Research on Haptics Feedback

for Wearable Computing course

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Abstract: the haptic technology takes into consideration the human sense of touch and gives a new dimension to the way people communicate. The research conducted in this field opened the doors for exploring a human body and tactile receptors spread all over the surface of the skin. The results of this paper show that with a reduced number of vibration patterns realized using only one dimension of encoding the information (i.e. rhythm), an overall recognition rate of 89,17% can be achieved when placing the device in the neck area (which was not taken into consideration in previous similar researches). The experiment conducted and the results proved to be valuable for this field and offer a new way of understanding where the vibration devices can be placed and what sort of features they need to have.

Keywords: haptics, vibration patterns, touch sense, rhythm.

I. Introduction

The use of mobile devices has grown consistently in the last decade. Today, many people own and use these things mainly for communication, sending texts and making calls. With the way the technology evolved, a phone has became more than a device used strictly for communication, as it was at the beginning. The smart phones opened the doors of the future for the human indirect interaction. But it is not necessary that we limit ourselves to using them in a restricted way when it comes to transmitting messages (simple text, mails, using social networks and applications). By taking into consideration the features they have, much more in the way we communicate and how we do it can be achieved. We may think of a way in which we can use all the available features so that the amount of information sent and received expands.

There are several situations in which a direct way of communicating an information can be improper. For example, when someone is making a speech and cannot be interrupted because that would mean disturbing the entire presentation. But when there is a message that needs to be transmitted to the person in case, a new approach should be found. This is where the common feature of a mobile device comes in use. We are talking about the vibration feature that every phone has.

Nowadays there is a necessary technology to design vibration patterns and adjust them to our needs. The design is adapted to the device and the features available with it. Some mobile phones do not support the modification of all the parameters. Also, the vibrating device from the phone has its limitations and cannot be used with the entire features that a special vibrating device has.

People become more and more aware of the possibility to use their other senses to perceive information. The research made in the haptic field is focused on the use of the human tactile sense. The skin is the outer coverage of the body and the largest organ we have. It is full with sensory receptors, around 4 million of them are all over the surface. The way they are spread around the entire skin surface varies. A larger concentration is found close to the elbow and the spine.

II. Motivation

This research was conducted because there is a constant need of information in the haptic field and new ways of transmitting meaningful messages may be found. At first, after studying previous researches, we decided on the idea of the study and the use it will have. Even though a reduced number of patterns was designed, there are areas of the body where the device has not been placed before. It is also important to take into consideration major aspects when developing ideas for wearable computing, such as user and social acceptance, easy to use and high portability.

III. Research question

Studies conducted before revealed that by using haptic vibration patterns [1], [4] (the so called tactons) a new approach in the way we communicate and what we receive from our devices can be established. It is not necessary to limit ourselves to understanding and perceiving single vibration patterns from or devices when there is a big possibility of understanding much more complex messages.

Tactons are defined as structured tactile messages. For a wide range of distinction between them, several encoding dimensions have been studied. The research made in this area revealed that with the right combination and number of patterns, the recognition rates are not that different [1]. But in any case, as the number of tactons grows, this rate drops. There are several limitations that need to be taken into consideration, such as the fact that confusion between messages is often encountered and the spatial localization plays a huge role for correct recognition as well user acceptance.

The way in which the information is encoded and how we distinguish the meaning of the message can prove challenging sometimes. When it comes to a big number of possible tactons, the chance of them being perceived as unique decreases [2]. The limitations are given by the incapacity of distinguishing between the patterns, if they are not clear. As for parameters, it is common to use frequency, amplitude, roughness and rhythm.

Another important aspect is the spatial localization of the vibrating device. The human skin does not have the same sensibility on its entire surface to perceive information. This is due to the innervation density that varies across the average area of two square meters of skin. In order to avoid confusion of some parameters, there has to be taken into consideration that the skin is not able to distinguish between frequency and intensity [3]. Also, studies shown that several areas of the body are more perceptive than others. In order to get a good perception of the pattern, the source of the vibration has to be situated close to the elbow or the spine [4]. For less sensitive parts of the body, not much research has been conducted.

In order to successfully transmit information using vibration patterns, all these aspects are needed to be taken into consideration. In this research, we assume to:

* achieve a good overall recognition rate (more than 80% of correct patterns recognition);

* have user acceptance of the device and the idea behind;

* figure out parameters that affect general recognition rate score;

* discover if the neck area can be an alternative for the spatial localization.

In order to achieve that, we decided on the following points regarding the number of patterns and the spatial localization. We designed four patterns using different lengths and time pauses between the vibrations (i.e. rhythm for the messages including more than one vibration). A rhythm was realized with this combination. Each pattern in experiment had a clear message behind. Four messages meaning speak louder; speak quieter; speak slower; speak faster were encoded using this way. In case of an extended vocabulary, it’s recommended to add at least one more variable parameter (intensity for instance). In one of the studies conducted [5], the results shown that a combination of rhythm and intensity offers a higher recognition rate than using rhythm and roughness.

As for the location, the side part of the neck was used, since there are no studies that reveal if the neck is perceptive or not, a reduced number of patterns was designed (based on rhythm). The main goal behind the study is to see how perceptive this area is, how users accept the device and if people are able to act accordingly to the information received, when engaged in a speaking activity.

IV. Overview of Related Works

Idea of using tactile senses while being engaged into activity requiring visual and acoustic attention is not a totally new one, several studies and experiments were already made, but still this field has a lot of to investigate. To figure out which aspects and conditions were not researched earlier, we've made an overview of related works before our experiment.

In experiment by Sebastian Feige [6] pre-tests with a mobile phone located in a pocket were made. They showed results far from being satisfactory to make it possible for user to distinguish different vibration patterns, that's why a prototype in a form of wristband with embedded vibromotor was built and used. Five patterns with different rhythms were designed during iterative process which included pre-tests on each iteration until patterns showed to be discernible. Fourteen persons aged 19 to 46 (avg: 26.2, sd: 8.4) participated in the experiment and were randomly assigned to either the experimental or the control group that were of equal size. The difference between groups was in the environment where they received tactile patterns: control group - in a neutral room environment, experimental - in a mobile street environment where they had to walk according to route randomly selected for each participant. The results shown that environment does not makes any difference in the overall recognition score (about 93% (sd: 11.5) in the control group and even 94% (sd: 16.2) in the experimental group).

Another research conducted by Lorna M. Brown and Topi Kaaresoja [5] was devoted to investigation if regular mobile phone can be used as the source for vibrations to represent tactile patterns. Nine patterns with different roughness (from smooth to rough and very rough) and intensity (low-, mid- and high-level, controlled by vibromotor frequency) were used in experiment and the best overall recognition rate of 72% was achieved (by combination of rhythm and intensity in tactile patterns), what was compared to 71% - a result achieved with a high-price vibrotactile transducer in another research [7]. Important notice that patterns were designed taking a fact in account, that amplitude-modulated waveforms (used to create roughnesses) could not be reproduced on the phone motor. An approximation of roughness was created by using different speeds of on-off pulses. As for positioning, participants were holding a phone in non-dominant hand.

Series of experiments were made by Lynette A Jones et al [3] in order to evaluate how perceptive are the forearm and the back of a man when patterns realized by a mounted tactile displays. The results shown that back is more perceptive (up to 98% correct pattern recognitions, lowest - 75%), while for the forearm correct pattern recognition rate was only between 30% and 96% depending on specific patterns. When participants were engaged in different activities, like physical or cognitive tasks, the results of accuracy of identification were up to 92% (for back). Amount of patterns used during this experiments varied from 7 to 8 and some of the patterns were adjusted during procedures. The big difference with many other haptic experiments and with one we've conducted, is in the type of vibrotactile devices and patterns used. Here mounted tactile displays constructed from several (9 for forearm and 16 for back) vibro motors were used, so tactile patterns were encoded not with a roughness or intensity, but with a sequence of active motors. This combination made it possible to give sophisticated navigation commands with application to military forces and with a minimum amount of tactile patterns training required. Even though the solution can be considered highly scalable and effective, it is also a sophisticated and expensive one.

After some more papers and experiments were studied ([1], [2]), we were able to conclude that there were no experiments conducted where vibromotor was placed on the neck. No papers reveal if neck is sensitive enough to recognize tactile patterns and acceptable for user and public. This paper describes experiment which included designing of tactile patterns applicable for public speaking activities and investigation of neck area for the recognition rates and social acceptance.

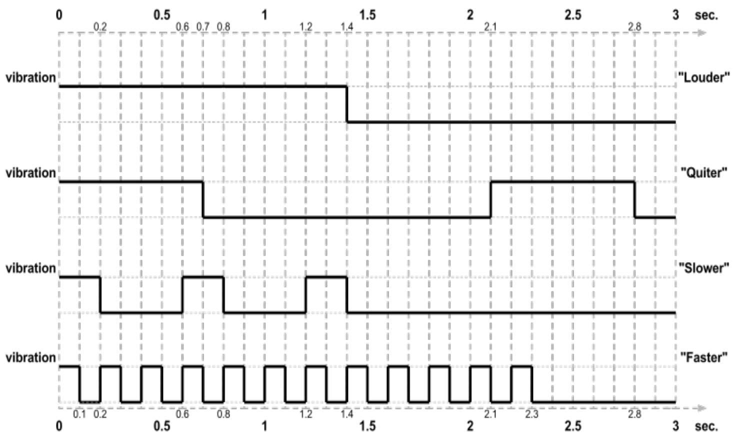
V. Experimental setups

A mobile phone Huawei U8800 Pro running Android v.2.3.5 operating system was used as the source for vibrations. Device was attached to the participant's neck using an elastic band. In everyday life some special elements of fashion could be developed for use as a vibrating device, like a tie for men or a necklace for women. For data transmission a Bluetooth Logical link control and adaptation protocol (L2CAP) was used.

Pic. 1. Phone attached to participant's neck with elastic band.

The purpose of this research was also to determine if a person that is engaged in a speaking activity can perceive and act according to the information received through the vibrating device without being noticed (i.e. acting naturally). Also, there is no information regarding if the neck area is receptive to any kind of stimulus from vibration. This is one of the reason why the vocabulary included only four patterns. There is also the question of not only understanding the message, but acting according to it. A person engaged in a speaking activity can loose the concentration and stop in order to interpret the vibration. This can prove to be unpleasant for the other people around and it is not the purpose of the experiment because it will not pass as user and socially acceptable. Another goal of experiment was to collect participants opinions about the positioning of the device, about the patterns and acceptance of a vibrating device on neck.

There is a total of four patterns. Each of them is specific to a certain way of speaking. In case the participant is requested to speak louder, a single long vibration of 1400 ms, without any pause is used. This creates a constant rhythm. For speaking not so loud, two average long vibrations of 700 ms with a 1400 ms pause in-between are used. Because of the pause that has a consistent length, the rhythm seems slower. For speaking slowly, three short vibrations of 200 ms each with a pause of 400 ms between each are used. The length is short and the pauses are a little longer, so that a more faster rhythm than before can be distinguished. For speaking faster, twelve 100 ms long vibrations with a 100 ms pauses in between are used. This alternation between the same length for vibration and pause, in a big number, realize a fast, easy distinguishable rhythm. These patterns were chosen within several experiments during the development of the software. The goal was to design four patterns that will be easy to distinguish not only during still training procedure but also in a stressful situation like speaking in front of large public. The design was also made with the assumption that user would make connections between feelings produced with a pattern and it's meaning, so vibrations were adapted in appropriate way: pattern one, speak louder - one long vibration; pattern two, speak quieter - two shorter vibrations (slow rhythm); pattern three, speak slower - three short vibrations (mid- slow rhythm); pattern four, speak faster - twelve short vibrations (very fast rhythm). A time scale of patterns is given below.



Pic. 2. Time scale of used vibrotactile patterns.

A number of ten persons participated in this experiment. At first, the idea and the purpose of experiment were explained and each participant was familiarised with the vibration patterns by holding the mobile device in his hand. After this short introduction, each person had an unlimited amount of time to explore the four patterns. During training as well as experiment the device was attached to one side of the neck using the elastic band. The software user interface allowed him to select the desired pattern that was transmitted to the device as many times as he or she needed to study it.

Before experiment, a pre-experiment was made and participant was asked to determine patterns that were sent in a random order (20 times in total by default, can be configured). The software developed has a testing mode which shows the percentage of correct answers after completion of this part. If the result of this first part is above 75%, the person takes part in the public speaking experiment, otherwise person has to go back to previous stage and train better.

VI. Software description

The software developed in order to conduct the experiment has two parts: client and server. The server in this case is a vibrating device which is capable of receiving data via bluetooth and interpret tactile patterns with vibrations. The client is an application which is capable of searching nearby bluetooth devices and bluetooth profiles they support, connect to discovered devices or to a device by providing it’s bluetooth address and send either data with coded vibration pattern or simply any text message to a connected device.

Another capability of client is a testing mode which allows to ensure that experiment participants are able to distinguish correctly at least 75% of all patterns they receive. In this mode patterns are send from client to the server in random order, after each vibration participant should answer which pattern was that. When test is finished - overall percentage of correct answers is displayed.

Both client and server are written in Python (2.6+) language and source code is available for download on GitHub (https://github.com/galkindmitrii/HapticFeedback). There are two configuration files: *clientconfig.cfg* and *serverconfig.cfg* where configuration sections **[BT_client_settings]** and **[BT_server_settings]** are located. Following settings can be found:

```
[BT_client_settings]
port = 0x1001
discovery_duration = 8
flush_cache = True
training_attempts = 20
log_file = client.log
```

Pic. 3. Settings example for client application.

- *port* is a BlueTooth port used for communication;
- *discovery_duration* is a time limit for BlueTooth devices discovery, not recommended to set less than 8 (1 unit is equal to 1.28 seconds);
- *flush_cache* - when set to true, during each new device discovery list of previously discovered devices is being erased;
- *training_attempts* is an amount of vibrating patterns being send to a server during testing mode;
- *log_file* is a filename where log will be saved.

```
[BT_server_settings]
port = 0x1001
socket_timeout = 60
log_file = server.log
```

Pic. 4. Settings example for server application.

- *port* is a BlueTooth port used for communication;
- *socket_timout* is a maximum idle time for connection. After this time (in seconds) connection will be closed by server;
- *log_file* is a filename where log will be saved.

Both client and server have logging setted up, log file will be created automatically after first application launch in the same folder. Log filenames can be configured in *.cfg files as described above. Default level for logging is debug.

Protocol used for BlueTooth communications is a Logical Link Control and Adaptation Protocol (L2CAP). A pybluez library should be installed on both sides where client and server application are running in order to operate.

Overall requirements for server:

- Android 2.2+ (Tested on 2.3.5)
- SL4A_r6 (http://code.google.com/p/android-scripting/)
- Python 2.6+ for Android (Available for download: http://code.google.com/p/android-scripting/downloads/list)
- PyBluez 0.18+ (ARM version 0.19 can be found via link: http://code.google.com/p/python-for-android/downloads/list)

Overall requirements for client:

- Python 2.6+
- PyBluez 0.18+

  (http://code.google.com/p/pybluez/)

There are no specific operating system requirements for client, however GNU/Linux is recommended and all the development and testing was made on Ubuntu 12.04 x64.

When server is started primary information about the device is displayed, for instance:

```
--- Haptics Feedback Server ---
Name: U8800Pro
Address: 80:B6:86:58:DE:48
Port: 4097
Connection timeout: 60 sec
Log file: server.log
-------------------------------
```

Pic. 5. Server settings output.

When new connection is accepted a information about device BlueTooth address and port is shown. When message or a vibrating pattern is received appropriate message or received data (if it's just a text message) is displayed. When incoming message is a code of tactile pattern a small splash window is popped up with the number of received pattern.

When client application is started a main BlueTooth Client Menu is displayed. It allows to discover all nearby bluetooth devices (choice 1), to find all services supported by devices around (choice 2), to switch to connectivity menu (choice 3) or to exit (choice 0). Here is how main client menu looks:

```
----------BlueTooth Client Menu----------
 (1) Discover all near BlueTooth devices
 (2) Find all near BlueTooth services
 (3) Connect and send data
 (0) Exit

Please select option:
```

Pic. 6. Client main menu.

Making choice 1 or 2 results in a list of nearby BlueTooth devices or their capabilities respectively. Making choice 3 will switch to Connection Menu, where user has four options:

```
--------BlueTooth Connection Menu--------
(1)Connect to one of the recently discovered device
(2)Connect to a device with specified BT address
(3)Start training with a recently discovered device
(0)Back to the main menu

Please select option:
```

Pic. 7. Client connectivity menu.

Choice 1 allows to connect to one of a recently discovered device (if any). Choice 2 allows to input target device BlueTooth address. Choice 3 starts training mode with one of a recently discovered device. Last option switches back to previous menu level. When connection with BT device is established - a choice of four patterns or a text data to send is available. If the connection cannot be established - a message with reason is shown. Server application should be running prior to connection attempt otherwise connection will be refused.

VII. Experiment results

As was mentioned before, the experiment conducted consisted of three parts. At first participant was familiarized with the project, idea behind it, patterns and their meaning. Each participant first could feel the pattern with his or her hand and then on the experimental position - on the neck. Amount of training was not limited anyhow, but majority was ready to go for next stage after 2 or 3 training attempts of each pattern (maximum was 4).

Next part is devoted to the testing of participant's ability to distinguish learned patterns. We had to make sure that each participant could correctly distinguish at least 75% of patterns sent in random order. A testing mode of the client application was made for that purpose. Total of 20 patterns (in random order from first to the fourth) were send by the client to the server. After feeling each pattern participant had to input the number of the pattern into client application or tell it's meaning to the person managing experiment. When testing is finished - the percentage of correct recognitions is shown. There is also an option to change the amount of patterns used for testing via client configuration file, default setting is 20 patterns. During this part there was only one occurrence when participant had less than 80% of correct guesses (75% actually), in all the other cases participants had either 95% or 100% of correct recognitions from the first attempt.

Final procedure included participant speaking for any topic for about 7 minutes. During speech each participant received total of 12 patterns (each pattern for 3 times) in an order related to the speech. A pause of at least 30 seconds between patterns was maintained. So, if participant begins his or her speech slowly - a "Faster" pattern (number four) is being send to vibrating device. If the effect on the speech was not noticeable, pattern could have being sent once more after a while. After sending each pattern, experiment manager observes participant's reaction, his or her changes in speech and put his observations into the data table for each participant. Most negative reactions could be distributed in two groups:

- confusion, when participant recognizes the pattern, but feels unsure or unpleasant with a vibration and this affects his or her speech accordingly.

- interruption, when participant's speech was interrupted for a while and then continued.

These two are the most common reactions on vibrations and they can occur with correct pattern recognition (i.e. following the given hint), ignoring of the pattern (pattern could have been recognized but ignored or have not been recognized and ignored) or when pattern is recognized incorrectly (i.e. participant interpreted it as another pattern).

Totally, ten people participated in experiment, 3 females and 7 males in age between 21 and 32 (mean: 25,2; sd: 4,11). Body Mass Index (BMI) was in range from 19.0 to 30.4 (mean: 22,99; sd: 3,38), eight participants are in normal weight category (BMI range 18.5 – 24.9), one is in overweight category (BMI range 25 – 29.9) and one is in obesity category (BMI > 30). All of them have not experienced vibrotactile patterns used in experiment before, i.e. software developer did not participate due to fact that he had an excessive training during development and testing of the applications. Since each participant received 12 patterns, there were 120 patterns send in total and 107 of them were interpreted correctly, i.e. 89.17% correct interpretations, which is a good result taking into account fact that majority had only 2 or 3 (20% had two trainings, 10% had four trainings and rest 70% had three) trainings before the test and experiment itself.

Overall, most of the participants were able to act accordingly to a received pattern without showing any of mentioned emotions and reactions. So, the speech was not interrupted, there was no confusion or repeated speech in 80 correct interpretations, that is 74.766% of all 107 correct pattern recognitions or 66.667% of all 120 patterns being totally sent during experiment. The statistics for problems with the speech is the following: 14 speech interruptions, 11 confusions and 2 repeated speeches, all among 107 correct pattern interpretations.

Results of all pattern interpretations can be found in a table below:

	Pattern 1 “Louder”	Pattern 2 “Quieter”	Pattern 3 “Slower”	Pattern 4 “Faster”	Total / avg. %
Correct interpretation	28	23	27	29	107
Wrong interpretation	0	4	1	0	5
Ignored, no interpretation	2	3	2	1	8
Percentage of correct int.	93.33%	76.67%	90.00%	96.67%	avg. 89.17%
Percentage of wrong int.	0.00%	13.33%	3.33%	0.00%	avg. 4.17%
Percentage of non int.	6.67%	10.00%	6.67%	3.33%	avg. 6.66%

Table 1. Overall recognition results for all patterns.

From all above we could infer that neck can be a good place for usage of vibrotactile device and even phone can be used as such device. However, we must pay a lot of attention to the social acceptance, as well as user acceptance and usability issues, because if the device and system are helpful but rejected by public it won’t have any little success. It’s a very important aspect in wearable computing domain, that’s why after each experiment we’ve asked participants for their opinions and feedback, and here is a summary of what we were able to find out:

- the device was considered too big for the neck area and it created a discomfort for the participants (in order to have user acceptance, the device needs to be smaller and lighter).

- sometimes the speech was interrupted in order to interpret the patterns (since the difference between the patterns was often associated with the number of vibrations, it can be possible that the participants waited until the device stopped vibrating and counted the vibrations).

- because as for source of vibrations a smartphone was used, it’s vibromotor made noise and one participant stated that he associated the noise with the number of patterns.

From that we may see that most of users in experiment were dissatisfied with the device and it’s position on the body. There was also a participant who referred in his interpretations to the sound produced by vibromotor, not to the tactile feelings (due to vibromotor in a used smart phone was noisy while working). He explained that he made connections between the number of vibrations (can be calculated when sound of vibromotor is heard) and pattern number (first pattern has only one vibration, second pattern - two vibrations, third - three and the only exception - pattern four has 12 vibrations), which means that he used not haptics feedback, but audible feedback to understand the message. The possibility that some of the participants unconsciously acted the same way cannot be excluded.

As we can see from the above table, the second pattern (“speak quieter”) had the worst results (76.67% correct interpretations) due to similarity with the first pattern. That problem was raised by some of participants after the experiment. From time scale of patterns (picture 1) it is clear that first and second patterns have no difference up to 700 ms, which means that in some cases participants had to wait being concentrated until the second vibration starting from 2100 ms in case of second pattern, or till at least 2800 ms in case of first pattern. In other words, for some participants it was hard to distinguish between 700 ms and 1400 ms (length of first vibrations in pattern 1 and 2 respectively) vibration while being engaged into speaking activity. This often led to speech interruptions, confusions and wrong interpretations. And it serves as an additional proof that patterns should be carefully designed even when the set is small, in order to achieve high recognition rate.

Several participants mentioned that there is a chance that others could notice that you’re receiving some information or hints someway. As well 30% of participants stated that they can probably show better results after additional training. Finally, only one (10%) participant among all stated that placing a vibrating device on the neck is suitable for him and does not make a big disturbance. While most of the participants wanted to take the device off as soon as possible because it felt very unpleasant and disturbing, one of the participant totally not accepted the device and stated that he “felt like a dog” because of the elastic band and big vibrating device located on the neck.

VIII. T-TEST (STUDENT TEST)

For further analysis of the data obtained, we used the Student t-Test. The results were divided into two groups. In the first group (called A) were introduced all the participants that obtained a 100% score in the experiment (6 in total). In the second group (called B), were included the persons that achieved a lower score than 100% (4 in total, the values were: 91,67%, 83,33%, 50%, 66,67%.). The purpose of the test was to see if there is a connection between the number of trainings a participant does before the final experiment and the results obtained by the person in case in the experiment.

Group A	Group B
3	4
3	3
3	3
2	3
3	
2	

Table 2. Number of training attempts (participants with 100% pattern recognition - Group A; participants with less than 100% pattern recognition - Group B).

Both of the groups have a normal distribution (there are no extreme values). The hypothesis for the statistical research are:

H0: m1 = m2 (the two means are not significant)

H1: m1 != m2 (the two means are significant)

For the results, the Two-Tailed Student Test was used. The output of it is the following:

t-Test: Two-Sample Assuming Equal Variances		
	Variable 1	*Variable 2*
Mean	2,666667	3,25
Variance	0,266667	0,25
Observations	6	4
Pooled Variance	0,260417	
Hypothesized Mean Difference	0	
df	8	
t Stat	-1,77088	
P(T<=t) one-tail	0,057267	
t Critical one-tail	1,859548	
P(T<=t) two-tail	0,114533	
t Critical two-tail	2,306004	

Table 3. Results of the Two-Sample t-Test.

The mean for the first group is 2,67 and for the second group is 3,25. Even though these numbers show a difference, the variance between the values are similar (which signifies that the squared difference between the mean of each group and the values in that group is approximately the same for both groups).

The significance level is of 5% (the risk we are willing to take in rejecting the null hypothesis in case it is true). The value of t Stat is between -2 and 2 (-1,77) and *calculated p > significance p* (0,11 > 0,05). Because of these results, H0 (the null hypothesis) is accepted. This means that there is not a significance difference between the two means and that the result is not statistically significant.

Relating to the results of the study, it can be seen that the number of the trainings does not affects the overall recognition of the patterns. In group A (with a mean of 2,67) were included all the participants that had a perfect score. In group B (with a mean of 3,25) were included all the participants that had less than a perfect score. Even though in the feedback received from the persons that participated in the event, some of them said that with a better training, the recognition rate would have been better, statistics shows that there is no connection between the score and the number of trainings.

CONCLUSION

All in all, the experiment conducted proved once more that haptics feedback can be successfully used for communicating, especially in situations like public presentations and speaking when short hints may be send to a speaker in order to improve the quality of presentation.

One of the important aspects that needs to be taken into consideration is the actual parameter that affects the overall percentage of the experiment. Even though the recognition rate was almost 90%, we cannot base it on the number or trainings. From the data analysis and the feedback received, 3 participants (30%) said that with a better training, the result would have been better, while only one of them achieved score lower than the maximum possible. Which means that other two felt insecure about the interpretations of the patterns. But since they got a perfect score, that means that another factor influenced the recognition. It can be that because the number of patterns is quite small, the participants could associate meanings to each of them and they act according to these meanings. Confusions, speech interruptions and some of wrong interpretations occurred with the second pattern mostly, due to its similarity with the first pattern. Improper design was confirmed by both participants and results we've collected - in case of better design correct recognition rate would have been higher.

As for user acceptance, from feedbacks we've collected it is clear that participants did not really like the device, it's size and positioning, since they felt discomfort. These problems can be solved with introduction of vibrating device embedded into an everyday element of fashion, like tie, necklace or into shirt's collar. Another problem faced - vibromotor in a smartphone used was too noisy and at least one participant related to it's sound instead of feelings on a skin. There is a possibility that other participants related to this sound as well, without even realizing that, which could have affected the final recognition score. Another important fact is that participants did not reject the idea of receiving haptic feedback in a daily situations, people got used to cellphones vibrating in their pockets, feelings experienced during the experiment are in fact the same but with a different body part and holding much more sense behind than if there is just an incoming call or a notification.

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