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Engineering

SMARTPHONE USER TESTS FOR USER CENTERED DESIGN

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ABSTRACT:
THESE LAST DECADES SOME NEW INFORMATION AND COMMUNICATION TECHNOLOGIES BECOME POORLY ADAPTED TO ELDERLY, WITH THE INCREASE IN LIFE EXPECTANCY. IN PARTICULAR, THIS IS THE CASE OF DEVICES WITH SMALL SIZE AS SMARTPHONES FOR INSTANCE. IN THIS CONTEXT, IN ORDER TO PREDICT AND IMPROVE THE ACCESSIBILITY OF PEOPLE WITH LIMITED FOREARM MOTOR CAPACITY THIS PAPER DEALS WITH THE STUDY OF INTERACTION MODALITIES BASED ON EMG (ELECTROMYOGRAPHY) FOR HUMAN-COMPUTER INTERACTION, FOR A MORE TOLERANT INTERACTION IN THE FACE OF VAGUENESS OF THE GESTURE. FOR THIS PURPOSE SERIES OF TESTS FOR FINGER ACTIVITY ESTIMATION WERE PERFORMED ACCORDING TO AN APPROPRIATED BIO-MEDICAL PROTOCOL WHILE MANIPULATING A SMARTPHONE IN TWO CASES: WITH AND WITHOUT ERGONOMIC STRAP USED. THE EMG SIGNALS OF THE THREE MOST INVOLVED MUSCLES OF THE THUMB ARE RECORDED AND ANALYZED. THE RESULTS SHOW THAT: I). THE FINGER'S EMG SIGNALS FOR THESE MUSCLES ARE INTERDEPENDENT, II). THE RELATIONSHIPS BETWEEN POSITIONS OF TOUCH, FOR THREE LAYOUTS DOTS DISPOSED ON THE SMART PHONE SCREEN, AND APPLIED FORCE ARE NO LINEAR. USING LINEAR REGRESSION ANALYSIS THE QUANTITATIVE RELATIONSHIPS BETWEEN FORCE AND FINGERS' DISPLACEMENTS HAVE BEEN EXTRACTED. BY COMPARING FORCE-DISPLACEMENT RELATIONSHIPS, IT IS OBSERVED THAT THE THUMB INDUCES LESS ACTIVATING FORCE THAN THE OTHER FINGERS. IT WAS ALSO FOUND THAT THE RELIEF OF THE FINGER MUSCLES INVOLVED IN THE GRIPPING OF THE SMARTPHONE ALLOWS TO REDUCE THE MUSCULAR ACTIVITY OF THE THUMB AND THUS TO DELAY THE APPEARANCE OF MUSCULOSKELETAL DISORDERS.

KEY WORDS: USER CENTERED DESIGN, ERGONOMICS, ACCESSIBILITY, BIOMECHANICS

INTRODUCTION

Today our world is becoming more and more "*connected*" thanks' to new information and communication technologies allowing us access to information by the emergence of the Internet,

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and its enabling tools. Smartphones, for instance, are ones of the most effective ways to navigate in this virtual world. Their small size and intuitive interface have made them familiar, indispensable and ubiquitous devices. These devices offer a variety of possibilities through an increasingly large touch screen. If the interaction with the phones of yesterday was done mainly by means of a keyboard located under the screen, in today designed phones the whole surface of the devices are used thus increasing their functionalities. However, people with limited hand mobility can experience fatigue-related problems when using such devices [4],[5]. More generally, the long-term effects of everyday use of a smartphone (including young people) are still unknown, but it is reasonable to suppose that illnesses may appear, such as tendinitis [6],[7]. These masse designed devices are mainly based on interaction with gesture or touch: which requires specific gestures especially for elderly [8],[9]. Thus, scientific and technological advances have to be proposed to take this reality into account. To this end a question arises, namely: *How to improve the accessibility for this class of devices*?

A two-step touch method (*Press and Flick*) for website navigation on smartphones was presented in [8]. It consists of finger press and flick motions: *i).* a target hyperlink is selected by a finger press motion; *ii).* a finger flick method is conducted for error correction if the initial interaction (press) failed. Authors comprehensively examined its effectiveness using the goals, operators, methods, and selection rules (GOMS) model and user testing. For this purpose they compared the two-step touch method with the current touch method through the GOMS model and user testing. The results show that the two-step touch method is significantly superior to the current touch method in terms of error rate and subjective satisfaction score. However, it seems that its superiority in terms of number of interactions and touch time is vulnerably affected by error rate. Recently new ergonomic solutions were available on the market. The designed ergonomic keyboards "*Word Flow*" from Microsoft was an example. Supposed to do writing easier and faster, it was abandoned last year. The smartphones with classical "*QWERTY*" and "*AZERTY*" keyboards seem not to be obsolete anymore and are still predominant on the market today. For this reason our study concerns the manipulation of these widely used classical devices.

An extended review of control with hand gestures by older users was presented in [4]. Authors first reviewed issues about age and its related characteristics. Then two major

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[4] S-F. M. Liang, Y-J. B. Lee; *Control with Hand Gestures by Older Users: A Review, Lecture Notes* in *Computer Science* book series (LNCS, volume 9754), International Conference on Human Aspects of IT for the Aged Population , ITAP 2016: Human Aspects of IT for the Aged Population. Design for Aging, pp 350-359

[5] H. Hwangbo , S.H. Yoon, B.S. Jin , Y.S. Han; *A Study of Pointing Performance of Elderly Users on Smartphones*, pp. 604-618 (2012), International Journal of Human–Computer Interaction, Volume 29, 2013 - Issue 9, Pages 604-618

[6] S.C. Lee, M.C. Cha, H. Hwangbo, S. Mo, Y.G. Ji; *Smartphone form factors: Effects of width and bottom bezel on touch performance, workload, and physical demand*, Applied Ergonomics 67 (2018) 142–150

[7] I. Bautmans, S. Vantieghem, E. Gorus, Y-R. Grazzini, Y. Fierens, A. Pool-Goudzwaard, T. Mets; *Age-related differences in pre-movement antagonist muscle co-activation and reaction-time performance*, Experimental Gerontology, 46 637–642 (2011).

[8] K. Jung, J. Jang; *Development of a two-step touch method for website navigation on smartphones*, Applied Ergonomics 48 (2015) 148e153

[9] I. G. Motti, N. Vigouroux, F. Gorce; *Improving accessibility of tactile interaction for older users: lowering accuracy requirements to support drag-and-drop interaction,* Procedia Computer Science, Elsevier, vol. 67, 366-375, (2015).

applications of gestural user interfaces, "gesture-on-surface" and "gesture-in-midair," are investigated. It is shown, that *while gesture-on-surface refers to gesture control on touchscreens, gesture-in-midair denotes that hand gestures are performed without touching anything*.

A study of pointing performance of elderly users on smartphones was presented in [5]. Pointing performance was measured by the time taken to complete the pointing task and the number of errors during a task. For this purpose authors conducted two experiments. For the first one (three target sizes and two target spacings), they analyzed whether touch screen pointing performance is dependent on the location of the target. For the second experiment (three types of feedback; auditory, tactile, and audiotactile) the results show that*: i.)* pointing performance of elderly was significantly influenced by size, spacing, and location of target, and *ii*.) the performance was higher in audio tactile feedback condition.

Recently an investigation of the effect of two smartphone form factors (width and bottom bezel) on touch behaviors with one-handed interaction was presented in [10]. For this purpose, authors performed user experiments on tapping tasks for four widths (67, 70, 72, and 74 mm) and five bottom bezel levels (2.5, 5, 7.5, 10, and 12.5 mm). In order to examine the touch behavior, authors collected: task performance measures (success rate and task completion time), electromyography, and subjective workload data (NASA-TLX method).

The performance of two scrolling techniques (*flick* and *ring*) for document navigation in touch-based mobile phones using three input methods (*index finger*, *pen*, and *thumb*), with specific consideration given to two postures: *sitting* and *walking* were examined by Huawei et al. in [11]. The authors find out that*: i.)* in both sitting and walking postures, for the three input methods, *flick* resulted in shorter movement time and fewer crossings than *ring*, suggesting *flick* is superior to *ring* for document navigation*; ii.)* for sitting posture, regarding pen and thumb input, *ring* led to shorter movement time than *flick* for large target distances.In [12] authors relate age and muscle mobilization during a prolonged reaction-time (*RT*) test. For this purpose they studied the evolution of reaction time with relief of the muscles involved in the gripping of a smartphone by young and older subjects.

Note that other studies dealt with improving the accessibility of tactile interaction for older users by lowering accuracy requirements to support drag-and-drop interaction [13]. Some of them deal with electromyography (EMG) signal processing, and the flourishing use of smartphones. It was proven that the peak value of EMG signals after root mean square (RMS) processing is an index of fatigue [14] when subjects are performing the task at the same level of force when

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[10] S.C. Lee, M.C. Cha, H. Hwangbo, S. Mo, Y.G. Ji; *Smartphone form factors: Effects of width and bottom bezel on touch performance, workload, and physical demand*, Applied Ergonomics 67 (2018) 142–150

[11] T. Huaw, R. Xiangsi, T. Feng, F. Wang; *Evaluation of Flick and Ring Scrolling on Touch- Based Smartphones*, International Journal of Human–Computer Interaction , Vol. 30, 2014 - Issue 8: Human Computer Interaction in the Asia-Pacific Region,pp. 643-653, https://doi.org/10.1080/10447318.2014.907017

[12] S. Vantieghem, E. Gorus, E. Lauwers, Y. Fierens; A. Pool-Goudzwaard, I. Bautmans; *Age-related differences in muscle recruitment and reaction-time performance*, Experimental Gerontology, Volume 70, October, 125-130 (2015).

[13] I. G. Motti, N. Vigouroux, F. Gorce; *Improving accessibility of tactile interaction for older users: lowering accuracy requirements to support drag-and-drop interaction*, Procedia Computer Science, Elsevier, vol. 67, 366-375, (2015).

[14] S. Boyasn, A. Guenel, R. Naik Ganesh; *Endurance time prediction using electromyography*. In Applications, Challenges, and Advancements. In Electromyography Signal Processing*:* Bd. v. 219-233: IGI Global, ISBN 978-1-4666-6090-8 (2014).

manipulating daily used devices as smartphones. In this optic, the speed of motions of the thumb and the intensity of segmental muscular EMG activity of the *abductor pollicis longus* (*APL*) muscle of the hand during an upward writing test were investigated in [15].

Interesting results concerning the optimal range of smartphone form factors for one-handed interaction, which could contribute to the design of new smartphones, were obtained in [10] where the EMG signals of two thumb muscles, namely the first *dorsal interosseous* and *abductor pollicis brevis*, were observed. It seems that: *i). the task performances deteriorated with increasing width level*; *ii).* the subjective workload and electromyography data show similar patterns with the task performances; *iii).* the tasks became increasingly difficult as the bottom bezel level decreased.

After reviewing and analyzing some studies related with the subject of this paper, a part of which was presented here above, seams that they partially improved accessibility of smartphones touch screen. However, they do not take into account of the vagueness of the gesture thus limiting the performances of the proposed solutions.

Thus, our aims is to show the interdependencies amongst the work done by the thumb and the others fingers while gripping the phone, via the experiments to measure the muscular activity of the thumb. The results obtained on the decrease of muscular activity of the thumb with strapped phone are interesting and encouraging. They can contribute to the design of new generation mobile touch screen devices and application button layout in the frame of user centered design. As designers of current smartphones try to include a lot of information and input control in the same display, the latter often include too much information. As a result elderly users with osteoarthritis of the thumb as rhizarthrosis (or trapeziometacarpal) experience pain during and after using such devices.

The materials and the methods are detailed in Section 2. Then, the results are presented and discussed in Section 3. Conclusions and future work are suggested in Section 4.

METHOD

To carry out a complete study of human limb's movements it would be necessary to study the functionality of a lot of muscles. In fact, the movements of a human limb are possible thanks to a complex network of muscles and tendons, and interaction amongst them. Studying all the hand muscles while manipulating a smartphone seems to be a very complicated task. For the sake of accessibility, we studied the behavior of three out of eight more loaded and involved muscles of the hand namely: *adductor pollicis* (*AP*), *abductor pollicis brevis* (APB) and *interossei dorsal muscles* (*DIM*). (Fig. 1.a).

The main points of the proposed methodology are: *i).* performing experiments to measure the muscular activity of the thumb during two tests for each subject while manipulating a smartphone in both ergonomic cases: with and without a strap used; *ii*). comparing the data retrieved on each of the tests in order to evaluate the activities of the three more involved muscles of the thumb in these both cases.

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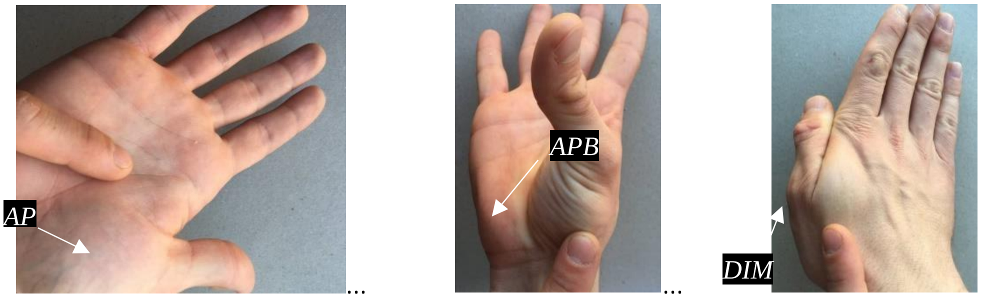
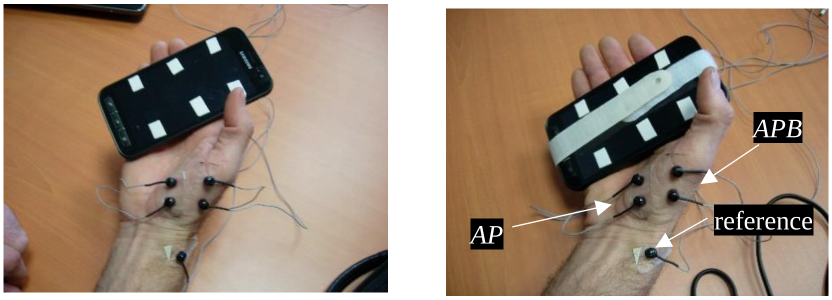
[15] G. Thérèse Simard, P. Esem Cerqueira; *Fine motor control: An EMG study of ability of the thumb in healthy hands of adult subjects*, Journal of Electromyography and Kinesiology, 2 (1), 42-52 (1992).



a) b) c)

Figure 1: Locations of: a). adductor pollicis (AP), b). abductor pollicis brevis (APB), c) interossei dorsal muscles (DIM).

According to the proposed methodology, during the tests, subjects had to use the thumbs of their predominant hands when touching the smartphone screen as shown in Fig. 2.



a) b)

Figure 2: Test bench for the experiments carried out: positions of the sensors for target dots on the Smartph. screen; manipulation of the Smartphone without a strap (a) and with a strap (b).

BIOPAC EL503 Vinyl 1-3/8" electrodes were used to record the EGM signals of *adductor pollicis* (AP), *abductor pollicis brevis* (APB) and *dorsal interossei muscles* (DIM) according to the SENIAM (surface EMG for non-invasive assessment of muscles recommendations)[16] and analyzed with four channel EMG-BIOPAC MP150 system, the fourth channel being the reference one. The smartphone used in the performed experiences was an iPhone 4S. On the touch screen (*3.5 in*., *88.89 mm*) six square visual indicators were spaced from their center regularly (Fig. 2a) to crisscross the entire screen in three different trajectories (layout types) as shown in Fig. 3.

Prior to the three-order Dot disposals tests, a familiarization session consisting of five trials was dedicated for each participant. After *5* minutes of recovery, the participants performed the tests. According to the proposed medical protocol, during the tests, subjects (in sitting position)

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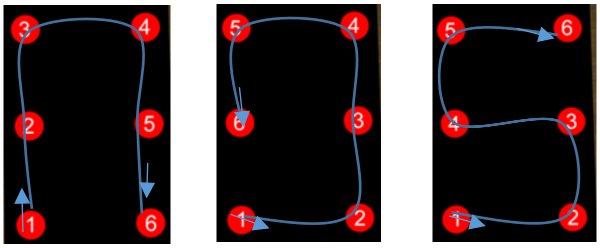
[16] H.J. Hermens, B. Freriks, C. Disselhorst-Klug, G. Rau; *Development of recommendations for SEMG sensors and sensor placement procedures*. Jour. Electromyogr. Kinesiol. 10 (5), 361–374 (2000).

had to only use their predominant thumb finger when touching the screen. The first phalange of the little finger was placed on the table and remained in this position throughout the experience.

Two tests, of 3 minutes each, are performed according to the bio-medical protocol. During the first one, subject held the smartphone in his agile hand, resting elbow and wrist on a fixed support (table). While squeezing the smartphone with his supporting hand, the subject had to touch the six visual markers with the thumb in a specific order (Fig. 3) for 180 seconds, changing the orders every 60 seconds. In order to maintain the same speed of action for all subjects, for both tests, a metronome set at *60 bpm* (beats per minute) gave the tempo to touch the indicators with a frequency of *1 Hz*. During the second test, the subjects have to repeat the same movement as in test one. However, a strap passing in the back of the hand and in front of the smartphone screen was attached, as shown in Fig. 2b, so that the muscles involved in the gripping by the fingers were completely relieved. In other words, in this configuration the subject does not need to actively hold the phone while in the first case it must tighten it.



a) b) c)

Figure 3: Three-order Dot disposals (layouts) on the Smart phone screen.

Eight unpaid, voluntary and healthy subjects (all males, two of them left-handed), aged from 20 to 62 participated in the experiments. All subjects have declared not having: *i).* corrected visual impairment; *ii).* impairments of haptic sensitivity (sensitivity of touch, numbness of the fingers and loss of finger location perception); *iii).* diseases or symptoms which induce hand movement disorders. All subjects declared also being naive to the purpose of the experiment. The study was approved by the Ethics Committees of the University Grenoble Alpes and all participants gave written informed consent. After a briefing about the experiment, participants filled out a background survey.

During the test, finger involvement, is estimated by the treatment of EMG signals emitted by the three more involved muscles of the thumb, while manipulating the Smartphone, in the two cases: without and with a strap. In Figure 4 the EMG row signals of muscles *APB* (channel 2) for subject *Corsel* and *AP* (channel 1) for subject *Michel* are presented. However, these signals require treatments in order to be analyzed and compared after then for biomechanical analysis of the finger movement.

For this purpose, first, all raw sEMG signals were simultaneously sampled at *1250 Hz* and filtered with Butterworth 2-nd order, band-pass 10–5000 Hz and notch-filtered as in [17] using

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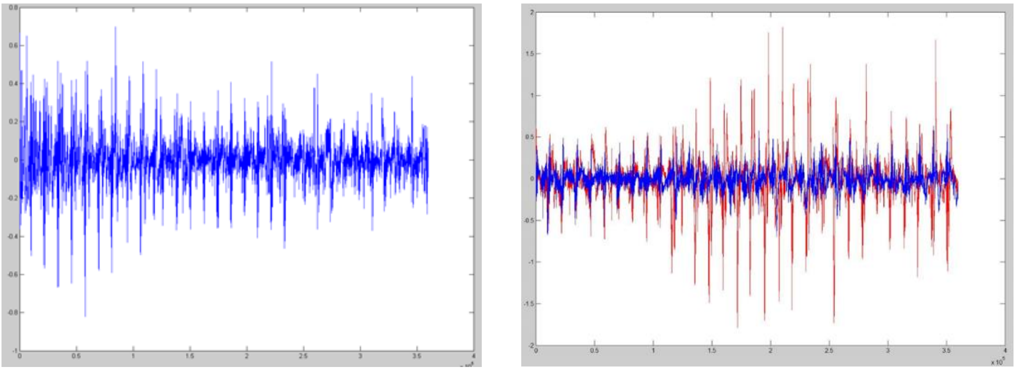
[17] J.F. Stins, M. E. Michielsen, M. Roerdink, P. J. Beek; *Sway regularity reflects attentional involvement in postural control: Effects of expertise, vision and cognition*. *Gait & Posture*, *30*(1), 106–109 (2009).

MATLAB (MATLAB 2014a, MathWorks) software in order to erase the various parasites. Note, that the low frequencies are trained parasites due to external factors such as: cable movement, blood passing in the hand, while the high frequencies represent often the parasitic movements of the hand. Then sEMG signals are RMS (root mean square) processed over a short *2 s* period and the maximum RMS values obtained between the different tests are compared. Consequently the absolute values of those signals are taken. Finally those modified signals of the three muscles for each subject are compared in order to find the more leaded one, while manipulating the Smartphone, with and without a strap. Here, it is assumed that the subject is not tired and therefore the EMG/force relationship remains constant.

Concerning the statistical analysis, first, Shapiro-Wilk method has been applied to verify the normality of the EMG data. Then, a *two-way* Analyses of variance (ANOVA) were performed to test changes on RMS-EMG (i.e. dependent variable) while manipulating the smartphone in both cases: with and without a strap separately for the three muscles. Significance was set a priori $p<0.001$. All the statistical analyses were performed under the MATLAB Software (MATLAB 2014a, MathWorks). The standard error of mean (SEM) of finger's pressing forces of all subjects were calculated as well.



a)

b)

Figure 4: EGM raw signals: a). APB muscle (subject Corsel) without a strap) and AP muscle (subject Michel) red without a strap, blue with a strap

RESULTS AND DISCUSSION

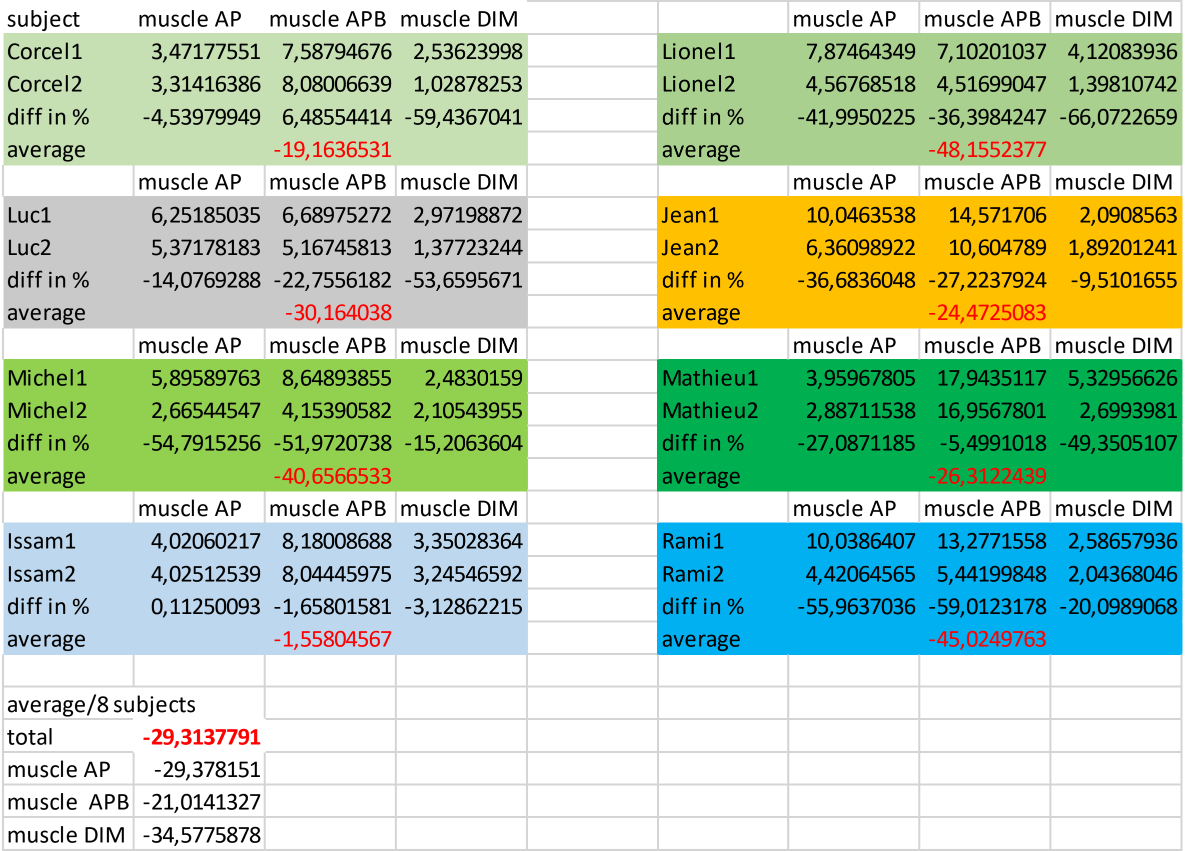
Recall that, for each subject, after filtering, the RMS value of the EMG data were compared and averaged (Matlab Software) to get the overall value of the activity by averaging the differences of the three channels in both cases: with and without a strap. Then the average difference for each muscle and for all three muscles on seven subjects were calculated in both cases (without a strap *1* and with a strap *2*). The results are presented in Table.

From Fig. 4, is seen that muscle activities are less important while manipulating the strapped phone. This is confirmed also by the values reported in Table 1. It is seen, that the overall muscle activity of the thumb decreased for all the subjects (over *27%*). For all of them, the average activity decreased: for *AP* muscle (over *25%*), for APB muscle (over *19%*) and even significantly for *DIM* muscle (over *36%*). However, it seems that this trend is not followed by some muscles because the *APB* activity of *Subject Corcel* and *AP* activity of Subject Issam increased. This may be due to a wrong electrode location for these subjects or a specific muscle involvement associated to the great variability in muscle involvement across subjects. However, it can be assumed that the strap helps the subject significantly if properly used because it keeps the phone without the need for great muscle intervention.

After then the muscle activities in the Points *1,2…6* for each orders Dots disposals, (called *Trajectory 1*, *Trajectory 2* and *Trajectory 3*) were compared in order to estimate the difficulty to reach a specific zone of the touch screen. For this purpose, after filtering the row EMG signals with a *BP filter* (*20-500 Hz*) the RMS values over small periods (*2 s*) are calculated in order to visualize the contractions of the muscles in these points (Fig. 4a). Finally the RMS value are filtered toer smooth the curve.

For the right handed subjects the major peaks correspond while touching the bottom left side of the smartphone screen corresponding to the surrounding zone of *Point1*of the three Trajectories (Fig. 3 a, b, c). While, for the left handed subjects the peaks correspond while touching the bottom right side of the smartphone screen corresponding to the surrounding zone of *Point 6* for *Trajectory 1* (Fig. 2.a) and *Point 2* for *Trajectories 2* and *3* (Fig. 3b, et Fig. 3c respectively). Thus, the effort to reach these points is more important, which requires most muscle activity.

Table 1: Average RMS signals values (*Voltage*) for the three muscles of each of the eight subjects (without a strap *1*, with a strap *2*)



subject	muscle AP	muscle APB	muscle DIM			muscle AP	muscle APB	muscle DIM
Corcel1	3,47177551	7,58794676	2,53623998		Lionel1	7,87464349	7,10201037	4,12083936
Corcel2	3,31416386	8,08006639	1,02878253		Lionel2	4,56768518	4,51699047	1,39810742
diff in %	-4,53979949	6,48554414	-59,4367041		diff in %	-41,9950225	-36,3984247	-66,0722659
average		-19,1636531			average		-48,1552377	
	muscle AP	muscle APB	muscle DIM			muscle AP	muscle APB	muscle DIM
Luc1	6,25185035	6,68975272	2,97198872		Jean1	10,0463538	14,571706	2,0908563
Luc2	5,37178183	5,16745813	1,37723244		Jean2	6,36098922	10,604789	1,89201241
diff in %	-14,0769288	-22,7556182	-53,6595671		diff in %	-36,6836048	-27,2237924	-9,5101655
average		-30,164038			average		-24,4725083	
	muscle AP	muscle APB	muscle DIM			muscle AP	muscle APB	muscle DIM
Michel1	5,89589763	8,64893855	2,4830159		Mathieu1	3,95967805	17,9435117	5,32956626
Michel2	2,66544547	4,15390582	2,10543955		Mathieu2	2,88711538	16,9567801	2,6993981
diff in %	-54,7915256	-51,9720738	-15,2063604		diff in %	-27,0871185	-5,4991018	-49,3505107
average		-40,6566533			average		-26,3122439	
	muscle AP	muscle APB	muscle DIM			muscle AP	muscle APB	muscle DIM
Issam1	4,02060217	8,18008688	3,35028364		Rami1	10,0386407	13,2771558	2,58657936
Issam2	4,02512539	8,04445975	3,24546592		Rami2	4,42064565	5,44199848	2,04368046
diff in %	0,11250093	-1,65801581	-3,12862215		diff in %	-55,9637036	-59,0123178	-20,0989068
average		-1,55804567			average		-45,0249763	
average/8 subjects								
total	**-29,3137791**							
muscle AP	-29,378151							
muscle APB	-21,0141327							
muscle DIM	-34,5775878							

In summary, *Trajectory 1* (Fig. 3a) requires more muscular effort than the other ones. In contrary *Trajectory 3* (Fig. 3c) requires less effort. These findings suggest that it can be interesting to investigate on these displacements to create the smartphone's interface most ergonomic possibly. SEM) of finger's pressing forces of all subjects were calculated as well.

CONCLUSION

In this study we investigate the behavior of muscle thumb EMG during manipulation of a Smartphone in two cases: with and without a strap. Through experiments (EMG signal processing) which involve the three more loaded muscles of the thumb finger, subjects' pressing involvement have been recorded and analyzed while touching the smartphone screen for three different trajectories. The results shown that the finger's EMG signals for the three most involved muscles are interdependent thus increasing the difficulties for a precise finger force analysis. They also shown that: *i).* the relationships between positions of touch, for these three-order dots disposed on the smart phone screen (layout, trajectories), and EMG level were no linear; *ii).* the EMG decreases significantly while manipulating strapped phone.

In the near future the study will be deepened in order to determine strap's true utility and if so to optimize its ergonomics. Thus, it is expected that through further study about people interaction with electronic devices, they will fill more comfortable while using these new technologies. At this stage of the study it may be stated that the use of the strap seems to bring significant help to the thumb for smartphone use by people with limited fingers' mobilities.

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REFERENCES

1. **S-F. M. Liang; Y-J. B. Lee**; *Control with Hand Gestures by Older Users: A Review, Lecture Notes* in *Computer Science* book series (LNCS, volume 9754), International Conference on Human Aspects of IT for the Aged Population , ITAP 2016: Human Aspects of IT for the Aged Population. Design for Aging, pp 350-359
2. **H. Hwangbo; S.H. Yoon; B.S. Jin; Y.S. Han**; *A Study of Pointing Performance of Elderly Users on Smartphones*, pp. 604-618 (2012), International Journal of Human–Computer Interaction, Volume 29, 2013 - Issue 9, Pages 604-618
3. **S.C. Lee; M.C. Cha; H. Hwangbo, S. Mo; Y.G. Ji**; *Smartphone form factors: Effects of width and bottom bezel on touch performance, workload, and physical demand*, Applied Ergonomics 67 (2018) 142–150
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5. **K. Jung; J. Jang**; *Development of a two-step touch method for website navigation on smartphones*, Applied Ergonomics 48 (2015) 148e153
6. **I. G. Motti ; N. Vigouroux ; F. Gorce**; *Improving accessibility of tactile interaction for older users: lowering accuracy requirements to support drag-and-drop interaction*, Procedia Computer Science, Elsevier, vol. 67, 366-375, (2015).
7. **T. Huaw; R. Xiangsi; T. Feng; F. Wang**; *Evaluation of Flick and Ring Scrolling on Touch- Based Smartphones*, International Journal of Human–Computer Interaction , Vol. 30, 2014 - Issue 8: Human Computer Interaction in the Asia-Pacific Region,pp. 643-653, https://doi.org/10.1080/10447318.2014.907017
8. **S. Vantieghem; E. Gorus; E. Lauwers; Y. Fierens**; **A. Pool-Goudzwaard, I. Bautmans**; *Age-related differences in muscle recruitment and reaction-time performance*, Experimental Gerontology, Volume 70, October, 125-130 (2015).
9. **S. Boyasn; A. Guenel; R. Naik Ganesh**; *Endurance time prediction using electromyography*. In Applications, Challenges, and Advancements. In Electromyography Signal Processing*:* Bd. v. 219-233: IGI Global, ISBN 978-1-4666-6090-8 (2014).
10. **G. Thérèse Simard; P. Esem Cerqueira**; *Fine motor control: An EMG study of ability of the thumb in healthy hands of adult subjects*, Journal of Electromyography and Kinesiology, 2 (1), 42-52 (1992).
11. **H.J. Hermens; B. Freriks; C. Disselhorst-Klug; G. Rau**; *Development of recommendations for SEMG sensors and sensor placement procedures*. Jour. Electromyogr. Kinesiol. 10 (5), 361–374 (2000).
12. **J.F. Stins; M. E. Michielsen; M. Roerdink; P. J. Beek**; *Sway regularity reflects attentional involvement in postural control: Effects of expertise, vision and cognition*. *Gait & Posture*, *30*(1), 106–109 (2009).