Background: Recent studies have established that a high proportion of patients diagnosed with mild (or diffuse) traumatic brain injury (mTBI) exhibit binocular vision dysfunctions, particularly deficiencies in the binocular coordination of eye movements. Such a loss of coordination may result in deficits that have pronounced negative impact on their ability of estimating distance to targets in depth, tracking moving vehicles, reading, and other activities of high civilian and military importance, and on the quality of life in general. Effective treatment of these oculomotor problems requires accurate diagnosis of the source of the problem. However, oculomotor control involves an incompletely understood complex of brainstem, subcortical, and cortical pathways, any of which may be disrupted by TBI. Severe brain injury is often visible by structural brain imaging, such as X-radiography or magnetic resonance imaging (MRI). However, milder effects that are invisible to these techniques may nevertheless cause severe oculomotor disruptions in mTBI.

Brainstem Effects in mTBI: The basis of this proposal is the recently established result that what was previously considered to be diffuse brain trauma does in fact have a focal effect centered on the brainstem. The main forms of impact that produced concussion in such head impacts are oblique impacts that caused shear stresses and neural damage in the upper brainstem, precisely the region of the main oculomotor control nuclei for binocular coordination (as inferred from monkey studies and human brain injury cases). This analysis led us to the novel hypothesis that functional imaging in the oculomotor brainstem and cerebellum pathways of the mTBI patients should provide the needed insight into the nature of the deficit that is persistently clouding their lives. We have recently been successful in making the first neuroimaging measurements of oculomotor activation in the brainstems of humans (or any other species). This breakthrough will allow us to test this hypothesis with innovative fMRI studies of the functional losses in each oculomotor nucleus in the brains of the mTBI patients. We will also determine the eye movement capabilities with extensive measurements of both the dynamics of the eye movements and the way the two eyes work together in a large control population for evaluation of this behavior in the group of mTBI patients.

Relation to Health Care Needs: The control of the ocular convergence or divergence of the viewing axes of the two eyes (or, more generally, vergence control) is a generally under-rated visual capability, although it is critical for maintaining the single percept of the separate images from the two eyes (Strube and Büttner, 2007). When vergence control is disrupted, we have binocular difficulties, such as confusing “double vision,” or diplopia, of perceiving the two separate images overlaid on each other, making it difficult to read, drive, coordinate visually guided hand movements, estimate distance in depth, and so on. Since there are two images of everything, we no longer know which is the “true” object, disrupting the sense of the space around us and the locations of the objects within it. Disorders of binocular vision thus would have a severe impact on most of the activities of everyday life in affected mTBI patients.

Potential Impact: The potential impact of the current proposal in understanding for the first time which specific brain structures/nuclei are injured to cause visual dysfunctions associated with mTBI in both the military and civilian populations is extremely significant. It is well documented that these dysfunctions have a profoundly negative impact on both the ability of performing military or other professional duties and on the quality of daily living. However, current clinical interventions for such visual dysfunctions are controversial and guided by untested hypotheses and clinical trial and error studies. The development of successful diagnostics, medical treatments, and
rehabilitation must be guided by a detailed understanding of the brain injury that causes the dysfunctions. This proposal will provide the first accurate knowledge of the oculomotor pathways in the human brainstem and their functional and structural changes in mTBI patients. Thus, the proposed study will not only provide new scientific knowledge, but this knowledge will have a huge potential for improving the lives of hundreds of thousands of troops and civilians with mTBI and related visual dysfunctions.