Examining Transient Motion Cueing and Sustained G Motion

By Robin Valinski

Aircraft motion stimulates the human body’s visual, vestibular, and tactile sensors. Simulators are used to mimic certain motion conditions within an aircraft, but because a simulator is grounded, complete rotational and translational affects of real flight are illusive. However, due to numerous technological advancements over the past few decades, simulators now are able to imitate quite accurately most flight conditions. The degree and quality of imitation, is determined by the capability of the motion system of the device. For this discussion let’s discuss two types of motion: Transient Motion Cueing and Sustained G Motion.

In six degrees of freedom (6 DoF) simulators, the body reacts at the onset of a profile to the initial acceleration. The brain responds and adjusts instinctively to this motion cue, countering it and balancing its affects according to our vestibular system’s personal gauge. Simulation combines cues that arouse the Visual, Vestibular, Somatosensory, and Auditory senses. Theoretically, all motion can be simulated in various forms of simulators from the non motion variety right through to higher fidelity 6 DoF devices but nothing can be sustained. Non-sustained motion is called a Transient Motion Cue. This cueing is suitable training for normal flight conditions in a relatively benign environment such as a commercial airliner on a long haul flight where pitch, yaw and roll are limited.

Transient Motion Cueing is a process by which an impulse is directed but not held. Like the name implies, a Transient Motion Cue is a motion cue which accelerates in a particular direction at a particular velocity, but almost immediately begins to decelerate, albeit more gradually, than it accelerated.

When the directed impulse is coupled with visual cues it fools the human body into believing and responding as if the motion were to continue. Internal physiological systems interpret this continued motion cue, transferring data to the brain. The brain interprets the sensations based upon experience and instinct.

A cue: Sensory signal used to identify experiences, facilitate memory, or organize responses. Such as a visual image of series of lights on a runway.

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1 [http://www.spiritus-temporis.com/six-degrees-of-freedom/robotics](http://www.spiritus-temporis.com/six-degrees-of-freedom/robotics) Six degrees of freedom (6 DoF) refers to motion of a rigid body in three-dimensional space, namely the ability to move forward/backward, up/down, left/right (translation in three perpendicular axes) combined with rotation about three perpendicular axes (pitch, yaw, roll). As the movement along each of the three axes is independent of each other and independent of the rotation about any of these axes, the motion indeed has six degrees of freedom.

A motion cue: Sensory signal used to identify a situation to organize a response. It is a suggestion which fools the body into believing a specific scenario or triggers a natural response in the body based upon instinct and experience.

Such as when a motion base is pitched backward while an image simultaneously appears before the individual of a horizon falling out of view.

But now the signals to our brain are in conflict—our brain has been cued to believe that it must be prepared for a real motion but that never actually happens. This conflict results in motion sickness or coriolis as the transient motion cue washes out.

To prevent wash out we must “hold” the directed impulse or said another way: “sustain” it. This is called Sustained G Motion. We sustain a force by adding either translational or rotational motion forces to the three linear axis, g_x, g_y, and g_z. This is accomplished with the use of a centrifuge. The translational or rotational motion forces created in a centrifuge are applied to the pilot as the acceleration begins and then unlike the Transient Motion Cue, the motion created by the centrifuge is sustained as would happen in a real aircraft under extreme conditions. Sensing the accelerations of the centrifuge, the human body’s vestibular; skin; sensational and proprioceptive systems are piqued and sustained. Because the G motion is sustained, our brain is not in conflict and all physiological systems respond as they would in a real flight. Therefore, the resulting Sustained G Motion provides the truest representation of the flight experience.

Sustained G Motion experience is not only important for the highly dynamic flight environments experienced by fighter pilots, but commercial airline pilots as well due to the high number of Loss of Control (LOC) incidents that have occurred. Effective Upset Recovery and Air Combat Training both require ongoing transference of sensational data from the aircraft to the pilot through the aircraft’s rotational forces giving way to the development and intuitive understanding of the x, y and z axes in linear accelerations.

Relating basic principles of physics to sustained G forces, we are reminded that g is the acceleration in this case as it relates to earth. Thus “grounding” our system in earth’s atmosphere, g = G as it relates to the amount of force applied to an object and all of the components that make up this object. Sustaining G’s, however, is more complicated as we consider the make-up of the human body: bones, circulatory system, muscle and tissue and their associated size, weight and density. The fluid components in particular, offer great challenges for understanding our ability to tolerate G forces. G tolerance is

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affected by things such as the distribution of blood within the body and its viscosity. It is a combination of these and other considerations that make up a truly valid training environment for a combat fighter. For the commercial pilot, a centrifuge can help prepare him or her for any conditions experienced outside the normal flight envelope, i.e., equipment failure or poor weather conditions.

Transient Motion Cueing simulation therefore is simply not enough to provide a realistic tactical flight and upset recovery training experience. In a centrifuge, pilots are exposed to sustained G levels beyond the normal level of human exposure (up to 9 G) as they would in an actual aircraft. Pilots learn to consider and conserve their own energy as well as the energy held by the aircraft. A good fighter or strike fighter pilot is taught to intensify his/her G loading capability preparing him/her for the intense physiological effects of pulling and sustaining G's. And the good fighter pilot knows that flight training without physiological stresses is not flight training. Increased stamina maximizes a tactical pilot’s ability to preserve physical energy for a successful mission.

Tactical flight in Combat Aircraft is very different indeed from flight in Commercial Aircraft. However, both situations have demands for understanding and operating within an extreme flight environment. The commercial pilot’s job is to minimize turbulence, overcome visual distractions and system failures, and limit the effects on passengers and cargo. Unfortunately, LOC events have and continue to remain the number one cause of passenger fatalities. While the combat ready fighter or strike fighter pilot has an entirely different mission—to outlast his/her opponent in an often hostile and foreign environment—both the commercial and military fighter and strike fighter pilots need a solid understanding of the principles required to survive an environment involving extreme maneuvering. Fortunately, both groups of pilots can now better experience the forces of extreme maneuvering in a safe and controlled environment, one that is realistically reproduced by a sustained G high-performance motion system. So in the end, there is a time and place for Transient Motion Cueing; however, when it comes to training pilots in extreme maneuvering, a Sustained G High-Performance Motion system is necessary.

**Flight Training Without Physiological Stresses...**

**...Is Not Flight Training.**

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4 Burton, R.R. Human Effectiveness Directorate, Air Force Research Laboratory, AFB, TX 78235-5118 “Tolerance to Sustained +Gz Acceleration” an article in International encyclopedia of ergonomics and human factors, Volume 2 edited by Waldemar Karwowski
5 [http://www.faa.gov/pilots/training](http://www.faa.gov/pilots/training) While specific values may vary among airplane models, the following unintentional conditions generally describe an airplane upset: Pitch attitude greater than 25 deg, nose up. Pitch attitude greater than 10 deg, nose down. Bank angle greater than 45 deg. Within the above parameters, but flying at airspeeds inappropriate for the conditions.