Engineering 1

[00:00:02.30] In this sequence of lectures, we're going to review principles of engineering, common neural engineering devices that already exist, and methods of measuring the brain and nervous system. First, I want to draw a distinction between engineering and science. The goal of engineering is primarily oriented towards designing tools, systems, or machine that manipulate the environment as their primary goal. And it's oriented towards products and implementations, so the ultimate goal is to build something that can change the environment around you and make that a reality. And it can be considered an applied form of research.

[00:00:42.58] And in contrast, the goal of science is primarily to identify phenomena, objects, or patterns in the natural world around us. And any time we manipulate the environment, such as for an experiment, it's to look for a pattern or an effect. And that's not the primary goal of our experimental designs. It's the design itself is not the end goal. And it's oriented towards knowledge and creating scientific theories.

[00:01:10.81] Which a scientific theory is not like a colloquial theory, which is like a guess. A scientific theory is a model that describes the world and the rules that it follows. And it can be considered a basic area of research which doesn't mean easy or simple. It means fundamental. It describes the base principles of the world around us.

[00:01:37.89] So I've listed here some of the most common and widespread areas of engineering. And those that contribute primarily to neural engineering are materials, computer science, electrical, mechanical, biological, or biomedical, and nanoengineering. And, of course, also contributing to neural engineering is neuroscience, psychology, math, philosophy, and all of the various fields of medicine that are involved in the care of individuals who are receiving neural and engineering treatments, including neurology, neurosurgery, psychiatry, rehabilitation, medicine, orthopedic surgery, physical therapy, occupational therapy, nursing care, nursing care for all of these specific specialties as well, and more.

[00:02:28.94] As we consider any area of engineering, not just neural engineering, we have all of the different components of a design. What is the goal of the design? What do we want to accomplish? Who will use it? A design that doesn't have a user is not very useful. What does the user actually need, and what is their situation? How can we develop a device that will actually meet the real-life needs of the individuals who we hope will use it and will be practical for their everyday use? What kind of design obstacles, such as the size, weight, material of the device do we need to overcome? As well as the financial obstacles especially in the manufacture of the device and in its adoption. What are the intermediate steps or designs that we can test out like incrementally in order to develop the more complex higher level design? Especially important for neural engineering where many treatments are not easily reversible, and the disease and damage can be severe. What are the risks, known issues, defects, and other liabilities in the design?

[00:03:37.62] And finally, how long will it take to design and manufacture the device? Every time we discuss a neural engineering device for the rest of the course, remember this slide. Remember this list of criteria that any design needs to incorporate. In addition to all of the other design considerations that apply to any engineering device, there are a variety of additional considerations that are special or unusual in neural engineering even relative to other biomedical engineering.

[00:04:11.62] Neural engineering deals with an extremely diverse user base in terms of injury or disease type, age, and level of capability and as a consequence requires an extra level of end-user input and adaptability in order to design devices that users will actually want to and be able to use. Because of the implementation of neural engineering devices requires a significant amount of medical care and support, it needs to be able to fit into existing care frameworks, it needs to be medically feasible, and designers need to be able to provide training for care providers.

[00:04:57.11] FDA approvals which provide consumer protections for medical devices can take up to 10 years to acquire, and in that period where its an experimental device, it can be implemented in a limited way experimentally, but it can't reach a wide user base. The cost of neural engineering devices, both for their initial implant or installation and for their maintenance, needs to be considered as well. Neurological conditions are extremely expensive to treat, and if the device isn't covered by a patient's insurance, they are unlikely to receive it. The long-term maintenance of these devices would also need to be a major consideration because they're designed for lifetime use.

[00:05:42.71] A person isn't going to likely be using a neural engineering device for a year or two years. They're going to want to use it for the rest of their life. So if a company develops a neural engineering device and then goes out of business, who is going to maintain it? The number of users for neural engineering systems is also quite low. Especially relative to general engineering systems outside of the world of biomedical engineering.

[00:06:11.87] And finally, the nervous system itself provides a number of unique and major challenges with regard to the immune response, the specificity, and level of injury that can be caused in the nervous system and the complexity of the nervous system itself. This is one way of thinking about the process of engineering a device. So you start by identifying a problem. This could be that the existing designs for that solution are inadequate or they just don't exist. Or it could be a new design need has emerged. And you start by coming up with the design, doing research, and brainstorming possible solutions, which you would then build and then test with users or test subjects. If it didn't work, which it probably won't on the first time around, you refine the design, go back to the research process, and build it again. And then continue cycling through this process until it works and then you release the design.

[00:07:15.44] The cycle of science is pretty similar. You start by identifying the problem, which in science might include answering the question, modeling a system, or connecting to known systems in a new way, or any other thing that you might want to discover about the natural world. You design an experiment to try to determine the answer to your question. Then you collect data, analyze, and interpret your data.

[00:07:42.50] If you didn't answer your question on your first try, which you probably won't, you identify points of clarification, ways that your experiment could have worked better, or new things that you need to figure out, design another experiment, or redesign your first experiment, collect data and continue until it worked. And then instead of releasing the design to a user base, you would publish your results so other people know what you learned. And eventually, the findings of your science might appear in an engineering design. That's not the end goal of all scientific experiments. It's not the point of science to be used for engineering, but in especially in neural engineering, that is definitely a major role of the scientific research.