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Could ‘nerves of steel’ guide sensory signals?

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Abstract

This article makes assumptions of the consequences of having coaxial steel cables for nerves. It is found that if a person would have coaxial steel cables instead of axons, the body would have to find a way to impose an initial potential of about 90 mV onto the beginning of this axon since the signal is now passed on passively instead of actively. This signal is however not seriously damped within the cable. This nerve would however be able to handle impulses of a higher frequency at a higher speed, allowing one to have a higher maximally ‘feelable’ intensity of sensations.

Introduction

‘Having nerves of steel’ refers to someone having ‘an impressive ability to remain calm in dangerous or difficult situations’, according to Webster [1]. Since this expression is widely spread, even throughout multiple languages, it is interesting to examine the hypothetical consequences of it. This article explores some of the effects on the guiding of sensory signals that steel nerves, or rather having steel wires instead of nerves, might have on the human body.

Normal nerves in a nutshell

The cells which are discussed in this article are called “neurons”. The neurons considered here are assumed to have one long “axon”, which is the long arm of the cell that is connected to a sensory cell. Due to the nature of the expression that is examined, the words “axon” and “nerve” are used as synonyms whereas in reality a nerve is a bundle of axons.

In an ordinary human being, the nerves act as a guide for an action potential [2]. This means that locally, the charge density within the nerve differs from that just outside the nerve. This potential is generated and extinguished by the entrance of Na^+ and exit of K^+ ions respectively, through gates in the membrane of the nerve that let these ions in or out. The local peak in potential is then passed on to the adjacent region of the nerve, all the way to the synapses that through this system receive the signal to release their neurotransmitters. The axons of the nerves are surrounded by a layer of myelin (assumed 2 μm thick [3]) with the exception of small, periodical bare regions where the ion-exchange happens.

Guiding signals

If nerves were not made of cells with membranes with gates for ions but rather consisted of steel, as is assumed in this research, naturally the guiding of signals through the body could not depend on the exchange of ions through a membrane. If it is assumed that the synapses of the original nerves somehow are attached to these steel wires, and that these synapses will need to receive a signal similar to that received by normal nerves in order to work properly, the steel nerves are required to deliver a pulse of about 90 mV against a resting potential of -60 mV (therefore causing a peak potential value of 30 mV [1]). The steel nerves are considered to be coaxial cables, with the outer radius minus the inner radius equal to the thickness of the myelin layer of the original cell.

The way ordinary nerves work, only a 15 mV signal has to be imposed onto the resting potential at the starting end of the nerve in order to reach the threshold potential that starts the ion-exchange process which takes care of the peak potential having the correct value [2]. Since nerves of steel do not have this ion-exchanging system, the signal that is imposed onto the starting end of the nerve needs to be great enough by itself to deliver the peak of 90 mV above resting potential to the synapses. It is thus assumed that the cell delivering the trigger to the nerve is able to impose a voltage great enough to create a 90 mV voltage above the resting potential at the nerve’s end. Since the expression ‘having nerves of steel’ refers to the sensory rather than the motoric system, it is assumed that the signal is imposed by some sensory cell.

In order to assess how great the starting potential has to be, a calculation is needed on the damping of the signal that happens due to the fact that the nerve is now a coaxial cable guiding a signal of some frequency. The inner and outer conductors are made of steel, and the dielectric material in between them has the same dielectric constant as myelin which is found around ordinary axons as we want our steel nerves to resemble ordinary nerves as much as possible. The calculations require further assumptions: the length of the nerve is taken to be 1 m, and the inner radius 5 μm, based on the order of magnitude of the radius of axons in the human body [3]. It is assumed that the signal will be damped exponentially by:

$$V(x,t,T) = e^{-\sigma x} V(x_0,t,T), \tag{1}$$

in which σ is given by:

$$\sigma = \frac{R\sqrt{C}}{\sqrt{2L}}\left(1+\sqrt{1+\frac{R^2T^2}{4\pi^2L^2}}\right)^{-\frac{1}{2}}, \tag{2}$$

with R the resistance of the cable (here taken to be that of the inner conductor), C the capacitance, L the inductance and T the period of the signal. The derivation of this equation is too long and complex to include in this paper, but can be found in the references [4]. R, C and L are given by:

$$R = \frac{\rho l}{A}, \tag{3}$$

$$C = \frac{\kappa\epsilon_0 2\pi}{\ln\left(\frac{b}{a}\right)} l, \tag{4}$$

$$L = \frac{\mu}{2\pi}\ln\left(\frac{b}{a}\right) l, \tag{5}$$

Where ρ is the resistivity of steel, l the length of the cable, A the area of the inner conductor, κ the dielectric constant of the (myelin-like) dielectric, ε_0 the electric permeability of vacuum, a the radius of the inner conductor, b the radius of the inner conductor plus the thickness of the dielectric, and μ the magnetic permeability of the dielectric. These equations give the following graph:

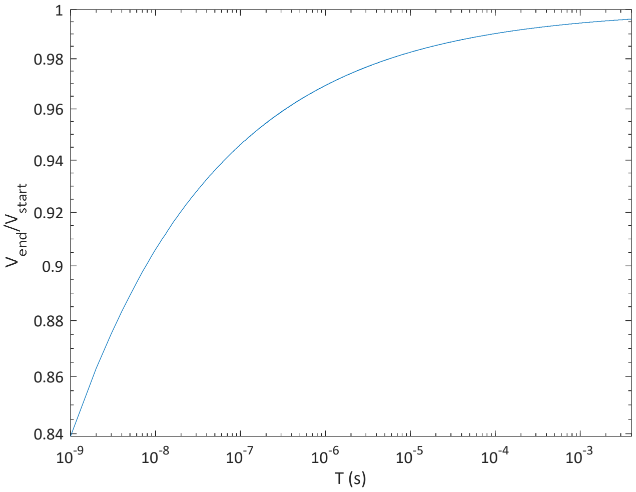

Figure 1 – Relative transmission of the signal vs. period of the pulse

It can be seen at a period of a couple of milliseconds, which is typical for nerve impulses [2], there is practically no damping (about 0.5 to 1%).

Another consequence of the impulse now travelling through a coaxial cable is a very high signal velocity of a couple of tenths of the speed of light. Also, because of the fact that no use is made of a system of gates for ions, there is no refractory period required other than some minimum interval to prevent signals overlapping. Since the intensity of a sensory sensation depends on the amount (or frequency) of the pulses delivered through the nerve (rather than the magnitude of the pulse, which is always the same), steel nerves would allow for the owner to sense more ‘intense’ things. This is not the same as being able to sense smaller stimuli (softer sounds, weaker smells, less light, lighter touch) but it rather increases the upper limit of what one could sense (louder noises, brighter lights, more pain), assuming that the cells receiving the signal are capable of handling higher frequencies.

Conclusion

In conclusion, having nerves of steel has a negative impact on the body in some ways (for example that the initial potential needs to be as high as the actual action potential) but a surprisingly good one on others (there is no refractory time needed so one will have a higher limit to maximally intense sensations and the signals are transported through the nerve much faster). Whether or not this helps one remain calm in a dangerous situation however remains up for speculation.

References

[1] Merriam-Webster (2019) *Nerves of Steel*. Merriam-Webster.com. Available at: http://www.merriam-webster.com/dictionary/nerves%20of%20 steel [Accessed 4th February 2019].

[2] Freudenrich, C. (2018) *How nerves work*. Health.HowStuffWorks.com. Available at: https://health.howstuffworks.com/human-body/systems/nervous-system/nerve4.htm [Accessed 4th February 2019].

[3] Graf von Keyserlingk, D. & Schramm, U. (1984) *Diameter of axons and thickness of myelin sheaths of the pyramidal tract fibres in the adult human medullary pyramid*. Anatomischer Anzeiger **157,** 97-111.

[4] Hashemi, K. (2008) *Transmission Line Analysis*. Brandeis University. Available at: http://alignment.hep.brandeis.edu/Lab/XLine/XLine [Accessed 4th February 2019].