Gruppe (Russische PI: I. Kozlovskaya, E. Tomilovskaya, L. Kornilova).

Diese Studie stellt einen Beitrag zu dem vereinbarten kooperativen Programm zwischen IBMP- und ESA/DLR- Wissenschaftlern zur Untersuchung der sensorisch-motorischen Koordination während und nach einem Aufenthalt in der Mikrogravität dar.

Teil 3.

Erweiterung des ETDs mit dem Healthlab-System

Das HealthLab-System erlaubt die Untersuchung der vestibulo-autonomischen Regulation beim Menschen. So wird das bestehende Vorhaben zur Untersuchung des vestibulären Systems mit Hilfe des 3D Eye Trackers durch die zusätzliche Registrierung von objektiv erfaßbaren vegetativen Parametern erweitert.

Das integrierte System wurde im Rahmen einer Parabelflugkampagne für die ersten Machbarkeitsstudien in kurzzeitiger Schwerelosigkeit eingesetzt.

Die Messungen wurden weitgehend erfolgreich durchgeführt und werden im Labor in Zusammenarbeit mit Dr. B. Johannes (DLR, Hamburg) ausgewertet.

STATUS DER ISS MESSUNGEN

Nach der ursprünglichen Planung sollten Messungen sowohl bei NASA Astronauten bei kürzeren Missionen (ca. 10 Tage) als auch bei Astronauten bzw. Kosmonauten, die sechs Monaten auf der ISS verbringen, durchgeführt werden. Aus operationstechnischen Gründen fielen die geplanten Messungen bei den US-amerikanischen Astronauten aus. So wurden sämtliche bisherigen Messungen in Zusammenarbeit mit den ESA Astronauten und den russischen Kosmonauten gemacht.

Der Hauptexperimentteil (Teil 1) wurde zum ersten Mal während der zehntägigen Delta Mission von einem ESA Astronaut (AK) durchgeführt. Eine weitere Meßreihe wurde während der zehntägigen Eneide Mission mit einem zweiten ESA Astronaut (RV) durchgeführt. Ein dritter „kurzzeitiger“ Astronaut wird für die „Malaysischen“-Mission trainiert.

Seit ISS Inkrement 9 wurden äquivalente Preflight- Inflight- und Postflight-Messungen mit einer Reihe von russischen Kosmonauten während ihres sechsmonatigen ISS Aufenthalts erfolgreich durchgeführt.

Bei diesen Testpersonen wurde auch der zweite Experimentteil der russichen Wissenschaftlergruppe (IBMP) trainiert und während der Preflight- Inflight- und Postflight-Phasen der Missionen durchgeführt.

Die erste Experiment-Familiarisation und Training-Session für die LDM Mission mit den Astronauten Reiter und Eyhart wurde im Mai 2005 im EAC abgehalten.

Die während der Laufzeit des Vorhabens erfolgten Meßreihen sind in der folgenden Tabelle zusammengestellt:

ESA / Delta	Astronaut AK	April 2004	
ESA/ Eneide	Astronaut RV	April 2005	
Malaysian	Astronaut MS	Oktober 2007	
Inkrement 9:	Kosmonaut GP	April 2004 –	September 2004
Increment 10:	Kosmonaut SS	Oktober 2004 –	März 2005
Increment 11	Kosmonaut SK	April 2005 –	Oktober 2005
Increment 13	Kosmonaut PV	April 2006 –	Oktober 2006
Astrolab:	ESA Astronaut TR	Juli 2006 –	Dezember 2006

Dementsprechend fanden die Preflight-Training und BDC-Sessions weitestgehend im GCTC, Sternstädtchen bei Moskau statt. Die Experimenteinführungen bzw. Familiarisation-Sessions fanden zum größten Teil im EAC in Köln-Porz statt.

Laut vereinbarter Flugprozedur wurden die Inflight-Experimente jeweils 8 mal in Intervallen von etwa 3 Wochen durchgeführt. Bei jeder Testperson wurden die Postflight-BDC-Messungen über das vorgesehene 14-tägige Intervall nach Landung durchgeführt. Es wurde auch bei den meisten Testpersonen etwa 60 Tage nach Landung zu Kontrollzwecken im berliner Labor bzw. im EAC, Köln-Porz nochmal gemessen.

Nach jetziger Planung bzw. Vereinbarung mit der ESA werden die Untersuchungen auf der ISS nach dem Inkrement 15 Ende April 2008 abgeschlossen.

Data Transfer

Die aufgezeichneten Experimentdaten werden nach wie vor am Ende jedes ISS-Increments an Bord des Sojuz-Transporters zurück zur Erde gebracht. Die Auswertung der Daten erfolgt im berliner Labor bzw. bei IBMP in Moskau.

Data Return

Wegen der Komplexität des Experiments bzw. des Fehlens ausreichender Trainingszeiten konnte nicht bei allen Testpersonen eine ausreichende Datenqualität bei den Inflight-Messungen erreicht werden. Einzelheiten sind in dem Anhang 2 zusammengestellt.

Status des ETD Flugsystems

Das sich an Bord der ISS befindliche ETD System wurde weiterhin erfolgreich von Anfang 2004 (Delta Mission) bis zum Increment 15 (April 2008) eingesetzt. Die Anlage bleibt im russischen Teil der ISS installiert.

Bei dem Inkrement 13 wurde berichtet, daß die Befestigung einer Augenkamera (links) mangelhaft war. Sowohl Kosmonaut Vinogradov als auch Astronaut Reiter konnten effektive Workarounds verwenden. Eine Reparaturprozedur wird für Inkrement 16 vorbereitet und voraussichtlich von dem malaysischen Kosmonauten durchgefuhrt.

Als Ergänzung des Eye Tracking Device wurde eine Miniatur-Kalibriereinheit mit dem Sojuz-Launch für Inkrement 13 an Bord der ISS gebracht.

Im Laufe des Astronauten- und Kosmonautentrainings und bei der Durchführung unseres Experiments an Bord der ISS hat sich herausgestellt, dass das ursprüngliche Kalibrierungsgerät einige Nachteile aufweist:1) bei einem 1-Person Subjekt/Operator Szenario, wie es jetzt der Fall ist, ist ein Montieren und Einstellen des Geräts zeitaufwendig;2) die schwierige Handhabung des jetzigen Geräts führt dazu, dass der kopfmontierte Eye Tracker öfters verstellt wird. Dieses Verrutschen verwirft jede Kalibrierung und somit die gesamte Datenqualität.

Mit dem neuen Gerät sind diese Nachteile eliminiert worden. Das neue Gerät wurde bei allen folgenden Inkrementen verwendet.

Kontrollmessungen im Labor

Im eigenen Labor wurden Messungen durchgeführt, zum einen, um das Experimentprotokoll und die Prozedur zu verifizieren und zum anderen, Normdaten für die zwei Hauptaspekte der Studie – die Koordinaten der Listing’schen Ebene und des 3-dimensionalen Vestibulo-okulären Reflexes - zu bestimmen. Dafür wurde das Experimentprotokoll mit einer Gruppe von gesunden Probanden durchgeführt.

Kontrollmessungen im Parabelflugzeug

Wie vorgesehen, wurden auch Kontrollmessungen im Rahmen des Parabelflugprogramms vom DLR durchgeführt. Die Experimente wurden ausschliesslich in dem Parabelflugzeug von Novespace, Frankreich durchgeführt.

In erster Linie dienten diese Messungen der technischen Kontrolle der Anlage und des ISS-Meßprotokolls unter schwerelosen Bedingungen. Aus wissenschaftlicher Sicht kann aber auch die unmittelbare Wirkung von kurzfristigen Veränderungen der Schwerkraft auf das vestibuläre System – speziell auf die Stabilität des internen Koordinatensystems – effektiv während der Parabelflugmanöver untersucht werden. Ähnlich wie bei den ISS Experimenten wird diese Stabilität durch Bestimmung der Listing’schen Ebene und die Orientierung des 3D VOR gemessen. Insofern komplementieren die Parabelflugmessungen diejenigen, die unter langandauernder Schwerelosigkeit auf der ISS gemacht werden.

Die Experimente wurden während der von der DLR organisierten Parabelflugkampagne im September 2005 bzw. im April 2005 durchgeführt. Dabei konnten insgesamt an 10

Testpersonen die Messung des 3D vestibulo-okulären Reflexes sowie die der Orientierung der Listing'schen Ebene durchgeführt werden.

Erweiterung des ETDs mit dem Healthlab System

Um die vestibulo-autonomische Regulation beim Menschen zu untersuchen, wurde ein HealthLab System der Fa. Spacebit beschafft und mit der ETD Anlage kombiniert. So wurde das bestehende Vorhaben zur Untersuchung des vestibulären Systems mit Hilfe des 3D Eye Trackers durch die zusätzliche Registrierung von objektiv erfaßbaren vegetativen Parameter erweitert.

In der nächsten Phase wird die HealthlabAnlage an das ETD System technisch angepasst und die ersten Machbarkeitsstudien durchgeführt. Vor allem wird die Herz-Kreilauffunktion anhand der Parameter - Herzrate, Herzratenvariabilität, Atemrate, Blutdruck, Pulswellenlaufzeit, Hautleitwert, periphere Hauttemperatur - gemessen.

Die Handhabung der kombinierten Anlage wurde unter schwerelosen Bedingungen Bei der Parabeflugkampagne im April 2006 untersucht. Dabei wurde die erste vestibulo-autonome Untersuchung mit der Anlage erprobt. Die Daten von 8 Probanden konnten aufgezeichnet werden.
Bei dieser Kampagne wurde das ETD System zusammen mit dem neu entwickelten Healthlab-System (Fa. Spacebit) getestet.

Weitere klinische Studien mit dem ETD

Im Labor für Gleichgewichtsforschung liefen neben dem DLR Vorhaben eine Reihe von klinischen Forschungsstudien. Sie wurden in Zusammenarbeit mit den Abteilungen für Neurologie und Neurochirurgie der Charité bzw. mit der HNO Abteilung des Unfallkrankenhauses Berlin durchgeführt. Dabei wurde das ETD System für sämtliche Messungen eingesetzt.

Berichterstattung

Vorläufige Ergebnisse aus den Parabelflugexperimente sowie aus den ISS Experimente konnten bei dem DLR Parabelflug Workshop (Mai 2004) und dem DLR Humanphysiologie Symposium (Mai 2004) sowie bei dem Delta-Mission Symposium bei der ESTEC (Juni 2004) vorgetragen.

Desweiteren wurden diese Ergebnisse bei der internationalen Tagung der Bárány Society in 2004, bei dem „International Astronautics Federation“ Meeting in 2005 sowie das „European Conference on Eye Movements in 2005 sowie bei der Tagung der Arbeitsgemeinschaft der deutschsprachigen Audiologen und Neurootologen (ADANO) in Berlinvorgestellt.

Auf Einladung wurde im „Space Symposium“ bei der Bárány-Tagung auch ein Überblick über die neurovestibulären Experimente, die zur Zeit bei den europäischen Weltraumbehörden unterstutzt werden, vorgetragen.

Weitere Ergebnisse aus den Parabelflugexperimenten sowie aus den ISS Experimenten konnten bei dem Deutsch-chinesischen Symposium in Xian (April 2006), beim Bárány Society Space Satellite Meeting at ESTEC (Juni 2006), beim ESA ISS Symposium in Toledo (Juni 2006), bei dem European Conference on Visual Perception in St. Petersburg (Juli 2006) sowie bei dem Hennig Vertigo Symposium in Berlin (November 2006) vorgestellt werden.

Veröffentlichungen in Review Journals

2004

von Brevern M, Radtke A, Clarke AH, Lempert T 2004 Migrainous vertigo presenting as episodic positional vertigo. Neurology 62:469–472.

Ernst A, Basta D, Seidl RO, Rodt I, Scherer H, Clarke AH (2004) Management of posttraumatic vertigo. Otolaryngology, Head & Neck Surgery (in print).

Von Brevern M, Zeise D, Neuhauser H, Clarke AH, Lempert T (in print) Acute migrainous vertigo: Clinical and oculographic findings. Neurology.

Schlosser G, Brock M, Clarke AH (in print) Galvanic evoked vestibule-ocular monitoring in comatose patients. J Neurosci Methods.

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Von Brevern M, Zeise D, Neuhauser H, Clarke AH, Lempert T 2005 Acute migrainous vertigo: Clinical and oculographic findings. Brain 128-2, 365-74.

Schlosser H-G, Unterberg A, Clarke AH 2005 Galvanic evoked vestibule-ocular monitoring in comatose patients. J Neurosci Methods 145, 127-131.

Basta D, Todt I, Scherer H, Clarke A, Ernst A. Postural control in otolith disorders. Hum Mov Sci. 2005 Apr;24(2):268-79

Ernst A, Basta D, Seidl RO, Todt I, Scherer H, Clarke A. Management of posttraumatic vertigo. Otolaryngol Head Neck Surg. 2005 Apr; 132(4):554-8.

Helling K, Scherer H, Hausmann S, Clarke AH 2005 Otolith mass asymmetries in the utricle and saccule of flatfish. J Vestib Res 15, 59-64.

Clarke AH 2005 On the vestibular labyrinth of Brachiosaurus brancai. J Vestib Res. 15(2):65-71.

2006

Helling K, Schönfeld U, Scherer H, Clarke AH Testing utricular function by means of on-axis rotation. Acta Otolaryngolica 2006, 1-8.

Diamond SG, Markham CH, Clarke AH Dynamic pitch rotation affects eye torsion. Acta Otolaryngolica 2006 126:248-253.

2007

Clarke AH, Haslwanter T The Orientation of Listing's Plane in Microgravity. Vision Res 47 (2007) 3132–3140.

Clarke AH Listing's Plane and the otolith-mediated gravity vector. Prog Brain Res 2008 (in press).

Clarke AH Ocular torsion response to active head-roll movement under one-g and zero-g conditions. J Vestib Research 2008 (in press).

Buchbeiträge

2007

Groen E, Clarke A, Bles, W, Wuyts F, Paloski W, Clément G. Ch.4 Physiological Targets of Artificial Gravity: The Sensory-Motor System 2007 In: Clement G, Bukley A (Eds) Artificial Gravity. Space Technology Library, NY.

Clarke AH 2007 Das vestibuläre System – eine kurze Beschreibung. In: Biesinger I (Ed) HNO Heute Band 27m Springer, Berlin, NY.

Clarke AH 2007 Zur Funktionsprüfung der Otolithenorgane. In: Scherer H (Ed) Das Gleichgewichtssinn – Neues aus Forschung und Klinik. Springer, Wien, NY.

Vorträge bei Fachtagungen

2004

Helling, U. Schönfeld, H. Scherer, A.H. Clarke 2004 Der isolierte einseitige Schaden der Macula utriculi- Diagnostik und Charakterisierung. German ENT Congress.

U Schönfeld, C Hamann, H Scherer, AH Clarke 2004 Einseitige Otolithendiagnostik mit der subjektiven visuellen vertikalen während minimal exzentrischer Rotation. German ENT Congress.

K Helling, A Halbach, U Schönfeld, H Scherer, AH Clarke 2004 Saccular and utricular dysfunction in Menière's disease - a longitudinal study with low-dosage gentamicin treatment XXIII Congress of the Bárány Society, Paris 2004

Differential Diagnosis of Unilateral Otolith (and SCC) Function. Clarke, K Lewandowitz, U Schönfeld XXIII Congress of the Bárány Society, Paris 2004

AH Clarke Microgravity-related neurovestibular research - an overview of European activities XXIII Congress of the Bárány Society, Paris 2004

2005

A.H. Clarke The influence of prolonged microgravity on the orientation of Listing's Plane. IAF Tagung, Graz, Mai 2005.

A.H. Clarke & T. Haslwanter The collinearity of Listing's plane and the vestibulo-oculomotor response in microgravity. ESA Life Sciences Symposium, Köln. Juni 2005.

K. Helling, U. Schönfeld, H. Scherer, A.H. Clarke Funktionsprüfung der Macula utriculi durch zentrische Rotation. Jahrestagung der deutschen HNO Gesellschaft, Aachen, Mai 2005.

A.H. Clarke, T. Haslwanter. The influence of prolonged microgravity on the orientation of Listing's Plane. European Conference on Eye Movements (ECEM), Bern. August 2005.

Clarke AH Die Otolithenfunktion in der Schwerelosigkeit. Tagung der Arbeitsgemeischaft der deutschsprachigen Audiologen und Neurootologen (ADANO), Berlin. Sept 2005.

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Clarke AH The otolith-mediated gravity vector and its role as a common reference in the central nervous system. Chinesisch-Deutsches Symposium, Xian, April 2006.

Schönfeld U, Waltmann K, Clarke AH Unilaterale Otolithenfunktionsdiagnostik. Deutsche Gersellschaft für Audiologie, München, Mai 2006.

Clarke A.H., Haslwanter T. The collinearity of Listing's plane and the vestibulo-oculomotor response in microgravity. Bárány Symposium, ESTEC, NL, Juni 2006

Clarke A. H. Recent aspects of neurovestibular research in the ESA microgravity program. Sino-German Workshop, Berlin, Oktober 2006.

Clarke, AH; Haslwanter, T; Krzok, W; Druen, K The influence of prolonged microgravity on the vestibular and oculomotor frames of reference. ESA Symposium, Toledo, July 2006.

Clarke A.H. Zur Funktionsprüfung der Otolithenorgane. Hennig Vertigo Symposium, Berlin,

EREIGNISSE IM BERICHTSZEITRAUM

2004

April 29 – Mai 13 2004	Postflight-Messungen während der ersten 14 Tagen nach Landung des Astronauten der Delta Mission, Star City, bei Moskau.
Juni 10-11 2004:	Debriefing Symposium für die Delta Mission, ESTEC, Noordwijk.
Juni 18 2004:	Follow-up BDC Messung mit Delta-Astronauten. Berlin
Juli 6-10 2004	Berichterstattung (2 Vorträge, 1 Poster) bei der internationalen Bárány-Society Tagung für Vestibularisforschung. (Es wurde auch das Eye Tracking Device durch die Fa. Chronos Vision ausgestellt).
September 13-19, 2004	Teilnahme an der DLR Parabelflugkampagne (Novespace Airbus) in Köln.
Mai – Oktober 2004	In 3-wöchigen Intervallen - ETD Messungen an Bord der ISS mit der russichen Crew.
Oktober 21 – 30, 2004	Postflight BDC Messungen mit russischem Kosmonauten in Star City bei Moskau.

2005

2. Mai 2005:	Crew Familiarisation für die Long Duration Mission mit den Kandidaten Reiter und Eyhart.
23 - 25 Mai 2005:	IAF Tagung in Graz. Präsentation der ersten Ergebnisse aus den laufenden Untersuchungen.
13. Juni 2005:	ESRIN, Rom, I. Debriefing für die ENEIDE Mission.
27 – 29 Juni 2005:	ESA Life Sciences Symposium, Köln, D, Präsentation der ersten Ergebnisse aus den laufenden Untersuchungen.
10. August 2005:	Crew Training mit den Astronauten Reiter und Eyhart.
16 – 19 August 2005:	European Conference on Eye Movements (ECEM) in Bern, CH Präsentation der ersten Ergebnisse aus den laufenden Untersuchungen.

12.-16. September 2005:	DLR Parabelflugkampagne, Toulouse, F. Technische Erprobung der ETD – Healthlab- Anlage.
29 / 30 September 2005:	Tagung der Arbeitsgemeinschaft der deutschsprachigen Audiologen und Neurootologen (ADANO) in Berlin, D. Übersichtsvortrag zur Gleichgewichtsfunktion in der Schwerelosigkeit.
11 -25 Oktober 2005:	Postflight BDC Messungen in GCTC, Sternstädtchen, Moskau mit Kosmonaut Krikaliev.
11 -16 November 2005:	Society for Neurosciences, Washington DC, USA. Ausstellung der kommerziellen Version des ETD Systems zusammen mit der Fa. Chronos Vision.
22 -23 November 2005:	Investigator Working Group (IWG) Sitzung bei ESA/ESTEC für future neuroscience experimentation on ISS
30 November 2005:	DLR Debriefing /PR Veranstaltung für die Parabelflugergebnisse.
31 November 2005:	Investigator Working Group (IWG) bei ESA/ESTEC Definitionsphase der ausgewählten ILSRA 2004 Experimente.

2006

13 - 18 Februar 2006:	Kosmonautentraining in GCTC mit Kosmonaut Vinogradov.
2 März	Astrolab Pressekonferenz EAC Köln-Porz.
8 -10 März	Crew training für Astrolab Mission (Reiter / Eyhard)
13 – 14 März	Kosmonauten-Training & Preflight BDC in GCTC mit Kosmonaut Vinogradov
	Launch der Sojuz - Increment 13 Mission
10 -11 April	Astronauten-Training in JSC, Houston für Astrolab Mission.
15 - 21 April	Delegation zum Deutsch-Chinesisches Symposium in Xian, China
7 - 9 Juni	Vortrag: Bárány Symposium in ESTEC, NL.
20 - 23 Juni	BDC /Training für Astrolab Mission im JSC, Houston.
27 - 30 Juni	Vortrag: ESA Sympsoium , Toledo, S.

24 – 26 August	Vortrag: European Conf on Visual Perception, & IMBP Treffen, St. Petersburg
20 – 21 September	ESA Program Board, ESTEC, NL.
29 September	Landung Increment 13
– 11. Oktober	Postflight BDC mit Kosmonaut Vinogradov
8 – 11 Oktober	German- Chinese Workshop, Berlin
13-18 Oktoner:	Society for Neurosciences, Atlanta, USA. Ausstellung der kommerziellen Version des ETD Systems zusammen mit der Fa. Chronos Vision.
17 – 18 November	Vortrag: Hennig Vertigo Symposium, Berlin.
19 Dezember	Kennedy Space Center / Vorbereitung für Astrolab Postflight BDC
21 Dezember	Landung Astrolab / Postflight BDCs bis 5. Januar 2007

2007

4 – 6 Februar 2007	Debriefing /Iterim Report Session beim ESTEC.

November 2006

ANHANG 1: ESA LIFE SCIENCE RESEARCH PROTOCOL

The influence of prolonged microgravity
on the orientation of Listing's Plane

1. Cover Page

1.1 **Dutch Soyuz Mission**

1.2 **DSM-OLP**

1.3 N/A

1.4 Title: **The influence of prolonged microgravity on the orientation of Listing's Plane**

1.5 Organization: **Freie Universit Berlin, Berlin, FRG**

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Signature of Principal Investigator:____________________________ Date:_____________

2. Table of Contents

3. ABSTRACT

The purpose of the experiment is to evaluate the ***orientation of Listing's plane*** *(OLP)* under different gravity conditions , and in particular under prolonged microgravity conditions.
Examination of the orientation of Listing's plane during the course of a prolonged microgravity mission is of particular interest, given the evidence that under one-g, Earthbound conditions it appears to be dependent on head position to gravity, i.e. dependent on otolithic input (Haslwanter et al, 1992; Hess & Angelaki, 1996).
A second question is to what extent the orientation of Listing's plane is altered by the vestibular adaptation to microgravity.
A corollary aspect is to what extent Listing's Plane is dissociated form the internal co-ordinate frame of reference of the vestibulo-oculomotor response (VOR) during prolonged. Under one-g condition the two have been shown to be collinear (Crawford et al, 1991), but preliminary findings in microgravity indicate that the VOR frame of reference is modified by the absence of otolithic loading, whereas Listing's Plane remains stable (Clarke et al, 1996).
A further question is whether compensatory mechanisms substitute for the missing sensory input from the otolith organs during long-term spaceflight. Possible sensory information which could serve as compensatory input are neck afferents and vision. Accordingly, it is proposed to record Listing's plane with different static head postures without visual input and with different static whole body orientations within the spacecraft with visual input.
Supporting experiments are being carried out during parabolic flight, where the influence of short-term hypergravic and hypogravic conditions can be examined.

The proposed experiment is complementary to the experiment by Dr. Bos and co-workers, involving vestibular adaptation to hypergravic conditions in the human centrifuge.

Objectives 1) To determine the influence of prolonged microgravity and the accompanying vestibular adaptation on the orientation of Listing's Plan
2) To determine whether Listing's Plane as a measure of the coordinate frame of the visual system dissociates with that of the vestibular system.
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Measurements. Listing's Plane can be examined fairly simply, provided accurate three-dimensional eye-in-head measurements can be made. Identical experimental protocols will be performed during the pre-flight, inflight and postflight periods of the mission. Accurate three-dimensional eye-in-head measurements are essential to the success of this experiment. The required measurement specifications (< 0.1° spatial resolution, 200 Hz sampling frequency) are fulfilled by the Eye Tracking Device (ETD).

4. HYPOTHESIS

The working hypothesis is that in microgravity the orientation of Listing's Plane is altered, probably to a small and individually variable degree. Further, with the loss of the otolith-mediated gravitational reference, it is expected that changes in the orientation of the coordinate framework of the vestibular system occur, and thus a divergence between Listing's plane and the vestibular coordinate frame should be observed.
While earlier ground-based experiments (Haslwanter et al,1992, Böckisch & Haslwanter, 2001) indicate that Listing's Plane itself is to a small degree dependent on the pitch orientation to gravity, there is more compelling evidence of an alteration of the orientation of the VOR in microgravity. The proposed experiment is intended to resolve these questions.

5. Purpose of Research

Background and Significance

Why study eye movements in microgravity?

Orientation and the perception of movement in three-dimensional space involves transduction of three degrees of freedom for angular rotation and three degrees of freedom for linear translation. In the vestibular system, this is provided for by the semicircular canals and the otolith organs, respectively. Via the vestibulo-ocular pathways in the brainstem, the afferents from the vestibular end organs are utilized synergistically for the purpose of gaze stabilization and are reflected by compensatory eye movements in the three orthogonal planes governed by the extraocular muscle pairs. Thus, any physiological stimulation to the vestibular receptors, either by rotatory, gravitational or translatory acceleration, or a combination thereof, will potentially elicit a systematic, compensatory eye movement consisting of horizontal, vertical and/or torsional components, i.e. the three-dimensional vestibulo-ocular reflex.

For a full understanding of the vestibulo-oculomotor system, it is necessary to examine the three-dimensional processing of the afferent information from the semicircular canals and otolith organs and to determine their respective contributions to the elicitation of the compensatory reflex eye movements. Adequate measurement of the vestibulo-oculomotor response is arguable the most important inroad in the case of human experimentation. Inflight measurement of the binocular 3D-VOR was performed for the first time during the Euromir 95 mission. The results from one subject are summarised in Fig. 1.

Preflight (one-g)

		H_x	H_y	H_z
E_x	r	-0.43	-0.16	0.09
	l	-0.46	-0.08	0.03
E_y	r	-0.21	-0.76	0.08
	l	-0.06	-0.69	0.11
E_z	r	0.36	0.03	-0.81
	l	0.33	0.04	-0.79

Late Inflight (zero-g)

		H_x	H_y	H_z
E_x	r	-0.26	-0.07	0.08
	l	-0.20	-0.01	0.01
E_y	r	-0.08	-0.82	-0.01
	l	0.05	-0.93	0.07
E_z	r	0.18	0.06	-0.86
	l	0.18	0.06	-0.95

Postflight (one-g)

		H_x	H_y	H_z
E_x	r	-0.29	0.05	0.05
	l	-0.28	-0.11	0.05
E_y	r	-0.10	-0.94	0.07
	l	0.09	-0.94	0.08
E_z	r	0.29	-0.01	-0.71
	l	0.26	0.03	-0.70

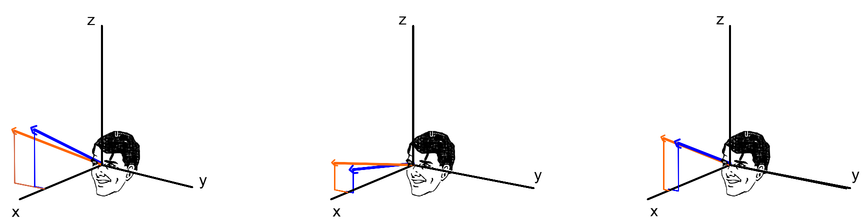


Fig 1. 3D velocity gain matrices and the corresponding minimal gain vectors for one subject tested during the preflight inflight and postflight periods. Data from three test sessions are averaged in each case. The modification of the VOR c-ordinate frame is reflected in the altered orientation of the minimal gain vectors.

Listing's Plane and the 3D-VOR co-ordinate frame.

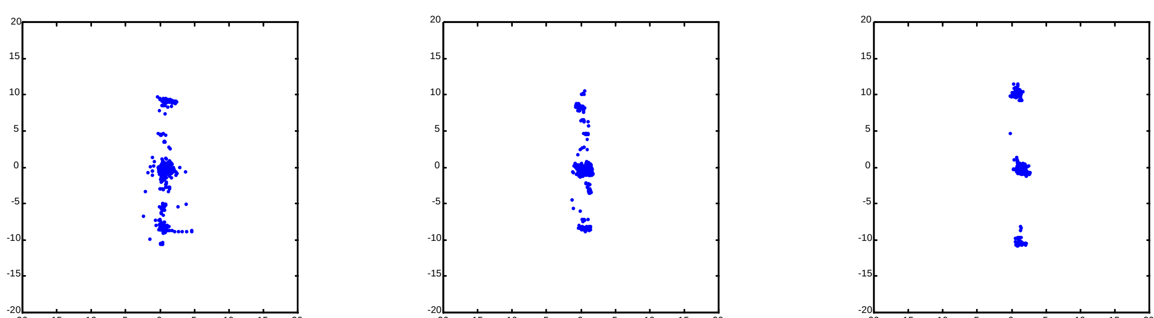
Since the late 19th century (e.g Helmholtz, 1867), it has been known that under normal visual conditions the torsional orientation of the eye is independent of the path that the eye takes to reach any secondary or tertiary eye position. This restriction implies a reduction from three to two degrees of freedom for the eyeball, and is known as Listing's law; thus, all axes about which the eye rotates from the so-called primary position lie in one plane, called Listing's plane. Listing's plane can be visualised by plotting 3D eye positions as quaternions (Tweed & Vilis, 1987) or rotation vectors (Haustein, 1989). Recent investigations have verified the validity of Listing's law during fixations, saccades and smooth pursuit (Straumann et al, 1996), and it has been argued recently that Listing's plane is primarily under visuomotor control (Hepp et al, 1997).

In order to monitor any influence of microgravity on the stability of Listing's plane, it is instructive to compare the Listing's co-ordinate frame with that of the 3D-VOR. The collinearity between these two systems has been examined by Crawford et al (1991) under one-g conditions.

Spatial aspects of the vestibulo-oculomotor system can be evaluated by measuring the orientation vectors associated with slow phase eye velocity generated by the VOR. In the present study, attention will be directed towards the three-dimensional gain matrix and vector representations of head and eye movement. The requirements for the formal representation of the 3-D aspects of this response were first addressed by Robinson (1982) who discussed the idea of 3-D gain matrices for the angular VOR. This approach has been extended by rotation vector and quaternion representations of eye position and velocity (Tweed and Vilis 1987; Hess and Angelaki 1996) and has recently been examined experimentally for passive rotation of humans around the three orthogonal axes (Tweed et al. 1994) and in spaceflight during active movement by Clarke et al (1996, 1997). The results of the spaceflight experiment are illustrated in Fig. 1A.
Examination of the collinearity between the Listing and VOR co-ordinate systems is of key importance for the hypothesised existence of a uniform representation of three-dimensional space across of those CNS areas related to spatial orientation (Cohen, 1988).

Is the orientation of Listingís Plane and the 3D-VOR altered during and after exposure to prolonged microgravity ?

The well-documented occurrence of OCR when the head is tilted in one-g conditions is reflected in the translation of Listing's plane along the x-axis of the head. In addition, the position of Listing's plane has been observed to change during head pitch, causing a tilt of Listing's plane opposite to the head pitch (Haslwanter 1992). In a detailed analysis of vestibular fast phases, Hess and Angelaki (1997) demonstrated that the resulting displacement plane is dependent on head orientation to gravity. Corresponding to these changes in the orientation of Listing's plane, the subjective straight ahead direction of gaze (Citek & Ebenholtz, 1996) has been observed to change with static pitch and roll. On the other hand, Crawford et al (1991) were able to demonstrate Listing's Plane remains collinear with the co-ordinate frame of the 3D-VOR. Here the VOR frame of reference is characterised by the minimal gain vector - defined as that vector parallel to the head axis around which the VOR has minimal gain. Furthermore, they also demonstrated that Listing's plane was only slightly deformed by static changes of head pitch position relative to gravity.



*Fi*g 1B. First measurement of Listing’s Plane during the course of a spaceflight mission. The data were obtained from the same subject as in Fig. 1 during the preflight, inflight and postflight periods. The quaternion data from the calibration fixation sequences were employed for this purpose. The average tilt (X-Z plane) was -1.8°, -2.1° and -2.3° respectively. These preliminary results indicate that Listingís plane remains constant during microgravity. (From Clarke et al, 1997).

In microgravity, recording of the orientation of Listing’s plane relative to the head should provide more information on its dependence on the gravito-inertial vector, respectively the otolith-mediated vertical. Preliminary results from one subject tested during the Euromir 95 mission are shown in Fig. 1B. Binocular recordings will be made in order to explore further the indication that Listing’s plane is both vergence dependent, and differs between dominant and non-dominant eye.
The question as to whether the co-ordinate system of the VOR is collinear to the Listing's plane has been examined in monkeys (Crawford and Vilis 1991) using the search-coil technique. They reported that listing’s plane remained collinear with the VOR co-ordinate system, as described by the minimal gain vector. Similar investigation of the orientation of the VOR coordinate system in humans during a longterm spaceflight mission (180 days) has indicated modification of the 3-D gain matrix during such prolonged microgravity (Clarke et al. 1996, 1997). The experiment is therefore directed at the question of the collinearity between the VOR and Listing coordinates. Finally, it should be determined to what extent cervical afferences or visual input substitute for the lack of a gravitational reference during adaptation to microgravity.

6. Data Analysis and Statistics

The ETD hardware permits acquisition of each eye image with a spatial resolution of 512 x 512 square pixels of 8-bit depth (256 discrete grey levels). The ETD also provides online data and digital storage of relevant image data for comprehensive offline evaluation. The digitally-stored image data will be processed in the PI’s laboratory using custom-designed software for a Windows NT workstation. The current software operates with selectable image sampling rates of between 100 and 200 Hz for three-dimensional measurement. On a frame-by-frame basis, the centre of pupil is determined by geometric analysis of the binarised image. This provides the horizontal and vertical co-ordinates of eye position. This approach employs the generalised Hough transform and is insensitive to artefacts such as partial lid closure and shadowing effects. Based on the current center of pupil, the co-ordinates of a circular sample (typically 40 deg arc) around the iris are calculated and the corresponding luminance profile extracted. This polar sample permits calculation of the torsional position of the eye by calculating the cross correlation function between the current sample and a zero reference (first described by Hatamian & Anderson, 1983). Furthermore, the necessary numerical routines for the conversion image coordinates to Euler angles (respectively Fick coordinates) and the subsequent transformation into quaternions have been implemented in the acquisition software. The ETD equipment thus yields three-dimensional eye position data in Fick coordinates sampled at a rate of typically 200 samples per second.

In order to ensure correct description of the 3D-rotational kinematics, quaternion calculus was employed throughout.
For the **determination of Listing’s Plane**, the eye position data will be transformed from Fick coordinates to rotation vectors respectively quaternions. For the evaluation of the 3D-VOR components, slow phase eye velocity will be obtained by differentiating the eye position components or alternatively, in order to take into consideration the instantaneous eye position via transformation into quaternions.

For the data from the **head oscillation (3D-VOR**) trials, 10 cycles of slow-phase eye velocity, for each condition and test frequency, will be processed. Each of the three components of the eye position records will be desaccaded using order statistic filtering techniques. The eye-in-head position data will be transformed into quaternions and the velocity components obtained. The orthogonal components of head velocity will be obtained from the head tracking devices. The 3 x 3 gain matrices relating head velocity and eye velocity will be computed by stepwise least square regression, starting from the main diagonal components.

$$\omega^{e} = G\,\omega^{h},$$

where $\omega^e = (\omega^e_x, \omega^e_y, \omega^e_z)$ and $\omega^h = (\omega^h_x, \omega^h_y, \omega^h_z)$ are the angular velocity of eye and head respectively.

The minimal gain vector is defined as the head angular velocity unity vector ω^h such that $G\omega^h$ is minimal in Euclidean norm.

For the unilateral OOR data, the three components (H,V,T) of the eye movement responses will be processed individually. Each component will be averaged over the ten cycles of eccentric displacement for each frequency.
GIA tilt is calculated as the angle between the vector sum of the radial and gravitational acceleration, and the earth-vertical. OOR gain is expressed as the ratio of ocular torsion in degrees to effective GIA tilt in degrees.
For each subject, the ocular torsional position and the y-axis linear acceleration will be averaged over the ten cycles of lateral translation stimulus. Each individual response will be normalised by dividing by the rms amplitude. In this manner, the absolute amplitude and the response form are separated for each individual. The distribution of the rms amplitudes yields information on the response gain, while the normalised waveforms yields a measure of the inter-individual variability in symmetry.
The results will yield the frequency response for gain and phase, which can then be compared to the results of the control group, and intraindividually over the time course of the mission.

Custom-designed programs in C, Matlab and Asyst are available in the PI's laboratory for this analysis. Statistical testing is based on the Student’s t-test (two-tailed, matched pairs).

7. RATIONALE FOR USE OF HUMAN SUBJECTS

This research is solely concerned about the study of the behaviour of the human body in space. Research subjects will be selected upon availability during the proposed and eventually other space missions. Ideally whole the crew should participate.

8. RESEARCH PLAN AND SCHEDULE

Training and Familiarisation.

In total four training sessions are proposed.
The first session will be used for familiarisation of the crew and the ESA personnel.
The 2nd and 3rd sessions will be hands-on sessions with the flight candidates,
The 4th session will deal with off-nominal procedures**.**
Familiarisation with the concepts of the experiments, procedures to be learned, equipment and data collection will be arranged in collaboration with ESA-ESTEC and will start as soon as possible.

Preflight and Post-flight measurements

are essential to establish stable baseline performance values and to evaluate the re-adaptation to one-g conditions after return to Earth.
Familiarisation with the concepts of the experiments, procedures to be learned, equipment and data collection can be arranged in collaboration with ESA-ESTEC and will start as soon as possible. It is foressen that the ESA astronaut shall perform the inflight measurements autonomously.
The Eye Tracker Device (ETD), developed by DLR and designated as a standard facility for the HRF on the ISS will be used throughout, for all measurements. An identical model will be used for the ground-based training and BDC measurements.
Pre- and post-flight data collection will be performed with the assistance of the investigators, so that minimal training for these measurements is needed.

The preflight and BDCs will be performed by the ESA astronaut candidates and if feasible, by their Russian counterparts. The same experiment protocol will be used during inflight and BDC sessions. This is described in detail in Section 9 (Experimental protocols and equipment) of this document.
The training model and qualification model of the ETD equipment will be available for training and BDC sessions If any vestibular (deconditioning) training is performed, it is important tha the PI is informed on this and that preflight BDC's be performed before and after the training period. Otherwise, the precise timing of preflight BDCs is not critical.
Postflight measurements should be obtained as soon after landing as possible and at specified intervals thereafter.
BDC Schedule for Preflight and Postflight Periods (subject to modification w.r.t. vestibular deconditioning program).

It is imperative that during the BDC sessions and the inflight measurements, the test candidates be free of the influence of any medication, or any other substance, known to effect the peripheral or central vestibular system. This includes indulgence in alcoholic beverages.
It is mandatory that the PI be fully informed by the responsible crew surgeon on this matter, particularly if any constraints become necessary.

		Point in Time	***Duration***
Preflight			
	Session 1	L-6 months	30 minutes

(preferably before beginning vestibular conditioning / training)

Session 2	L-3 months	30 minutes
Session 3	L-21 days	30 minutes
Session 4	L-14 days	30 minutes
Session 5	L-07 days	30 minutes

Postflight

Session 6	R+0	30 minutes
Session 7	R+2	30 minutes
Session 8	R+4	30 minutes
Session 9	R+6	30 minutes
Session 10	R+8	30 minutes
Session 11	R+10	30 minutes
Session 12	R+12	30 minutes
Session 13	R+60 (+/-10)	30 minutes

(! These data are tentative, and will be negotiated according to the constraints of the mission schedule).

Despite the necessary restriction during early postflight, it is emphasised that an additional shortform measurement on R+0 (maximum duration 10 minutes) would provide extremely useful data. This request is based on the observatioms made on the Euromir missions, where testing could be performed at R+11 and 12 hours.

Location for training and BDC sessions: Star City, Russia or TNO Soesterberg (in parallel with the Bos experiment) or FU Berlin.

Subjects: Designated ESA astronaut, and if possible his Russian counterparts.
Duration: Pre-flight and postflight measurements and will require *in toto* 30 minutes per session.

Flight tests

will be performed by the ESA astronaut. The same experiment protocol will be used during inflight and BDC sessions. This is described in detail in Section 9 (Experimental protocols and equipment) of this document.
It is planned to perform the inflight session on days 2, 4, 6, 8 of the mission.
The experiment should be performed at the same time on each test day.

Associated ground based studies:

Control experiments with a group of normal volunteer subjects will be performed at the PI's lab, using a comparable experiment protocol. In addition, the first of a series of parabolic flight experiments has been conducted. The results of these studies will be used to support the scientific validity of the mission findings.

Study Schedule The laboratory experiments should be completed by March 2004. The first parabolic flight experiments were performed during the DLR campaign in October 2002. A further study is planned for September 2003.

Facilities and Performance Site All measurements will be performed using the DLR Eye tracker device (ETD). No further equipment or facilities are necessary. It is planned to complement the study by Dr. Bos of the TNO in Soesterberg with parallel measurements, again using the ETD.

Management Plan

Prof. Clarke will serve as the Principal Investigator for this project, and will have overall scientific and operational management of the project. Prof. Clarke is a Senior Research Scientist and the Head of the Vestibular

Research Laboratory at the ENT Clinic of the Benjamin Franklin Medical Center of the Free University of Berlin (Germany). Prof. Clarke has been studying eye movements induced by caloric and vestibular stimulation for over 12 years, and has accumulated a large database of responses measured in healthy subjects and in patients. Prof. Clarke was the Principal Investigator of neurovestibular studies during the German MIR'92 and MIR'92 extension space missions and during the ESA EUROMIR'94 and EUROMIR'95 space missions. He has been actively involved in space-related neurophysiological studies for more than 10 years, having performed definitive studies of the vestibulo-ocular response in microgravity and has been instrumental in the development of three-dimensional videooculography techniques. As Principal Investigator on this project, he will be actively involved in the definition of the experiment requirements, processing of the 3-D eye movement data derived by the ETD, and interpretation of results.

Dr. Haslwanter will serve as Co-Investigator for this project. Dr. Haslwanter is a senior research scientist at the Dept. of Neurology and the Dept. of Theoretical Physics at the University of Zurich. He is a recognised authority on the mathematics of three-dimensional eye movements and has contributed several seminal papers in this area. He will contribute to the analysis and interpretation of the results of the study.
Dr. Bos is also a senior researcher at the TNO in Soesterberg and has substantial experience in both vestibular and oculomotor research. He will serve as a Co-Investigator for the project. He is also PI of a second vestibular experiment on the DSM, and the results of both experiments will be evaluated and interpreted together.

Data privacy: Data will be stored in a protected database. Only the investigator team of this project will have access to the data. Data will be used for scientific purposes only.
All data will be anonymised to protect the identity of the test subjects. If data from more than one subject has been evaluated, appropriate statistics will be published.
All data will be stored on removable discs, which will be ket in a secure location in the PI’s lab..

Data sharing: Data will be shared with DR. Bos of TNO, Soesterberg, who is conducting a complementary experiment on vestibular adaptation during the DSM.

Anomalous data reporting: in case of specific anomalous data, the ESA physician in charge of EAC will be informed.

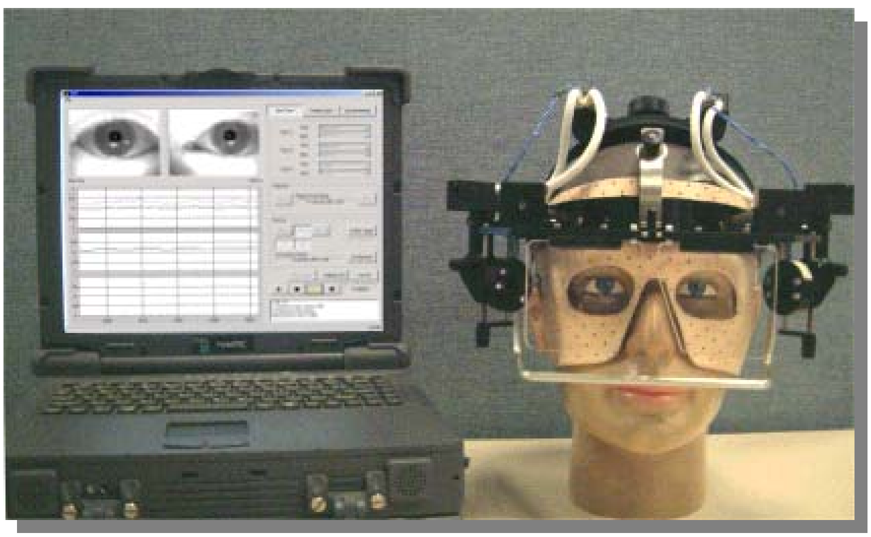
Injury/illness reporting: the subject will be requested to keep a log of any abnormal events or sensations that may be related to the experiment

9. EXPERIMENTAL PROTOCOLS AND EQUIPMENT

Equipment:

All measurement and evaluation of eye and head movements will be performed with the binocular, three-dimensional eye tracking device (ETD) scheduled for integration on the ISS (Clarke et al, 1999, 2000). The present science model is illustrated in Fig. 3. The performance of the ETD shall provide high resolution (<0.1°) and high sampling rate (200 Hz) measurement of 3D eye movement. The excerpt in Fig.4 demonstrates the performance of the present prototype, which delivers horizontal and vertical co-ordinates at up to 400 samples / second.

Head rotation and translation will be recorded synchronously by means of the triaxial angular rate sensors and linear accelerometers integrated in the ETD Head Unit and included as part of the ETD data stream. All sensors are sampled at the selected ETD image rate.



The designated ETD equipment consists of a ruggedised laptop (Dolch Notepac) and a head unit, which shall be mounted on the head of the test subject.

Experiment protocols:

Preflight and Postflight testing

will be performed under the supervision of the investigators. The step procedure is as follows**:**

a) Preparation

1. Prepare subject, don ETD Head Unit and adjust;
2. check and adjust video images of each eye;

Time Estimated for performance: ***approx. 5 min.***

b) Start recording equipment, announce experiment and record experiment

		Actual RecordingTime in Seconds
1.	Initiate recording unit & announce experiment, date & time	*30s.*
2.	Fit calibration unit for right eye& perform calibration	*30s.*
3.	Repeat for left eye (& remove cal unit)	*30s.*
4.	Switch metronome on, fixate target on cabin wall &	
5.	Perform five head oscillations in 1) roll, 2) pitch and 3) yaw	
	(5 cycles at 0.8 Hz => 4 sec. + 4 sec. pause => 8 secs)	*24s.*
6.	Repeat step 5 - with mask closed and imaginary target	*24s.*
7.1	Perform eye saccades for 20 secs with head upright	*20s.*
7.2	Perform eye saccades for 20 secs with head tilted to left	*20s.*
7.3	Perform eye saccades for 20 secs with head tilted to right	*20s.*
7.4	Perform eye saccades for 20 secs with head tilted forward	*20s.*
7.5	Perform eye saccades for 20 secs with head tilted backward	*20s.*
8.	Announce end of experiment & stop recording units	*10s.*
	Subtotal	*248s*
	(allowance for unplanned pauses)	*52s.* ***(=5 mins)***

c) Termination

1. Remove ETD Head Unit and stow;
2. Verify data records.

approx. 5 mins*,*

Flight procedure

The experimental procedure is identical to preflight and postflight BDCs. During inflight sessions howver, additional time is presumably required for equiüpment setup and stowing. (In the following step procedure, it will be assumed that the ETD equipment is installed in a fixed location in the station and connected to the onboard 28 Vdc supply.

a) Unstow ETD Units & Setup

1. Unstow ETD equipment, connect and initiate;
2. Setup target;
3. Don ETD Head Unit and adjust;
4. Check and adjust video images of each eye;

Time Estimated for performance: 15 min.

b) Start recording equipment, announce experiment and record experiment

		RecordingTime in SizeSeconds
1.	Initiate recording unit & announce experiment, date & time	*30s.*
2.	Fit calibration unit for right eye& perform calibration	*30s.*
3.	Repeat for left eye (& remove cal unit)	*30s.*
4.	Switch metronome on, fixate target on cabin wall &	
5.	Perform five head oscillations	*24s.*
6.	Repeat step 5 - with mask closed and imaginary target	*24s.*
7.1	Perform eye saccades for 20 secs with head upright	*20s.*
7.2	Perform eye saccades for 20 secs with head tilted to left	*20s.*
7.3	Perform eye saccades for 20 secs with head tilted to right	*20s.*
7.4	Perform eye saccades for 20 secs with head tilted forward	*20s.*
7.5	Perform eye saccades for 20 secs with head tilted backward	*20s.*
8.	Announce end of experiment & stop recording units	*10s.*
	Subtotal	*248s*
	(allowance for unplanned pauses)	*52s.*
	Total Estimated Time for Performance:	**300s. (5 min.)**

c) Disassemble & Stow

1. Doff ETD Head Unit
2. Check data storage & power down System Unit
3. Disconnect equipment and stow.

Estimated Time: 10 min

Total inflight experiment time: 30 mins.

10. HAZARD ANALYSES AND SAFETY PRECAUTIONS

The ETD has undergone extensive testing during its certification as part of the NASA Human Research Facility. .Full details of its performance as a certified medical device is available from the Data Safety Package by Kayser-Threde.

t

All measurements are non-invasive. Therefore No potential hazards are foreseen.

In-flight activities

Same as pre-flight

Post-flight activities:

Same as pre-flight

Ground based activities:

An identical model of the ETD will be used throughout the associated ground-based studies.

All studies:

No radioactive material is involved

11. POSSIBLE INCONVENIENCES OR DISCOMFORTS TO SUBJECTS:

In comparision ot previous devices, attention has been paid in the design of the ETD to facilitate comfortable fitting to the individual head (individually moulded facemasks).

The experiment involves the performance of small deliberate head movements. Comparable tests have been performed by sevenastro-/cosmonauts in previous missions and no discomfort or malaise has resulted. Thus, no inconvenience is expected in this regard.

12. EXTENT OF PHYSICAL EXAMINATIONS

Flight studies

Subjects are flight personnel and their annual physical will be relied upon.

Ground based studies: All volunteer subjects will be screened for any medical disorder, particularly related to neurological disease or history of dizziness.

13. AVAILABILITY OF A PHYSICIAN AND MEDICAL FACILITIES

No flight surgeon will be required during the preflight, inflight and postflight sessions, although ESA and Russian physicians are always present during measurements.

Ground based studies: During all associated studies performed in th PI’s lab there will by a physician available.

All studies: no medication or substances will be administered

14. INFORMED CONSENT: PROVIDED BY ESA

15. RESEARCH PERFORMED AT OFF-SITE (NON-ESA) LOCATIONS

Pre- and postflight BDC sessions will be performed in Star City (Moscow, Russia), at the TNO in Soesterberg, NL or in Berlin at the PI's lab.

During all BDC sessions the TM or TrM model of the ETD will be used.

Layman's Description

Under normal Earthbound conditions gravity provides a common reference for a number of body systems. These include the sense of balance (vestibular system) and the system for control of eye movements, which are normally closely coupled – or collinear. The aim of the proposed experiment is to determine whether the internal representations (in the brain) of these two systems are altered in microgravity. i.e. after loss of the gravity reference.

Appropriate measurements will be performed during the pre-flight, inflight and postflight phases of the spaceflight mission in order to determine whether the frames of reference for these two systems are influenced by prolonged microgravity, or by the return to gravity after spaceflight. From previous spaceflight studies it is known that some modification in the behaviour of the vestibular system is expected as it adapts to microgravity and again as it re-adapts to gravity after returning to Earth. While some ground studies indicate that eye movement control is to some extent influenced by gravity changes, the unique conditions of prolonged microgravity in space shall provide the ideal conditions to examine this more closely. Thus, the working hypothesis is that the two systems shall become de-coupled, or less collinear in microgravity.

The internal frame of reference for the eye movement control system can be determined by measuring the so-called Listing's Plane - this involves measuring three-dimensional eye movements while the test subject fixates a series of visual targets; the internal frame of reference of the vestibular system can be determined by the orientation of the three-dimensional vestibulo-ocular reflex (3D-VOR) – requiring the subject to perform regular oscillations of the head about the three main axes (x,y,z) and subsequent calculation of the eye-in-head orientation.

An essential precondition for adequate measurement of three-dimensional eye and head movements is the newly developed DLR Eye Tracking Device, which shall be flown for the first time on this mission.

ANHANG 2: DATA QUALITY – INTERIM REPORT AN ESA

ETD Experiment

INTERIM REPORT

Data quality from completed missions

31. January 2007

(supercedes version from 18.01.2006)

Prof. A.H. Clarke
Vestibular Research Lab
Campus Benjamin Franklin
Charité Universitätsmedizin Berlin

Data quality from ISS-ETD experiment Increments 9, 10, 11, 13, Astrolab
and DELTA & ENEIDE short term missions.

The ETD experiment has been performed by the designated crewmembers during the specified increments. The crewmember's task is to setup the experiment, mount and adjust the device for eye movement measurement on his own head, and finally to perform pre-defined eye and head movements. During the performance of these movements the subject's eyes are recorded on high speed video and his head movements are recorded synchronously by means of 3D accelerometers and angular rate sensors. (Full details of the procedure are given in the documents Step Procedure-ETD-LDM., LDM-ETD-200).
The experiment is designed to be performed in a one-man subject/operator scenario.
In essence, the task of the test subject is to adjust cameras and lighting elements correctly for the video eye movement recording, and to perform and record the pre-defined eye and head movements.

Given the one-man subject/operator scenario, familiarisation and training of the crew members has been recognised as critically important to the correct performance of the experiment and to the quality of the data return. In particular, since the accurate measurement of eye movements depends entirely on image processing of the recorded video sequences, any maladjustment of the cameras or poor image quality will potentially endanger the success of the experiment.

The following points have been identified as particularly critical to the experiment success:

*Understanding and acceptance of the experimen*t objectives by the crew members:
This has been very positive in all trained cosmo / astronauts.

Adequate training with the crew members:
Experience has shown that the required amount of training differs from subject to subject. Those with knowledge of areas related to the experiment (i.e. physiology, neuroscience, three-dimensional navigation, image processing) or from previous participation in similar experiments obviously have some advantage in understanding the critical elements of the science and the exp. Procedure.

Particularly detrimental to the quality of data return are:

Lack of adequate training time due to timeline pressure during the acute preflight phase is in most cases the major reason for poor experiment performance. On numerous occasions the allocated time has been shortened due to timeline pressure, delays and priority changes.

Incorrect eye and head movements. This is most likely to occur when insufficient training has been available, i.e. the candidates have not “internalised” the principles of the experiment.

Poor image quality of the eye videos. Good image quality requires that the eye is in focus, and centrally positioned in the video image, and that the eye is held wide open during image recording. I.e. the pupil and iris structure of the eye must be sharply focussed and free of artefacts.
Poor image quality can result from incorrect adjustment of the camera & illumination modules – e.g. eye not centred on image, shadows and dark patches in image due to incorrectly adjusted illuminators, image out-of-focus. It can also be the result of “difficult eyes”. This refers to such phenomena as “droopy” eye lids that occlude large sections of the iris and even the pupil (both of which should be visible and well-focussed for good image processing). Other problems can include occlusion of pupil by eyelashes, reflections due to tear-fluid build-up.
While these aspects are also dependent on the individual anatomy of the cosmo / astronauts, much can be resolved or improved with adequate training time and motivation of the candidates.

Obviously, we cannot select cosmo / astronauts on the suitability of their eye features; so the data quality shall inevitably vary between test subjects.

Low level of alertness (fatigue) while performing the experiment – can lead to procedural errors and, more critically, to incorrectly adjusted camera images, drooping eyelids and blinking, which cause considerable difficulties during postflight image analysis.

The following table summarises the data quality from the five longterm candidates and the two short-term ESA astronauts tested to date.

(Data quality according to offline analysis of video eye movement recordings, assessed on a 1-5 scale (1=poor, 5 = very good)).

Mission	**Dates**	**Experiment Section**				
		IBMP	**Calibration 1**	**Listing’s Plane**	**Calibration 2**	**3D-VOR**
Inc 9	19.04.2004 - 24.10.2004	**4**	**4**	**5**	**4**	**3**

Inc 10	29.09.2004 - 25.4.2005	**3**	**3**	**1**	**3**	**1**
Inc 11	15.04.2005 -1.10.2005	**4**	**5**	**4**	**5**	**3**
Inc 13	- 29.09.06	**3**	**4**	**3**	**4**	**2**
Astrolab	31.07.2006 -22.12.2006	**4**	**5**	**4**	**5**	**4**
DSM	19.04.2004 - 24.10.2004	**na**	**5**	**4**	**5**	**4**
ISM	15.04.2005 - 25.05.2005	**na**	**4**	**2**	**4**	**3**