The hypothesis of connecting two spinal cords as a way of sharing information between two brains and nervous systems

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Direct communication between different nervous systems has been recently reported through brain to brain interfaces and brainet. Closed loops systems between a brain and the spinal cord from the same individual have also been demonstrated. However, the connection between different nervous systems through spinal cord has not yet been considered. This paper raises the hypothesis of connecting two spinal cords (spinal cord – spinal cord connection) as an indirect mean for communication of two brains and a direct way of communication between two nervous systems. A concept of electrical drug or electrical fingerprint of a chemical drug is introduced. The notion of the connection between two parts of the same spinal cord to treat a paraplegic patient is also introduced. It is discussed that external information injected to a spinal cord as well as spinal cord – spinal cord connection can become new tools to 1) study the physiology of the nervous system, 2) modeling specific behaviors, 3) study and modeling disease traits 4) treating neuropsychiatric disorders and 5) information sharing between two nervous systems.

Keywords

Spinal Cord; Spinal Cord Stimulation, Brain-to-brain Interface, Spinal Cord – Spinal Cord connection
INTRODUCTION

In February 2013, it was reported that it was possible to share sensorimotor information between the brains of two rodents (Pais-Vieira et al. 2013). Soon after, other works corroborated this phenomenon, others have demonstrated that it is possible to transmit information between the brain of a human and the brain of an animal and between the brains of two people (Deadwyler et al. 2013), (Yoo et al. 2013), (Grau et al. 2014),(Rao et al. 2014),(Stocco et al. 2015). In 2015, it was demonstrated that it is possible to connect the brain of more than two animals creating what was coined brainet (Pais-Vieira et al. 2015; Ramakrishnan et al. 2015). It was already shown that it is feasible to form a closed loop for artificial communication between a brain of a primate and its spinal cord (Zimmermann & Jackson 2014). However, the communication between the nervous system of two different animals through a connection of the spinal cords has not yet been considered. The hypothesis presented in this paper was inspired, in part, on the published work and protocol regarding spinal cord stimulation to treat epilepsy induced with pentylenetetrazol (PTZ) (Pais-Vieira et al. 2016), the papers and protocols of brain-to-brain interface (Pais-Vieira et al. 2013), brainet (Pais-Vieira et al. 2015; Ramakrishnan et al. 2015) and also by the application of spinal cord stimulation to treat rodents models of Parkinson’s Disease (Fuentes et al. 2009).
THE HYPOTHESIS

This paper proposes the hypothesis that it might be possible to share information between the nervous system of two rodents through the connection of their spinal cords.

The evaluation of the hypothesis

To test the hypothesis, adults Long Evan rats weighing between 250 g – 350 g will be used. Each rat will be implanted with both brain electrodes and spinal cord electrodes. The brain electrodes will be implanted in the right M1 and left S1 areas according to the procedure described in previous works (Pais-Vieira et al. 2016). These electrodes aim to record the Local Field Potential (Lin & Gervasoni 2011) as well as single unit activity (Wiest et al. 2008). The spinal cord electrode will be implanted under the thoracic vertebrae 2 (T2) as described before in a work about spinal cord stimulation in rodent models of Parkinson’s Disease (Yadav et al. 2014). As each spinal cord electrode has two leads, the connection cable will consist of two wires that will be plugged to each lead. This cable will have a switch to establish or interrupt the connection between the two spinal cords. The signal to be transmitted or shared between the two rats will be seizures activity provoked by the injection of Pentylenetetrazole. The procedure to induces seizures with PTZ is described elsewhere(Pais-Vieira et al. 2016). Besides the electrical recording of LFP and single units, the seizures activity and the behavior of the animals will also be monitored using a video recording system. The protocol for the connection of the two spinal cords is summarized in Figure 1 (A and B). After injecting the sender rat with intraperitoneal PTZ, the simultaneous LFP and video recording session of the two rats will begin. However, during the first five minutes, no connection between the two spinal cord will be made to allow a baseline recording where the sender rat will have seizures episodes and the receiver rat will not experience seizures. Following this period,
the switch of the connection cable will be turned on to establish the connection between the two spinal cords. It will be created an induction period of about 23 minutes to allow a free communication between the two nervous system. After this time, the connection will be switched off for 5 min. After that, it will follow an ON/OFF periods of 5 min each meaning that the connection will be established during five minutes and then also interrupted during 5 minutes. The total duration of this experiment will be 60 minutes counting from the beginning of the baseline recording. During the whole experiment, the seizure activity will be recorded in video, single units and LFP.

### DISCUSSION

1. **The receiver rat will have seizures after the connection of the two spinal cords**

After the first connection of the two spinal cords, it is expected that the receiver rat will develop seizures after few seconds/minutes. This seizure would be caused by the electrical information that codifies the seizures induced by the chemical substance PTZ.

This can show that the spinal cord can be a way to send codified electrical information
from an external source to the cortical region of a receiver. It may also show that the artificial bridge between two spinal cord will be possible even with a direct connection without amplifiers.

2. Once induced, the receiver rat will experience seizures episodes even during the disconnected periods

One can speculate that this would be possible due to the property that neuronal network has to memorize and reproduces repeated electrical activity and also due to neuroplasticity. The fact that the information is coming from an external source would not be an exception to this neurophysiological phenomena (the source of neuronal code can possibly be of any kind, either from another animal – such as in this case – or from a computer for example). Indeed this can be a mechanism that would have physiological applications such as 1) modeling and study of stimulus codifying neurophysiological mechanisms or behavior that can be injected in the nervous system via the spinal cord; 2) modeling of disorders: an information that codifies a specific trait of disease can be injected in the nervous system via the spinal cord.
Of the several futuristic speculations, the author would like to highlight the notion of an electrical drug (Figure 2). For example, when PTZ is intraperitoneally injected on an animal, there will be seizures activity recorded on the brain LFP. If this neural activity (neuronal code) is injected (or delivered) in the spinal cord of a second animal, it is hypothesized that the second animal will have brain LFP that is equal to the LFP caused by the drug that is injected intraperitoneally.

Another notion is that one can connect two parts of the same spinal cord in a paraplegic or tetraplegic patient to send information from the spinal cord portion below the lesion to the spinal cord segment that is above the segment (Figure 3). Moreover, this connection can be combined with other treatment approaches for paraplegic patients such as stem cells graft, walk again projects or spinal cord stimulation.
Spinal Cord-Spinal Cord Connection can be a new way of sharing information between two nervous systems. Complex codified electrical stimulation (such as the PTZ causing seizures) can be memorized and reproduced by the brain of a receiver. This principle may allow new methods to study neurophysiological process in the brain as well as new tools to model neuropsychiatric disorders. The connection of two spinal cords causes a shunt of the information from an affected animal to a healthy one. This property can also be used therapeutically. The protocol proposed here can create a connection between two spinal cords that does not use amplifiers. A concept of electrical drug or electrical fingerprint of a chemical drug is introduced. The notion of the connection between two parts of the same spinal cord to treat paraplegic tetraplegic patients is also introduced. It can be said that information injected into the nervous system through the spinal cord as well as spinal cord – spinal cord connection can allow news ways of 1) study neurophysiology, 2) modeling specific behaviors, 3) study and modeling disease traits, 4)
treatment of neuropsychiatric disorders and 5) information sharing between two nervous systems.

CONFLICT OF INTEREST

None
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