Collecting Traces of Activity in Orofacial Muscles during Auditory Verbal Hallucinations in Schizophrenic Patients

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Abstract

Schizophrenia is one of the most frequent and severe mental disorders. Among the typical symptoms of schizophrenia are auditory verbal hallucinations (AVH). Inner speech dysfunction is often incriminated in the pathogenesis of AVH. The long term aim of our research is to collect EMG and EGG data on schizophrenic patients during AVH, to examine the inner speech dysfunction hypothesis. In this methodological paper, we validate an experimental protocol which will be applied in this aim.

1 Introduction

1.1 Background

Auditory verbal hallucinations (AVH) are a common feature of the schizophrenia psychosis, affecting 50% to 80% of the patients [1]. They often have a stressful impact on the patient's daily life. AVH are defined as a speech perception in the absence of an external auditory stimulus [2].

One appealing hypothesis is that the production of inner speech is disturbed in a way that the verbal thoughts of the patient are considered as external (not self-generated) voices [3]. The efference copy, a mechanism responsible for the monitoring of our actions, coming from the frontal cortex, cannot alert the auditory cortex that the verbal thoughts are self-generated, leading to the misattribution of inner speech to an external agent. This hypothesis is supported by neuroimaging studies showing abnormal patterns of activations between the frontal and temporal lobes in schizophrenic patients [4,5].

Further support comes from measurements of orofacial muscle activity, using electromyography (EMG), either with inserted electrodes or non-invasively with surface electrodes (sEMG). EMG activity has been detected in the speech musculature during verbal mental imagery, silent reading and silent recitation [6-8].

The first study supporting a relationship between the occurrence of AVH and subvocal speech was from Gould [9]. Using an electroencephalograph to explore the activity of the vocal musculature, Gould observed that 83% of the patients experiencing AVH showed an increase in muscle potentials in the lips and chin, whereas 90% of patients not experiencing AVH showed no increase. This result suggests that the AVH are associated with activity of the speech musculature. A similar report was made by McGuigan [10] on one subject. McGuigan observed a significant increase in chin muscle action potential and breathing amplitude immediately prior to reporting an AVH. The increase in chin activity was accompanied by a faint whisper. Inouye and Shimizu [11] also reported increased EMG activity from the speech musculature in nine hallucinating patients. The patients had to hold a switch down until the end of a hallucination. The authors measured a rise in EMG activity in the speech-related muscles (cricothyroid, sternohyoid, orbicularis oris, and depressor anguli oris) in 47.6% of the hallucinations. They also noticed a correlation between the length of verbal hallucinations and the duration of intensification of EMG activity. Bick & Kinsbourne [12] asked patients to perform three simple procedures while experiencing AVH. They consisted of opening the mouth wide (experimental condition), closing the eyes and making a fist (control conditions). The findings reveal a reduction of self-report of hallucinations when the subjects opened the mouth but not when they performed the two control conditions. This indicates that subvocal activity is associated with the experience of AVH.

Meanwhile, Junginger & Rauscher [13] recorded vocal and nonvocal EMG activity of 19 hallucinating and 22 nonhallucinating psychiatric patients. The authors failed to find a relationship between increases in vocal EMG and reports of hallucinations.

The studies cited above presented methodological limitations (limited number of subjects, lack of clear correlation between EMG measurements and AVH reports, imprecision in the time-windows observed); nevertheless, they provided some original findings.

1.2. Aim

The advent of more adapted techniques such as sensitive surface electromyography, and more robust signal analysis methods has opened up new possibilities of testing subvocalisation during AVH.

The long term aim of our research project is to record orofacial sEMG signals during the occurrence of AVH in schizophrenic patients. This would determine whether sEMG activity during AVH is higher than the baseline rest activity. This would corroborate the hypothesis that AVH result from a dysfunction of inner speech production. In this paper, we validate a methodological protocol to be applied in this aim.

2 Methods

2.1 Subjects

Patients are recruited at the *Centre Hospitalier Universitaire* of Grenoble. They are all diagnosed paranoid schizophrenic under the DSM-IV criteria (America Psychiatric Association, 1994) by experienced psychiatrists. Patients presenting language and/or auditory deficits are excluded from the study. All patients are native French speakers and give written consent to participate in the study. All patients are receiving antipsychotic medication and are experiencing frequent hallucinations at the time of the study (PANSS, AIMS). Control healthy subjects are also examined.

2.2 Material

The experiment takes place at the *Centre Hospitalier Universitaire* of Grenoble. Data are recorded on a Biopac MP150 surface EMG system, using the Acqknowledge software. Bipolar sEMG recordings are obtained from orofacial speech muscles. Laryngeal data are also obtained by electroglottography (EGG). EGG can allow the quantitative measurement of vertical laryngeal movement. The experiment is video monitored using a Canon video camera to track visible facial movements. A microphone is placed 15 cm from the patient's lips to record the patient's speech during the overt reading conditions. sEMG, EGG and audio data are all recorded through the Biopac acquisition system and are thus synchronised.

2.3 Procedure

Four conditions are examined.

In the *overt speech reading* and *in the whispered speech reading*, patients are asked to read sentences at a comfortable delivery. The reading conditions last approximately 10 minutes. The overt speech condition is used to obtain reference sEMG activation level for overt speech in each subject for all the muscles. From pilot tests on one healthy subject, it was expected that muscular activity should be reduced in the whispered speech condition, compared with overt speech, if the subject's whispers were low enough. The whispered speech condition was thus used to check that our sEMG system is sensitive enough for low muscle activation.

In the silent condition, the subjects are asked to remain silent and not to move for 10 seconds.

In the hallucinatory condition, they are asked to remain silent, not to move, and not to refrain from hearing voices. They are asked to signal when they hear a voice by pressing a button[1]. They are told not to establish a verbal interaction with the voice, to limit the occurrence of subvocal speech associated with the patient's response to the voice. This condition lasts approximately 15 minutes, depending on the patient's responsiveness, degree of anxiety and hallucination frequency.

We expect to find higher sEMG activations in overt than in whispered speech in all speech muscles. In addition, we expect to observe a sEMG activation continuum, with similar types of activations but with decreasing amplitude, from the overt speech condition to the silent condition (where a quasi-null activation is expected) through the whispered speech condition and the hallucinating state.

The patients take a pre-experiment questionnaire on the frequency, latency, nature and content of their everyday AVH and a post-experiment questionnaire on the frequency, latency, nature and content of the AVH experienced during the hallucinatory condition.

The experiment is thus shaped: pre-experiment questionnaire, silent condition, overt reading condition, silent condition, whispered reading condition, silent condition, hallucinatory condition, post-experiment questionnaire.

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[1] In a first version, patients were asked to press a button as soon as they heard a voice and to press it again at the end of the hallucinatory fragment (sentence, word or discourse).

2.4 Data Processing

Data are exported from the Acqknowledge software and then resampled using Matlab software. The mean amplitude values over the duration of each sentence in each of the reading conditions and for each hallucinatory fragment are calculated. The hallucinatory periods are detected from the button presses. The results are then compared to the baseline, obtained from the mean amplitude value in the baseline condition, for each patient. Figure 1 shows the sEMG trace for the orbicularis oris inferior (first panel) during overt reading for one patient. The second panel shows that the control EMG trace for the forearm flexor is flat. The third panel displays the button pressing signal and the last panel provides the audio trace.

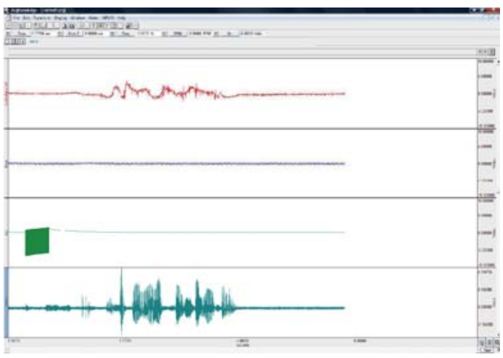

Figure 1: *Orbicularis oris inf. and forearm flexor sEMG graphs during overt reading*

3 Protocol Evaluation

In order to design a valid experimental protocol, our original protocol underwent various changes through the eight patients tested so far: P1, P2, … P8.

3.1 Baseline determination

The silent condition was originally designed as a control to measure the resting activation of the muscles. However throughout the experiments, two patients reported having experienced AVH during this condition. Therefore it could not be used as a control (nonhallucinatory, baseline) condition anymore. Instead we took parts of the hallucinating condition where the patient indicated, by not pressing the button that he/she was not hallucinating. These parts became our baseline condition for the further data analyses.

3.2 Corpus determination

The first corpus that was elaborated contained 20 sentences derived from schizophrenic patients' testimonies as well as our own created sentences. They were of various lengths. P1, P2 and P3 were recorded using this corpus. We then decided to change to a more phonetically adequate corpus, i.e. the CNET corpus [14] and we added 9 vowel-consonant-vowel (VCV) sequences where V was /a/, /i/, /y/ and C was /b/, /d/ or /g/. The total of sentences was 26. P4, P5, P6, P7 and P8 used this corpus. The latest change consisted of reducing the number of sentences to 15 so as not to wear the participants out.

3.3 Muscle set determination

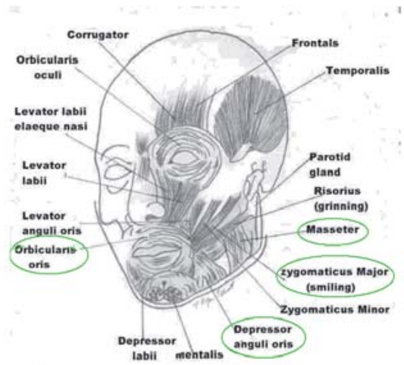

Figure 2: *Set of orofacial muscles examined*

Apart from the nondominant forearm flexor – control muscle, all the muscles examined are involved in speech production, overt, whispered or covert [11]. Throughout the different versions of the protocol, the orbicularis oris superior, the orbicularis oris inferior and the zygomaticus major muscles were always measured. In a first version (P1, P2, P3), we also examined the mentalis. We observed this muscle was not strongly activated, we therefore decided to suppress it from our protocol. In the second version we added the depressor anguli oris and the masseter. As a result, we now examine five orofacial muscles (see Figure 2) and one non-speech muscle.

3.4 Reaction time determination

In order to estimate the reaction time between hearing a voice sound and pressing a button, we designed an overt listening task where the participants had to press the button down once they heard the played voice and keep it pressed until the voice ended. This test allows us to measure each participant's mean reaction time in order to analyze the hallucinatory data more accurately: the mean reaction time is subtracted from the measured time of onset of each hallucination, as detected from the button press. After series of tests on healthy subjects to determine an average reaction time, P8 was the first patient to take the test.

4 Preliminary results

The results presented here are not sufficient for statistical analysis yet.

Only sEMG data for seven subjects (six schizophrenic patients and one control subject) are presented here. Inter-speaker and inter-muscle variability was observed, as expected. The orbicularis oris inferior showed the most activation in all conditions, which could be expected, as it is strongly involved in speech, especially in French [15].

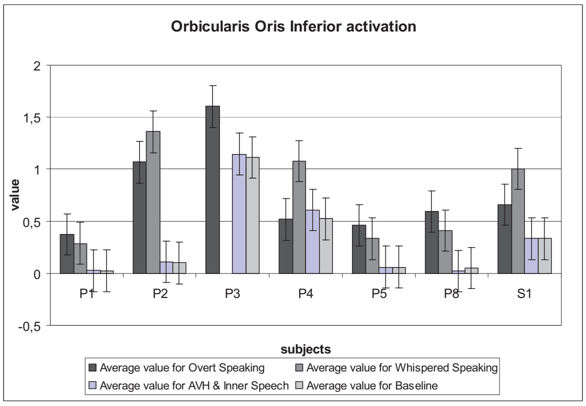

Figure 3: *Mean orbicularis oris inferior activation for each participant and condition.*

As shown in Figure 3, in five patients out of six, sEMG activity for this muscle was lower in the hallucinatory condition than in the overt and whispered speech conditions.

The overt speech condition was associated with higher sEMG levels than the whispered speech in only three subjects (out of seven). The instructions were probably not clear enough. A comparison with the baseline condition was also carried out. In three patients out of six, mean sEMG activation in the orbicularis oris inferior was slightly higher in the hallucinatory condition than in the baseline condition.

5 Perspectives

More analyses are in progress to examine potential speech muscle activity during the AVH. Furthermore, we are currently in the process of improving the sEMG signal pre-processing and analysis. New control healthy subjects will be examined with the latest improvements of our protocol.

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