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Portable Device Validation to Study the Relation between Motor Activity and Language: Verify the Embodiment Theory through Grip Force Modulation

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***Abstract* - Studying the link between the motor function and the linguistic function has become increasingly popular over the past decade. Often, the subject is studied with the use of expensive devices (EEG, fIRM…) limited because they need a proper space. Following the studies of Frak & al. (2010), Aravena & al. (2012-2014) and Nazir & al. (2015), at CML (*Cerveau, Motricité et Langage)* laboratory, we developed a portable device that analyses the grip force modulation. This device provides us with the opportunity to put in place a developmental study with children in Canada and Brazil. We analyzed the grip force modulation of fourteen Canadian teenagers (Can.) and fifteen Brazilian teenagers (Bra.) after experiencing linguistic stimulation through the use of action words (e.g. grab) and non-action word (e.g. storm). The maturity of teenagers' intraparietal area is similar to that of adults. Thus, we can compare our results with the those of Frak & al. (2010). The force modulations are analyzed using grip force sensors that are recording a variation in millinewton (mN) every millisecond (ms). Our choice in material and technic to normalize the data is based on our previous study concerning grip force sensors and linguistic stimulation. Our results show a superior modulation after listening to an action word compared to the non-action word in the two groups. We reproduce the results of Frak & al. (2010). The validation of the portable device could facilitate research by giving access to a both a larger and diverse population.**

Keywords: Adolescent, Equipment Design, Embodied Language, Grip-force Sensor, Motor Activity, Psychomotor Performance, Time factors.

I. INTRODUCTION

The study of the link between motor activity and language is attracting an increasing interest. After [1], demonstrating the link between the movement of a limb and the reading of the word associated with them by a similarity in the cerebral activation of M 1. Research using electroencephalogram, magnetic resonance imaging, transcranial magnetic stimulation don't stop deepen this link over the last decade. Even new technic emerges to investigate. In 2010, [2] presents an innovative device to check the motor activity following linguistic stimulation. With the grip force sensor, it is possible to record online the modulations of the force of the precision grip. Showing than manual actions words develop more variability of force than the non-action words. Using a similar system, [3], [4] shows that the lexical context affects the grip force modulation (GMF). In 2015, [5] demonstrates again the links between motor and linguistic activity by means of a more refined data processing technique enabling future studies to be comparable.

Even with all these research tools, developmental research on the subject are rare. Our group want to explore the link between motor activity and language during the development. Research with children bring complexity. Not about the actual knowledge or the parameter of the experiment. The main research problems: the search for participants, the costs associated with the participants and the costs of the equipment (the risk of being broken). To augment the possibility of a bigger sample size without busting the cost. A portable device was needed to go to school doing the experiment with the child. The grip force sensor setup is a small device. But the triaxial sensor is expensive. The first study,[2], with a grip force sensor working on the link, motor activity and language, correlated the results between the data including the three axes (Fx, Fy, Fz) and the data without the vertical force (Fx). With this in mind, UQAM's Cerveau, Langage et Motricité (CML) laboratory produces a portable system of grip force sensors at a lower cost (a uniaxial sensor (Fz)), enabling a team of researchers to move in place of the participants. This portable equipment was produced to be also used in partnership with the rehabilitation and rehabilitation hospital of Goiânia in Brazil (CRER). Data were collected in Canada and Brazil.

Children who participated were between 5 and 17 years old from north and south America. How can we assess the validity of the portable grip force sensor? The parietal area of the brain is a link to the simulation of the action, function activate for the decoding of action manual word or tool word [6]–[8]. This area is mostly mature, similar to an adult, 13 years old or older [9]. A comparison between the modulation of adults and teenagers, which is supposed to be similar, will indicate the validity of the portable device.

In 2015, the data processing technic was the issue of standardization [5]. Following this, single words stimuli are kept after then been shown by magnetic resonance imaging, than an action verb, even in a non-action linguistic context,

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activate the intraparietal area [10].Single words facilitated the task for the youngest child aim by the project.

This project is not only innovative because it is developmental. Also because it looks at the motor activity of both hands after linguistic stimulation. The analysis of the GMF is uni-symmetrically in Canada and is bimanual in Brazil, but only the right-hand data are used to validate the results of previous research.

II. MATERIALS AND METHODS

A. Experiment 1: Canadian group

1) Ethics statements

All participants and all parents or tutors, in this study gave an informed written consent. The study was approved by the ethical committee CIEREN (Comité institutionnel d'éthique de la recherche avec des êtres humains) of UQAM, Montreal, Canada, and the research comity (services éducatifs, secteur jeunes) of the Commission scolaire de Laval.

2) Participants

All of the participants were French high school students (13-17 years old ; mean age = 14.9, SD = 1.5) and right-handed (Edinburg Inventory [11]). They all have just a basic level of English, base on the school classification. They have no hearing problem and no reported history of psychiatric or neurological disorders. Fourteen subjects (9 females and 5 males) participated in this study. Six participants were eliminated from the study. Two participants were rejected because more than 25% of their data was rejected by the rejection artifact [5]. Four other participants were also eliminated from the study after the outliner statistical test, the modified Thompson Tau test.

3) Stimuli

A list containing 70 French words, served as stimuli. They were divided into two groups: 35 action words and 35 non-action words. The action words consist of verbs in the infinitive, related to hands or arm action (e.g. grab). The non-action words consist of nouns that are not related to an action (e.g. storm). The word list used in this study is the same as the one used by [2]. The words selected were all bi- or trisyllabic. They were controlled by the number of letters, the frequency and the bi- and trigram frequency. All of these have been verified with a frequency dictionary [12]. The mean word duration was 684 ms (SD = 98 ms). The words were recorded by a French male adult.

With the 70 words, 40 blocks have been made. Half with an action word as a target and the other half with a non-action word as a target. The target word is the attention center of the participant. It's repeated between 10 to 12 times during a block. In each block, 35 non-action word are also there as background words. The order of the words in each block is pseudo-randomly organize. The only rule was that the target word is always after a background word. The 40 blocks have been made with the Audacity 2.0.3 software.

The duration of the block was between 1 minute 15 secondes and 1 minute 20 secondes. For each participant, 4 action target blocks are randomly chosen. And it is the same for the non-action targets block for a total of 8 trials.

The data analyze in this study is only the grip force before and after the beginning of the target word.

4) Equipment and Data Acquisition

The grip force sensor in Fig. 1 is uniaxial. It has two 5 cm diameter aluminum washers screwed to each side. It gives it 1,8 cm of thickness. The sensor can withstand a pressure of up to 1 kg. The amplitude of the output signal is 1.0 +/- 10% mV / V. The linearity error and the hysteresis are 0.02% (on the total scale). The temperature compensation scale is -10 degrees C ° to 40 degrees C °. It is connected to a Honeywell DV10L amplifier. Which is connected to the acquisition card (measurement computing usb-1608GX) and it's connected to a portable computer. The stimulus is coming from the same computer. The sound files have a trigger at the beginning of each word going by the right channel. The left channel is for the stimuli. The wire for the sound it split and the right channel goes to the acquisition card and the left have headphones (MDR-7502 of Sony) connected for the participant. The Fig. 2 show the complete setup, except the computer. This study is part of a bigger project in which the participant use 2 grips force sensors.

The data transmitted in 1 kHz from the acquisition card to the computer are processed by the Dasylab 11.0 software. The software filters the data with the following filters: 15 Hz with fourth zero, low pass butter worth filter and notch filter 50 hz.

5) Procedure

The experiment was done in a quietly and empty local in the high school of the participant. The participants were sitting in front of a desk on a chair, adjusted to their height. They wore headphones. Their forearms were affixed to the desk covered with a foam mat for better comfort (Fig. 3). The target words of the first block are communicated to the participant. The participants grab the grip force sensor with a precision tridigital (thumb, index and the middle finger) neutral grip. The side of the hand is on the mat, but the sensor do not touch it. The participant will apply a grip strength of 1.5 N following our hint. The participant was requested to not applied voluntary force. When the grip force is stable, the participant close his eyes. The first block begins. While listening to the words, he has to count the target word. When the block is finished, he has to say about the amount of time he heard the target word. If it is less than 70%, the block is not retained. The same routine is repeated 8 times in total. Two blocks with right-hand grips counting the action word as target.

Figure 1: The grip force sensor.

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Figure 2: The portable device. We can see the grip force sensors, the amplifiers Honeywell DV10L, the data acquisition card measurement computing usb-1608GX and the headphone. The sound console is use in a other project.

Same thing with the non-action word as target and it's identical with the left hand. The hand of the first block is choice randomly. After the right and the left altered. The target word and the order were also choice randomly. There is a one-minute break between each block, to avoid muscular fatigue. The total duration of the experiment is 20 minutes.

6) Data Analysis

The data analysis of the grip force modulation (GFM) of every target word. This way, we were sure the result will be from the linguistic stimuli and not from others thought of the subject. The strength of the grip is variable in every block and between the begin and the end of a block. To have an objective analysis, the data is normalized for every target word. The data use is between 300 milliseconds before the beginning of the word to 1000 milliseconds after. The mean of the data between -200 ms and 0 is used as the baseline and this value is subtracted to every data of this word. This way is possible to have a negative value if the GFM is inferior to this mean. It doesn't mean a negative strength. Which is impossible. After we use rejection artefacts for isolate the outliner modulation, which the reason can be a movement of the hand. The data is ejected when is superior to 200 milliNewton (nN) or when a modulation of 100 mN within 100 ms is present. If more than 30% of the data is ejected for a participant, he is ejected from the analysis. Two participants have been ejected with the rejection artefact.

For the statistical analysis, the target window is to 100 ms to 800 ms after the stimulus. This window of time is used in previous study [3]–[5]. But there is too much data in this online record, so the data is regrouping in a mean from the data in a window of 50 ms. From 100 ms to 800 ms, we have fourteen windows.

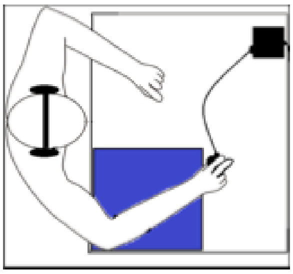

Figure 3: Position of the participant in experiment 1.

The group is small, so we use an additional rejection method to remove outliners: the modified Thompson Tau. The relatively low number of participants, a participant with a higher or a lower average than the others easily affected the group average. Thus, we performed a statistical test of outline data. This statistical test makes it possible to find an outliner by using a table to compare our data with the help of the mean and the standard deviation of the group (Eq. (1)).

$$|x - \bar{x}| > Tau * \sigma \quad (1)$$

The Tau value can also be obtained with the Eq. (2). The *t* value is the result of Excel's "STUDENT.INVERSITY" function with an alpha of 0.05 and a degree of freedom of n-2.

$$Tau = \frac{t*(n-1)}{\sqrt{n}*\sqrt{n-2+t^2}} \quad (2)$$

For each 50 Msec window, the modified Thompson Tau was applied. The number of aberrant windows per condition was counted and when more than 40% of a condition was aberrant, the subject was excluded from the statistical analysis. In total, four participants were rejected.

Statistical analyses were performed on version 22 of the IBM SPSS software. There were two different analyses of the data. The first is a comparison of the means of each condition to the baseline. It's a one-value t-test done for the fourteen windows. The second is a repeat measure ANOVA followed by a post-hoc comparison test. The ANOVA have 4 factors, 3 intragroup factors and 1 intergroup factor. The three factors are hands (right and left), words (action and non-action), and windows of time. A LSD post-hoc (least significant difference) compares averages across all factors. No alpha correction was applied because only the simple effects were compared by post hoc. These two analyze are done separately in order to provide a complementary look at the motor response following stimuli. As a reminder, only the result of the adolescent interests us in this study and will be show in the next part.

B. Experiment 2: Brazilian group

1) Ethics statements

All participants and all parents or tutors, in this study gave an informed written consent. The study was approved by the ethical committee CEPHGG (Comitê de Ética em Pesquisa do Hospital Alberto Rassi- HGG) link to a national database of research records involving human in Brazil.

2) Participants

All of the participants were Brazilian high school students (13-17 years old ; mean age = 15.8, SD = 1.1) and right-handed [11]. They were all monolingual. They do not have a hearing problem nor have reported history of psychiatric or neurological disorders. Twenty subjects (12 females and 8 males) participated in this study. Five participants were eliminated from the study. They have been rejected on the same base as the experiment 1.

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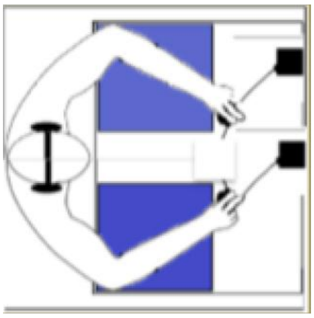

Figure 4: Position of the participant in experiment 2.

3) Stimuli

The stimuli were the same translate into Brazilian Portuguese. In Brazilian Portuguese, no frequency dictionary exists like in French. So we use most of the same word. We change only the word in Portuguese who is more than trisyllabic, has many purposes or did not interpallate Brazilian (e.g. floe). In experiment 2, the background words were action and non-action word mixed.

4) Equipment and data acquisition

The exact same equipment and data acquisition technic from experiment 1 was used.

5) Procedure

It is significantly identical than experiment 1. The difference being that the participant does the experiment with both hands at each block (Fig. 4). It is a symmetrical bimanual task. With this group, only one block with action words as target and one block with non-action word as target. This means the experiment is also shorter, with just 2 blocks to listening. For the experiment 2, the total length of the experiment is less than 10 minutes.

6) Data Analysis

The data analysis is almost the same as experiment 1. The difference is in the Anova. There is no group factor and only the data of the right hand have been extracted. In the Brazilian part of the project, we only have the teenager's data. So, it is a two-way ANOVA.

For this group, one participant was excluded with the artifact rejection and four with the modified Thompson Tau test.

III. RESULTS

A. The baseline comparison

There are a lot of results of the baseline analysis. To facilitate the lecture because it is a continued analysis, only the significative and tiny *t* values are showing there. For the Canadian group, the GFM is significantly superior to the baseline after listening an action word from 300 ms to 800 ms ($t(7)=2.905$, $p<0.05$). In the same group, we also found two windows of time significantly superior after listening to a non-action word at 450 ms to 500 ms ($t(7)=3.624$, $p<0.01$) and 700 ms and 750 ms ($t(7)=2.368$, $p<0.05$). For the Brazilian group, only the action word made a modulation strong enough to be significantly superior from 350 ms to 800 ms ($t(14)=2.264$, $p<0.05$).

B. . The Anova Results

The result of the Canadian group came from a four-way repeated ANOVA. Maulchy's test indicated that the assumption of sphericity had been violated, $\chi^2(90)=433{,}805$, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .16$). The results show a significant interaction between the hands, the word, the windows of time and the group at $F(2{,}082, 35{,}402)=10.494$, $P < .001$. Only the results of the pairwise comparison of the action and non-action words of the right will be shown in the next section.

For the Brazilian group, the ANOVA was also significant. Maulchy's test indicated that the assumption of sphericity had been violated, $\chi 2$ $(90)=321{,}183$, $p<.001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .147$). The results show a significant interaction between the word and the windows of time, $F(1{,}906, 26{,}679)= 3{,}889$, $P < .05$.

C. Post-Hoc, Pairwise Comparison (LSD)

The first comparison is between the action words and the non-action words. We find a similar result in the two groups. The action words significantly modulate more strength than the non-action words. For the Canadian group, the difference in the mean of the GFM is significant from 400 ms to 700 ms ($p<.05$). For the Brazilian group, it is significant from 250 ms to 800 ms ($p<.05$).

The second comparison is temporal. We look at the difference of the mean between the windows of 100 ms to 150 ms with 150 ms to 200 ms. The last one with 200 ms to 250 ms and it continues like that until 800 ms. For the action words, the results of the Canadian group show two periods when the augmentation of the GFM is strong enough to be significant. The windows of 150 to 200 are significantly superior of his predecessor ($p<.01$) and the period of 350 ms to 550 ms, in which every window of 50 ms is significantly superior of his predecessor ($p<.05$). For the Brazilian group, the first period was every window of 50 ms is significantly superior of his predecessor is 350 ms to 450 ms ($p<.05$). The second period is 650 ms to 750 ms ($p<.05$). The non-action words bring only one GFM significantly superior of his predecessor. It was for the Canadian group at the windows 450 ms to 500 ms ($p<.01$).

IV. DISCUSSION

A. Reproduction of Anterior Results

In the previous study using word as stimuli [2], the results shown was significantly stronger amplitude following the action words compared to the non-action words. The difference was between 260 ms and 430 ms.

Our results show a stronger modulation following the action words in comparison to the non-action words. If we look at the difference between our studies and the past one. For the Brazilian group, it is significant almost at the same time, 250 ms, but it's continuing until 800 ms. In the Canadian group, it's significantly later, 400 ms, until 700 ms.

Theses differences caused a distinction in the normalization. They used normalization between zero and one while we use a baseline correction. Which is more common with online data like with electroencephalogram analysis. In second, the cause can be the population. The Canadian has a population inferior to the Brazilian group. But the results from the previous study came from six participants, it is less than the Canadian group.

For now, it's not the timing of the result that should keep our attention but the result itself. In our two groups, who talk in different languages, the result is the same. The action words show superior modulations than the non-action word. We reproduce the result with a portable device by doing the experiment in high school. We use less expensive material like a uniaxial grip force sensor. Which are less complicated to replace if it happens to be broken. We project to use the material with younger children, meaning more risk in the manipulation of the grip force sensor.

B. Similarity and Difference

The previous section looks only at the result of the comparison between action and non-action word present in the older study [2]. But the recent study, [3]–[5] use other statistical tests to look at diverse aspect of motor activity following stimuli. We do mostly the same tests. However, direct comparison of the results has to be taken with a little distance because the stimuli and the purpose of these was different. They look more the effect of the grammatical structure of the motor activity than the word itself. So for there, a look at our results with using mostly the same statistical method will be enough.

The results of our two groups show some distinction. The first one is the modulation following the non-action words. There is no significant GFM for the Brazilian group (none of the baseline and the temporal analysis). Also, the results of the Canadian group show baseline and temporal modulation significant. These differences can be related to distinction in the sample and the task. For the Brazilian, it was bimanual and the Canadian, unimanual.

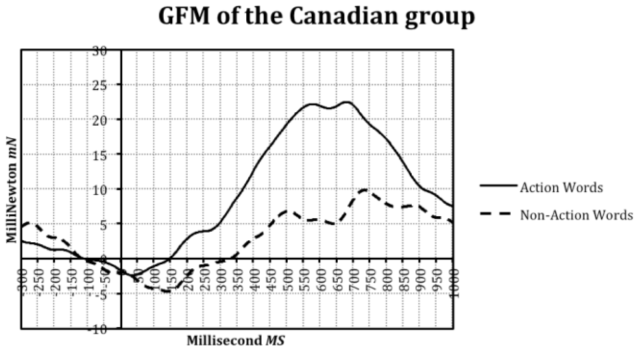

Figure 5: The grip force modulation of the Canadian group after the stimuli.

We not only analyzed the similarities between action/non-actionwords, but a variety of others. The GFM is significant at one window of interval (Can. 300 ms; Bra 350 ms). A microanalysis of a certain time frame could show the smallest interval. Additionally, at 350 ms, there is significant temporal GFM. It possible to see it in the Fig. 5 and Fig. 6. This happens after the beginning of the lexical semantic retrieval windows [13] related to motor activity by previous study [4]. These similitudes between our groups correlates to previous studied that have indicated the validity of the portable device.

Which is, the action word does influence the motor activity. In comparison, non-action words show few windows of significant modulations, and only in the Canadian group. If the effect of the non-actions need more exploration for clarified it effect. The effect of the action word on the motor activity as a result of an intraparial [10] and M1activation [1] is clear and even produce the modulation of the grip force.

C. Possibility of a Portable Device

At the beginning of a research project, one question is universal. How many it will cost? The budget question affects a big part of the research. Studying "normal" adult population, who live around the university center, is not too expensive and difficult to find. But when you look for a population of medical profile with limitations, for children or for a population in a more peasant area, it's complicated and more expensive.

The portable device therefore allows easier access to the target populations as well as the possibility of having a larger sample by moving a research team in environments. In hospitalization center, we can bring the material in it easily or events in the room of the participant in a long care services establishment. So the participant with limited mobility does not have to do a difficult travel or we didn't need to pay for the accommodation necessary.

Like us, it's possible to go to a school to have access to a large population of children. Normally with children, we have to accommodate the scheduled of the family and their trip. A lot of research center are far from the residential area. Additionally, like it was explained before, using sensitive materials with kids can be tricky. The low cost of this device compared to triaxial sensors, give possibilities in the budget for a replacement piece.

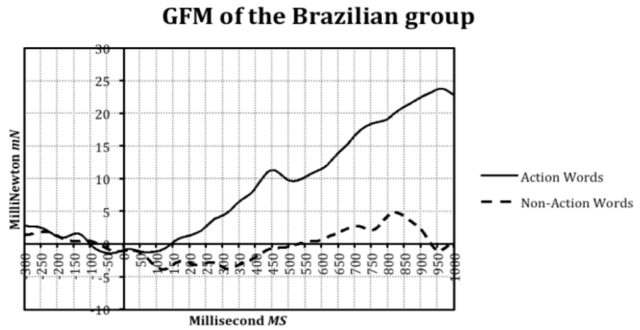

Figure 6: The grip force modulation of the Brazilian group after the stimuli.

In the future it can also be interesting to see the effect of a specific sport language and its effect on the motor activity. Even make a comparison between amateurs and professionals athletes. With the portable device, we can just go to the sports center where they train.

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Some linguists are always interested in language of withdraw population who live away from industrial cities. The specific language or linguistic structure related to the motor activity of a different way of life can be analyzed with this portable device. Essentially with professionals in contact with these civilizations.

V. CONCLUSION

The validity of the portable grip force sensor is strong. It offers flexibility towards a variety of environments. It diminishes the cost of his material and minor need of compensation for the participant. It's has shown to be good device to explore the link between motor activity and language in diverse contexts, such as in medical, developmental or in cultural issue. Finally, this device can be used to link other functions to motor activity. The brain has many functions, which have shown to work together.

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