Follow-up Experiments on Haptic Interaction Design Guidelines

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Haptic Interaction Design Guidelines

1 Background

As a member of the Haptics Group at Certec I have performed research and development on haptic interfaces for blind people since 1995. We formulated our first guidelines for haptic interaction design in 1998 and since then they have been revised on a regular basis.

The guidelines have its roots in observations that we have made when developing and testing haptic applications for blind people. After the initial observation is made we try to find out if there is something that can be generalized from the special case to gain knowledge that can be used in future. We normally iterate several times between “reflection-in-action”, “reflection-on-action” and further observations. The concept of reflection-in-action is from Schön (1983). Many of these observations prove to be special cases, but in certain cases we end up with a piece of information that is general, relevant and useful enough to be called a guideline.

Previous versions of the guidelines have been published in (Sjöström 1999, Sjöström 2001a and Sjöström 2001b). The current version of the guidelines is part of my doctoral dissertation.

For the current generation of guidelines I decided to make a follow-up study on parts of the two oldest guidelines where explicit tests had not been conducted before.

2 Aims and questions of the study

The aim of this study is to gain more information on three areas of haptic interaction design:

1. Virtual object and interface widget design
2. Reference points in the virtual environments
3. Usage of constraints and gridlines in the virtual environment

On point one, I want to explore what difference the design of the virtual objects and widgets can make to the overall experience of a virtual environment. Sharp corners of virtual objects have been proven to give some interaction problems in our earlier tests (Sjöström 1999) so for this test I designed a new button shape with rounded corners and a dent in the middle of the button to prevent slipping off it.

We have also seen that some people very distinctly use the corners of the virtual room as reference points to aid when navigating. To test the importance of this kind of reference points I here compare the results of a virtual room with the sidewalls (and thus the corners) and a room without any sidewalls at all.

Grids can be used to aid in precise navigation and to add extra reference points in the environment. When used in drawing programs and similar for sighted people, gridlines can normally be turned on and off by the user and it seems reasonable to believe that a similar solution could be helpful in a haptic environment.
3 Material and Methods

3.1 SUBJECTS
Ten sighted but blindfolded users carried out the test. All were related to the Department of Design Sciences at Lund Institute of Technology. All of the test users had tried the Phantom one or a few times before, but none of the test users had more than moderate experience of haptic interfaces. Three of the test users were female and seven were male. All the test users were right handed and thus held the Phantom-pen in their right hand.

3.2 APPARATUS
I used a Phantom Premium 1.0 from Sensable Technologies for the touch interaction (see Sensable 2002a). The Phantom was equipped with a rebuilt pen with a rubber grip instead of the standard stylus.

3.3 TEST PROGRAMS
Four different programs were made to compare the different interaction designs. The programs were memory games with haptics and sound, similar to memory games that we have tested before (see e.g. Sjöström, Rassmus-Gröhn 1999).

The tasks involved in playing the game is exploring the environment, getting an inner picture of it, pushing the buttons, remembering the position of the different sounds, getting back to the remembered position etc.

All the programs functioned exactly the same except for one parameter that was changed from the reference game. The general task in the memory games is to find pairs of buttons with the same sound. When the user pushes two buttons with the same sound in sequence the buttons disappear and the game is finished when all buttons are gone. The games in this test had twelve buttons and thus six pairs with different sounds. The six sounds were the same in all games, but the position of each sound were randomized each time a new game was started.

All the programs for this test were written in Visual C++ using the GHOST SDK from Sensable Technologies (Sensable 2002b). All the games have the buttons on the back wall of the virtual room. The size of the virtual room is 130 mm * 140 mm * 50 mm (width*height*depth). The buttons are approximately 25 mm wide. All the buttons in the environments use the same amount of friction: 0.4 static and 0.3 dynamic (friction coefficients as defined in the GHOST SDK).

The test programs used in this test can be downloaded from our web site: http://www.certec.lth.se/haptics/software/GL/

Test program 1
This program has been used as the reference. It has a virtual room with four walls, a ceiling and a floor (see Figure 1). The buttons in the game has a rounded and scooped shape that was designed specifically to be effective in haptic interaction. The rounded shape is supposed to make it easier to trace the shape of the object and the small dent in the middle of the button makes it easier feel where the center of the button is and harder to slide off the button unwillingly (see Figure 2 and 3). The button was designed in 3D-Studio Max and exported as a VRML-file. The VRML-file was then be used as a shape in the GHOST program.
Test program 2

Test program number 2 used standard flat boxes as the button shape instead of the scooped button used in the other tests (see Figure 4). The result of this design compared to the first design give information about the effect of optimizing the haptic widgets in tasks like this. Since the memory
game task to a large extent is a navigational one the effect of widget optimizations cannot be expected to be very large.

Figure 4 Screen dump from Memory test program number 2. The buttons are flat instead of scooped as in test 1.

Test program 3
This program tests how important reference points like the corners are in a virtual environment. The test program uses the same buttons as program 1, but in this virtual environment there are no sidewalls (see Figure 5). The only wall is the back wall of the room where the buttons are placed. This wall covers the whole working area of the Phantom, so in practice the virtual room is limited by the flat wall on the back and the spherical workspace of the Phantom device on all other sides.

The walls and the corners of the virtual room can normally be used as reference points in the virtual environment and they also work as limitations of the workspace so that the user never get too far away from the buttons. Reference points are particularly useful if the user looses orientation for some reason. In this program it is still possible to use the buttons themselves as reference points, but not the corners or walls.

Figure 5 Screen dump from Memory test program number 3. The virtual environment has a backwall but no sidewalls.
Test program 4

This program tests the usage of gridlines in the virtual environment (see Figure 6). Gridlines can help finding the buttons but they could also be disturbing to the user. In this program the gridlines were cylinders with a radius of 1,1 mm. The shape and size of the lines were chosen to make the gridlines as little disturbing as possible but still clearly feelable. The gridlines line up with the buttons horizontally and vertically.

The gridlines could also make it easier for the users to feel were there has been a button since the crossing gridlines are still there even though the button is gone.

![Figure 6 Screen dump from Memory test program number 4. The gridlines on the back wall line up with the buttons to make them easier to find.](image)

3.4 TEST SETUP AND PROCEDURE

The test procedure started with the test leader explaining how the test was going to be carried out and what was going to happen. Prior to the real tests, all test persons underwent a pre-test phase. This pre-test is included to let the test users get acquainted with the Phantom and to get by some of the initial problems of virtual haptic interaction. Since the users in this test all had some experience of the Phantom the pre-test was limited to about 15 minutes per user. During the pre-test the users first got the possibility to feel and identify 8 different virtual models of geometrical objects. After this the user tried a special pre-test version of the Memory game. This pre-test memory had mixed buttons to avoid any influence on the button preference in the test. Each user completed the pre-test Memory game two times.

In the test phase the user played the four different Memory games one after each other. The sequence of the games was randomized to compensate for possible effects from learning etc that could change the user’s performance over time. The users were instructed to play as fast and securely as possible without rushing.

The programs automatically logged time from start to success, number of button pushes needed, user position and reaction force during the whole game. The test leader took notes about comments from the users during both pre-test and test. After the test the users were asked to rate the different designs compared to the reference and to comment on their experience in general. This combination as quantitative and qualitative measures gives a good and complete picture of the specifics of each interaction design.
During the whole test, the users sat at a desk with the Phantom and speakers but nothing more on it (see Figure 7). The whole test including introduction, pre-test, test, and discussion afterwards took about 45 minutes per user.

![Figure 7 Test setup](image)

### 4 Results

The time to success, number of button pushes needed and rating for each test and user is shown in Table 1.

#### Table 1 Summary of the test results

<table>
<thead>
<tr>
<th>User</th>
<th>Test 1 Reference, scooped buttons</th>
<th>Test 2 Flat buttons</th>
<th>Test 3 No sidewalls</th>
<th>Test 4 Grid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time</td>
<td>N</td>
<td>Rating</td>
<td>Time</td>
</tr>
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<td>0</td>
<td>02:19</td>
</tr>
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</table>
Test 3 for User B was terminated after 3 minutes and 15 seconds and more than 50 button pushes since the user was frustrated and did not progress. One pair was taken at that time. The average results for this test is calculated using an estimated result of 6:00 minutes and 50 button pushes for this specific test and user.

5 Discussion

The reference design was better than the other designs on all the parameters time, number of button pushes and user rating. The difference was largest with the gridlines and the environment without walls whereas the difference between the results of the different shapes was not that large.

5.1 Reference Points

It is clear that the lack of walls and corners as reference points makes a big difference for a vast majority of the users. A few of the users do get about the same time one this test as in the reference program but all users agree that this environment is harder to handle than the one with walls. The average time for completion and number of button pushes is also considerably higher in this test than in the reference.

This test was the only test in which one user did not manage to solve the task. This user said that the difference with walls was “totally crucial”.

The user had a lot of comments on the virtual environment without sidewalls, here are a few of them:

- Awkward without the walls I think…
- Hard if you loose your orientation, then you want to be able to get back to a corner.
- The buttons are good, but it’s a tough job to concentrate without the walls as a security.
- This was a lot harder…
- You loose your references here.
- Especially when the buttons were gone it was hard having nothing to relate to.
- Hopeless!
- This was harder than with the walls, but not a huge lot harder.

Reference points are indeed important in all kinds of navigation but in the case of blind users in a navigation heavy virtual task it is apparent that the reference points provided by the walls and corners can make a real difference and in some cases even imply the difference between success and no success.

5.2 Gridlines

The test with gridlines got the highest average time for completion of all the tests. All but two users thought that the gridlines were more of a disturbance than help. Two users thought that the gridlines did help them but they both got longer times and more button pushes than in the reference program. The interesting thing about this test is that the difference in times a markedly higher than the difference in number of button pushes. Actually all users got higher times with this game but only 6 of them got more button pushes than in the reference. It seems as though the gridlines disturb the free scanning for many of the users but still help when it comes to a more mechanical use of the memory game.

Many users complain that the gridlines disturb them and that it takes more time because you do not know immediately if you are touching a line or a button.

This is a selection of the user comments on the game with the gridlines.
It was disturbing; you couldn’t feel the difference between the different things.
- The lines disturb the scanning
- I have to look for the buttons instead of remembering the sounds.
- You think that it is a button, but then you understand that it is a gridline
- I thought that this would be good, but it was only disturbing.
- It jerks…
- Good with the lines as an orientation, you can feel if you go upp or down a row

5.3 BUTTON SHAPES
The different button shapes apparently make the least difference in the result of this task. Both the average times and number of button pushes are slightly higher with flat buttons than with the scooped button but the difference is not as large as in the other tests. Looking at the results for each user we can see that half of the users have better times with the flat buttons and half of the users have better times with the scooped buttons. The same holds for the number of button pushes. It is thus hard to tell for sure if the scooped buttons really make a difference on performance in this kind of task, even if we get an indication that it might be so.

The real difference in this test though is the user rating of the environments. 6 of the users preferred the scooped buttons, two thought that the scooped buttons were slightly better but that it did not matter in this kind of task and two thought that the flat buttons were better.

User comments on the different button shapes:
- It was quite a big difference on the buttons; the scooped ones were easier to handle even though I actually did not notice it from the start. But the rounded sides were not only good.
- The scooped buttons were better, but it’s not a huge difference.
- It was easier to handle the scooped buttons because you don’t slide away from them.
- The flat buttons were easy to slip off, the scooped ones were better in that sense.
- The scooped buttons were good because it was easy to feel what it was.
- The flat buttons work well too, once you have learned to handle them.
- The flat buttons feel more distinct

The comments “it was easy to feel what it was” and “you don’t slide away from them” indicate that this design has a better haptic affordance. Gibson discussed the term affordance in “The Ecological Approach to Visual Perception” (Gibson 1979).

Gibson writes “The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. The verb to afford is found in the dictionary, but the noun affordance is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment…”

Norman gives the term a slightly different twist in “The psychology of Everyday Things” (Norman 1988). Norman writes ”When used in this sense, the term affordance refers to the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used. A chair affords (“is for”) support, and, therefore, affords sitting.” And in a note: ”I believe that affordances result from the mental interpretation of things, based on our past knowledge and experience applied to our perception of the things about us.”

Haptic affordance has been discussed by Arthur Kirkpatrick in his dissertation ”Force plus graphics is not equal to vision plus haptics: Towards usable haptic environments” (Kirkpatrick 2000). Kirkpatrick writes that ”Visual affordances tend to indicate possible actions, as for example
the sight of a doorway affording the possibility of entering a room… By contrast, haptic affordances always guide action.”

The way affordance is used today it often refers to a quality that indicates that an action is possible or in a subtle way help a persons to understand what an object is for.

The users comments on the scooped buttons in my test suggest that the shape of the button both indicate what this object is for and guide the user when performing that action. The haptic affordance of this button is thus not only of the kind that is suggested by Kirkpatrick, but also similar to the classic definition of affordance but communicated in a purely haptic way.

6 Conclusions

The final conclusions here is that reference points, for example in the form of corners of a room, are very important for many users and do not seem to disturb the interaction in any way. It is thus highly recommended to include flat walls (and corners) in a virtual environment, especially if the task is navigational heavy.

Gridlines can help but seem to disturb for a majority of the users and should thus not be included if the added exactness is not needed. It is possible that a grid designed in a different way (e.g. with grooves instead of the cylinders used in this test) can give a better result, but most likely a large portion of the disturbance will still be there. In most cases I would recommend having gridlines as an option that be turned on and off by the user.

The shape of the haptic widget does not seem to make a very big difference on performance in this kind of task but the scooped and rounded buttons are indeed better liked by a clear majority of the users. Widget design can thus make a real difference and there is a need for improvements on this point. Haptic affordance is also an area where further research is needed.

7 References


