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Synchronized presentation of a language task to the electrical stimulation of cortical regions during speech mapping in an awake surgery

Abstract: Intraoperative speech mapping is performed to preserve language function during tumour resections that involve eloquent cortical areas. For this technique the synchronization of the picture presentation to the patient with the electrical stimulation of the cortex is of major importance. During the operative routine images are manually presented by a psychologist or neurologist to the patient and have to be coordinated with the neurosurgeon stimulating the cortex by a neurostimulator, operated by an engineer. To increase the efficiency of this procedure and to minimize the time needed to localize functional cortical areas, images should appear automatically with electrical stimulation. To achieve this synchronization, the potential combination of an existing neurostimulator with commercially available software for image display was studied. A trigger signal was created to induce the presentation of a series of line drawings showing different objects. The software to control the neurostimulator and the software for image displaying were installed on two different computers. A cable was developed to transfer the trigger signal from the neurostimulator to the computer used for picture presentation. It was shown that it is possible to induce the image display via the neurostimulator using square-wave pulses of 5 V and a width of 10 ms. Thus, we present a system that enables the automated picture presentation synchronized to the electrical stimulation of cortical regions.

Keywords: Intraoperative speech mapping, direct cortical electrical stimulation

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1 Introduction

The extent of tumour resection influences the outcome of the operation for patients [1]. However, larger resection volumes increase the risk of postoperative neurological deficits. Therefore, it is crucial to identify the exact location of eloquent regions to remove as much pathological tissue as possible without causing any deficits in speech. Although broad brain regions that serve certain functions exist, the precise location varies interindividually [2, 3]. Additionally, cerebral lesions can shift anatomical markers. Intraoperative speech mapping provides the opportunity for precise localization of language areas during tumour surgery. It was shown that intraoperative language mapping supports neurosurgeons to maximize tumour resection and minimize postoperative neurological deficits [3, 4]. Language outcomes were especially good for patients where no language sites were detected intraoperatively.

Figure 1: Setup for intraoperative speech mapping. Direct cortical electrical stimulation is applied to the cortex with the neurostimulator. At the same time/moment line drawings of different objects are presented to the patient that have to be named. The patient’s behavioural feedback determines whether the stimulated site is necessary for speech. Ideally, the neurostimulator also induces the picture presentation synchronous to the electrical stimulation (the illustration of the patient is by Patrick Lynch, medical illustrator, C. Carl Jaffe, MD, cardiologist, https://commons.wikimedia.org/wiki/File:Human_head_and_brain_diagram.svg)

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Figure 1 illustrates the intraoperative setup for speech mapping. To determine whether a certain cortical area is required for language comprehension or speech production, direct cortical electrical stimulation is applied to the cortical site. Simultaneously, the patient has to perform different language tasks such as object naming. For this task, pictures showing different objects are presented to the patient. If the electrical stimulation leads to speech errors such as speech arrest or anomia, the stimulated site is expected to be relevant for speech and should not be resected [5].

Picture presentation has currently been done manually and has to be coordinated with the neurosurgeon stimulating the cortex. The situation of being awake during brain surgery is a psychic burden for patients. Therefore, it is essential to perform intraoperative speech mapping as efficient as possible. To reduce the time spent for localizing eloquent areas, the images used in a language task should appear automatically to the cortical stimulation. Hence, we studied the possibility to use a device for direct cortical electrical stimulation to induce the image presentation.

2 Materials and Methods

2.1 ISIS Neurostimulator

The ISIS Neurostimulator (inomed Medizintechnik GmbH, Emmendingen, Germany, www.inomed.com) is a medical device used to deliver electrical current. The stimulator contains twelve channels for high-current stimulation with up to 250 mA and one additional channel for direct nerve or cortical stimulation with up to 25 mA. Furthermore, the ISIS Neurostimulator provides the possibility for intraoperative impedance measurements to assure a good contact between the stimulated tissue and the electrode.

The stimulator can be controlled via standalone software optimized for customized stimulation (ISIS Neurostimulator Software, inomed Medizintechnik GmbH, Emmendingen, Germany) or by software used for complete intraoperative neuromonitoring including EMG and evoked potentials (NeuroExplorer, inomed Medizintechnik GmbH, Emmendingen, Germany). Both software applications provide the opportunity to configure different wave forms by varying the amplitude, pulse width, frequency and number of pulses. Alternatively to the CE certified applications, a direct access to the stimulator can be realized via a DLL for customized investigations.

2.2 Presentation Software

The Presentation software (Neurobehavioral Systems, Inc., Berkeley, CA, www.neurobs.com) is a program used for behavioural experiments. It is specialized for the delivery of multimodal stimuli with high temporal precision. Supported stimuli modalities include various visual, auditory and video stimuli. Furthermore, the Presentation software can record responses from many different input tools. The program can also interface with external devices by input and output ports such as MRI scanners or eye trackers.

Experiments are implemented using the Presentation Control Language. This scripting language is roughly comparable to the programming language C.

2.3 Connecting the Neurostimulator to Presentation Software

The standalone software to control the neurostimulator and the Presentation software were installed on two separate computers. A square wave signal generated with the neurostimulator was used to induce the stimulus delivery in Presentation. A cable was developed to conduct the output signal from the stimulator to the Presentation software. The amplitude and pulse width of the square wave pulse were varied to find the optimal values for triggering the image display in the Presentation software with the ISIS Neurostimulator.

Additionally, a script was written in Presentation that fulfils the needs of an intraoperative speech mapping procedure.

3 Results

Presentation supports standard serial ports for external hardware interfacing. To monitor simple TTL signals it can also record logic changes one of three different serial port pins. Therefore, a 9 pin female D-sub was chosen to connect the computer with the Presentation software. The opposite side was equipped with a connector fitting to the ISIS Neurostimulator. Figure 2 shows the cable used to connect the neurostimulator to the Presentation software. Presentation can monitor logic changes on pin 1, pin 6 or pin 8. The cable
was designed to deliver the square wave pulse to pin 6. The electrical current from the stimulator and a resistance of 1000 Ω were used to produce square wave pulses. The electrical current was set to 5 mA to achieve a pulse with a 5 V amplitude. The pulse width was stepwise increased from 500 µs until an incoming signal was detected in the Presentation software. The first signal was detected for a pulse width of 5.6 ms. If a series of pulses with a width of 5.6 ms were sent, a number of pulses were not detected. To assure the detection of all pulses, the individual pulse width was further increased. A series of square wave pulses could reliably be detected by the Presentation software if every pulse had a pulse width of 10 ms.

The Presentation script written for intraoperative speech mapping was structured in two parts. The first part served the setup. The user was asked to define three parameters: the duration of an individual image display, how many times the pictures should be displayed and which type of pictures should be presented, such as objects or actions. The setup part was finished with a summary of the defined parameters (see Figure 4). This screen is also saved as an image-file for patient’s records. If the values were set correctly, the actual speech mapping could be started. Once the experiment was started the Presentation software displayed a screen with the sentence “Waiting for stimulation”. By starting the electrical stimulation via the standalone software the image display in Presentation was initiated as well. There was no subjective detectable time delay between the start of the electrical stimulation and the picture presentation. Simultaneously to the individual image display an auditory feedback was generated to indicate the presentation of a new picture.

Figure 2: Cable used to conduct a TTL signal from the neurostimulator.

Figure 3 displays the final experimental setup. The ISIS Neurostimulator is connected to two laptops. The left one is used to control the neurostimulator via the standalone software, the right one is used to display various line drawings with the Presentation software. The connection to the laptop on the right side is realised with the cable developed in this project (see Figure 2) and an USB to RS-232 serial adapter as many modern laptops do not provide serial ports anymore.

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Figure 4: Screenshot of Presentation. Before the start of the actual speech mapping, a summary of all predefined values is shown.

4 Discussion

The goal of tumour surgery is to achieve maximal resection. This process introduces the risk of postoperative neurological deficits if eloquent areas are resected. Intraoperative speech mapping provides the opportunity to precisely locate eloquent areas and therefore optimize the extent of resection while preserving function. To reduce the time needed for language localization, an efficient method is crucial. One possibility is to preoperatively define eloquent regions by...
functional MR imaging [6]. An automated system that synchronizes the image display for a language task to the electrical stimulation of cortical areas can further increase the efficiency of intraoperative speech mapping. To build such a system we studied the possibility to connect an existing neurostimulator with commercial available software for picture presentation.

We were able to demonstrate that the image display in the Presentation software can be synchronized to the start of the electrical stimulation with the ISIS Neurostimulator. For this we developed a cable that conducts square wave pulses with a 5 V amplitude and a pulse width of 10 ms sent from the neurostimulator to the Presentation software. Furthermore we wrote a script using the Presentation Control Language to set up an experiment that fulfils the requirements for intraoperative speech mapping. This includes setting of several parameters such as the picture duration, loading of many images separated by their category and responding to external input signals.

The synchronisation of the picture presentation to the electrical stimulation gives neurosurgeons the opportunity to concentrate on the surgical procedure and increases the efficiency in optimizing tumour resection and will be investigated in the next steps.

Author Statement

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References