Transcranial Magnetic Stimulation (TMS) is a non-invasive neuromodulation technique that is growing in acceptance by the medical community and the general public. TMS was approved by the U.S. Food and Drug Administration (FDA) for treating major depressive disorder (MDD) in 2008, certain types of migraine headaches in 2013, obsessive-compulsive disorder (OCD) in 2018, and short-term smoking cessation in 2020. Researchers are also investigating how TMS can be used for enhancing the recovery of motor functions after a stroke as well as other debilitating illnesses. Investigating the biological mechanisms involved in the brain’s response to TMS is a growing area of study with many challenges. Two of the largest hurdles for researchers to overcome are the ethical standards and safety regulations that protect animals and people during the testing of new TMS devices and TMS protocols on subjects. In order to address these issues, researchers use two types of models (computer and biological) that recreate the brain and its components for TMS research. Computer models are used to simulate the neurological system’s responses to the magnetic fields generated during TMS. They are used to simulate the effects of new coil designs and stimulation protocols on different types of head models (i.e., a healthy brain versus a brain damaged by head trauma).  Biological models use cell culture lines developed from animals. Cell lines recreate the aspects of the cells in the human brain that are affected by TMS.

The research presented in this dissertation shows the experimental results using both types of models to investigate the underlying mechanisms of TMS. Computer models were used to investigate the effects of novel coil designs on head models derived from MRI scans. Two types of biological models were used to investigate, at the cellular level, the effects of magnetic fields generated by a commercial TMS system on neuronal cells in vitro.