INTRODUCTION
Although numerous studies have been done on frontal and rear impact collisions and the resulting occupant kinematics, relatively few have considered the effects of lateral impacts on occupant kinematics. Understanding the kinematics of the head during lateral impacts can assist in determining how the passive response of the human body relate to one another when presented with such a stimulus. This information is invaluable in the design of motor vehicle safety systems, amusement park rides, and other situations where an unexpected lateral impact may occur.

METHODS
Fourteen volunteers (nine males, 19 to 59 years, 177.5 ± 3.9 cm, 84.6 ± 11.3 kg; five females, 18 to 58 years, 163.6 ± 2.8 cm, 68.3 ± 17 kg) were subjected to four lateral impacts each (Figure 1). The subject was seated in a stationary bumper car equipped with a triaxial accelerometer (Endevco Corporation, San Juan Capistrano, California, USA). The bullet vehicle was a bumper car operated by a 93.0 kg individual. A contact switch located on the side of the target vehicle triggered the data acquisition and a flash bulb. The average bullet vehicle speed just prior to impact was measured with a Stalker ATS speed trap (Applied Concepts, Inc., Plano, Texas, USA). Coronal plane vehicle and occupant kinematics were captured with a Redlake MotionXtra HG-100K high-speed video camera (Redlake, Tucson, Arizona, USA). The high-speed video was recorded at 250 frames per second at a resolution of 1504 x 1128 pixels, which corresponded to a spatial resolution of approximately 1.5 x 1.5 mm. Targets were placed on the front of a hat and the front of the vehicle to assist in tracking their motions. Image Express software (Itronx Imaging Technologies, Westlake Village, California, USA) was used to track and plot the target motion. The test procedures were approved by an Institutional Review Board at Exponent, and the volunteers gave written informed consent.

RESULTS AND DISCUSSION
The position and velocity of the bumper car and the occupant’s head were tracked through time (Figure 2). The average bullet vehicle closing speed across all subjects and trials was 3.6 ± 0.5 m/s. The average occupant’s head remained stationary for 211 ± 51 ms after initial contact from the bullet bumper car. The target bumper car reached its maximum velocity of 2.6 ± 0.6 m/s at 119 ± 21 ms. The occupant’s head reached its maximum velocity of 4.7 ± 2.4 m/s at 360 ± 72 ms. The consistency of the bumper car’s motion as evidenced by the lower standard deviation contrasts with the great variation seen in the motion of the occupant’s head. For example, an individual’s size, gender, or preparedness may influence his/her response to a lateral impact.

CONCLUSIONS
Having an understanding of how different individuals may respond to a lateral impact will assist in the design of safety systems in automobiles, amusement park rides, and other similar applications.