Transmission of Information in Active Channels

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Shannon's Capacity Theorem is the main concept behind the Theory of Communication. It says that if the amount of information contained in a message, to be transmitted through a physical channel of communication, is smaller than the channel capacity, the message can be transmitted with a low probability of errors. This theorem is usually applicable to ideal channels of communication in which the information to be transmitted does not alter the passive characteristics of the channel that basically tries to reproduce the source of information. Here, we show that for active (non-ideal) channels of communication, such as a complex network formed by elements that are dynamical systems (such as neurons, chaotic or periodic oscillators), the information signal entering the network might generate the ideal environment for its transmission by altering the information capacity of the channel. We also show in which conditions synchronization, in an active channel, implies more information transmission. Contrary to the current belief, we show that synchronization does not necessarily imply more information transmission.

Shannon's Capacity Theorem [1] imposes a limit in the amount of information that can be transmitted through a channel (physical media). This limit, regarded as the channel capacity, is a characteristic of the channel and independs on the nature of the information signal to be transmitted. If we think of our mind/brain as a physical channel of communication, our capacity to process information would be physically bounded. However, the experiments in [2] show that humans can reproduce a rapidly presented series of no more than seven (+/-2) words or random letters in correct serial order [2] (see also [3]). That points to that our brain capacity may change in order to account for the relative invariance of this "magical number seven" across widely differing amounts of information contained in such "messages". For example, if letters are taken as the fundamental unit of information, then seven words each composed of, say, five letters represent a much larger amount of information than seven random letters. Thus, given the ability to recode bits of information rapidly into meaningful "chunks", the classic Channel Capacity Theorem is obviously not a sufficient framework to characterize the capacity limit of short-term memory. One of the keys to understanding the capacity of our Mammalian brain machinery to transmit information relies on the complex interaction between external stimuli and our intelligent "channel of communication", our brain. Here, we show how the information-theoretical concept of an active channel will account for such adjustments of capacity for information transmission and provide, once again, a formal basis for modeling complex cognition.

Synchronization is vital for modern methods of digital communication that rely on the synchronous operation of many subsystems [4]. Similarly, transport networks depend crucially on the synchronous operation of each subnetwork. If one subnetwork gets out of synchrony, the whole network might failure to function properly. So, it would be intuitive to say that complex systems should have subsystems that operate in synchrony for a proper functioning. In fact, synchronization between neurons in the brain is believed to provide a good environment for information transmission. This comes from a fundamental hypothesis of neurobiology [5–8] that synchronization [9, 10] functionally binds neural networks coding the same feature or objects. This hypothesis raised one of the most important contemporary debates in neurobiology, but is still controversial [11–13] because desynchronization seems to play an important role in the perception of objects as well.

In this work, we build a bridge between Shannon's Theory of Communication [1] and the Theory of Information in dynamical systems [14] contributing to the development of a nonlinear Theory of Communication, shading some light in these two paradigms of experimental psychology and neurobiology. These new ideas, concepts, and theoretical approaches unravel the relation between stimuli, information capacity, and synchronization, in a nonlinear media of communication, the active channel, a network formed by elements that are dynamical systems. In addition, we provide more analytical insights in order to better understand the conjecture in Ref. [15] that shows how to calculate the amount of information exchanged between two subsystems in a chaotic network, and generalize it to other types of active channels as the ones formed by periodic dynamical systems or the ones formed by two time-scales bursting/spiking neurons.

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