RECORDING ELECTROMYOGRAPHIC SIGNALS IN A CLASSICAL CONDITIONING EXPERIMENT

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Abstract *— We describe in the following a measurement system for electromyographic signals created for an experiment to examine the influence of respondent learning on muscle tension on chronic pain patients and healthy controls. The data acquisition system is based on a DSP-board fitted with two analog-to-digital conversion modules of the OMNIBUS type. This provides us with the ability to record from 8 channels with 5kHz sampling rate simultaneously. The high computing power of the M67 DSP-board enables us to analyze incoming signal online, while still controlling the stimulator device. In the following, we describe the experimental procedure and show some analytical methods, which are able to select single unit activity in the EMG.*

Keywords *— EMG, digital signal processor, classical conditioning, pain, muscle tension*

Introduction

Although everybody agrees that learning processes and muscle tension play a decisive role on the emergence and maintenance of chronic pain [1], experimental evidence of underlying processes is missing. We hypothesize that the process of classical conditioning provides a major explanation. According to the conditioning model, the repeated association of the neutral stimulus with an aversive stimulus leads to a so-called conditioned reaction that is very similar to the original response to the aversive stimulus and that is now triggered by the neutral stimulus [2]. To clarify our thesis we conducted an experiment administering an intracutaneous painful stimuli. We are recording seven electromyographic signals from muscles close to the body surface and one electrocardiographic signal to detect the heart rate. During our procedure, we apply either an aversive tone coupled with an individual painful electric stimulus to a finger or a neutral tone with no painful stimulus.
The purpose of our recording system and in particular the Graphical User Interface is to display, discriminate and analyze the muscular activity and reactivity induced by our experimental proceedings.

Materials

The data acquisition system is based on off-the-shelve DSP boards (M67) residing in a PC running Windows XP. This DSP board is augmented with two analog digital conversion modules (ADC). We are using two A4D4 modules, which together provide the ability to record from 8 channels simultaneously and may be extended to 32 channels by multiplexing add-ons. The DSP Board and the AD conversion modules are manufactured by Innovative Integration, California, USA. Figure 1 shows the board equipped with ADC modules. Each A4D4 module provides the M67 board with 4 channels of high speed 50 kHz, 16-bit resolution analog input to digital output conversion per module site. The board features a Texas Instruments C6701 DSP and is connected with the host system via the PCI bus, which in turn consists of a 2,8 GHz Pentium IV with 512 MB SDRAM, 80 Gbyte harddisk.
For the power limit determination of the pain stimulus we applied an electric stimulus to the left forefinger (18 ms duration) with a small dedicated electrode. The stimulus apparatus is an adapted TENS-device G43 by Bentronic.
The surface electromyography was performed with shelve-adhesive EMG electrodes, connected to miniaturized amplifiers (3000x gain) from Biovision.

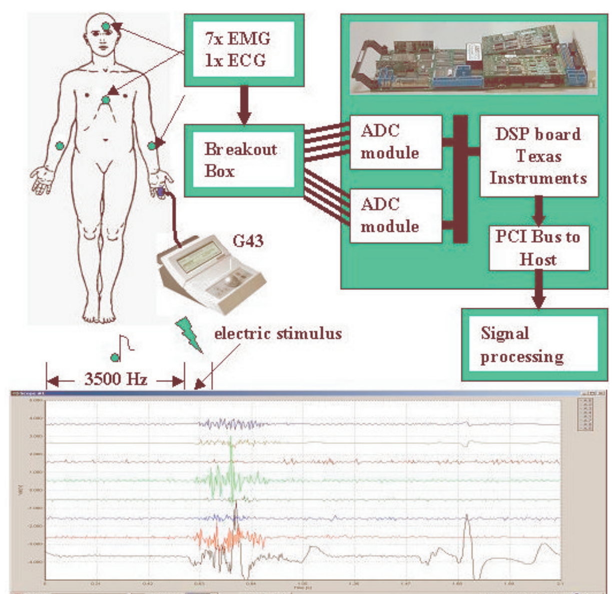

Figure 1: Schematics of the setup, for explanation see text.

Methods

In the run-up of the experiment we determine each participants individual pain stimulus that he obtains during the main experiment. In this so-called calibration method

stimuli with rising intensity are applied through the electrode beginning with 0,02 mA and each stimulus has to be rated on a 9-point scale according to its pain intensity (0=not noticeable to 8=immensely painful). When the participant first scores a “7” the stimuli are given in reversed order. This procedure is repeated twice. To assess the individual pain, the mean value of the mA values between 3 and 4 of the subjective classification is determined and doubled [3].
EMG-electrodes are placed pair wise on following locations to obtain differential and accurate signals:

1. the right and left lumbal Erector Spinae
2. M. Trapezius both sides
3. M. Flexor Digitorum, respectively right and left
4. M. corrugator supercilii, left („forehead wrinkling“)
5. heart rate was measured with only one channel

As an experimental conceptual design we have chosen a fixed differential pavlovian paradigm:

- CS+ high-frequency tone (3,5 KHz)
- CS- low-frequency tone (500 Hz)
- UCS intracutaneous electric pain stimulus

Event (Phase II)	**Duration**	**EMG -recording**	**CS+**	**UCS**	**CS-**
1	4 sec	x			
	5 sec	x	x	x	
	10 sec	x			
2	4 sec	x			
	5 sec	x			x
	10 sec	x			
3	4 sec	x			
	5 sec	x			x
	10 sec	x			

Table 1: Section of the proceeding- plan.

EMG- recordings are accomplished during the whole experiment. The G43 stimulator unit is controlled via the PC’s serial port, audio output is done by its sound card. A scheduler task takes control over every stimulus and processes the execution scheme (Table 2).

Phase I **Acquisition**	Phase II **Intermittent Reinforcement**	Phase III **Extinction**
8 CS+ with UCS	8 CS+, only 4 with UCS	8 CS+, none with UCS
8 CS- without UCS	8 CS- without UCS	8 CS- without UCS

Table 2: Execution scheme of the whole experiment

During data acquisiton it is possible to display a spectogram of the signals to optimize signal quality on each channel. Off-line analysis of multichannel signals is implemented with several methods. There are special filters with GUI-controlled modifiable parameters or de-noising by wavelets implemented by lifting scheme [4], [5].
Pain reactions are visible on our GUI on any of the channels by an increase of the multi unit nerve spike activity and consequently by an increase in the signals energy. We use a sliding window (N = Number of Sample Points, here 128) to compute the signal’s energy:

$$E_S = \sum_{n=1}^{N} s^2(n)$$

To identify a muscular reaction, we compare the energy with the *rms* value of the signal or the spike rate with the background count, respectively. When a muscle under investigation is contracted as response to the stimulus, a group of nerve action potentials of varying rates and amplitudes appears.
On positive identification, the full set of signals are stored on harddrive for further investigation.

Results

Figure 2 depicts exemplary above the described methods. Two EMG-signals following a tone and an electric stimulus may be seen. A clear increase in amplitude of the raw myo-potential is correlated to the energy and spike signal.

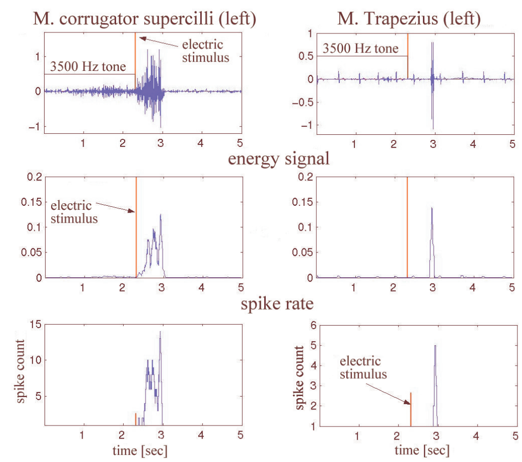

Figure 2: Unconditioned reaction of two EMG-signals.

Our technological goal was to build a new data acquisiton system for a pain conditioning experiment in order to bring signal quality to an unprecedented level for subsequent analysis.
We are interested in the detection of muscular reactions following the conditioned stimulus (tone) and the unconditioned stimulus (electric impulse) and are able to observe these by a higher incidence of spikes and an increase in signal amplitude after the electric stimulus, see Figure 2.
With this technology in place we measured good electromyographic signals from several subjects and are now in the process to conduct a study to investigate the “learning hypothesis of pain”.

References

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