Static and dynamic tactile directional cues experiments with VTPlayer mouse

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Abstract

Braille cells have good potential to provide information. Users don't have to know the braille alphabet to be able to use them. In this study we show that it is possible to create 4×4 patterns to give the users some directional information. Two kinds of icons have been designed: static patterns and dynamic ones (animations). It appears that users rather like, and recognize better static icons.

Keywords: haptic, tactile displays, braille displays, icons

1 Introduction

Our goal in this study is to use the tactile sense to give direction information. Tactile (or cutaneous) sense refers to what we feel through the skin, like pressure, stretch, vibrations, heat and pain. Chouvardas et al. [2] classified tactile hardware in four categories: pressure, vibration, electric field and temperature. The work described in this paper uses braille displays. The most common type of hardware category used to display braille information is pressure [5]. The principle is to push a lever to raise a pin (with a piezo crystal for example). The braille devices consist of one or more pin-matrices made of such a mechanism, like the device we used in this study: the VTPlayer mouse (figure 1). It has two 4×4 matrices on the top, and four buttons, two on each side.

Figure 1: VTPlayer tactile mouse

The drawback with common braille cells is their size. Most of the devices that use braille cells are very big and thus not ergonomic. Pasquero and Hayward [11] try to use a vibrating hardware in order to display tactile patterns. The STReSS device (figure 2, on the left) has been designed with 100 piezoceramic actuators, laid out in a square matrix. They can slightly move in order to deform the fingertip skin so that the user feels virtual bumps. The device can display tactile 2D movies at $700hz$. It has been modified in order to make the Virtual Braille Display [8] (figure 2, on the right), which is simpler than the STReSS device: it can only display one-row of information (1D). The authors have tested the user's ability to discriminate virtual two-pins sequences. It appears that most of the users recognize almost 100% of the virtual pins configurations.

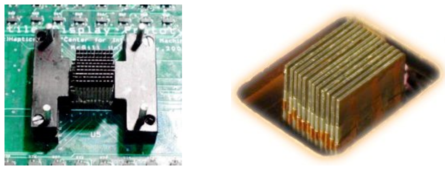

Figure 2: The STReSS device, and the Virtual Braille Display

Some other "homemade" devices are referenced in the literature. Lecolinet and Mouret [7] added a 2×4 braille cell on three devices to add tactile information. The first one, called TactiBall, is a trackball: the braille cell replaces the scrolling wheel. The second one is called TactiPen, and replaces the PDA stylus. The third one is the TactiTab, and replaces the pen of a Wacom-like pen tablet. These devices have been designed for sighted people in order to give them information that could not be displayed (due to the small size of a PDA screen for example). Four test-applications have been created to examine the possibilities of such devices. The first one displays the pixels of the screen around the cursor on the braille cell. However it's not sufficient to just translate picture from visual to tactile in order to have a good recognition: it is necessary to remove some details or give other information [3]. The second one aims to give directions, as we propose to do. The problem with these devices is the cell size: it's hard to indicate the diagonal information with a 2 pin large cell. The third software is a car simulation game. The cell is used to indicate to the user when he must turn right or left: in fact it's a particular case of the previous software. The last software is a notification program: an "alarm signal" is displayed at a certain time of after a certain lag. It's a good example of using the braille cells without using braille alphabet nor reproducing a picture but icon-like information.

Another example of visual to tactile direct translation is given in a study by Wall and Brewster [14]. They have studied graph recognition efficiency with tactile pin arrays. The VTPlayer mouse was used as a pin array display, and the Wingman Force Feedback mouse was used to compare the cutaneous technique with the kinaesthetic technique. Then a raised paper model was used to compare these two techniques with what the visually impaired people are used to use. The task was to recognize whether a line goes upwards or downwards when the user slides over it from left to right. The recognition threshold with VTPlayer is $\pm 4.7°$, against $\pm 3.25°$ for the force feedback mouse and $\pm 2.42°$ for the raised paper. The authors explain the superiority of the raised paper by the combination of tactile and kinaesthetic sense that doesn't exist in the two other models. Another explanation is that with raised paper the user has the possibility to explore the scene with two hands. This study shows that the pin array technique is not adapted for precision tasks, but it's sufficient to recognize positive or negative line gradient to within $\pm 4.7°$ degrees of the horizontal.

The experiment of Jansson and Pedersen [6] is another example.

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They used a VTPlayer to examine the navigation of a user over a map of the USA. The software used is the one provided with the VTPlayer. While the user slides over a state, the system tells him the name of the state, and feels a texture with the VTPlayer. The goal was to pass through a sequence of states. The tests had been conducted with visually impaired people and sighted people, all of them were blindfolded. For both, some of them did the tests with tactile information, and the others without. It appears that the tactile information didn't provide any significant help. Most of the users stated that the task was difficult or very difficult, but thought it was amusing or very amusing and useful or very useful. The users had some difficulties when there weren't any information (speech or haptic). There's clearly some place for more tactile information here. The non significant tactile textures displayed could be replaced by guidance information.

Some studies about tactile help for navigation have already been conducted. Maingreaud et al. [9] studied a way to indicate a blind user obstacles while moving in a 3D environment. They tested the recognition of arrows displayed on a device called VITAL which uses a 8×8 matrix. Two kinds of arrow were tested : with the edge of the arrow only, and with the middle line too. Only 4 directions were tested : north, south, east and west so the alphabet used is limited. It appears that only the arrows with the lines were recognized efficiently. The problem with such patterns is that the patterns are too close each other, so it is difficult for people who don't read braille to feel all the pins one by one. Mandic et al. [10] defined a notion of distance between two braille codes in order to optimize the alphabet so that most common letter are easily discriminative. This distance is defined as the number of different states (raised or lowered) of each pin from one pattern to another.

Vibro-tactile information has also been used to display information. We can cite the tactons of Brewster and Brown [1]. They designed different vibrations by changing some parameters like waveform, rhythm and spatial location. Evreinov et al. [4] built a vibro-tactile pen in order to display tactons. They use vibrations to guide a user through a maze for example. The tests conducted shows that simple tactile games allow to facilitate both the learning and the usability of the tactons.

In a previous work we have tested direction information [12, 13], given with a force feedback device: the PHANToM. Two interaction techniques have been tested: the first one is when the user is completely dragged by the device in order to feel a bump. In the experiments, the users could feel 6 direction bumps. Several amplitudes have also been tested. It appears that the users never had difficulties to recognize the direction, but when using more than two amplitudes they didn't manage to differentiate all of them. The other interaction technique consists of creating a bump on a line the user slides onto. Once again the users didn't have difficulties to recognize directions. However, the amplitude recognition have also been tested and this time the users had some difficulties to differentiate two amplitudes, and we can say they can't discriminate efficiently three amplitudes. The experiments below is a continuation of these studies, with a tactile device.

2 Tactile Icons

The device used in this study is the VTPlayer. It has more pins than Lecolinet's devices, so we could display more complex patterns. However even if the Hayward's STRESS device has a better resolution, it is not commercialized and thus we can't use it for our tests. We only use the left cell of the device so that the user will use the forefinger of the dominant hand, as all the users were right-handed.

We create *patterns* with pins configurations in order to display shapes for example. Thus we designed some *icons* based on this patterns. Some of them are *static*: they consist of a single pattern. Other ones are *dynamic*: they are actually animations. Each step of the animation is a *frame*, on each frame we display a pattern (one pattern could be displayed on several frames).

The icons designed will represent 8 directions: upwards, downwards, leftwards and rightwards will be called *radial* icons, and towards the four corners *diagonal* icons (figure 3). We will simply call a "set" the icon set representing the 8 directions, as we will test several sets. The idea is to create information that is not a transcription of visual information. This kind of information could be used as guidance information for map or graph exploration for example.

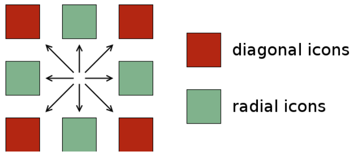

Figure 3: Radial and diagonal icons

Our goal in this study is to find some sets of static and dynamic icons easy to discriminate. We did four experiments to test our sets. In the first one we tested those we designed. Then in the second one we tested some of the sets suggested by the users of the first experiment. In the third one we did more tests on the best sets in order to confirm our results. After that, it appears that we had not found any satisfying dynamic icons, so we did a fourth experiment to find some good dynamic icons.

3 First experiment

This experiment was conducted to find out some interesting sets. Then an experimental protocol was established, and we started the tests.

3.1 Experiment setup

All the icons designed are symmetrical so that the user has the same kind of information whether he feels the right or left icon for example. In most case we tried to use the same number of pins for all the icons of a set so that the user feels the same area under his fingertip.

The first idea is to use each pin for one and only one icon. Knowing that a 4×4 matrix has 16 pins, and if we want to use different pins for the 8 icons, we could only use 2 pins for each one. So for the radial icons we used the two middle pins, and for the diagonal ones we used the two diagonal pins. We can see the first two sets (representing the eight directions) on the figure 4, each square represents the icon of corresponding direction. The difference between the first set and the second one is that the first set blinks: there is a blank frame (of the same duration) after the pattern frame. We can make the hypothesis that this set will be hard to discriminate because there are few pins raised.

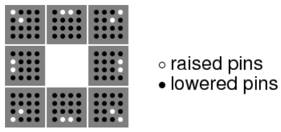

Figure 4: Patterns of the sets 1 and 2, the first one blinks and the second is static

The third set has been designed with waves. The idea is to "move" a line towards the direction we want to display. The cell has a size of 4×4 so for the radial icons we moved lines of 4 pins on 4 frames. The difficulty was to find good diagonals because in a given direction there are 7 diagonals of pins: with

1, 2, 3, 4, 3, 2 and 1 pins in spite of 4 lines of 4 pins. In order to design icons of the same duration, we get 4 diagonals among the 7 ones. We decided to remove the diagonals of 1 pin, then we just had to choose which 2-pin diagonal we wanted. We thought it was logical to get the one in the direction we wanted to display. The drawback is that if a is the amplitude of the radial icons movement (the size of the cell in fact), the amplitude of the diagonal icons will only be $\frac{a\sqrt{2}}{2}$. We thus made a compromise between duration regularity, and movement amplitude regularity. Finally we added two blank frames to make a pause between two waves. These pauses are important because without them, given a direction it seems to be very hard to recognize the sense of the movement. The sets is shown on the figure 5.

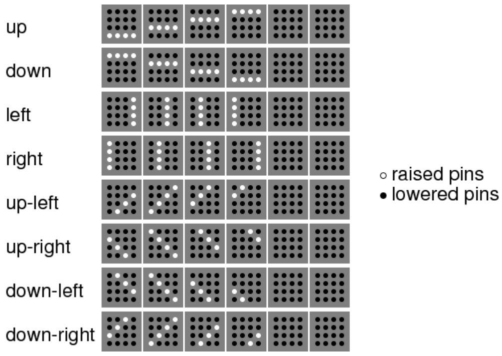

Figure 5: Set 3

The icons of the fourth set are similar to those of the second one, but they are larger. They are static, but instead of using only two pins, we used four pins. For the diagonals we used the corners so that these icons are different enough to each other. We couldn't use the same number of pins than for the edges because to be symmetrical we had to get $2n+1$ pins: 1 for the corner, and n pins on each adjacent edge. After some preliminary tests we decided to use 5 pins instead of 3, because the 3 pins seemed to be harder to discriminate than the 5. The set is shown in the figure 6.

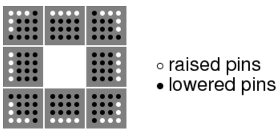

Figure 6: Set 4

For all the icons of all the experiments, the frame duration of the dynamic icons was set to $100ms$.

3.2 Experimental procedure

There were nine users, between 24 and 48 years old, all were sighted (but blindfolded), right-handed and used to deal with computers. They all tested the four sets: there was one block for each set. In each block the users had to feel 100 icons.

The users started with a little trial in order to accustomate themselves to the set and to the device. The software displayed a square divided in 9 zones like on the figure 7. If the user moved the cursor on a zone, the icon representing the given direction was displayed on the cell. When the user felt he was ready, he pressed a key and the first icon started. The icon was displayed on the left cell of the VTPlayer until the user clicked in the zone he thought the icon corresponds to. Then he had to go back in the central zone to run the following icon. After the 100 icons, the application displayed the number of errors, and the user had to answer a questionnary. In addition to the number of erroneous answers, the software also logged the answer time for each icon proposed.

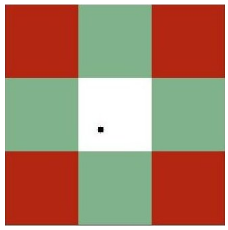

Figure 7: Screenshot of the software

3.3 Results

The errors and the times are represented in the charts of the figure 8. The four bars for each user represent the number of errors and the answer times for the sets 1, 2, 3 and 4.

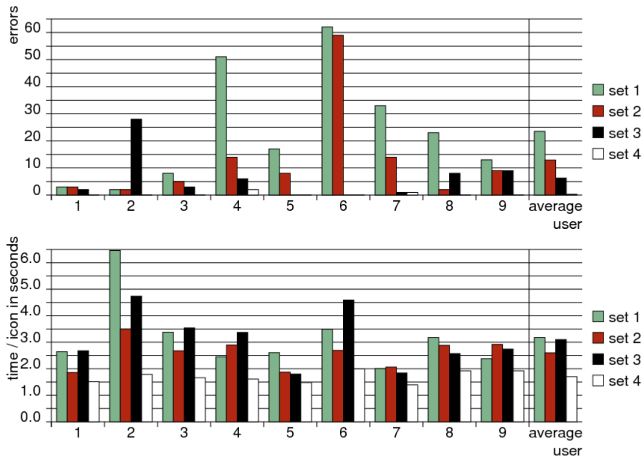

Figure 8: Results of experiment 1 : errors and time

All the users but one (user 2) made more errors with the two first sets than with the others. According to their answers in the questionnary there were not enough pins raised to recognize easily the direction. It confirms our hypothesis about this icon. We thus suppose the fourth icon set was very efficient because it uses the whole size of the cell to indicate the direction. We can also notice that this set is the quickest recognized for all the users, and all the users preferred this one to the others so we can conclude it's the best set among those proposed in this experiment.

The user who made a lot of errors on the third set (the "waves") stated that he hates dynamic icons. The users mostly prefer the static icons to the dynamic one in general. The icons of the third set are quite long to recognize: $3,1s$ in average. As there are 6 frames of $100ms$, one wave is $600ms$ long. Thus in average the user felt 5 waves in order to recognize the icon. The radial icons took $2.8s$ in average (more than 4 waves) and the diagonal icons took $3.5s$ (almost 6 waves). We conjecture it is possible to design icons such that the users needs less waves in order to recognize them.

4 SECOND EXPERIMENT

The users of the first experiment suggested some sets. We did some preliminary tests to choose the expected best ones among them for this experiment. The explanation of the choices are explained below. We also decided to test the best set of the first experiment (number 4, figure 6) to compare the results.

4.1 Experiment setup

Three new sets have been selected during the preliminary tests. One set is composed of dynamic icons and the two others of static icons.

The dynamic set is the fifth set tested (figure 9). The pattern is a "growing wave". The goal is to emphasize the direction we want to show, because we think that the user will remember the biggest pattern. So the icon is small on the first frames and big on the last ones. The idea of the diagonals is to use the whole size on the cell. The third set (figure 5) diagonals had a $\frac{a\sqrt{2}}{2}$ amplitude: these ones have $a\sqrt{2}$, ie. two times more. We expect the diagonals will be easier to discriminate.

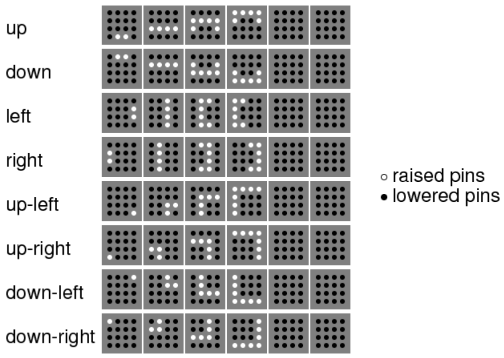

Figure 9: Set 5

The next set is number 6 (figure 10, on the left). As the users seem to prefer the icons with more pins, they thought about patterns with more pins. These icons are just triangles: the radial icons use 4 pins on the line of the direction concerned and the two middle pins of the previous line. The diagonal icons fill the three diagonals in the corner on the diagonal concerned. This time, all the icons uses the same number of pins: 6 in this case. The difficulty we can fear is that with this set, the users will probably have to recognize the position of the pattern because the shapes of adjacent direction icons are quite the same. Thus we conjecture these icons are hardly discriminative.

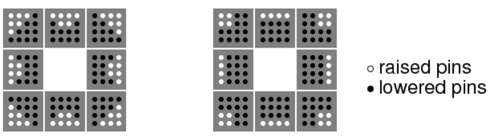

Figure 10: Sets 6 and 7

Set 7 (figure 10, on the right) is an attempt to modify the fourth set in order to have the same number of pins on each icon, so that the same tactile surface will be used for each pattern. The radial icons are the same, but for the diagonals we used the 2×2 square in the corner of the given direction. So this time all the icons have 4 pins. On this set, the difference between radial and diagonal icons is more important. We thus hope this difference will help good discrimination. However the shape of the diagonal icons is exactly the same for all of them. The users will have to guess the position of the shape in order to recognize the diagonal icons.

4.2 Experimental procedure

11 users, sighted but blindfolded took part of the experiment. They were all computer science students between 23 and 27 years old. The procedure was exactly the same as in the first experiment.

4.3 Results

The errors and time are reported in the charts of the figure 11. The bars represent the sets 4, 5, 6 and 7 from left to right.

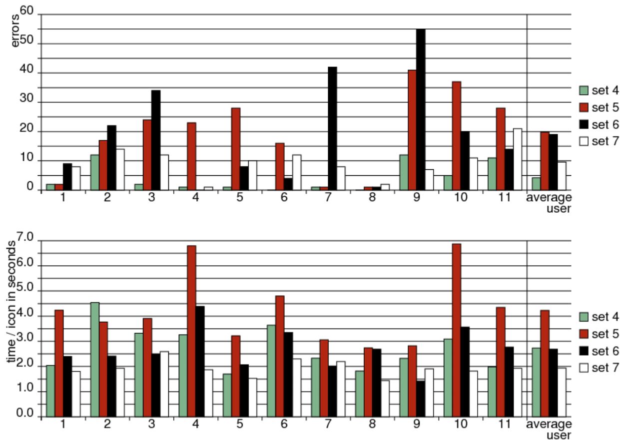

Figure 11: Results of experiment 2 : errors and time

These users also made the least errors with set 4. However one of them (user 9) had better results with set 7 and one (user 4) with set 6, but the difference is slight. They all have more difficulties with sets 5 and 6 in general: they made on average 19.8% and 19.0% on these ones against 4.3% and 9.64% on sets 4 and 7. Most of the users say sets 5 and 6 are the worst.

Set 5 is the slowest: its icons were on average two times longer to discriminate than those of set 7. Only one user (user 2) spent more time on another set: set 4. We can notice this user was quicker from each block to the next one, so we can conjecture this is caused by learning. So the hypothesis about the growing shape is not verified: the users don't recognize the pattern very well. The answer time is very high, and thus we can conclude it's not necessary to display the little patterns: they just slow down the user's recognition. As the waves were $600ms$ long and the average recognition time for this set was $4.2s$, it appears that on average the users needed 7 waves to recognize them.

As we thought, the sixth set is hard to discriminate. The users told there are too many pins used for each icons, and the difference between two icons was not obvious enough. Users 2, 3, 7 and 9 answered quickly to this set compared to the other sets, but made more errors. At the opposite, users 4, 8 and 11 made less errors, but spent more time. So as one user said, the recognition is not impossible, but it needs time. We will remember that it's not a good idea to use too much pins.

Most of the time, the users took about the same time for sets 4 and 6, and a little bit less for number 7. The users made about two times more errors with set 7 than with set 4. They misunderstood 3.7% of the radial icons and 15.3% of the diagonal icons (2.8% and 6.1% with set 4), so the diagonals of the seventh set are very problematic. The conclusion about that is users have difficulties to guess the shape position on the pattern. The user's impression about the fourth and seventh icon sets were quite the same : they like their simplicity, but regret the lack of reference point. It must be the cause of the shape location problem. It should be interesting to see if braille-readers have such problems.

Half of the users preferred set 4 and the others preferred set 7. Some of the users who most like set 7 made less errors with set 4. We can conclude that users rather prefer the static icons than the dynamic ones, and that set 4 is the easiest to understand among those already tested.

5 THIRD EXPERIMENT

This time we selected the best three sets tested and did some more tests with more users. The sets selected were number 3 (figure 5), 4 (figure 6) and 7 (figure 10). The goal of this experiment is to confirm the results above.

5.1 Experimental procedure

The users of this experiment are more diversified. Some of them were younger than usual and some of them older. Only few of them were computer scientists.

They had to feel 50 icons this time, and tested only 1 set among the 3 available. 15 users tested set 3, 23 tested set 4 and 16 tested set 7. The tests has been conducted in a quite noisy environment.

5.2 Results

The average number of errors and answer times for each icon is represented in the table 1.

All the users of the three sets spent around the same time in average : 4.24s per icon for set 3, and 3.92s for sets 4 and 7. So we can't establish any difference on that criteria. We just note that for the dynamic icons (set 3), users needed 7 waves to recognize them. About the errors, we can notice the users made far less errors with the fourth set than with the others. In average the users made 6% of mistakes for the fourth whereas those who tested the third and the seventh made 16% or errors. As in the experiment 2, the users made far more errors on the seventh set's diagonal than for the radials. We can confirm set 4 is easily recognizable, and the position of the shape is hard to guess for set 7.

	set 3	**set 4**	**set 7**
errors global	16.27%	6.09%	16.27%
errors radials	17.46%	6.35%	12.31%
errors diagonals	15.40%	5.80%	20.56%
times global	4.24s	3.92s	3.92s
times radials	3.98s	3.12s	3.75s
times diagonals	4.43s	4.79s	4.09s

Table 1: Results of the experiment 3, average errors and time

6 FOURTH EXPERIMENT

At this time we haven't already found any good dynamic set, so this experiment aims to find one. The main idea for these two sets is to make a difference between radial and diagonal icons.

6.1 Experiment setup

The first idea is to make a mix of the previous dynamic icons: number 3 (figure 5) and number 5 (figure 9), and take the advantages of the good static icons. We decided to remove the "growing" shape of the radial icons of set 5 because they took too much time to be recognized. Those of set 3 are simpler, so we conjecture that they will be understood easily if we manage to distinguish them from the diagonal icons. So we decided to take the diagonals of set 5. The hypothesis is that the growing shape could be an interesting effect if it's used to differentiate the radials and diagonals. The deep intuition is to use the good points of set 4: the last frames of these new icons are in fact almost those of set 4. The animation is similar to the motion of the user's fingertip on set 4. This gives us the set represented in the figure 12.

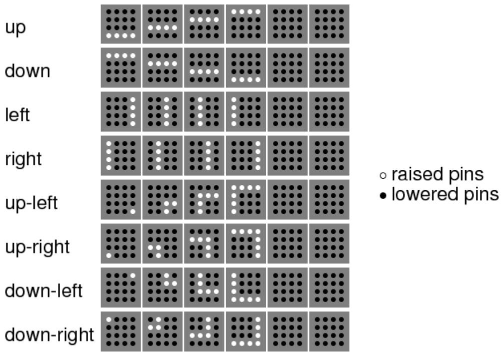

Figure 12: Set 8

The second idea is to modify the third set (figure 5) in order to get the full diagonals. Remember that for this set we selected four diagonals among the seven possible in order to have the same number of frames for the radial and diagonal icons. This time we get the seven diagonals, so the diagonal icons have more frames than the radial ones. This change gives us two advantages: the whole size of the cell is used, and so a bigger tactile surface is used. Moreover the duration of the radials and the diagonals are different: The first ones have four "patterned" frames and two blank frames, which makes 600ms; and the second ones have seven "patterned" frames and two blank frames, which makes 900ms. Here the hypothesis is that the duration differences between radial and diagonal icons could improve the recognition. This set is represented in the figure 13.

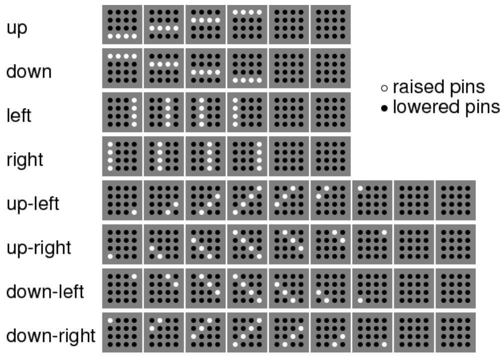

Figure 13: Set 9

6.2 Experimental procedure

The users were the same as those of the first experiment. They did 2 blocks of 100 icons, each block consisting of one set. The protocol was the same as in the other experiments.

6.3 Results

The errors and time are reported in the charts of figure 14. The two bars of each users represent sets 8 and 9.

The results are quite the same: the average error rate is the same for the two sets, and set 9 average answer time is slightly lower than the one of set 8. Three users (users 2, 3 and 7) made more errors with set 9 than with set 8, and one other (user 8) made less errors

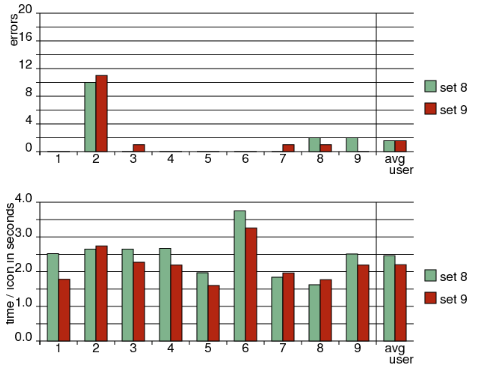

Figure 14: Results of the experiment 4 : errors and time

with set 8 than with set 9. The other users made as many errors with one set as with the other. For set 8, the users misunderstood 2.44% of the radial icons, and 0.67% of the diagonal icons, and for set 9, they made 2.36% of errors on the radial icons, and 0.84% on the diagonal icons. In fact only user 2 (who did not like dynamic icons) made errors with diagonals. Moreover all the users noticed that for set 9, the diagonal were slower than the radial ones and they said it was useful for the recognition. We could say our hypothesis about adding a difference between radial and diagonals helped to recognize easily the diagonals.

The next improvement we could do is obviously on the radial icons. We could lower the animation speed because some users (including user 2) felt the animation was too fast, so on the radial icons they recognized the direction, but not the sense: 9 errors among the 11 made on the radials of set 8 are errors between upwards/downwards or leftwards/rightwards. However for set 9, this rate is only of 4 among 10, but user 2 made 2 errors among 7 in this context, so it remains only 2 errors among 3 for the other users.

Only three users (users 2, 7 and 8) took more time to recognize set 9 than for set 8. The average recognition times are $2.46s$ and $2.20s$ for sets 8 and 9. So the users needed up to 4 waves in order to recognize the icons, and a little bit more than 2 waves for the diagonals of set 9 (they are $900ms$ long). The user's feelings about this set are the same for both. The user 2 still doesn't like dynamic icons (even if he made two times less errors than with the 3), and the others users prefer these ones than set 3.

7 Conclusions

Several icon sets have been tested. Some of them are static and other ones are dynamic. Most of the user prefer the static ones; their advantage is that we can easily palpate the cell since the pattern doesn't change. The users have difficulties to recognize the patterns with few pins raised (sets 1 and 2), or those with too much pins raised (set 6). The better recognized sets are those with shapes very pronounced (sets 4 and 7). For example if we display a line, it should be large and thin so that there is no ambiguity about the orientation. However the position of the shape on the pattern is sometimes hard to feel because of the bad ergonomy of the VT-Player (set 7). Icons which use a little tactile surface have problems of recognition (set 3). A problem common to several sets is the lack of difference between radial and diagonal icons (sets 1, 2, 3 and 5). In the case of set 5: the same effect (growing shape) is used for all the icons, which leads to ambiguity. In the case of static icons a solution is to use different kind of shapes (set 3), and for the dynamic icons to change the shape during the animation (set 8) or to use different motion length (set 9). To conclude the best static set is number 4 and the better dynamic set is the number 9. Since these tests have been conducted with sighted people, we can expect better or different results with visually impaired people. Other tests are currently conducted with icons which combine static and dynamic, and with different animation speed.

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