Motor control in unstable dynamics

Meeting 2, Linköping, Sweden, May 23-24 2013

The second Delta-g ESA Topical Team meeting was organized on 23 and 24 May 2013 in Linköping, at the Dynamic Flight Simulator (DFS) facility (http://www.fpc.qinetiq.com/what-we-do/test-facilities/Pages/dynamic-flight-simulator.aspx). QinetiQ, represented by Jon Scott, kindly welcomed the team and organized the logistics. Minutes of this second meeting are presented below. More substantial information is available on the TT website at deltag.weebly.com.

The objectives of this second meeting were:

1. Make the most of this unique opportunity to (a) visualize what is technically feasible with a centrifuge and (b) test a few trials with an instrumented device.

2. Discuss how to structure the planned scientific proposal in terms of work packages.

An Ice Breaker has been organized on Wednesday evening to allow participants to meet prior to the workshop. A diner was shared by everyone during the evening of Day 1.

Participants

Present: Dr. Jan Babic (SI), Prof. Ola Eiken (SE), Prof. Joachim Hermsdörfer (DE), Prof. Charalambos Papaxanthis (FR), Dr. Jon Scott (UK), Prof. Jean-Louis Thonnard (BE), Dr. Arne Tribukait (SE), Dr. Jack Van Loon (NL), Dr. Olivier White (FR).

Dr. Oliver Angerer (ESA/ESTEC) presented an overview of ESA Topical Team instruments and provided insightful comments during our exchanges.

Day 1

The meeting was held at the QinetiQ Dynamic Flight Simulator (DFS) facility (http://www.fpc.qinetiq.com/what-we-do/test-facilities/Pages/dynamic-flight-simulator.aspx).

After a quick and warm welcome by James Cooper (facility manager) and Jon Scott, the team had a detailed tour in the installations dedicated to pilots training (hypobaric chambers, swimming pools etc). The centrifuge was in use by the Danish Air Force. We could access the control room and see the centrifuge spinning as high as 9Gz (along body axis).

Olivier White introduced the meeting with a brief presentation. The background of the TT has been reminded, specifically for those who are new to the team. Then, a series of simple yet different experiments was proposed and described (for instance, the influence of passive exposure in hypergravity to sensorimotor control, the influence of mental practice in hypergravity to sensorimotor control, sensorimotor adaptation to changing g-levels or to a constant g-level for several minutes, the integration of dynamics (mass, gravity, passive forces) on motor commands etc). The goal was to choose one or two pilot experiments that we could conduct in the DFS with a simple hardware kindly provided by Joachim Hermsdörfer (who arrived at around 11am).

After this quick informal talk, discussions started and we decided to perform two experiments. Experiment 1 is intended to provide fundamental insights into transfer of skills across hypergravitational environments. Experiment 2 builds on Experiment 1 and is devoted to analyze what happens when we move an object during several seconds while the environment itself changes.

Figure 1. The grip wireless instrument equipped with strain gages to record orthogonal grip force and accelerometers to record longitudinal load forces. See right figure for sketch of forces.

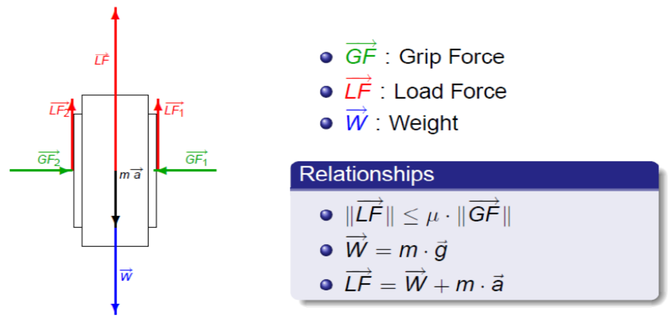


Figure 2. Object stability is a result of a complex interplay between various parameters, such as friction, mass, acceleration and gravity. We need to anticipate tangential constraints (LF) that challenge grasp stability in order to program an appropriate normal force (GF).

Initially, we expected to start the experiments during the afternoon of Day 1. However, an unexpected event occurred and the Danish Air Force continued their training during that afternoon. We used that time to refine our experiments and also discuss strategy to submit a proposal. The idea is to write a high level draft of a single proposal structured in work packages. Each work package should have a leader and present clear objectives related to the main topic. Science must be the driver, feasibility is also important; format of the proposal will follow. In other words, format – or available budget – of a proposal should not dictate scientific projects. It was felt that a major issue is the find human resources (post doc or PhD student) to enroll in this activity. It was proposed to contact national agencies such as DLR and CNES.

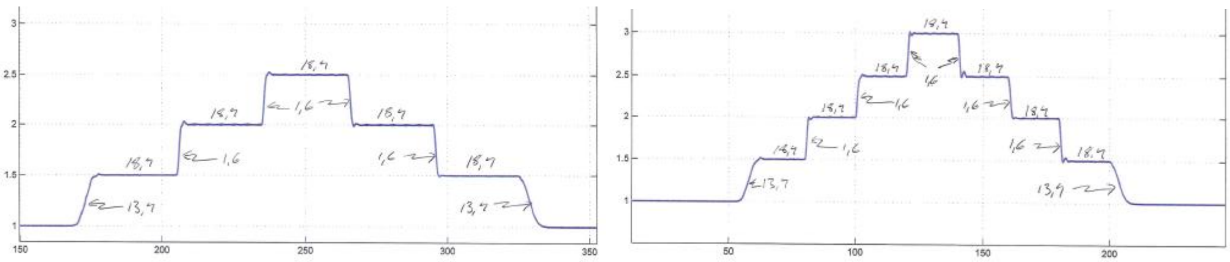
Anyway, we really focused on this small experimental campaign which should provide a unique opportunity to get preliminary data and write a sound proposal with a lot of credibility.

At the end of Day 1, both experiments were ready and "flight" profiles were sent over to the control room for programming. A diner was organized between participants.

Day 2

This entire day was devoted to running the two experiments.

<u>Experiment 1:</u> Transfer of dexterous skills across g-levels. We asked participants (n=7) to lift, hold and replace an instrumented apparatus (m=0.1kg) during stable phases of gravity (+Gz) in a range 1:2.5g. There are subtle parameters that can be analyzed in the grip force/load force coordination to see whether transfer occurred from one gravitational environment to another.



<u>Experiment 2:</u> Cyclic movements in varying gravitational contexts. Here, participants (n=6) were asked to continuously oscillate the same device as in Experiment 1 at free pace while Gz varied from 1g up to 3g, and back to 1g.

The figures below present the gravitational profiles programmed for Experiment 1 (left) and Experiment 2 (right). Local gravity along body axis is reported on the Y axis in g over time in seconds (X-axis). Profiles were similar across experiments except that we had a 3g plateau in the second experiment. Durations of plateaus (18.4s) and transitions (1.6s) were the same. Note the longer transition time required to go from 1g (idle, no movement of the gondola) to 1.5g.

In Experiment 1, participants performed 5 lifts in each gravitational phase and were not doing anything during transitions. Experiment 2 consisted of two sessions (right panel above) separated by a 5-minute pause to allow the vestibular system to reset. Initially, we asked participants to start moving the device at free pace from the idle position (1g), throughout the whole profile. However, the task revealed itself nearly impossible to achieve. Indeed, the torque command required to move the arm and upper arm plus the object was too high and the first participant gave up during the second 2.5-g (in the descending phase of the profile). Therefore, we decided to (1) limit the durations of continuous movements to intervals of [T-5s;T+5s] (T=transition) and (2) only perform upper arm movements. We therefore recorded data during transitions.

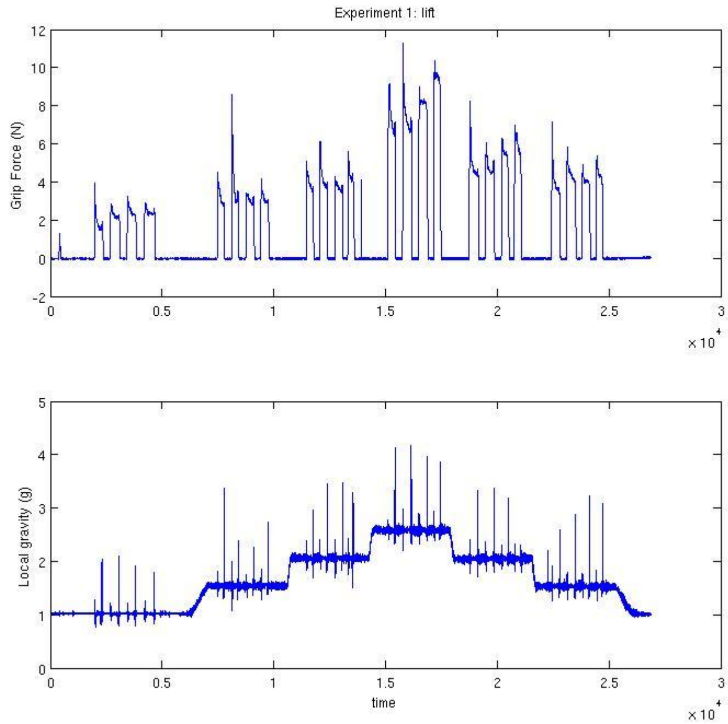


Figure 3. Complete profile of one participant during Experiment 1. The upper trace depicts grip force over time (units are samples). One can already infer the modulation of grip force according to ambient gravity. The lower trace reports Gz acceleration (in g). This matches the local g-profile felt inside the gondola.

Figure 4. The gondola and its rotating arm in the chamber.

Figure 5. One participant and team member ready to perform the first experiment. The QinetiQ staff was extremely helpful and flexible to allow us optimize the experiments.

At the end of the experimental sessions, we debriefed. We realized we could record a significant dataset that might even be adequate for a potential publication. Data analyses are clearly required. Joachim Hermsdörfer proposed to find a student to work on the dataset. In parallel, Olivier White will also dig into the dataset. This step is required in order to adjust future scientific ideas. Jean-Louis Thonnard and Philippe Lefèvre proposed to discuss the results in close collaboration with Joachim and Olivier. Of course, the outcomes of these experimental sessions will be circulated across the team members.

Action plan

- Analyze the data (JH and OWH).
- Discuss preliminary report with JLT and PL.
- Contact CNES (OWH) and DLR (JH).