


# First Middle East Aircraft Parabolic Flights for ISU Participant Experiments

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Received: 10 December 2016 / Accepted: 2 February 2017 / Published online: 16 February 2017  
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**Abstract** Aircraft parabolic flights are widely used throughout the world to create microgravity environment for scientific and technology research, experiment rehearsal for space missions, and for astronaut training before space flights. As part of the Space Studies Program 2016 of the International Space University summer session at the Technion - Israel Institute of Technology, Haifa, Israel, a

series of aircraft parabolic flights were organized with a glider in support of departmental activities on ‘Artificial and Micro-gravity’ within the Space Sciences Department. Five flights were organized with manoeuvres including several parabolas with 5 to 6 s of weightlessness, bank turns with acceleration up to 2 g and disorientation inducing manoeuvres. Four demonstration experiments and two experiments proposed by SSP16 participants were performed during the flights by on board operators. This paper reports on the microgravity experiments conducted during these parabolic flights, the first conducted in the Middle East for science and pedagogical experiments.

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**Keywords** Aircraft parabolic flights · Microgravity experiments · Grob G-103 Twin II glider · International Space University · First microgravity flights in Middle East

## Introduction

Aircraft parabolic flights are widely used throughout the world (Pletser et al. 2015a, b, 2016) to create a microgravity environment to conduct scientific and technology research, to rehearse experiment and to prepare for space missions, and to train astronauts before space flights. The use of parabolic flights is complementary to other microgravity carriers (drop towers, sounding rockets), and preparatory to manned space missions on board the International Space Station and other manned spacecraft, such as Shenzhou and the future Chinese Space Station.

It was shown (Callens et al. 2011, 2016; Perez-Poch et al. 2016, Pletser et al. 2005) that involving students in preparing, conducting and evaluating results of gravity related experiments on different space and microgravity platforms was most successful in attracting youngsters to and

promoting the Science, Technology, Education and Mathematics (STEM) studies.

As part of the Space Studies Program 2016 (SSP16) of the International Space University (ISU) summer session (ISU 2016a) at the Technion - Israel Institute of Technology, Haifa, Israel, a series of aircraft parabolic flights were organized in support of departmental activities (DAs) on ‘Artificial and Micro-gravity’ within the Space Sciences Department. Five flights were organized with a Grob G-103 Twin II glider from the Megiddo airfield close to Haifa with a series of manoeuvres that includes several parabolas giving each 5 to 6 s of weightlessness, several bank turns with acceleration up to 2g’s and a ‘chandelle’ manoeuvre to induce disorientation in the on-board operator.

Four short demonstration experiments in physical sciences and in human physiology and two experiments proposed by SSP16 participants were performed during the flights.

This paper reports on the microgravity experiments conducted during these parabolic flights, the first conducted in the Middle East for science and pedagogical experiments.

The ISU Space Studies Program 2016 and the department activities of the Space Sciences Department are introduced in “[ISU SSP16 and the Space Sciences Department](#)”. The Grob G-103 Twin II glider used and the flight manoeuvres are exposed in “[The Grob G-103 Twin II Glider, Piloting Techniques and Manoeuvres](#)”. The four demonstrative/pedagogical experiments and the experiments proposed by SSP16 participants are introduced respectively in “[The Demonstrative / Pedagogical Experiments](#)” and “[The SSP16 Participants Proposed Experiments](#)”. Preliminary results are presented in “[Experiment Results](#)” and conclusions are drawn in “[Conclusions](#)”.

## ISU SSP16 and the Space Sciences Department

The International Space University (ISU 2017a) located in Illkirch-Graffenstaden, near Strasbourg, France, is a private non-profit institution, formally recognized as an institute of higher education in France (Elaerts and Peeters 2006). ISU is dedicated to a “3Is” philosophy providing interdisciplinary, intercultural, and international scholarly pursuits related to space exploration and development by offering a curriculum covering all disciplines related to the space sector like space sciences, space engineering, business and management, policy and law, life sciences, humanities, and space applications taught by the ISU global faculty. The ISU strives to promote an understanding and appreciation of the cosmos through the constant evolution of new programs and curricula in relevant areas of study. The main focus is graduate-level training and professional development for future leaders of the emerging global space community at

its central campus (one year Masters program (ISU 2017b) and one week Executive Space Course (ISU 2017c)) and at host site locations around the world (two months Space Studies Program (ISU 2017d) or five week Southern Hemisphere Space Studies Program (ISU 2017e)). Applicants must have a Bachelor’s Degree or the equivalent, including three years of studies as a minimum, awarded by an accredited university.

The SSP is an intensive professional development course for postgraduate participants, as well as for young and seasoned professionals of all disciplines. It is a unique educational experience with a curriculum that covers the principal above mentioned space-related fields, both technical and non-technical. The interdisciplinary curriculum offered in the SSP, with its emphasis on international cooperation, exposes participants to broad new perspectives on world space activities that might otherwise be reserved for those with many years of diverse professional experience. The program is packed with a wide variety of activities including lectures by renowned experts, hands-on activities and projects, team work assignments, and professional visits. All of this is organized into three interrelated phases: core lecture series, departmental activities, and team projects (ISU 2016b). SSP16 comprised of 103 participants from 24 countries and more than 200 faculty and staff from over 15 countries (ISU 2017f). The department activities provide deeper examination of some of the topics covered in the core lectures within small groups and more interaction with faculty members and visiting lecturers. The Space Sciences Department, one of seven SSP16 departments with 15 participants from nine countries, introduces the principles, concepts, tools, and techniques necessary to investigate and understand the space environment. This is done in hands-on workshops as well as professional visits to learn about space sciences from experts in the field in the following topics during SSP16: investigation of the microgravity environment by preparing and conducting microgravity experiments; understanding of the fundamentals of astronomy and astrophotography using telescopes; remote operations of a planetary rover prototype to conduct science missions at a Mars analogue site, learning about the near space high altitude environment by developing and conducting a stratospheric balloon experiment, performing planetary geology and astrobiology exercises during a field excursion.

## The Grob G-103 Twin II Glider, Piloting Techniques and Manoeuvres

### The Glider

The G103 Twin II is a high-performance two-seater sailplane (see Fig. 1) made of glass fibre by Grob Aircraft.



**Fig. 1** The Grob G103 Twin II glider used for the first experimental parabolic flights in the Middle East from Megiddo airfield, Israel (Photo: V. Pletser)

The aircraft is of T-tail configuration, and is fitted with a non-retractable undercarriage and upper surface airbrakes. It is used for training, high performance, and simple aerobatic flying. Table 1 gives some characteristics of the glider.

**The Parabolas and Other Flight Manoeuvres**

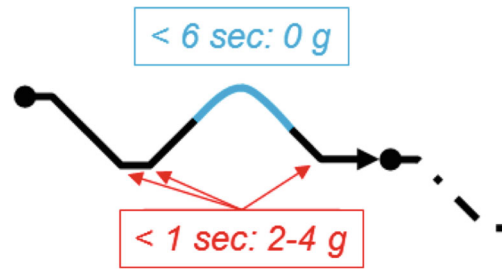
Three different flight manoeuvres were flown several times per flight, namely 0 g parabolas, high bank turns, and high-g chandelles, used to conduct experiments in respectively microgravity, continuous high g-loads and quickly changing high g-loads.

*Parabolas*

When aiming to perform a parabola manoeuvre with a glider plane, one should bear in mind that due to the lack of an engine and the significantly reduced maximum speed (often referred to ‘never exceed velocity’, or  $v_{ne}$ ), the parabola

**Table 1** Characteristics of the Grob G-103 Twin II glider

Crew:	Two
Length:	8.18 m
Wing span / area:	17.50 m / 17.8 m <sup>2</sup>
Height:	1.55 m
Aspect ratio:	17.1
Empty / Gross weight:	390 / 580 kg
Maximum / Cruising speed:	250 / 85 km/h
Matriculation:	4X-GAT
Based at:	Megiddo airfield



**Fig. 2** Aresti diagram of the parabolic flight manoeuvre with the Grob G103 Twin II glider plane

is smaller in size and shorter in duration when compared to parabolas flown with a motored aircraft, e.g. the Airbus A310 ZERO-G (see Pletser 2015a). As kinetic energy needs to be converted into potential energy and vice versa, the plane needs to be accelerated to a speed close to the  $v_{ne}$  (with a safety margin) by performing a 45° dive. The Aresti diagram in Fig. 2 outlines the whole sequence: from a straight and level flight, descend at 45° until a velocity of 200 km/h is reached; come to a straight and level flight again, then pull up to 45° (injection) with accelerations between 1.5 and 2 g for maximum 1s; release the stick and control the pitch to achieve a parabola figure to achieve 0 g for 5–6 s; when the diving angle reaches 45°, pull out of the dive with accelerations between 1.5 and 2 g for maximum 1 s, coming back to a straight and level flight again.

*High Bank Turns*

Glider planes, like all airplanes, are built to withstand hyper-gravity loads of more than 4 g. An acrobatic plane like the G103 Twin II is capable to handle up to +5.3 and −2.65 g.

To achieve high-g loads, the easiest method is to fly a high bank curve by pulling the stick to achieve the required load factor, such as 2 g. Figure 3 shows the Aresti diagram of the performed high bank curve sequence: from a straight and level flight, descend at 45° until a velocity of 120 km/h is reached; come to a straight and level flight again, then bank the plane to 80° and pull on the stick to achieve a g-load between 1.5 and 2 g for 20 to 40 s, before coming back to a straight and level flight. The duration of the bank turn is limited by the ability of the passenger to withstand the g-loads, before eventually blacking out.



**Fig. 3** Aresti diagram of the high bank curve or turn flight maneuver with the Grob G103 Twin II glider plane

## Chandelles

While the chandelle is not a classical acrobatic figure like the looping or the turn, it is still a very efficient figure to put the test subject under physical and psychological stress. This stress factor is mostly due to the quickly changing g-loads, accompanying the effects of swift changes in orientation of the plane. In short the operator, if not experienced, will be subjected to sudden disorientation coming along with alternating g-forces.

The flight profile flown within the chandelle manoeuvre is as follows: from a straight and level flight, descend at 45° until a velocity of 200 km/h is reached; come to a straight and level flight again, then pull up to 90° (injection) with accelerations between 1.5 and 4 g; release the stick and control the pitch and rudder to turn the plane before it would stall at a standstill (0 g is achieved for 2–4 s); then pull out of the dive with accelerations between 1.5 and 4 g, coming back to a straight and level flight again.

## Overall Operations

The manoeuvres that were flown included three to 21 parabolas depending on the operator's flight experience, one or several bank turns at 80° and one or two chandelle manoeuvres in attempt to induce disorientation in the operator seating at the back. The flight duration was about 20 to 25 minutes and was repeated five times allowing to change the operator seating in the back.

The flights took place on Saturday, 13th of August 2016, afternoon from the Megiddo airfield, near Haifa. Weather was good with light wind. All manoeuvres were flown between the airfield and the coast of the Mediterranean Sea, in Israeli air space.

## Experiment Set-Up

All experiment equipment was installed in the glider cabin, in front of the back seat for the operator to conduct and monitor all experiments. Some equipment was mounted on top of the glider instrument panel in front the operator, some other experiment equipment was strapped to the operator's thighs and some procedure and paper figures were either pasted on the canopy or placed in a seat side pocket.

Precautions were taken to ensure that all operations during flights were conducted safely and that flying participants were adequately prepared for the repeated high and low gravity conditions. All equipment and their attachment to either the operator legs with straps or to the glider internal structure with Velcro and tape were verified prior to flights. Additionally, all items were tethered to avoid accidental floating away in case of detachment. All liquid containing enclosures were verified for tightness.

## The Demonstrative / Pedagogical Experiments

Four simple and short experiments were proposed by the academic staff to demonstrate the effects of microgravity to participants. Two experiments belong to the physical sciences category and two others are dealing with human physiology.

### The Newton Cradle Pendulum

The Newton cradle pendulum (see Fig. 4) is a well-known toy-like system that demonstrates conservation of momentum and energy using a series of swinging marbles. When an end marble is lifted and released, it strikes the stationary marbles; a force is transmitted through the stationary marbles and pushes the last one upward. The frequency of the swinging marbles is of course a direct square root function of the gravity acceleration  $g$ . So, in higher g-phases, it is expected that the frequency would increase, while in 0 g, the frequency is nullified and the last marble does not come down anymore. The pendulum cradle structure was secured on top of the glider back seat instrument panel and filmed by CCD GoPro cameras fixed inside the glider cockpit and on the operator head.

### Three Phase Fluid Mixes

Simple mixtures of water, oil and air and of water with liquid soap were enclosed in small transparent plastic



**Fig. 4** Newton's cradle pendulum and two small plastic containers with liquids fixed to the pendulum structure. The whole set is attached on top of the glider back seat instrument panel. (Photo: V. Pletser)

containers (see Fig. 4) and shaken on ground to demonstrate the natural separation of air and oil from water and the drainage of water from a soapy emulsion. The separation and drainage were enhanced when the small containers were accelerated centrifugally showing the effect of a high g environment on these processes. During the flight, an accelerated separation and drainage during the high g phases and no separation and less drainage in the 0 g part of the parabolas were seen.

### Modified Cardiovascular Output

There is a large amount of evidence (see e.g. Clément 2005; Aubert et al. 2004) showing that in microgravity the body fluids shift from lower extremities toward the torso and the body upper part, resulting in an apparent hypervolemia in the torso. The net effect is a slowing down of the heartbeat within seconds of entrance in 0 g and a slight increase in the stroke volume in 0 g. These two effects disappear in the high-g phases where the opposite is normally observed, i.e. an increased heart beat and a smaller stroke volume.

The subject sitting at the back was wearing a sport ECG band on the torso (Garmin Forerunner 410). Recorded data were processed after the flights by participants and faculty.

### 3D Optical Illusions

It was shown (see e.g. Clément and Reschke 2008) that in weightlessness, in absence of gravity stimulation of the inner ear balance system, the brain can no longer process properly simple two-dimensional drawings showing three-dimensional scenes (like a person walking down a stair) and the perception of the depth in the drawing disappears in 0 g.

Three images (see Fig. 5) showing three-dimensional scenes were either fixed to the glider canopy or were placed in a seat side pocket for the subject to hold them. The subject

had to look at them during the 0 g part of the parabolas and report whether he or she could still see the third dimension or not.

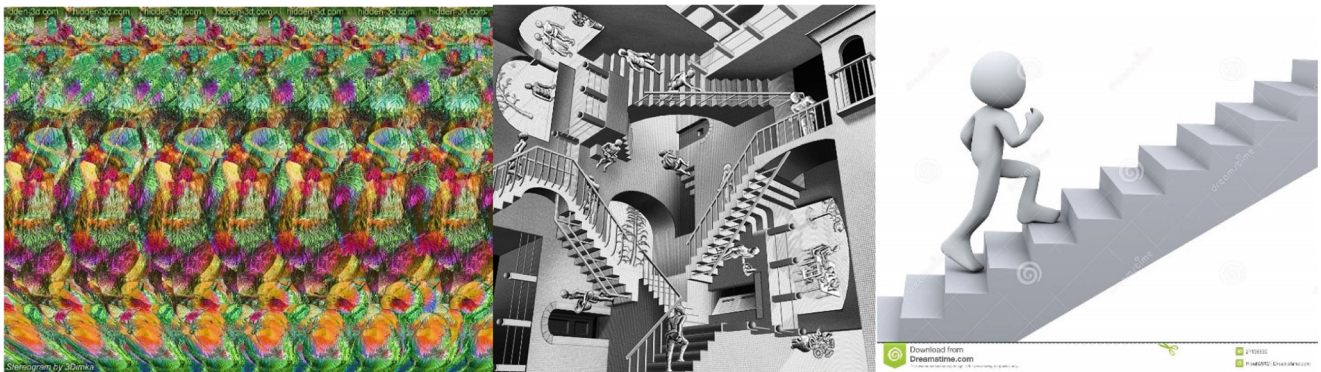
## The SSP16 Participants Proposed Experiments

### Tactile Experiment

This experiment, titled “An assessment of the effect of tactile-cortical sensation in the human brain during short episodes of microgravity”, was proposed by one of the co-authors (M. Foster).

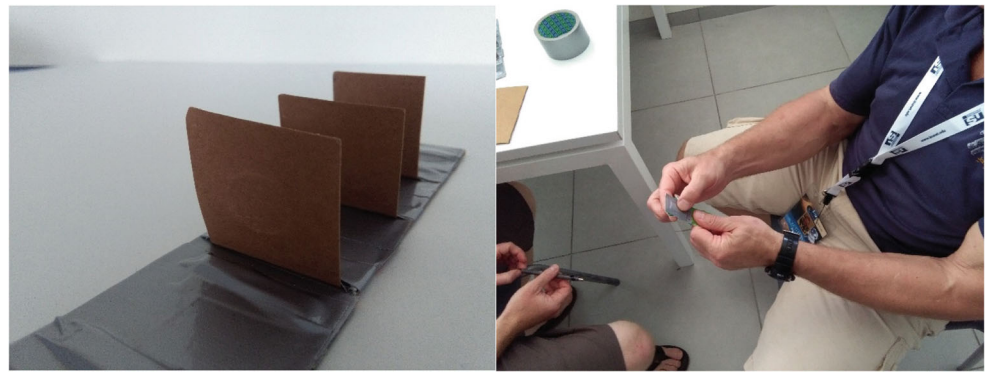
Tactile sensation and processing in the cortex of the brain is an important component of environmental awareness for humans. Two clinical tests for this are graphesthesia and stereognosis, and they are defined respectively by the ability to recognize what is written on the skin and by the ability to recognize common objects such as keys or coins when placed in the hand (McGee 2012). A deficiency in these abilities typically indicates cortical sensation impairment, however lesions in the dorsal columns of the spinal cord may also be a cause (Goetz 2007). Astronauts commonly experience spatial orientation difficulties while in microgravity and tactile cues help contribute to spatial orientation, though currently there is no evidence for tactile-cortical sensory dysfunction in microgravity (Clément and Reschke 2008).

The goal of this experiment is to provide further investigation for any dysfunction of tactile sensation and processing in the cortex of a human subject in short duration microgravity. It is hypothesized that there is no tactile-cortical sensory dysfunction in microgravity as there are no known gravity-dependent sensory receptors in this pathway. This experiment is to provide evidence to further support this hypothesis. This was evaluated by performing an



**Fig. 5** The three 3 D images: *left*: ‘Psyconuts’ by 3Dimka (<http://3dimka.deviantart.com/art/Psyconuts-119056939>); *middle*: ‘Relativity’ by Escher (<http://www.mcescher.com/gallery/back-in-holland/relativity/>); and *right*: ‘3d person running on stair’ by dreamstime (<https://www.dreamstime.com/stock-photo-3d-person-running-stair-image27138530>)

**Fig. 6** The tactile pads used for pre-flight control and for flight experiments (*left*); a subject getting trained before the flight (*right*) (Photos: V. Pletser)



analogue neurologic tactile-cortical sensation test on human subjects prior to (see Fig. 6) and in 0 g during parabolic flights to compare results.

The experiment, designed as an analogue of the standard clinical tests for graphesthesia and stereognosis, included two sets of tactile pads, one for pre-flight experiments and a different set for in-flight experiments. The tactile pads were a series of three cardboard tabs each embossed with a shape that was a square, circle, triangle or cross. Each shape was 1.5 cm × 1.5 cm in area. The tabs were held onto a cardboard base plate with duct tape. A sample of one of the shapes was given to the subjects prior to flights to ensure they understood the size and texture of the object.

One set of tactile pads was used for pre-flight control test while the subjects were already sitting strapped in the glider back seat to provide the same environment as in flight. The set of tactile pads for the flight experiments were strapped on the subject's left thigh (see Fig. 7). The pads were set up such that the subjects could not see the cardboard face of the tabs. The subjects used the index fingertip of their dominant hand to assess the embossed objects, and had five seconds to examine all tabs for the pre-flight portion and then again in microgravity. Each tab was examined from proximal to distal in order. The subjects verbally described their findings to the recording camera. Five healthy subjects (two females, three males) performed the experiment during at least one parabola per flight.

### Response Time Experiment

This experiment, titled “An assessment of the effect of different gravity levels on the response time of a simple tapping test”, was proposed by two of the co-authors (R. Spannagel, A. Szeszko).

Response time is the combination of the reaction time and movement time. It is the time a subject needs to respond to an external stimulation, e.g. hitting a button when a light is seen or a specific sound is heard. The average reaction

time for teenager individuals is about 160 milliseconds to detect sound stimulus, and approximately 190 milliseconds to detect visual stimulus (Jensen 2006).

Higher stress levels due to different gravitational forces depend strictly on subjects. Subjects can improve their control and anticipation of body movements under different g levels. Subjects experienced in microgravity flights have a different response to parabolic flight stress than new flyer subjects. The reaction time depends on age and experience. Senior subjects with significant high experience can have a better reaction time than younger subjects with just little experience (Green 2000; Truszczynski et al. 2013).



**Fig. 7** A subject sitting on the glider back seat equipped with the tactile pads strapped to the *left thigh* and the iPad for the reaction time test strapped to the *right thigh*. One sees also the ‘3d person running on stair’ picture on the canopy side part and the ‘Psyconuts’ picture in the seat side pocket (Photos: V. Pletser)

To test the responses of subjects, an Apple iPad mini was strapped to the subject's right thigh (see Fig. 7) and an application ('Game of Reactions!' from Unteam, freely available in the iTunes app store) was used to measure response times. After starting the application, subjects had to tap as quickly as possible on a blue dot appearing at different screen locations. This procedure was repeated five times in a row after a resulting average response time was shown. Results were recorded by the head mounted camera and read by subjects for backup voice recording.

Only four subjects, with different flight experience, participated in the experiment. Subject One was not available for this experiment. Subject Two had never flown in microgravity, but had experience with parachute jumps. Subject Three was used to skydiving. Subject Four performed thousands of 0 g flights in different airplanes. Subject Five had experience in different g levels due to skydiving, but no 0 g flight experience. All subjects had several minutes prior to the flight to get accustomed to the tablet and app interfaces and the test procedure.

## Experiment Results

### In-Flight Procedure

Prior to flights, the procedure for each operator/subject was prepared considering the limited number of parabolas, the limited space available in the cockpit to place all equipment (see Fig. 7) and the short duration of the flights. This procedure is given in Table 2.

### Some Comments from Subjects

Subjects were seating in the back seat and took care of the experiments while the pilot in the front seat was piloting

the aircraft. From the backseat, subjects had a large unobstructed view of the surroundings which contributed for some to the stress during the flights. One subject commented that it was like seating in mid-air moving at quite a pace between earth and sky and that the view during the down part of the parabola was quite spectacular. Two other subjects did not comment at all and were silent for quite a long time after the flight, while another subject was quite excited and very verbal. Finally, one of the subjects, who is a pilot himself, offered these comments made by his passengers of his 238 acrobatic glider flights while piloting.

Most of the passengers are usually nervous before the start, most likely because of the safety briefing before climbing in the cockpit. This briefing entails a familiarisation with the plane, its systems, the parachute and its operation. As soon as the passenger is tightly strapped into the seat to withstand the g-forces, heart beat is already close to the maximum. Finally, after attaching the glider to the towing plane and last checks, heart rate reaches its maximum. But this is normal, as take-off is the second most dangerous phase of flight after approach and landing. Last trims and checks, all looks fine, we are ready to go! The tow plane slowly moves forward, the tow rope stretches out. A last second of silence and then the tow plane applies full throttle. A forceful tug lounges us forward and we accelerate down the runway. 40, 50, 60, 70, 80 km/h, a small pull on the stick and we are airborne! A few seconds later the tow plane ascends also into the air and we both start to slowly climb up. This is usually the moment when the passenger exhales for the first time. From now on, he/she starts to enjoy the flight. The next 15 minutes represent the second most gentle part of glider plane flying, as soon as we detach from the tow plane and we are really on our own, the real fun starts. Flying without any engine is noiseless. We are part of nature and, if we are lucky, we can see storks and large birds of prey from very close. After all, to them, we are nothing else but a huge white bird. Entering the acrobatic procedures puts a different spin on glider plane flying. The most prominent reaction of all passengers is the observation that forces are much higher than in a roller coaster although they build up more gently. One senses also the potential danger, e.g. a deep dive clearly shows that we are hurling towards the ground with an ever-increasing speed, until pull up. Deep dive, stall, spin, these flight figures require a high level of trust in the plane and in the pilot. During these figures, most of the passengers usually start to feel a sense of panic, but stop short of screaming, probably being convinced that the pilot would not kill himself (and them incidentally). This roller coaster of emotions makes acrobatic glider plane flying so intense and unforgettable. "Awesome!", "Intense!", "Breath-taking!" are the words heard after landing.

**Table 2** In-flight procedure

1.	Pre-flight: Tactile experiment + Response time test + Optical illusion
2.	Parabola 1: Tactile experiment
3.	Parabola 2: Response time test No. 1
4.	Parabola 3: Response time test No. 2
5.	Parabola 4: Optical illusion
6.	Bank turn: Response time test (3×) + Tactile experiment
7.	Chandelle: Response time test (2× or more)
8.	Level and steady flight (immediately after chandelle): Response time test (2× or more)
9.	After landing: Response time test

## Some Results of the Pedagogical/Demonstrative Experiments

### *The Newton Cradle Pendulum and the Three Phase Fluid Mixtures*

The Newton cradle pendulum and the three phase fluid mixtures behaved as expected and videos filmed during flights could show the different behaviours at different gravity levels.

### *Modified Cardiovascular Output and Flight Logs*

The modified cardiovascular output experiment unfortunately did not provide all expected results as a technical problem lead to the loss of all data for three subjects. Only the first and last subjects were properly recorded.

Figure 8 depicts the three relevant data logged by the Forerunner 410. As can be seen on the green curve, the glider flight started towed by a motored plane with a rather constant ascent to 1000 m above ground, followed by altitude drops depending on flight manoeuvres. At approximately 9 minutes in flight (yellow marker in Fig. 8), the velocity peaks three times at ca. 200 km/h on the blue curve. This marks the end of the 45° dive to achieve injection speed for the three parabolas (at 09:04, 09:18, and at 09:30). The two following velocity peaks relate to the dive necessary for two bank turns and two chandelle manoeuvres respectively.

A slow increase in altitude commencing at 14:18 and lasting until 24:33 represents an ascent in an upward thermal

current, which was repeated once more thereafter, allowing for more acrobatic manoeuvres and a relatively long flight duration of approximately 40 minutes.

Figure 9 zooms into the three parabolas. The first parabola can be nicely seen in the altitude pattern (green curve), being initiated at 09:05 with 190 km/h and exited at 09:18 with 205 km/h. The maximum heart rate was 116 beats per minute (bpm), from 103 bpm before the parabola. During the second and third parabolas, the heart rate peaked at 120 and 132 bpm respectively. It shows that flying acrobatic manoeuvres repetitively comes along with a significant tiring effect.

It can also be seen that there is no apparent direct correlation timewise between the 0 g phase and the lowest heart rate, as the lowest heart rate is always visible at the end of the 0 g phase, the body reacting with some sort of hysteresis. The same can be observed for the heart rate peak when the body is exposed to hypergravity, the effect becoming visible after a few seconds at the earliest.

### *3D Optical Illusions*

The 3D optical illusion experiment showed contrasted results. First as there was little time only during each parabola, every subject was told to choose one of the three pictures available and to concentrate on this picture for at least one parabola. It was reported by two subjects who choose the ‘Psyconuts’ picture that the central figure that is visible on ground and during 1 g and 2 g flight phases disappeared in 0 g. The same effect was seen by another

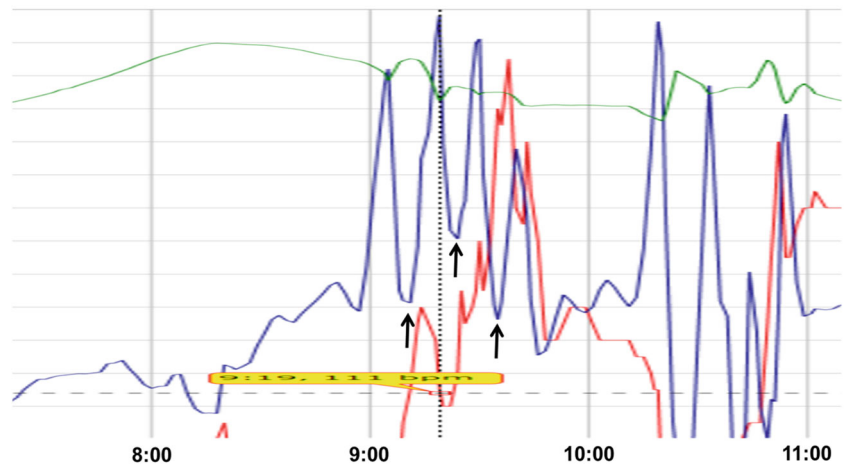


**Fig. 8** Print of the Garmin Forerunner 410 Log for a subject. The *green curve* represents the altitude (full scale: –100 to 1100 m with respect to the ground level), the *blue curve* the airplane velocity (scale:

0 to 240 km/h) and the *red curve* the subject's heart rate (scale: 80 to 140 bpm) versus time (scale: 00:00 to 42:00 minutes:seconds)



**Fig. 9** Zoom in on the three parabolas (three arrows under the blue curve) at 09:04, 09:18, and at 09:30



subject who selected the ‘3d person running on stair’ picture. The perspective visible on ground and during 1 g and 2 g flight phases disappeared in 0 g and the picture appeared completely “flat” until the 2 g pull-out. The same subject tried to look at the ‘Relativity’ picture during a following parabola, and there, no special effect could be detected neither in 1 g, nor 2 g, nor 0 g, as the entire drawing is by far more “complicated” than the simple ‘3d person running on stair’ picture.

**Some Results of the Student Proposed Experiments**

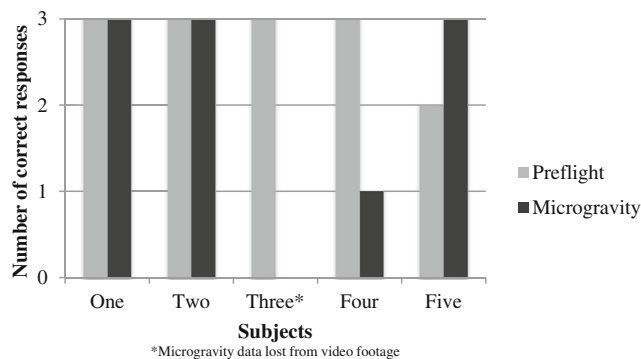
*Tactile Experiment*

The results from the tactile-cortical sensation experiment are incomplete due to loss of camera footage during the parabolic flight of Subject Three and this does limit the discussion, though there was one subject who demonstrated significantly reduced identification of the shapes in microgravity (see Fig. 10). This is notable since among all subjects during the control phase on the ground only a single error identifying the shapes was made (Fig. 10). Otherwise, the remainder of the subjects (except Subject Three)

did not demonstrate any changes in microgravity. However, it would be presumptuous when interpreting the results to imply that tactile-cortical sensory dysfunction in microgravity was identified, as there were significant limitations to the experiment. These limitations included small sample size, lack of subject baseline neurological examinations, use of an analogue tactile-cortical sensory test, environmental distractions from the glider cockpit environment, short duration of microgravity, and potential confounding from subjects conceivably guessing during the microgravity portion of the experiment. Four of the five subjects were interviewed briefly after the experiment, and interestingly three of the four did describe having difficulty identifying one or more of the shapes during microgravity. Further investigation could be considered to increase the sample pool size and provide increased reliability to the data generated studying this effect.

*Response Time Experiment*

For the response time test, the subjects have done different number of tests and unfortunately some tests have not been recorded. Some did more parabolas and some more chandelle manoeuvres. The number of recorded manoeuvres varied between two and six parabolas and between four and ten tests during chandelles of the different subjects. Table 3 shows the mean values of these measurements, along with the mean values and standard deviations (Std,  $1\sigma$ ) of all tests.



**Fig. 10** Pre-flight correct totals compared to microgravity correct totals

**Table 3** Mean and standard deviation for the response time test

	Subject two	Subject three	Subject four	Subject five
Mean of parabolas	0.570 s	no data	0.590 s	0.460 s
Mean of chandelles	0.537 s	0.645 s	0.545 s	0.545 s
Mean of all	0.542 s	0.645 s	0.607 s	0.471 s
Std of all	0.107 s	0.144 s	0.099 s	0.032 s

Subject Three, with the least experience, has the highest response time values and the highest standard deviation, which shows the higher variation of the measured values. Subject Five has the best results, best response time and very constant values, with a low standard deviation, and scored better than Subject Four although more experienced in 0 g flights. Perhaps, the skydiving experience and the younger age of Subject Five may explain the better scores. However, some subjects complained about the fact that during the parabola, as the orientation of the airplane changed with respect to the illumination of the sun, they could not see properly the screen for certain durations during the various phases of the parabolas, which somehow invalidated the results for these parabolas.

## Conclusions

During the Space Study Programme 2016 of the International Space University taking place at the Technion - Israel Institute of Technology, Haifa, Israel, several simple and pedagogical experiments were conducted during short duration microgravity provided during parabolic flights with a Grob G-103 Twin II glider. The results of these pedagogical experiments were used to illustrate to ISU SSP16 Space Sciences Department participants the effect of gravity and of its absence on simple physical systems and on some physiological aspects. Two participants proposed experiments were also conducted and these results were analysed as reported above. Results of these experiments will be placed in the ESA's Erasmus Experiment Archive (EEA) database.<sup>1</sup>

This campaign of glider parabolic flights allowed to show the versatility of the parabolic flight tool especially with a glider, and provided some interesting albeit limited results, due to the very nature of the flights, i.e. short duration of 0 g and limitation of experimental space in the glider cabin. Nevertheless, from a pedagogical as well as educational outreach point of view, it is believed that this series of flights was a great success with large visibility and allowed ISU SSP16 participants to have a hands-on experience of microgravity experimentation.

It must be emphasized also that these flights were the first microgravity flights conducted in the Middle East for science and pedagogical experiments.

**Acknowledgements** These experiments were conducted under the auspice of the ISU SSP16 Space Sciences Department. The hospitality of the glider club of Megiddo and its members is thankfully acknowledged. The active contribution and flying expertise of Arnon Yaffee, the chief pilot is highly acknowledged. All subjects are thanked for their voluntary participation and their dedication. Mrs Laurie Goldstein and Mrs Maria Lucas-Rhimbassen are also thanked for their support as well as Prof. em. David Degani and Mr Ofer Lapid. Vladimir Pletser is supported by the Chinese Academy of Sciences Visiting Professorship for Senior International Scientists (Grant No. 2016VMA042).

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