ANALYSIS OF UPPER LIMB MOVEMENTS OF ASTRONAUTS PERFORMING MOTOR IMAGERY TASKS ON THE ISS AND ON GROUND (ID #238)

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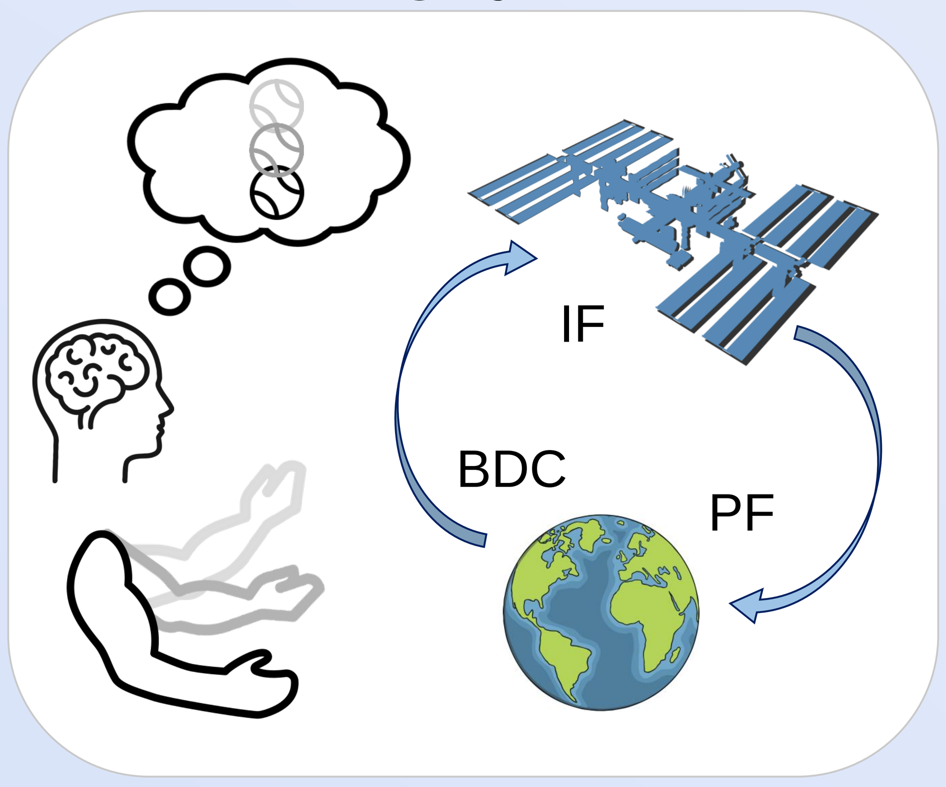
Introduction

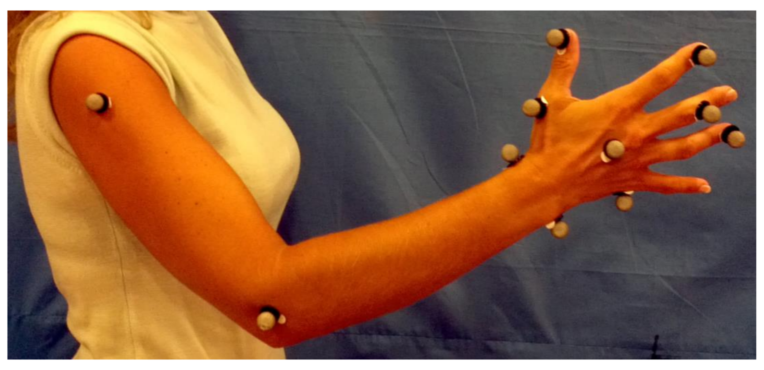
Motor tasks involving interactions with falling objects may seem intuitive, but they require internal models of both limb and object dynamics, which depend on the Central Nervous System (CNS) to correctly process information about the orientation of the gravito-inertial vector. Mental imagery research shows that the CNS can elaborate different models of imagined 0g and 1g object motion [1,2], while motor coordination research shows that under terrestrial gravity the CNS tends to executes simple actual motor tasks of the upper limb through stereotyped patterns of motion (“invariants”) [3,4]. Aim of this analysis is to answer to the following questions: Do motor strategies change when gravity conditions are altered? Do internal models of limb and object dynamics influence one another? Do invariants of movement exist among subjects? Data from astronauts performing motor imagery tasks is examined with the objective of extracting a method of analysis that may lead to a comprehensive understanding of motor coordination under altered gravity conditions.

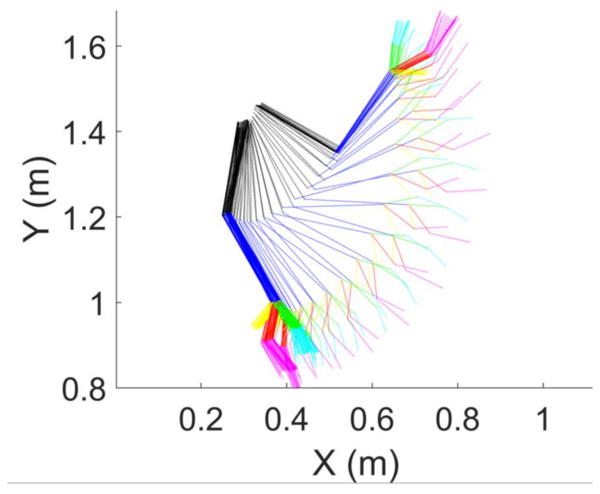
Mental Imagery Motor Task



Methods

The previously collected data represents the 3D position of eight retro-reflective markers applied to the arm of astronauts performing a mental imagery motor task. The positions were registered by means of the ELITE – S2 system (Kaiser, Italy). Subjects were asked to imagine grasping a tennis ball with the dominant hand, throwing it in an upwards direction against the ceiling and to imagine catching it after an elastic bounce. Some of the subjects performed the task on ground (Baseline Data Collection – BDC), on board the ISS (In-Flight - IF) and after returning from Space (Post-Flight - PF), while others only performed it on ground.

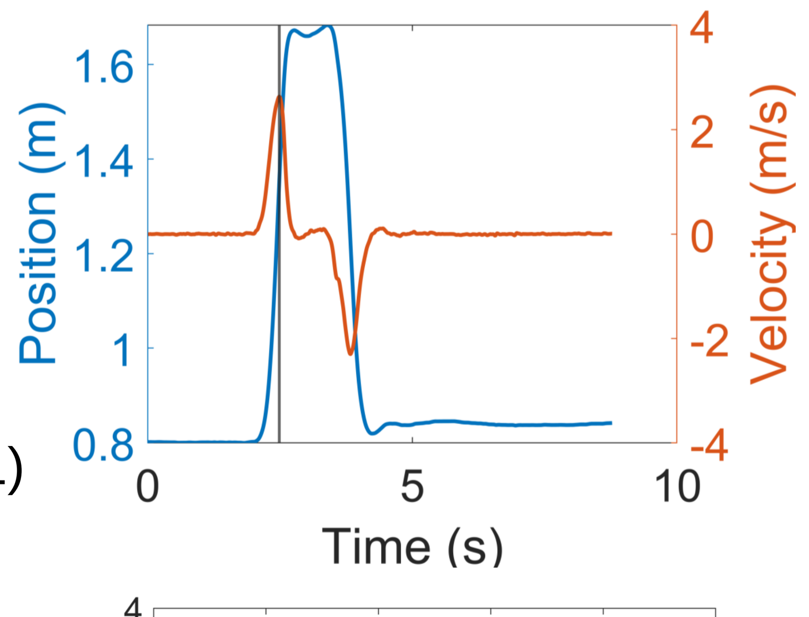




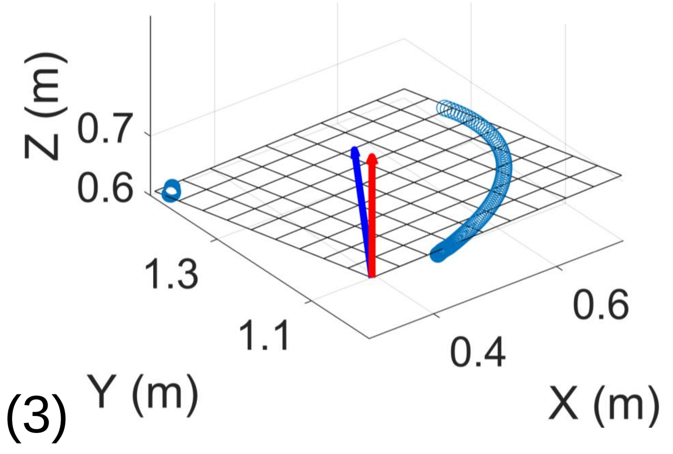
Signal elaborations and analysis:

- the data is interpolated, low-pass filtered and time differentiated
- the maximum index finger velocity indicates the instant of throw (1)
- the maximum and minimum velocity values are used to find the asymmetry coefficient of motion (2)
- the Principal Component Analysis gives the plane that corresponds to the performed planar throwing task (3)
- the 3D data is projected over this plane and is transformed into the 2D environment’s coordinates (4)
- the elevation angles of the arm and forearm segments can be calculated using the arctangent

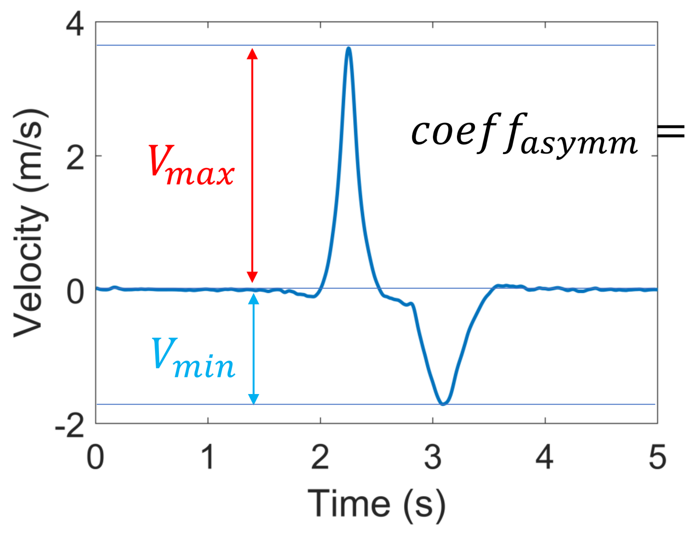
(1)



(3)

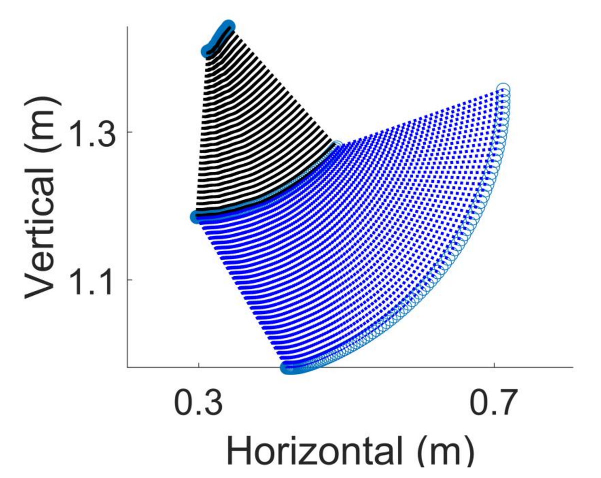


(2)



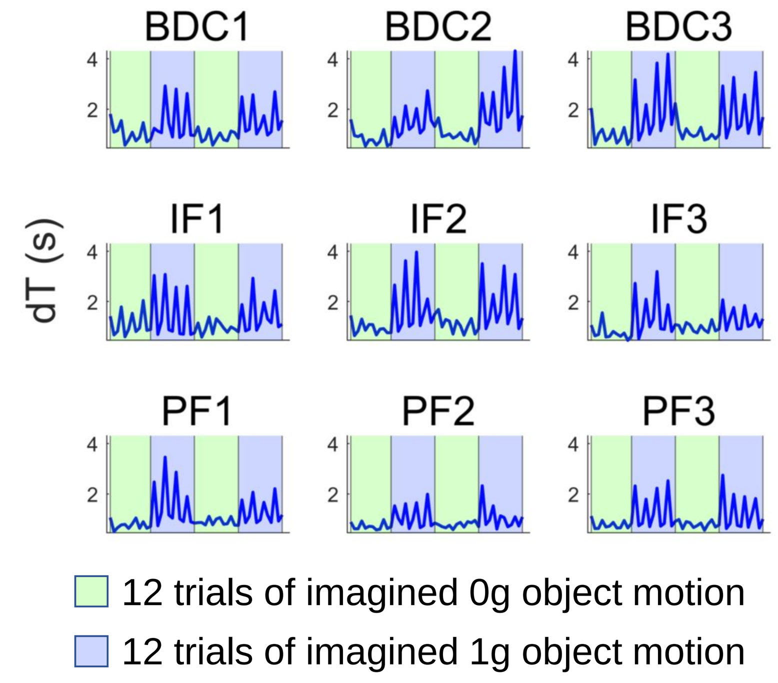
$$coeff_{asymm} = \frac{V_{max}}{V_{max} + V_{min}}$$

(4)

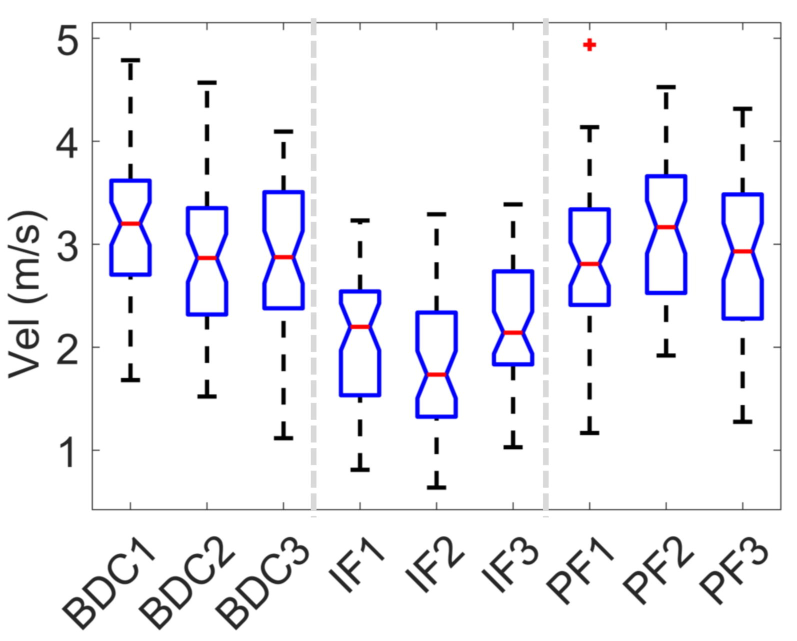


Preliminary Results

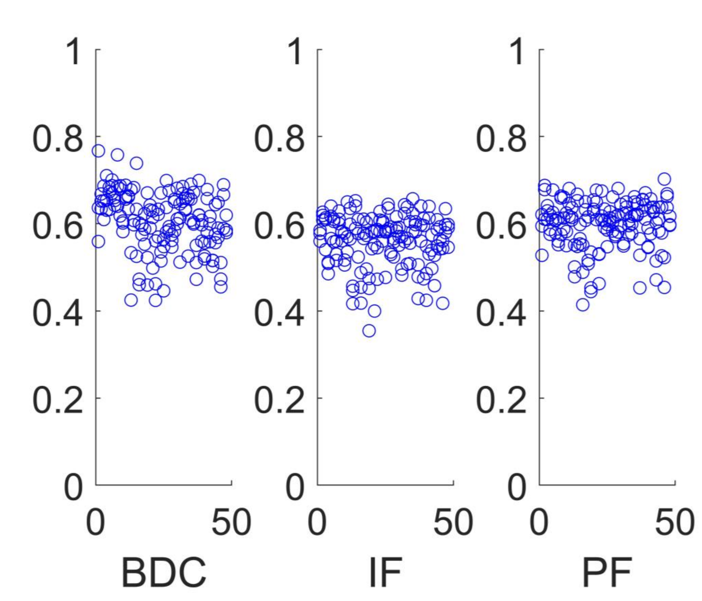
Example of a subject’s temporal intervals between throwing and catching instants in imagined 1g and 0g conditions



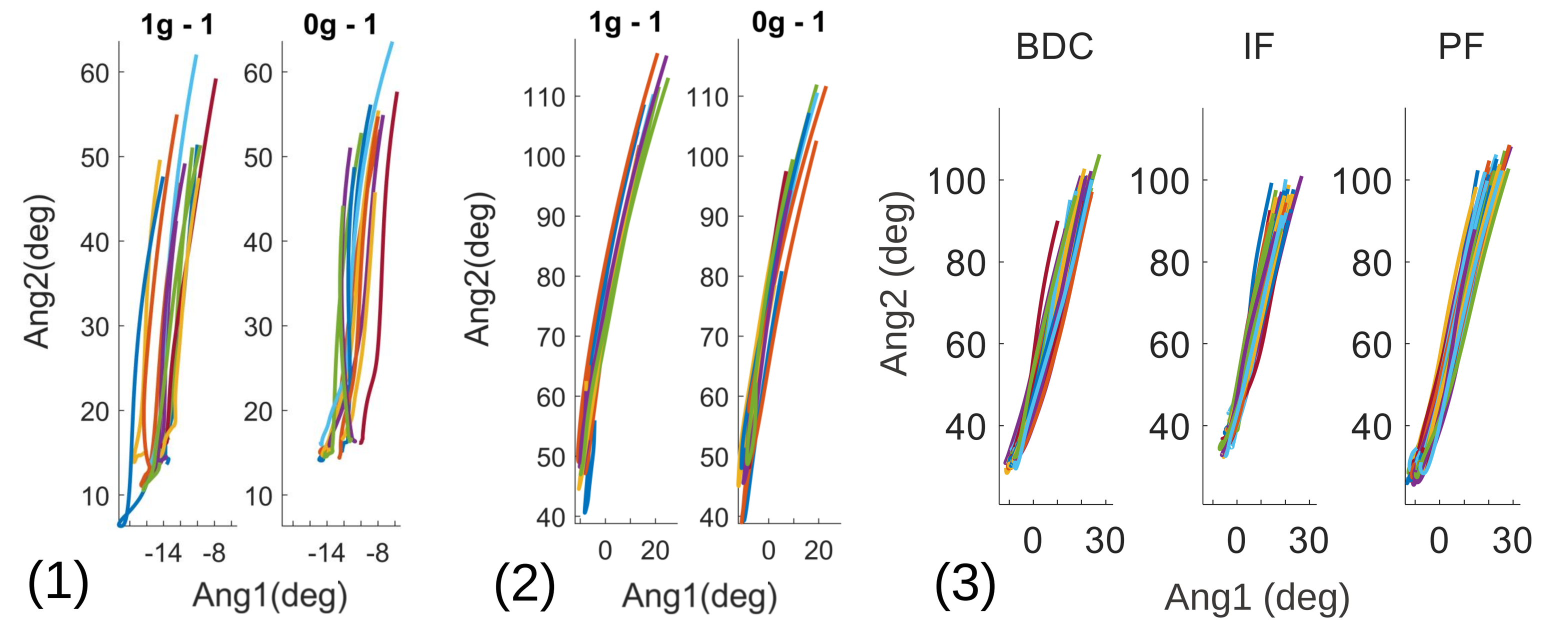
Example of a subject’s peak velocities in the different actual gravity conditions (1g - 0g - 1g)



One subject’s results of asymmetry coefficients in BDC, IF and PF sessions: one-way ANOVA analysis shows lower asymmetry coefficients in the IF session, with respect to the BDC and the PF sessions and this difference is of statistical significance (p-value < 0.01), while the PF and the BDC sessions do not show statistical difference (p-value >> 0.01).



Elevation angles profiles of two different subjects performing the motor task on ground (the specific shape of the curve depends on the subject, but remains consistent under imagined 0g and imagined 1g conditions) (1,2). One subject’s curves in BDC, IF and PF sessions. The specific shape seems to remain consistent in all the sessions, regardless of the actual gravity condition (3)



Conclusions

Mental imagery of object motion can differentiate between imagined 0g and 1g conditions, while peak velocities of the performed motor tasks are lower in actual microgravity conditions, with respect to terrestrial gravity conditions. There is an asymmetry in peak velocities in the upward movement with respect to the downward movement for all subjects (one subject shows statistically lower asymmetry coefficient values in actual microgravity conditions). The curves corresponding to the arm’s and the forearm’s elevation angles have distinguishable individual shapes among subjects: the imaginary nature of the task likely allows for a higher variability in the motor strategy. Nonetheless, these curves’ shapes in BDC conditions do not appear to change from trials of imagined 0g object motion to trials of imagined 1g object motion, thus suggesting that internal models of gravity effects on object motion do not have an a priori effect on internal models of limb dynamics. Further investigations with vaster datasets are being elaborated.

References

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