Human Factors Review of Space Habitat Feature Requirements

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Sending humans to other planets requires an understanding of the effects of the partial gravity on human motion before attempting to design or build buildings or plan mission tasks. Architecture is the most basic example of human-centered design as everything in a building is to "human" scale. While some modern studies (e.g., Capps, et. al, 1989) reference a study which looked at the humans and forces for the Moon landing (Hewes et. al, 1966), this study was never correlated with the actual lunar data and has many erroneous assumptions. Previous work in Biomechanics was reviewed and the elements of physics required to analyze human motion in partial gravity was analyzed and several basic questions were generated. Included in these studies are NASA studies which look at parabolic flight and apparatus to simulate the effects of partial gravity (NASA/TM-2010-216139, 2010). The key part of physics that drives the changes in human motion is the fact that the momentum of a human or object in motion remains the same while gravity reduces the normal forces on the feet which in turn cause a reduction in the friction reaction forces available for maneuvering or stopping. The study investigates design of several building features for space architecture. These include: Ceiling Height, Door Size, Railing Height, Stairs, Ladders, and Ramps. The first of these the ceiling height relates to the question of does a person "bounce" when they walk in partial gravity. Typical ceilings on Earth range from 2.44 m (8 feet) to 3.05 m (10 feet) Studies of walk to run transition speed for partial gravity were reviewed and they measured the vertical displacement of the hip. This measurement varied by less than 1 cm and correlated to a minimal head height change. Door sizes and railing heights related to the height of 99th percentile humans projected to the year of launch to Mars or the Moon and also included spinal growth caused by 0 g transit. These projections do lead to a taller door opening (25 cm) and raised railing (14.3 cm) as compared to earth. Stairs and ladders both ended up being related to joint angles and human preferences such that they remain the same as on Earth. Chair heights which also relate to counter heights were looked at by reviewing studies of the sit-to-stand motion and comparing the foot and buttocks reaction forces to the friction forces available on Mars and the Moon verses Earth standard. This leads to a recommendation to use Pub height chairs and counters. Flooring and ramps required scaling and also calculating equivalency values to make comparisons. It was determined that the required friction when scaled to Mars would be possible with fairly standard flooring materials. The Lunar case however, would require a combination of high friction flooring and training for nominal movement. To analyze ramps independent calculations were used for friction requirements and then correlated to a study of emergency personnel pushing a trolley with a patient up or down a ramp. Both these methods correlated to an extremely shallow 2.86 degrees (slope 1 in 20) ramp being possible on Mars and ramps not being usable on the Moon. Based on these factors it is recommended that many of features follow standards used on earth and that only the required changes be made such that the habitation resemble Earth structures as much as possible. In addition, Astronaut training should incorporate these factors into their procedures.

References

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