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Private sector neurotechnology:

While development in the area of neurotechnology is currently extremely rapid, there are a limited number of mature technologies that have been enjoying substantial application in the biomedical sector. Two in particular are in use in a large clinical population: cochlear implants to provide some sound input to deaf individuals, and deep brain stimulators for individuals with neurological disorders such as Parkinson's Disease and essential tremor. Both of these products provide signals to the central nervous system. Also in clinical testing is a product to provide visual input to the blind called *Second Sight*. Technologies for taking signals from the brain to control computers, robotic arms, etc., are now also in rapid development, and two companies, *Cyberkinetics* and *NeuralSignals* are doing clinical testing. These technologies are highly invasive, requiring implants directly into the brain, and so widespread application may be limited to individuals in extreme need.

To date, cochlear implants have had three main types of problems: an increased likelihood of meningitis; incidental damage to or stimulation of nearby neural, particularly the facial nerve which serves movement of facial muscles and taste, and the vestibular apparatus which helps with balance; and post-implant device failure.

Deep brain stimulators have also been associated with a variety of possible problems, including infection, side effects from the stimulation itself, bleeding into the brain, and failure of the devices. The rates of these side effects appear also to be in the 5-20% range, depending on the estimates, and are probably consonant with the level of side effects one would expect with other types of brain implant. A more complex side effect has been reported in the case of individuals who have two implants installed in the same surgery: some of these patients show transient cognitive or emotional changes that can last for weeks after the surgery.

In addition to these invasive technologies, there has been a recent growth in non-invasive neural interface technologies. Many of these techniques are outgrowths of clinical tools that have been used diagnostically, but that have been found to have robust signals that vary with neuronal activation. These include near-infrared imaging, magnetic resonance imaging and magneto-encephalography, electro-encephalography, and more recently an electrical monitoring device that can be worn around the neck to "interpret" speech. These methods have all been thought to measure signals that were too slow for complex applications such as control of a robotic arm, but work in the last five years suggests that may not be true.

Despite these problems, the projected benefits are adequate to expect an increasing growth in neuronal implants. Recent reports suggest that biomedical applications of neurotechnology will be an 8.8 billion dollar industry by 2012.

In addition, there are likely to be applications outside of the biomedical realm, particularly in the areas of gaming and the military. At the present time, the technologies involved in an individual neural interface are probably prohibitively expensive for most individuals, and those costs can only be borne by wealthier individuals and by the military. However, the expected cost of the technologies may drop if the market grows to reasonable proportions.

