Information display by haptic bumps

Affichage d'informations par des impulsions haptiques

Thomas Pietrzak - Benoît Martin - Isabelle Pecci
Université Paul Verlaine
UFR MIM, île du Saulcy
57000, Metz, France
{pietrzak,benoit.martin,pecci}@univ-metz.fr

RESUME

Notre but était de trouver des effets haptiques utilisables pour présenter des informations à l'utilisateur d'un périphérique haptique. Nous présentons une étude sur la discrimination d'impulsions haptiques effectuées par un périphérique à retour d'effort de type PHANToM. Les paramètres testés ici sont la direction et l'amplitude des impulsions. Les résultats montrent que la discrimination de direction est aisée alors que la discrimination d'amplitude n'est pas triviale. Seulement deux niveaux d'amplitude peuvent être distingués de manière exacte.

Mots Cles

Retour d'effort, affichage d'informations, multimodalité

ABSTRACT

Our goal was to find haptic effects that could be used to present information to the user of a haptic pointing device. We present a study on users' ability to discriminate between different effects presented with a PHANToM haptic pointing device. The effects we experimented with were bumps that the user could feel through the PHANToM. The direction and the amplitude of the bumps were manipulated. The results show that the direction is easy to discriminate, but the amplitude is not. Only two levels of amplitude could be reliably discriminated.

Keywords

Force feedback displays, information display, multimodality

CATEGORIES AND SUBJECT DESCRIPTORS

H.5.2 [User Interfaces]: Haptic I/O; H.1.2 [User/Machine Systems]: Human information processing

IHM 2005 Sep 27 - 30, 2005, Toulouse, France
Copyright 2005 ACM X-XXXXX-XXX-X $5.00

GENERAL TERMS

Human Factors, Measurement

INTRODUCTION

The research described in this article concerns information display. This can be made by several channels, whether to give the user the choice of the channel which suits him, or to use several of them at the same time, or to prevent a channel already very used from being overloaded. It enables specifically replacing a failing channel. The visual and auditory channels are heavily used even though other channels like haptic, which gather together tactile and force feedback, are still not widely used. Some studies on information display has been made. We can especially quote the auditory icons of Gaver [4] : they are sound metaphors which able to associate a sound to an object or an action. For example a file deletion can be notified using a paper crumpling sound. The drawback is the icons are chosen in an arbitry way and the comprehension of the information needs pragmatic knowledge between the creator of the icon and the user.

Another system has been created by Brewster [3] : the earcons. In that case, simple sounds aren't used, but rather notes. Several level codes are created to display hierarchical informations.The rhythm changes at the first level only, each rhythm corresponding to a category. To differentiate codes of a same category, Brewster creates informations of higher level by modifying the melody. At the next level it's the global tempo which changes. So we can link several informations by comparing the rhythm, the melody and the tempo. Meanwhile as the auditory sense is not suitable anytime (for example in the case of hearing impaired people or in noisy environment), Brewster and Brown [2] had spread out their approach to tactile icons called tactons. The idea is to create vibrations by varying rhythm, frequency and length. The principle is the same as the earcons : use three parameters to grade the codes. We want to know if this principle is extendable to force feedback and if yes, with what parameters.

MacLean and Enriquez [5] had made a study on haptic icons using force feedback. They use a DC motor which delivers forces on a rotation axis : the signal sent can be set up in magnitude, shape (sinusoid, square, etc.) and in frequency. The studies published show usertests where participants had to classify the icons in categories of their choice. It seems that the only criteria used by all the users for the classification is frequency.

Currently, force feedback messages display is less studied, this is the goal of the PICOB project (Haptic stickies by barcodes), itself integrated into the European project MICOLE in which we participate. This project aims to create a multimodal collaborative teaching environment.

FORCE FEEDBACK MESSAGE DISPLAY

To display a message you must first find a way to code it, then a way to represent it. A well known example is the morse code : it uses two digits to code alphanumeric characters. To display a message using this code you must associate a representation to each digit. A very used auditory representation is long beeps and short beeps, and for visual representation dashes and dots. To display the message "SOS" with the morse code you must use one of its representation. We get for example • • • − − − • ••. We can imagine a haptic representation, for example with upwards and downwards bumps. The coding would be the same and the message would be displayed ↓↓↓ ↑↑↑ ↓↓↓.

We are in a preliminary state of our research and among the representation types possible we have designed, we present the bumps in this article. The principle is simple : the goal is to move the user's hand back-and-forth on about some millimeters. A bump is defined by three parameters : length, amplitude and direction. The figure 1 represents bumps in six directions : upward, rightward, backward, downward, leftward and foreward. With a two degrees of freedom device, we will restrict to four directions.

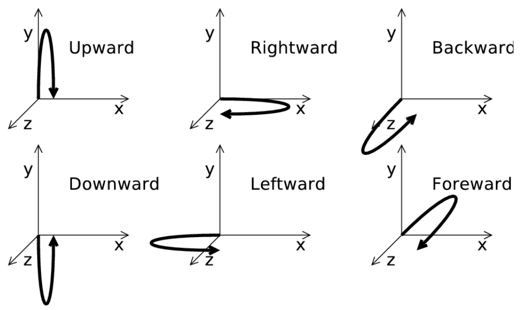

Figure 1. Impulsions in six directions.

The principle used to carry out these bumps is simple: the idea is to drag the cursor (○ on the figure 2) with a spring applying a force $\overrightarrow{F}$ towards the theoretical position of the bump (● on the figure)

EXPERIMENTS

The purpose of the experiments below is to study the discrimination of bumps of different directions and amplitudes. The goal of these tests is not to study a training but an immediate utilisability.

For each serie we gave the users 150 bumps, each of them lasting $250ms$. They had to recognize the direction or the

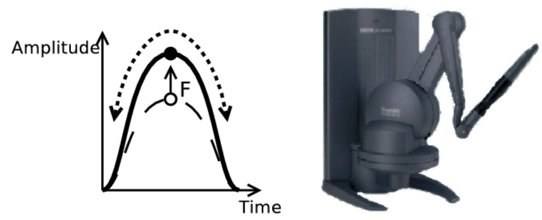

Figure 2. Principle and device used to give an impulsion to the user

amplitude according to the experiment. The duration of the bumps being fixed, discrimination according to this parameter was not tested: it will be the subject of another study. The duration and the amplitudes were selected after preliminary tests in order to have bumps a priori comfortable to use.

Processing

Right after explaining the principle of the experiment to the user, the experimenter starts the bumps one after the other. The user says the direction (upward, downdard, leftward, rightward, foreward and backward) or the amplitude (1, 2, 3 for small, medium and big) which he felt and a quarter of second later the next bumps were started. The participants were blindfolded in order to remove the visual assistance. Each experimentation consisted in making one or more random series and the users processed all the same series in order to not favour anybody a priori. The series were gathered in sessions, knowing that all the users made the same sessions at the rate of one per day at most. After each session the participants were given a survey to collect their impressions.

Hardware and software used

We used a PHANToM Desktop [6] (figure 2) in these experiments as haptic pointing device. It's a six degrees of freedom device (three in translation and three in rotation) and with force feedback on the three degrees of translation. The program used in these tests was written using the Reachin API [1] with VRML and Python.

Participants

Six users were recruted for these tests : three researchers (two men and a women) and three male students. The researchers and one student were used to manipulate the PHANToM, all are righthanded. The users were between 23 and 47.

Experiment 1

Experiments and procedure

In the first experiment we test the direction discrimination. The bumps given are on the six directions : upwards, rightwards, backwards, downwards, leftwards and forewards (figure 1). Five series has been conducted, each using a different amplitude : $0.4cm$, $0.7cm$, $1cm$, $1.5cm$ and $2.25cm$.

Results and discussions

The errors are reported in the table 1 : each row maps to a serie for which the tested amplitude is precised in the first column. The percentage of errors shown in the last column represents the percentage of erroneous answers among the total of all the users for the considered serie.

Amplitude (cm)	Utilisateur 1	2	3	4	5	6	Erreurs (%)
0.4	0	0	0	0	1	1	0.22%
0.7	0	0	0	0	0	0	0.00%
1	0	0	0	0	0	0	0.00%
1.5	0	0	1	0	0	0	0.11%
2.25	0	1	0	0	0	0	0.11%
total	0	1	1	0	1	1	0.09%

Table 1. Experiment 1 : errors in direction

Two users didn't make any mistake and the four others made an error among the 5×150 bumps. The number of errors is clearly negligible, therefore we can affirm that under these conditions we can discriminate bumps of six different directions. Only one user (not used to the PHANToM) acknowledges he sometime had difficulties to feel the differences between the directions and three other claim sometime had some hesitations. Two users thought they made more errors than they actually made. Two other users said they had the impression that the amplitude was not the same in different directions: a user had the impression that the right was stronger than up and down, whereas another user had the impression that up, down, left and right was stronger than foreward and backward. Let us note that the amplitude of $2.25cm$ was considered to be too violent by the users; this is why it was not used anymore in the following experiments. The big bumps causes problems in catching the stylus: it should be hold more firmly.

Experiment 2

Experiments and procedure

The purpose of this experiment is to test the discrimination of three different amplitude bumps. The bumps given in this experiment were all directed to the top, and the amplitudes were $0.4cm$, $0.95cm$ and $1.5cm$. Only one serie was carried out.

Results and discussion

The errors are shown in the table 2. The first three lines represent the errors by amplitude suggested and the last represents the total on the series. The last column represents the percentage of erroneous answers per amplitude suggested among the total of the users.

Amplitude (cm)	Utilisateur 1	2	3	4	5	6	Erreurs (%)
0.4	0	1	0	0	1	1	1 %
0.95	3	2	4	5	2	6	7 %
1.5	3	10	7	10	1	2	11%
total	6	13	11	15	4	9	6 %

Table 2. Experiment 2 : erreurs en amplitude

The errors are more important than in the previous experiment. The users made between 4 and 15 errors out of the 150 impulses. On average there is 6% of error, but the interesting point is that only 1% of the $0.4cm$ bumps were badly recognized, whereas with the two other amplitudes we obtain 7% and 11%. Moreover for the discrimination errors of the medium amplitude, the users always answered in favour of the big amplitude. For the other errors, on the small ones and big amplitudes, the answers of the users were in favour of the medium amplitude. Thus the users never made mistakes while answering ”small amplitude”. So, there is clearly a problem of discrimination between the medium amplitude and the big amplitude. This phenomenon is shown again in experiment 3.

Experiment 3

Experiments and procedure

What we want to test in this experiment is the simultaneous discrimination of direction and amplitude. For this purpose we propose bumps in the six directions, with two then three amplitudes. Three series were carried out: in the first there were only two amplitudes ($0.4cm$ and $1.6cm$). In the second there were three of them: $0.4cm$, $0.95cm$ and $1.5cm$. The same values than in the experiment 2 were used so that we could determine if the presence of several directions has an influence. The progression of these values is linear, we also tested a serie with exponential value progression as Nesbitt [7] suggests it. This was the third series and thus the amplitudes were $0.4cm$, $0.8cm$ and $1.6cm$.

Results and discussion

The number of direction errors is still low: only two users did a mistake among the three series. This is why the values will not be detailed. We can conclude rather easily that using several amplitudes at the same time towards several directions does not disturb the discrimination of the directions.

For the errors of amplitude, with regard to the first series, half of the users didn't make any mistake and the others did only one among the 150 bumps. The discrimination of such impulse is thus clear. On the other hand, with three amplitudes it is more problematic.

The errors of amplitude discrimination for series 2 are summarized in the table 3. Alike the experiment 2 we separated the errors by amplitude given on each line and the last column represents the percentage of errors on the total of all the users for the amplitude of the line.

Amplitude (cm)	Utilisateur 1	2	3	4	5	6	Erreurs (%)
0.4	0	1	3	5	0	0	3 %
0.95	10	10	19	4	5	2	19%
1.5	9	17	20	18	13	9	27%
total	19	28	42	27	18	11	16%

Table 3. Experiment 3, serie 2 : errors in amplitude

We get 16% of errors on average on all the serie. 3% of the small impulses ($0.4cm$) are badly interpreted, 19% of the medium ($0.95cm$) and 27% of the big ($1.5cm$). If we compare these results with those of the experiment 2 we can notice that on average there is between two and three times more errors. It is clear that the various directions disturbed the discrimination of the amplitudes. This observation is corroborated with the feelings of the users collected after the tests: they had the impression to feel different amplitudes according to the direction. The users were disturbed because the training which was proposed to them was very quick.

You can consult the discrimination errors of amplitude of the third serie in the table 4. In a general way it has to be noticed that there is a little less errors. There is always 3% of the small impulses which are badly recognized, but now there are respectively 11% and 19% of the averages and the bigs impulses which are badly interpreted.

Amplitude (cm)	Utilisateur						Erreurs (%)
	1	2	3	4	5	6	
0.4	1	0	2	1	3	1	3 %
0.8	2	23	8	2	1	1	11%
1.6	7	24	13	5	3	1	19%
total	10	47	23	8	7	3	11%

Table 4. Experiment 3, serie 3 : errors in amplitude

We can notice there's three times less errors compared to the previous serie, only one user made more mistakes. The percentage of small erroneous amplitudes doesn't change. On the other hand there is four times less errors for the medium amplitude and almost 40% less for the big amplitude. Thus, it would seem that the exponential progression of the amplitudes is more discriminatory than the linear progression. However the amount of errors remains high (11% on average). That makes us believe that without any training the discrimination of bumps of three different amplitudes is not possible under normal conditions of use of the peripheral used.

CONCLUSION

Information display by bumps of several directions and amplitudes is possible. The studies detailed in this article permit us to affirm that the discrimination of direction is easy, as well as discrimination of two amplitudes. However the discrimination of impulses of three different amplitudes is problematic. It would be interesting to study new values and especially if a suitable training allows this discrimination. Concerning the discrimination of two amplitudes it could be interesting to test the minimal difference of the values to have a discrimination without ambiguity.

By using six directions and two amplitudes we can use the principle of hierarchical codes of earcons and tactons on two levels. Our future work on the different duration bump discrimination will perhaps allow us to create a third level. In forthcoming studies we will be interested in other alphabets.

THANKS

This work is financed by European project MICOLE (IST-2003-511592) and by the CA2M (the Community of Agglomeration of Metz Métropole) within the project PICOB.

REFERENCES

1. *Reachin API 3.2 Programmer's Guide*. http://www.reachin.se.

2. Stephen A. Brewster and Lorna M. Brown. Non-visual information display using tactons. In *CHI '04: Extended abstracts on Human factors in computing systems*, pages 787–788, Vienna, Austria, April 2004. ACM Press.

3. Stephen A. Brewster, Peter C. Wright, and Alistair D. N. Edwards. An evaluation of earcons for use in auditory human-computer interfaces. In *CHI '93: Proceedings of the conference on Human factors in computing systems*, pages 222–227, Amsterdam, The Netherlands, April 1993. ACM Press.

4. William W. Gaver. Synthesizing auditory icons. In *CHI '93: Proceedings of the conference on Human factors in computing systems*, pages 228–235, Amsterdam, The Netherlands, April 1993. ACM Press.

5. Karon E. MacLean and Mario J. Enriquez. Perceptual design of haptic icons. In *Proceeding of the 3rd International Conference Eurohaptics 2003*, pages 351–363, Dublin, UK, July 2003. ACM Press.

6. Thomas M. Massie and J. Kenneth Salisbury. The phantom haptic interface: A device for probing virtual objects. In *Proceedings of the ASME Winter Annual Meeting, Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems*, pages 295–301, Chicago, November 1994. vol. 1.

7. Keith V. Nesbitt. Experimenting with haptic attributes for display of abstract data. In *Proceeding of the 2nd International Conference Eurohaptics 2002*, pages 150–155, Edinburgh, Scotland, July 2002. ACM Press.