Development of EMG Indicators for Measuring and Analyzing Pre-motor Activity on Muscles

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Abstract: In sport, it is well known that mental preparation to a physical effort increases drastically the performance. In this paper, we present a study that aims to evaluate the effect of movement preparation during pre-motor activity on the EMG signal. We considered the existence/no-existence of preparation and preparation duration as indicators. The results of this study performed on different muscles of the forearm show: i) female are sensitive to preparation warning whereas male are not sensitive, ii) contrary to deep muscles, superficial muscles are affected by preparation warning.

1 INTRODUCTION

ElectroMyoGraphy (EMG) is an electro diagnostic technique used to evaluate and record electrical activity produced by skeletal muscles (Gordon et al., 2004).
For voluntary motions, all muscle contractions (excluding reflexes) occur as a result of conscious effort originating in the brain. In fact, the brain sends signals, in the form of action potentials, through the nervous system to the motor neuron that innervates several muscle fibers (Cacioppo et al., 2007).

The major studies in literature focused on the study of the muscle activity during exercise. Most studies considered the latency time (or refractory time) which is the rest time preceding the muscle activity. It is a short period during which the nervous system is not excitable and can not respond to stimulation or excitation.

At our knowledge, few studies discuss the mental (psychological) stage before the motor task which concerns the pre-motor period. It is defined as the small muscle activity (if it exists) which happens between a warning signal motivating preparation and initiating motion (anticipatory postural adjustment) and the "go" signal for motion execution.

Pre-motor activity represents the muscular activity during mental or psychological preparation. In sport domain, researchers have begun to study the effect of specific mental preparation on motor performance. Some of the most popular techniques include imagery, self efficacy statements, attentional focus, preparatory arousal, and relaxation (Weinberg, 1981). Numerous studies have provided experimental, correlational and anecdotal evidence that patterns of thought can influence athletic performance (Corbin, 1967), (Richardson, 1967), (Shelton and Mahoney, 1978).

In this paper, we present a study that evaluates the effect of movement preparation on EMG signals of the forearm muscles during pre-motor activity. More precisely, we will answer the following questions: does movement preparation leads to effective preparation which appears as small contraction during pre-motor activity? In case where no preparation warning (instruction) is given, is there any spontaneous muscle preparation? If a cognitive preparatory period exists, how long it activates the muscle and what difference do we have in absence or presence of attentional focus? Is it possible to discriminate between both trials (absence or presence of attention) using only preparation time as descriptor?

This paper is organized as follows: in the first part, we will identify and analyze the preparation duration in all trials. In the second part, we will describe the different indicators involved in the preparation. Finally, we will discriminate between the presence or absence of a preparation duration

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using an analysis of variance statistical method.

2 EXPERIMENTAL PARADIGM

Surface EMG activity was recorded using bipolar surface electrodes equipped with a preamplifier with an inter-electrode distance of 25 mm (BIOPAC systems, Aero Camino, Goleta, USA). Electrodes were fixed onto the skin over the muscle with Elastoplast bands. Because no SENIAM guidelines are available for these muscles, the electrodes were positioned during a muscle contraction (Basmajian, 1979). EMG activity was recorded using Acknowledge data hardware (Model MP100A; BIOPAC Systems, USA). EMG signals were amplified, and sampled at a frequency of 10 kHz. A ground electrode was placed on the subjects wrist during measurements.
10 males and 10 females volunteers have participated in this study. Each volunteer realized maximal isometric contractions of finger flexors during a "hand grip" exercise. Two trials were carried. The first one needs attentional focus and the other one does not require attentional focus. All volunteers realized 5 contractions for each trial.

In the first trial, the EMG signal has three different periods: a pre-motor activity in which the volunteer has to prepare mentally and carefully the activity during 6.6 seconds until a hearing statement (bip) is given to ask him to begin contraction. Then a motor activity begins and lasts 4.4 seconds which is the effective contraction phase. Finally a rest period of 44 seconds ends the experiment.
In the second trial, the volunteer don't have preparation warning, he executes the movement when he wants during 4.4 seconds and the same rest period of 44 seconds follows.

In this study, we are interested only in he first period which is the pre-motor activity. The label of the first (resp. second) trial is "With" (resp. "Without") preparation warning. The studied muscles are: the Flexor Digitorum Profundus (FDP), the Flexor Digitorum Superficialis (FDS), the First Radial (FR) and the Common Extensor Digitorum (CED).
Note that the Flexor Digitorum Profundus activity can be measured by surface EMG (Bøg et al., 2011). Using temporal analysis, two indicators were selected: the number and the duration of preparation.The goal is to differentiate the two trials with these indicators.

3 STUDY OF NUMBER OF PREPARATION

3.1 Subject Behavior to Preparation

In this section, the goal is to know if each volunteer prepares its contraction during the time interval which is called the pre-motor time.

Using the data presented in the experimental paradigm section, Fig.1 shows the number of prepared contractions for each subject. The dashed (resp. solid) line concerns the trial "with" (resp. without") preparation warning. The results of Fig 1.a (resp. Fig 1.e) corresponds to male FDP (resp. female). Fig 1.b (resp. Fig 1.f) represents the data of male FDS (resp. female). The results of Fig 1.c (resp. Fig 1.g) are addressed to male FR (resp. female). Finally, the Fig 1.d (resp. Fig1.h) gives the number of preparation of male CED s(resp. female).

Note that all volunteers prepare muscle activity even when no preparation warning is given. However, the number of prepared contractions is not always the same. When comparing the muscles, we can note that, in the case of males, the number of preparation is important for the flexor digitorum profundus muscle (Fig 1.a) and for the flexor digitorum superficialis muscle (Fig 1.b). In fact, 5 volunteers of 10 have a complete preparation (5 for both trials) during contractions. The number of preparation decreases in common extensor digitorum muscle to 3 preparations (Fig 1.c). Hence, we can conclude that males have an important number of preparation in flexor muscles than in extensor muscles (Fig 1.a,b,c,d).
In the case of female volunteers, the number of preparation is more important in extensor muscles (Fig 1.g,h) than in flexor muscles (Fig 1.e,f). In fact,we show one complete preparation in (Fig 1.f) but in (Fig 1.h), there is three complete preparations.

3.2 Analysis of the Number of Effective Preparation

The objective of this section is to analyze the number of effective preparation. To do it, this number is used as input data. A simple statistical analysis using the mean, the median and the standard deviation of the number of preparation is carried and given in Tab.1 in case of first radial muscle. We show that male volunteers are characterized by an important median and mean values of preparation number in the case of "without preparation". But, the results are opposite in case of female volunteers: the number of preparation is slightly higher in case of "with

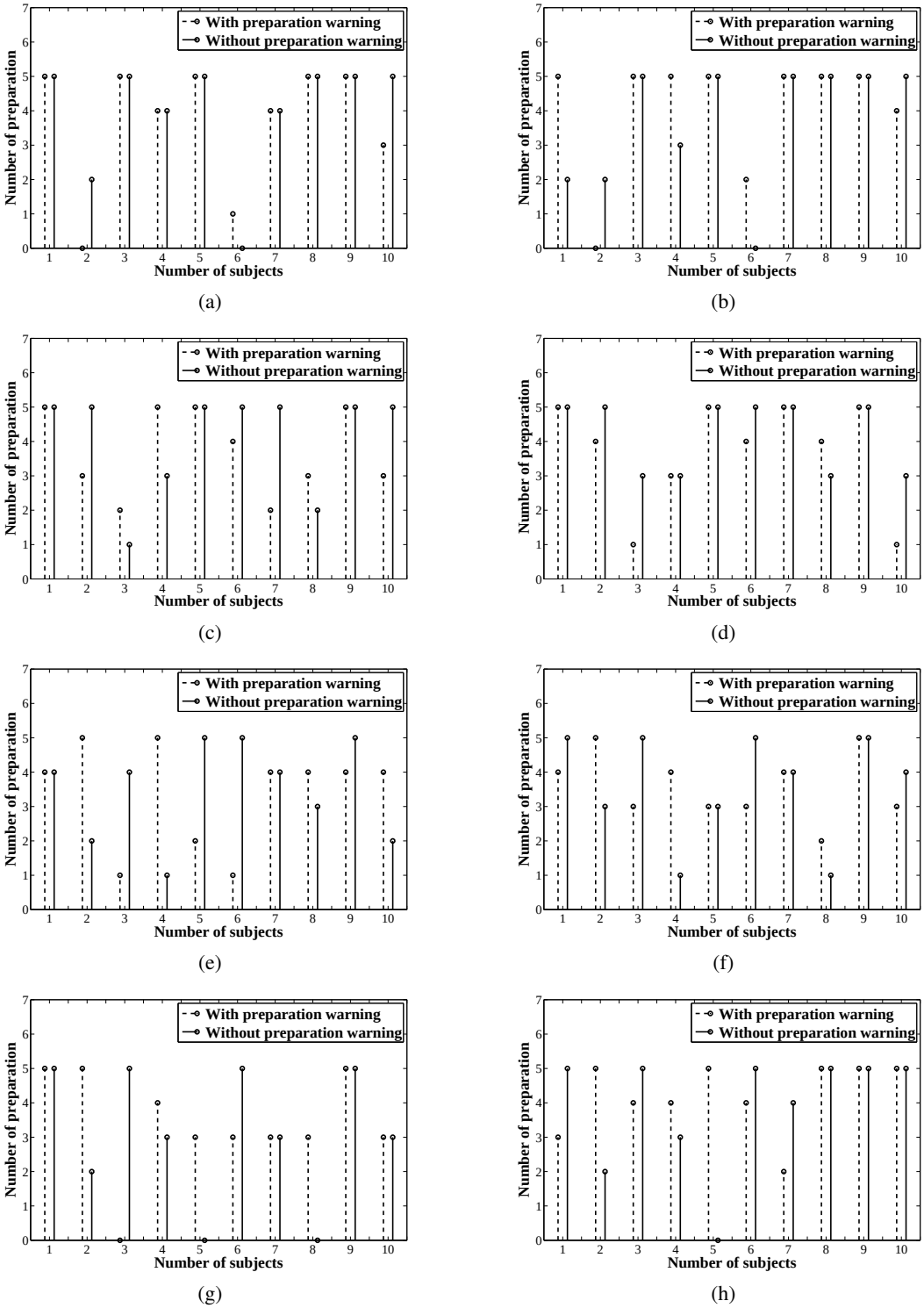


Figure 1: Number of preparation for each subject. (a): male FDP, (b): male FDS, (c): male FR, (d): male CED, (e): female FDP, (f): female FDS, (g): female FR, (h): female CED.

preparation warning" trial.

Table 1: Simple statistic values of number of preparation on first radial muscle.

		Mean	Median	Standard deviation
Males	With	3.8	4	1.55
	Without	4	5	1.5
Females	With	3.4	3	1.5
	Without	3.1	3	1.96

Tab.2 represents the number of preparation percentage in both trials, for both genders and for each muscle separately.
For male volunteers, the percentage of number of preparation is important when no preparation warning is given. We observe this result in three muscles (FDP, FDS, CED) except the first radial (FR) in case of 5 preparations.
The sum of percentage of number of preparation is equal to 80% for 3,4 and 5 contractions together. This result is valid for all muscles except the common extensor digitorum muscle who had an important percentage (100%) when no preparation warning is given.

The results are opposite in the case of female volunteers. We observed that the sum of percentage of number of preparation are more important in case of "with preparation warning" than in case of "without preparation warning" for 3,4 and 5 contractions together. We show this result in the three first muscles: CED, FDS, FR. The first radial (FR) muscle had 90% (resp. 70%) preparations in case of "with" (resp. "without") preparation, in FDS and CED .
However, for flexor digitorum profundus muscle, the percentage is equal to 70% between both trials. According to Tab. 2, we noticed that males prepare more than females in both trials.

4 THE EFFECT OF PREPARATION'S DURATION

4.1 Duration by Subject

This section aims to observe the dispersion of preparation's duration in the both trials.

Fig.2 shows the duration of preparation for each male and female volunteers of first radial muscle. For clarity reasons, symbols are discarded in the figure from the central values. The triangle (resp. circle) symbol represents "With" (resp. "Without") prepara-

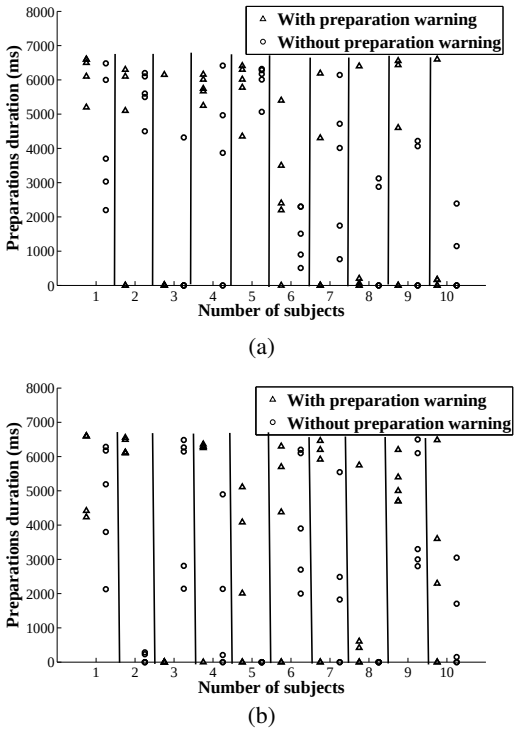


Figure 2: Preparation's duration of first radial muscle.(a): male volunteers,(b): female volunteers.

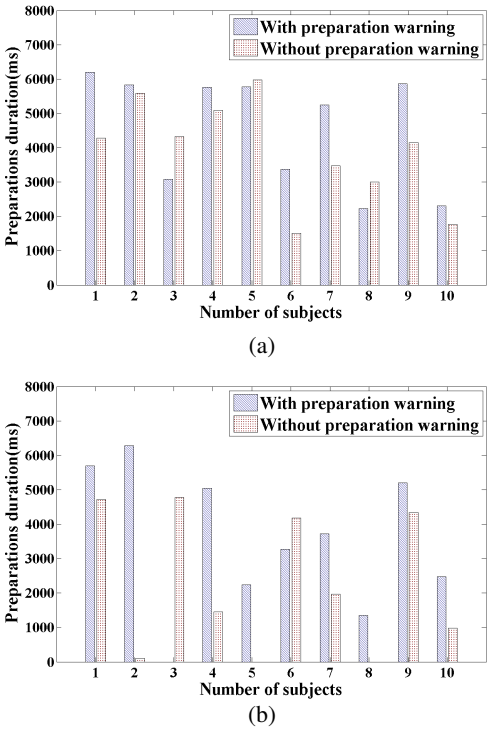


Figure 3: Mean preparationś duration of first radial muscle. (a): male volunteers, (b): female volunteers.

Table 2: Number of preparation percentage in both trials: with and without preparation warning.

		Male volunteers						Female volunteers					
Number of preparations(%)		5	4	3	2	1	0	5	4	3	2	1	0
FDP	With	50	20	10	0	10	10	20	50	0	10	20	0
	Without	60	20	0	10	0	10	30	30	10	20	10	0
FDS	With	70	10	0	10	0	10	20	30	40	10	0	0
	Without	60	10	10	20	0	0	40	20	20	0	20	0
FR	With	40	10	30	20	0	0	30	10	50	0	0	10
	Without	70	0	10	10	10	0	40	0	30	10	0	20
CED	With	40	30	10	0	20	0	50	30	10	10	0	0
	Without	60	0	40	0	0	0	60	10	10	10	0	10

tion warning. These two genders have different values of preparation's duration and don't obey to any obvious rules. Note that the range of all durations is between 0 and 6600 milliseconds (we recall that the duration of theoretical preparation is 6600 milliseconds).

Fig.3 illustrates the mean preparation's duration for each trial and for every volunteer. Fig 3.a (resp. Fig 3.b) represents males (resp. female) volunteers. The mean preparation's duration is higher in case of "with preparation warning" trial for 7 males and 9 females. Hence, we can conclude that volunteers prepare longer their contraction when a warning signal is given.

4.2 Boxplots of Preparation's Duration

In statistic analysis, the boxplots is a useful tool for studying large sets of data. It can provide information about data range, median, normality and skew of distribution. In this case, we deal with the distribution of preparation's duration for the two trials for all muscles.

In Fig. 4, we draw the preparation's duration boxplots for both gender when all muscles data are combined together. We can see that the dispersion is large when a preparation warning is given. For example, in Fig 4.a, the median duration value (line into rectangle) of pre-motor activity is important in "with preparation warning" (3.83 s) than "without preparation warning" mode (1.987 s).

Fig.5 represents the preparation's duration for each muscle for male and female volunteers separately. The results shows that the median duration value is higher in "with preparation warning" trial than in "without preparation warning" trial except the Fig5.a and Fig5.d who show that the median value is slightly higher when no preparation warning is given.

5 STATISTIC ANALYSIS: ONE WAY ANOVA TEST

In statistics, ANalysis Of VAriance (ANOVA)(Nuzzo, 2014) is a collection of statistical models used in order to analyze the differences between group means and their associated procedures (such as "variation" among and between groups). Anova test was used to compare the preparation's duration and try to separate the two trials with significance level equal to 5%.

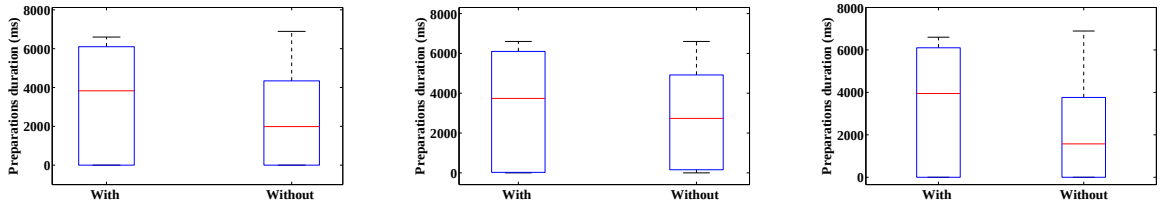
Tab.3 gives the results of discrimination between two trials. The symbol ($\neq$) (resp. (=)) means there is a (resp. no) significant difference between two trials.

Table 3: Difference inter-muscular between with and without preparation warning.

	Males	Females	Both gender
All muscles	=	$\neq$	$\neq$
FDP	=	=	=
FDS	=	$\neq$	$\neq$
FR	=	$\neq$	$\neq$
EDC	=	$\neq$	=

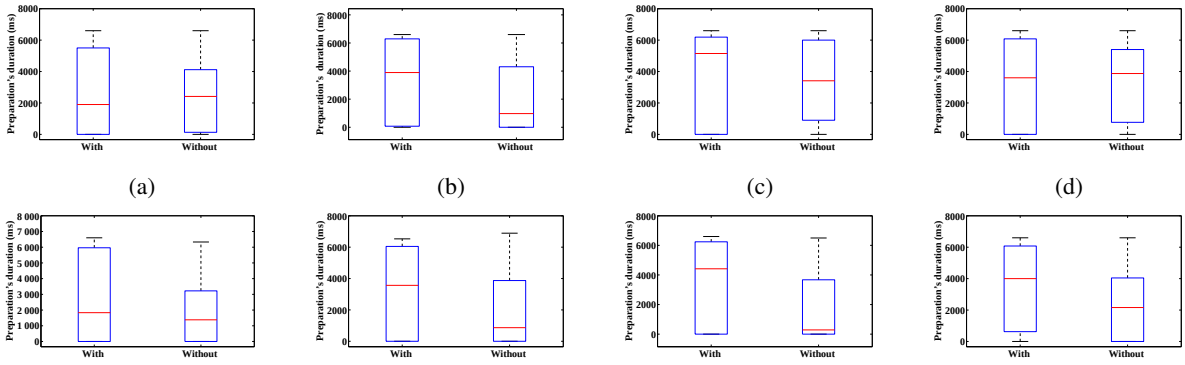
5.1 Difference between "With preparation warning" and "Without preparation warning" on Muscles

The results of Tab.3 show that there is a significant difference between with and without preparation warning for both genders and for all muscles considered together(T=14.48,p-value=0.0001). So, the preparation warning has an influence on the pre-motor activity.



(a) (b) (c)

Figure 4: Boxplots of preparation's duration for forearm muscles. (a):both gender, (b):male volunteers, (c):female volunteers.



(a) (b) (c) (d)

(e) (f) (g) (h)

Figure 5: Boxplots of preparationś duration for forearm muscles. (a): male FDP, (b): male FDS, (c): male FR, (d): male EDC (e): female FDM, (f): female FDS, (g): female FR, (h): female EDC.

5.2 Gender Difference in Pre-motor Activity

Tab.3 shows that preparation's duration differs by gender. In fact, there is no difference between without and with preparation warning for males (T=1.71, p-value=0.1922) but there is a significant difference in females (T=16.32, p-value=0.00005) for all muscles. These results confirm the brain behavior. In fact, in some previous studies such as (Ingalhalikar et al., 2014), it was shown that the brain behavior is different for each gender: the females outperform males on attention, word and face memory, and social cognition tests and males perform better on spatial processing and motor and sensorimotor speed. In this case and specially in "with preparation warning" ,volunteers must be attentional and concentrate. Female were able to do it. However, male volunteers weren't sensitive to preparation warning.

5.3 Inter-muscular Difference in Pre-motor Activity

When we separate the muscles, the results of Tab.3 show that there is no difference between with and without preparation warning in pre-motor activity for males (p-value $\geq$ 0.134). For females, we found a significant difference in Flexor Digitorum Superficialis, First Radial , Extensor Digitorum Communis muscles (T $\geq$ 4.72, p-value $\leq$ 0.032) but no difference in Flexor Digitorum Profundus (T=2.29, p-value=0.1302).

The muscles are classified into two families: the superficial muscles and deep muscles. The superficial (resp. deep) muscles are Flexor Digitorum Superficialis, First Radial and Extensor Digitorum Communis (resp. Flexor Digitorum Profundus). Due to the anatomical and biomechanical differentiation of the superficial and deep muscle fibers, a difference in fiber type distribution can be hypothesized: it is assumed that the deep muscle fiber has a higher portion of type I fibers compared to the superficial muscle fiber (MacDonald et al., 2006). Fibers of type I are slow twitch fibers, which are fatigue resistant and ideally suited to provide low load tonic activity. Type II fibers, are fast twitch fibers, are less fatigue resistant, but able to produce a higher load activity(Henneman et al., 1965).

During the pre-motor activity, the preparation was done only for superficial muscles.

6 CONCLUSION

In this work, we found two indicators that characterize the pre-motor activity. The first one is the number of preparation. It was shown to be important even when no preparation warning is given.
The second indicator is preparation's duration. It was shown a significant difference between "with" and "without" preparation modes for female in superficial muscles of the forearm. However, no difference of behavior are observed between the two modes for male.

Studying the motor behavior during the transition between the pre-motor activity and the effective motor activity and studying the brain activity using fMRI will be the topic of further research.

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