Information display by dragged haptic bumps

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Abstract

The utility of haptic interfaces is widely established now. Although many interfaces has been designed, few tests about immediate usability have been made. The purpose of this paper is a study of direction and amplitude discrimination when a user feels a bump while moving the hand along an axis with an haptic pointing device. The results show that users can discriminate two and four directions with few errors while using one amplitude. But in the case of two or three amplitudes, some users have difficulties. The amplitude discrimination is more problematic. With only two amplitudes some users don't manage to discriminate the bumps, and with three amplitudes most of them make a lot of errors.

1. Introduction

Haptic can be used to give the user some information. For example, Wall and Brewster [5] describe a system which allows the user to put bookmarks in the environment called beacons. Thanks to these bookmarks they can navigate from each recorded location to another: with a simple keystroke, the user is dragged to the bookmark's position. Their study exposes a navigation of bar charts. The user had to give the highest value between four given bars among twelve bars. The proportion of correct answers was 76% and the average time taken to answer a question was $50.92s$. It would be interesting to add some codes or icons on the beacons to give them a semantic. Some user tests could be done to let us know if adding informationd during the guidance can decrease the answer time and the error rate.

We can find two kinds of haptic icons in the literature. The first one has been created by MacLean and Enriquez [3]. They use a DC motor which delivers forces on a rotation axis. The signal parameters are magnitude (or force), shape (sinusoid, square, etc.) and frequency. They did some tests where users had to classify icons in categories. The results show that the only criteria commonly used by all the users is frequency. It should be interesting to create such kind of icons with a widely used device.

The other haptic icons are the tactons created by Brewster and Brown [1]. These icons are a tactile transcription of the earcons [2]. The idea is simple: the codes are created in a hierarchical way. One criteria is used per level, one value of a criteria maps to a code of the level associated. Tactons use three parameters: rhythm, frequency and duration. For example, you can create a rhythm for file and another for directory, then a frequency for ”open” and another for ”close”. And finally you create a duration for ”read only” and another for ”read and write”. So you will be able to code ”open file in read only” and to compare easily with ”open directory”. The first tests are not conclusive enough so other tests with other parameters are currently being processed.

In a previous paper, we studied haptic bumps where the user's hand was completely dragged [4]. It combines the idea of force feedback icons of the haptic icons, and the possibility to create hierarchical codes like the tactons/earcons. The idea was to drag the user on some millimetres in six directions (upward, downward, foreward, backward, leftward and rightward). We used two and three amplitudes in the same serie. The results have shown that we can discriminate the six directions and two amplitudes with very few errors. When using a third amplitude, there is an ambiguity with the medium amplitude which is often confused with the two others. We decided to experiment a similar system where the user is more active and should move along an axis to feel the bump. This is the purpose of this paper.

2. Haptic bumps

Haptic is a good alternative channel to provide the user some information when visual and auditory channels are not suitable. Interfaces for visually and hearing

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impaired people are good examples for that purpose. A widely used technique to prevent the user from being lost in the haptic space is to constraint him in the area he is supposed to explore. For instance, we often stick the user on a line: this could help the user to recognise a shape or a path. We designed some bumps we could put on a line to add informations on it (bold line on the figure 1). So when the user moves along the axis, he will be dragged in a direction, according to a code. He will feel like if the line was bent.

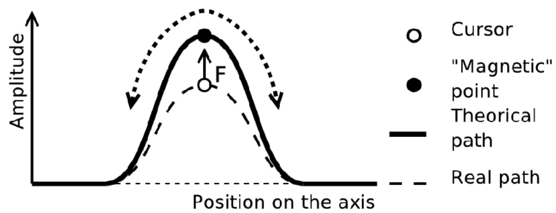

Figure 1: Bump felt by the user

It's impossible to control directly the position of the PHANToM device because he only renders forces. So we used a magnetic point to specify the theoretical position of the PHANToM: where he is supposed to be (● on the figure 1). Then the API renders a force towards this point to put the PHANToM (○ on the figure 1) as close as possible to this point. In the following, we will only consider the theoretical position.

3. Experiments protocol

In these experiments the user will use a PHANToM Desktop haptic device (figure 2). The force is exerted on a stylus the users hold in the hand. This version of the device has six degrees of freedom (three in translation and three in rotation), and renders forces on the three translation ones.

Figure 2: PHANToM haptic device

The purpose of these experiments is to test the discrimination of several direction and amplitude bumps. A pilot evaluation was done to design the procedure and to choose the parameters. Bumps were designed as shown on the figure 3: the bump was located at the right of the starting point. If the user moved to the left he was just constraint on an horizontal line. The bump was a sinusoid, and started $5mm$ after the starting point and ended $5mm$ after that, then there was a $2mm$ pause before stopping the bump. The parameters tested in these experiments are direction and amplitude. The goal is to experiment immediate discrimination and not learning.

The users have done several series, they were given 150 bumps in each. When the experimenter starts the bump, the system stores the cursor's position and sets the starting position at that location. Then the user has to move and feel the bump up to the stop position. After that, the user is not constraint anymore and says what he felt: the direction (upward, downward, foreward or backward) and the amplitude (from 1 to 3, 1 being the smallest and 3 the biggest). The experimenter stores the answers, and the next bump starts. After each serie, the user's impressions were collected.

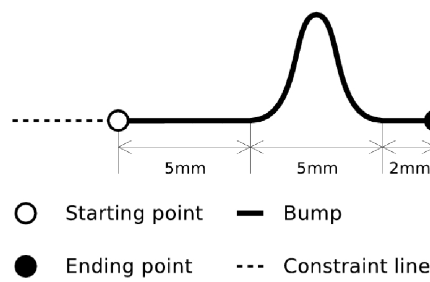

Figure 3: Bump design

The users were between 23 and 37, one female and five male. All are right-handed and sighted; they were blindfolded to prevent from giving visual aids.

4. Direction discrimination experiment

4.1. Experimental procedure

The first step of our study is to test the direction discrimination. Four series had been made. In the first two ones there were two direction bumps (upward and downward). In the first serie the amplitude was $0.4cm$ and $1.6cm$ in the second. In the last two series, four directions were used : upward, downward, foreward and backward. The two series used $0.4cm$ and $1.6cm$ again.

4.2. Results and discussions

The errors of the series with 2 directions are reported in the table 1 and those of the series with 4 directions in the

Amplitude (cm)	User						Errors (%)
	1	2	3	4	5	6	
0.4	4	0	2	1	0	4	1.22%
1.6	0	5	6	1	0	4	1.78%
total	4	5	8	2	0	8	1.50%

Table 1: Experiment 1 with 2 directions: errors in direction

table 2. Each row corresponds to a serie, the last line is the total.

As we can see the users make very few errors (table 1). Three users made as much errors in the first serie as in the second. The three others made almost all their errors in one serie and none in the other. Only the first user rather preferred the second amplitude. So if we take the user's favourite amplitude we get only 0.77% of erroneous answers. All the users thought the second amplitude was very violent, and they had to hold the stylus stronger to prevent from making errors. Two users were very disturbed by that and made more errors with the bigger amplitude than with the smallest.

Amplitude (cm)	User						Errors (%)
	1	2	3	4	5	6	
0.4	0	1	3	3	1	2	1.11%
1.6	0	4	2	2	0	0	0.89%
total	0	5	5	5	1	2	1.00%

Table 2: Experiment 1 with 4 directions: errors in direction

The amount of errors is less important than in the previous series whereas the task is supposed to be more difficult (table 2). You can notice that this time the users make more errors with the smallest amplitude than with the bigger amplitude. However, the users still prefer the smallest amplitude. We could explain the decrease of errors by a little learning, or by a better concentration because the task was more difficult. Some users had the feeling that some bumps of a serie hadn't the same amplitude as others in the same serie. Especially upward/downward and foreward/backward didn't seems to have the same amplitude. We could explain that in two ways. The first hypothesis is that the PHANToM uses one motor for each axis, so there could be a difference of calibration. The second one is that foreward and backwards are direction in the same axis than the user's arm, and upward and downwards are perpendicular to this axis. So the users have more natural resistance force against a foreward/backward bump.

5. Direction and amplitude discrimination experiment

5.1. Experimental procedure

The second step aims to combine all the previous parameters by proposing bumps of several directions and amplitudes in the same serie. Two series has been made: in the first one there were only two amplitudes ($0.4cm$ and $1.2cm$) and in the second one three amplitudes ($0.4cm$, $0.8cm$ and $1.6cm$) were proposed. In both series the four previous directions are used. The user had to recognise the direction and the amplitude at the same time.

5.2. Results and discussions

Direction errors are reported in the tables 3 and 4. This time each table represent one serie and each row shows the number of erroneous answers when the corresponding direction was given. The amplitude errors are in the tables 5 and 6, and the rows show the number of errors when the corresponding amplitude was given.

Direction (cm)	User						Errors (%)
	1	2	3	4	5	6	
upwards	0	1	3	1	0	0	2.98%
downwards	2	2	4	0	0	1	3.26%
backwards	3	0	1	2	0	0	2.33%
forewards	2	1	5	2	0	1	5.56%
total	7	3	13	5	0	2	3.33%

Table 3: Experiment 2 with 2 amplitudes: errors in direction

We get three times more errors than in the previous experiment (two last series). So using several amplitudes in the same serie obviously disturbs the direction discrimination.

Direction (cm)	User						Errors (%)
	1	2	3	4	5	6	
upwards	2	2	0	4	1	1	4.07%
downwards	2	0	1	2	0	1	3.57%
backwards	1	0	0	1	0	1	1.61%
forewards	2	0	1	6	0	0	3.00%
total	7	2	2	13	1	3	3.11%

Table 4: Experiment 2 with 3 amplitudes: errors in direction

The error rate is quite the same than in the last serie (table 4), so the number of different amplitudes doesn't matter with the direction discrimination. Thus we can conjecture the errors are caused by the fact of having other parameters to recognise at the same time.

As you can see the amplitude errors are higher than the direction errors. It is clear that the amplitude discrimination is a difficult task. An interesting point is

Amplitude (cm)	User						Errors (%)
	1	2	3	4	5	6	
0.4	0	1	9	1	0	1	2.78%
1.2	3	10	15	1	6	4	8.33%
total	3	11	24	2	6	5	5.67%

Table 5: Experiment 2 with 2 amplitudes: errors in amplitude

that there are three times more errors when the strong amplitude was proposed than when the weak amplitude was proposed. Moreover: only one user made more than one error among the 150 bumps displayed when a weak bump was proposed (user 3, table 5).

Amplitude (cm)	User						Errors (%)
	1	2	3	4	5	6	
0.4	9	4	6	7	0	3	8.63%
0.8	10	4	12	9	4	12	18.09%
1.6	13	8	17	26	12	26	36.17%
total	31	16	35	42	15	41	20.00%

Table 6: Experiment 2 with 3 amplitudes: errors in amplitude

One bump among five is misunderstood by the users. It is clear that users have difficulties to discriminate three amplitudes. Many users make a lot of mistakes because they think relative. So they don't feel the same amplitude when the previous bump was weak, medium or strong. It could be explained by the fact that people don't hold the stylus with the same strength whether the bump was weak or strong.

Two users made an interesting remark. They said that the direction was easier to understand when moving slowly, and the amplitude was easier to understand while moving quickly. This could explain the difficulty of trying to recognise both simultaneously. One of those two users was the user 5 and is one of the users who made the less errors. Due to this remark he deduced that he has to read all the bumps with the same speed. The experimenter noted that the users that made the more errors was often changing their reading speed. This fact is important and should be experimented.

6. Conclusion

The interaction technique described in this paper is a simple idea to give the user some informations using an haptic pointing device. The users can recognise the direction quite efficiently, and have some difficulties while trying to recognise the amplitude at the same time. The users made fewer errors in a previous tests with completely dragged bumps [4], so we think that we can obtain similar results if we put the bumps in a context, as suggested by some users. Sometime they had some hesitations and it caused quite many errors, so the possibility to read several times the code could help them to understand better.

This point should be fixed when we will do tests of bumps sequences on a large axis. This experiment was only a preliminary test of immediate utilisation. We will do tests with visually impaired children, and we will tests a learning on these icons. They are used in a software developed for the use of the European project MICOLE.

7. Acknowledgements

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