Handwriting with Brain Computer Interface

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Abstract. BCI is the acronym for “Brain Computer Interface”, which is now used to help the patients who suffer severe spinal cord injuries to interact with the world. The BCI will record the neuronal activities from the upper motor neurons, and subsequently, the scientists can analyze and decode these neuronal activity signals to enable the patients to interact with their surroundings. R. Wilett et al., conducted a study to use BCI to allow paralyzed patients to perform handwriting, which is one of the most essential steps for the patients to communicate with others. In this essay, the paper written by R. Wilett and his team will be reviewed, and thoughts on the future development of this technology will be given at the end.

1. Motor system
Motor system is essential for humans to initiate and perform some specific movements. There are four primary motor centers in motor system, which are upper motor neurons, lower motor neurons, cerebellum, and basal ganglia. Upper motor neurons are specified to initiate a movement, and then the upper motor neurons send signals to the lower motor neurons. Lower motor neurons then receive the signals and proceed it to the skeletal muscles to do the movements initiated by the upper motor neurons. Cerebellum can detect and correct the existing errors between the movement command and the movement outcome. Therefore, it allows the patients to perform precise and accurate movements. Basal ganglia can detect unwanted movements and prevent them from proceeding. For example, if people want to move their right hands, basal ganglia will shut the unwanted movement such as moving left hands. There are plenty of other things that basal ganglia can do for the human body, inhibition of unwanted movements is one of them and it is vital. Motor system can help us to interact with the world around us. When we are playing basketball with our friends, there are a lot of movements involved in this. We need to be able to shoot the ball, pass the ball, run for the ball and so on. Unfortunately, the people with spinal cord injuries cannot perform such simple movement because they are lacking some parts for their motor system. And it is where Brain Computer Interface steps in and tries to help these patients to communicate with the world as normal.

2. BCI relation with motor system
Brain Computer Interface (BCI) gives the patients a chance to communicate with the world. BCI involves recording neuronal activities from the brain and subsequently, the scientists can decide what the patient is intending to do from the recorded neuronal activities. The structures of the motor system make BCI applicable. It involves the upper motor neurons, where it remains intact after severe spinal cord injuries. If the upper motor neurons are not intact after experiencing severe injuries, the investigation will not be applicable because the patients still need them to initiate a movement so that
the scientists can analyze the neuronal activity signals generated. The lower motor neurons of the patients might be damaged, but BCI can ignore this loss and help the patients to perform the movements in a different way. In other words, the patients will not perform the movement by hands, but only in their brain. After carefully analyzing and decoding the neuronal activities from the upper motor neurons, the scientists can display the patients’ thoughts on the screen or other devices.

3. Description of the paper (High-performance brain-to-text communication via imagined handwriting [1])

R. Wilett et al., conducted a study to use BCI to enable paralyzed patients to perform handwriting. The patients of the study have experienced a high-level spinal cord injury, which makes them unable to move their bodies. The scientists are trying to apply BCI in this condition to see whether they can help the patient to perform handwriting despite being unable to move. To do so, the scientists used arrays of microelectrodes to record the neuronal activities from the precentral gyrus - the part of motor cortex dedicated to perform voluntary movements. In this condition, the precentral gyrus is being used to help the patient to perform handwriting. The scientists instructed the patient to imagine writing specific letters. Even though the patient is paralyzed, and cannot write any letters, they can still imagine doing the handwriting using their upper motor neurons. The scientists found different patterns of neuronal activities when the patient was imagining writing different letters. This allows the scientists to decode the imagined handwriting of the patient from the recorded neuronal activity signals.

The figure 1 demonstrates whether neural representation of handwriting in the motor cortex will remain intact or not when experienced a severe motor injury like paralysis. As the paper suggested before, the patient has experienced a high-level spinal cord injury from neck down. Figure 1 informs us that the neural representation of handwriting in the motor cortex does remain intact because the patient exhibits different patterns of neuronal activity in the motor cortex when being told to imagine writing different letters. There are blue and orange parts that represent the intensity of the neuronal activities. The blue color represents low intensity, which shows that the patient is possibly not imagining the letters. The orange part represents the high intensity, which demonstrates that the patient is imagining the letters and the neurons are getting more involved. For each letter, the patient has provided different patterns of neuronal activities. The figure informs us the way that the scientist instructs the patient to imagine writing a letter. The scientists tell the patient to imagine writing by giving them signals such as 'prepare' and 'go'. The patient receives the signal and starts to imagine themselves handwriting. The results have been quite clear and the patient has successfully written alphabets. Even though the patient cannot move their hands, the scientists can still decode how the patient would be moving the pen to write some letters from the neuronal activities in the motor cortex. The neuronal activities not only inform us what letter the patient is intended to write, but they also tell us the trajectories of the imagined hand movement of the patient that ultimately results in the letters. The neuronal activity was found to have motoric encoding. It means that if letters are written in similar ways such as 'm' and 'n', then the neuronal activities will be similar. The motoric encoding will allow the scientists to distinguish the letters more precisely. There are also some overlappings of signals of x and y. That is possibly caused by not only the similar shapes but also the ambiguous way of writing these letters, which, therefore, makes it challenging for the scientists to decode what the patient is trying to write. In order to solve this problem, the scientists use an autocorrector in the following investigation, which helps them to distinguish between those letters. For example, the autocorrector will correct 'yage' to 'wage' whenever it is detected. I think there is another way to solve this problem. Despite this method seems complex to perform, the scientists can instruct the patient to imagine writing in reverse order for ambiguous letters. For example, when the patient imagines writing the 'y', they can start from the bottom of the letter instead of the normal writing order. This will end up with different neuronal activities, and that will allow the scientists find it easy to distinguish between letters such as 'x' and 'y'. Eventually, the scientists will gain more benefits than just using autocorrect to manage the problem as it can sometimes be limited.
The results also tell us that the average error rates and the typing speed without autocorrect is 90 characters per minute with a 5.4%-character error rate.[4] That means to write 100 characters, the patient will only make around 5 mistakes with the speed of 90 characters per minute. Autocorrect methods can increase the successful rates of writing characters. When applying autocorrect methods, the average error rates fall to 3.4%. [5] The people who do not suffer severe spinal injuries type 190-200 characters per minute in average. [6] Compared to the normal average typing speed, the speed that the patients can type is still astonishing due to the severe injuries they suffered. In the investigation, the scientists asked the patient to imagine writing the following sentence, "you must be the change you wish to see in this world.", and "daisy leaned forward, at once horrified and fascinated." For the former sentence, the patient surprisingly does not have any error while imagining themselves to write it. For the latter one, it misspelled 'n' to 'r' for the word 'leaned', adds another 'o' to word 'horrified', and misspelled 'n' to 'r' again for the word 'the'. Although there are mistakes, but it is still a huge accomplishment for the patient.
4. Why do scientists use electrodes

In the investigation, the scientists implant electrodes in the precentral gyrus inside the brain. There are problems of using electrodes, such as they are implanted in the brain. It requires surgery to implant electrodes, and it will have risk of infection. After the investigation, the scientists will need to do another surgery to remove the electrodes. There seems to be other solutions which can be better than using electrodes. EEG, electroencephalography, as a non-invasive method, seems to have less risk than the electrodes. EEG is not expensive, which can be much easier to get for some scientists. EEG can be placed on the head so it does not require a surgery to place it or remove it. But EEG would only detect gross movement, so it cannot detect fine and precise movements such as the movements of the hand during handwriting, and they cannot decode fine movements because the spatial resolution and temporal resolution of EEG are too low. It means that EEG does not detect the activity of single neurons. Instead, it detects gross neuronal activity which is the average of plenty of neurons. To make the investigation applicable, the scientists need to have a clear and precise image of the neuronal activities of the neurons. Therefore, employing electrodes is still a better option since it goes deeper in the brain and they can decode fine movements, and the implanted electrodes have higher spatial resolution than the EEG. The scientists can analyze and examine the activities better and dedicate them to each alphabet.

5. Generalization of BCI

This paper shows that BCI is an astonishing and successful new tool for handwriting, and possibly it can be extended to be widely used in further areas. It can record the neuronal activity underlying each imagined alphabet and translate those into writings. BCI could also allow paralyzed patients to communicate with the world in other ways. The brain of the paralyzed patients is still intact and functional, BCI can understands it and dedicates itself to help those paralyzed people. BCI may be applied in other areas in the future, and it is exciting to see how far BCI can help the people. BCI is not limited to displaying the imagined handwriting of paralyzed patients, but it may can also be used in other areas in the future, for example in simulating playing video games. BCI can monitor the patient to imagine holding a controller for the game, and imaging to be playing the games. Then, the BCI can decode the neuronal activity and displace their imagination on the screen. In the future, as the paralyzed people can sometimes ‘write’ faster than non-paralyzed people, the patient can possibly beat the non-paralyzed people through video games!
6. References

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