

Interacting with Cubicle: is Calibration Vital in Playful Experience?

First Author Name (Blank if Blind Review)

Affiliation (Blank if Blind Review)

Address (Blank if Blind Review)

e-mail address (Blank if Blind Review)

Optional phone number (Blank if Blind Review)

Second Author Name (Blank if Blind Review)

Affiliation (Blank if Blind Review)

Address (Blank if Blind Review)

e-mail address (Blank if Blind Review)

Optional phone number (Blank if Blind Review)

ABSTRACT

This paper investigates the influence of calibration between physical-digital mappings on task performance and playful experience, using the Cubicle, a small tangible device, to control video clips. The results show that participants' performance got faster and better as they became familiar with the application despite changing and hard-to-calibrate mappings. They paid less attention to calibration and performed faster when there were less visual mapping cues. Also certain physical-virtual mappings lead to better performance even though participants 'gave up' on calibration. These results inform ongoing work on understanding natural physical interaction as well as specific design features for Cubicle interfaces.

Author Keywords

Input device, physicality, calibration, multimedia.

ACM Classification Keywords

H.5.2. User Interfaces – Input devices and strategies, Interaction styles

INTRODUCTION

Effective interaction through control/input devices requires precision and calibration. This is, of course, particularly important for dedicated controllers in games like Star Wars X-Wing Alliance, in which the joystick is used to fly the ship and to fire the enemies [3]. However, it is equally true where the device is used to control and manipulate functions: try to operate a mouse when rotated through 90 degrees, or on a dirty surface where the ball does not rotate freely.

These devices are manipulated in the physical world, but indirectly control applications through some digital

representation (e.g. screen location of mouse cursor). Calibration is usually important for this physical-digital mapping, and is often implicit or learnt over a period. For more novel devices, especially those in tangible devices, users may have trouble achieving calibration, or even knowing it is required or possible.

Cubicles are cubes, of various types and sizes, used as input devices. An early study of the Cubicle, suggested that a Cubicle-based user interface can provide an intuitive and more playful user interface to a TV [1]. In the study described in this paper, we build on this work, we manipulate the way a Cubicle controls a TV in order to investigate issues of calibration and ultimately to see how the effectiveness of mapping between physical-virtual cube relates to tasks completion and playful experience.

Our expectation was that performance in calibration would be vital as it helps the user to control the application. To investigate this we used two different physical-digital mappings, one where the virtual view of the cube is effectively a top down view (like a mouse) and one where it is side on. For each of these we used labeled and unlabelled cubes (using numbers) to make the mapping more or less explicit.

Our study aims to answer the following questions about calibration and performance:

- Do the numbers on the sides of the virtual cube assist participants to detect miscalibration and thus solve it?
- Does the viewpoint front aligned or top aligned affect calibration and performance?

We also aim to gain understanding on more open questions:

- Does the user encounter playful experience? In what conditions?
- What other experiences do the users encounter?
- How do participants interact and handle the cube?
- What are the designs features that most appealing to participants and what other features can we implement on the Cubicle?

We also aim to see which is more important to users, the effectiveness of a device (calibration) or a playful experience.

THE CUBICLE

A Cubicle is an accelerometer-driven, wireless tangible cube that uses Smart-Its technology to allow rapid prototyping of sensor-based systems [5]. The Cubicle was first built for the purpose of basic navigation and input [6]. A number of interest in the Cubicle can be seen in other work, such as cube affordances for wearable computing [4], and general application of the Cubicle [2].

In this usability study, we used the Cubicle (Figure 1) which was developed by Block et al., [1], with sides approximately 3 in (7.5 cm), with its purpose as an input device for playfully changing between different TV-channels.¹



Figure 1. Picture of numbered Cubicle.

The Cubicle that we used in this particular study selects movie trailers for Alien, Die Hard, James Bond, Love Actually, Lord of the Rings: return of the Kings and Matrix, from a screen by manipulating the Cubicle.

The Cubicle has an on-screen representation of itself, where each side of the cube displays a different media streams. Manipulating the Cubicle allows users to complete several different tasks (Table 1). For instance, rotating the Cubicle from one side to another allows users to switch between different images of movie trailers.

We designed four ways of manipulating with the Cubicle, in order to investigate the ways in which users are able to map the physical cube with the virtual cube and how well they manage to control the TV. The conditions independently manipulate viewpoint (front-aligned vs. top-aligned) and visual cues (numbered vs. unnumbered), giving a range of different calibration challenges for the user.

The front aligned view (see Figure 2a) is a condition where the virtual cube that faces the user represents the front side of the physical cube. The top aligned view (see Figure 2b)

is a condition where the virtual cube that faces the user represents the top side of the physical cube. This is highly significant when a user is trying to calibrate the physical cube with the virtual cube on the screen. Because the sensor in the cube is an accelerometer it can tell unambiguously which side is up, but not other aspects of the orientation of the cube.

When the virtual cube’s sides are numbered, respectively from one to six, the condition is said to be numbered. The unnumbered condition is when the virtual cube shows only the image of the movie trailers – no number being displayed. Displaying the numbers one to six on the sides of the virtual cube (on top of the movie images) would be expected to aid calibration with the physical cube which is also numbered.

Users, thus, can this interact with the Cubicle by orienting the physical cube against the virtual cube on screen according to these conditions:

- front aligned and numbered, or
- front aligned and unnumbered, or
- top aligned and numbered, or
- top aligned and unnumbered

Actions carried out on the physical cube are human-driven, meaning that they cannot occur without human intervention. However, actions carried out on the Graphical User Interface (GUI) can be both human-driven and computationally driven. Actions carried out on the physical cube are human-driven, meaning that they cannot occur without human intervention. However, actions carried out on the Graphical User Interface (GUI) can be both human-driven and computationally driven.

Action	GUI output
Rotation	Display different movie trailers’ images Full image of a movie trailer being displayed selects a movie trailer
No action (cube is placed on a table, or is held parallel to the ground)	Zoom out and play a movie trailer, provided that at that time the screen was showing just one side of the cube (one full image of movie theme)
Shake	Return to initial orientation (correct the calibration), or, zoom out the display if the application was playing a trailer (thus stop/pause the trailer)

Table 1. Cubicle actions and the associated GUI output.

USER STUDY

A usability study of the Cubicle was designed to seek under what condition the calibration is performed best and to

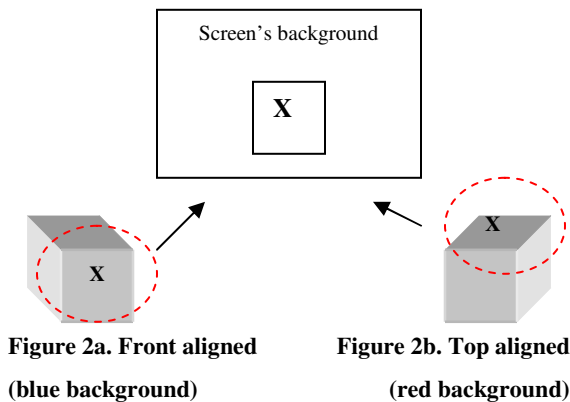
¹ More details on how the Cubicle is built for the purpose of controlling TV-channels can be found in this paper [1]

discover the calibration has any effects on playful experience. We designed the tests to consist of four sets which exhibit four different conditions as described earlier:

- Numbered virtual cube with blue background
- Unnumbered virtual cube with blue background
- Numbered virtual cube with red background
- Unnumbered virtual cube with red background

Different background colors, blue and red, respectively represent front aligned and top aligned as described earlier, (see Figure 2a and Figure 2b). The functionality of the cube application does not affected by the changes.

The test measured the overall performance of the application that includes amongst others the reaction time, accuracy in completing tasks, interactions and preferences, general comfort and experiences, i.e. playful, fun, frustration, and enjoyable. It was also designed to improve the existing design features.



Methodology

We designed our user study as a semi-exploratory design study, meaning that it wasn't entirely exploratory design study, as our study was both prescriptive and descriptive. We provided participants with a very simple set of instructions for the participants to follow (see Table 2).

Participants were first given time to familiarize themselves with the Cubicle interface. The following two steps were to give participants the idea of selecting a movie trailer by carefully rotating the Cubicle. The rest of the tasks were carefully designed to observe how participants manipulate the Cubicle, i.e. the calibration (if any), expressions, as they selecting the requested movie trailers.

Nonetheless, because of the novel nature of the Cubicle and then limitations of the technology, we realized that these tasks were more likely to explore the limits of interaction rather than to provide solid quantitative task analysis data.

A test consists of four sets (conditions), which are presented with a slightly different interface. Participants followed the same instructions for four sets. The interface is as follows:

- Numbered cube with blue background

- Unnumbered cube with blue background
- Numbered cube with red background
- Unnumbered cube with red background

The order of these four sets is not fixed, meaning, the users may begin their test with blue background then red, or vice versa. The conditions of numbered and unnumbered cube is also not fixed, meaning, users may begin their test with numbered cube then unnumbered, or vice versa. Nonetheless, the order is somewhat fixed in a way that the first two sets must be of the same color background before moving on to two sets of the other color background.

From our questionnaires and observations, we expected to outline the Cubicle performance as input device according to calibration, manipulations, experience and user preference by referring to our observations and time measurements results. Furthermore, our ultimate goal is to discover what type of orientation of control surface the calibration is performed best, and to seek whether this type in any way enhance the playful experience, thus enabling us to improve the design of the Cubicle.

Participants

We solicited volunteers from within our department and posted a call for participation on a university-wide mailing list. We required that our study not include anyone under the age of 17. The majority of our participants were postgraduate students, most of them coming from the Computing Department (8), and others from Psychology (3 participants) and Accounting Finance (1 participant) departments. Two participants were in their A-Levels. More than half our participants were men (9 male, 5 female). Five participants have used alternative input devices, such as haptic gloves, and two of them have used the Cubicle interface before the test. Volunteers were informed prior to the test that they were participating in a user study that will assist in determining guidelines for tangible device design.

Measures

To record our data, we use qualitative procedures, including observations and questionnaires. Observations were recorded with a video camera. Log files were used to record the data about the cube's orientation. These two results were then brought to synchronize, to show the orientation with respect to a requested task. Volunteers were asked to fill out a background questionnaire prior to the study and they were informed before beginning the test that they were going to be videotaped. Investigators recorded, via pen and papers, participants' non-verbal manipulation. At the end of the design study, users completed a short post-questionnaire. Using multiple forms of observation and data collection allowed for detailed evaluation and analysis of user behavior.

Procedure

Our design study took place over one week in our department. Each participant interacted with two

investigators before and after the test. The primary investigator was responsible for greeting and debriefing the volunteers and collecting questionnaires. A second investigator was responsible for videotaping. Both investigators were responsible for note taking during the study and for analyzing data and questionnaires after the study.

The Cubicle was evaluated in four separate stages. First, participants filled out a pre-test questionnaire individually, which allowed us to gather background data about each participant. Next, we observed how participants interacted with the cube. On each testing day participants were given a list of instructions in which they conducted via the Cubicle. During each test, participants followed the instructions listed in Table 2 for each of the four sets. Investigators directly observed participants and collected data concerning these observed activities. As well as investigators directly observing participants, investigators used video camera to record (audio and visual) user activity, whilst the log data recorded the Cubicle movements. Thirdly, volunteers completed a post-test questionnaire individually which included both independent and dependant ratings of the Cubicle. They were asked to comment on the procedures, tasks, cube attributes and overall study. Lastly, an HCI expert and investigator analyzed the collected data.

<ol style="list-style-type: none"> 1. Pick up the cube 2. Play around with the cube, until you feel comfortable 3. Then, manipulate the cube in your hand(s) so that any three sides of the cube visible on the screen 4. From 3, make one of its side (left or right) visible on the screen <i>Please tell instructor after you finish this.</i> 5. Select Matrix trailer 6. Place the cube on the table 7. Watch the movie for a few seconds 8. Pick the cube up again 9. Select a different movie trailer 10. Then place the cube on the table, or make the cube parallel to the floor 11. Watch the trailer that you just selected for a few seconds 12. If you placed the cube on the table, pick the cube up again, or continue moving the cube 13. Now, resume the Matrix trailer 14. Place the cube on the table once you select this 15. You can now browse to any other trailers available if you are interested <i>Please tell instructor once you finished.</i>
--

Table 2. List of instructions.

Data Collections

Individual responses were collected via the pre and post-test questionnaires and indirectly collected via video and log files. Both the independent and dependent ratings from the post-test questionnaires results were converted into charts in order for investigators to discern the overall performance of the Cubicle. When analyzing the video data, investigators collected information on how each user handled the Cubicle, for example, rotating or flipping the

cube, using one or both hands. As well, investigators measured how long participants took to complete a task. When analyzing the log data, investigators matched the mapping of movements of the physical cube to the mapping of the virtual cube. We then matched these results to the comments participants made via the questionnaires and observations taken during the tests.

ANALYSIS RESULTS

The results are presented into three categories: observations results, overall performance, and user preference.

Observations results

Observations results illustrate the whole experience of manipulating the Cubicle performed by the participants. Descriptions below were elaborated in accordance to the list of instruction (see Table 2).

Step 1-4

In almost all tests, participants picked up the cube that was placed on a table next to the screen with one hand. One participant who was cautious and careful used both hands. The cube was then brought up to the centre against the screen. At this point, the cube was handled with two hands. Out of 13 participants, only one participant continued to hold the cube single-handedly.

We observed that during the first few minutes of the first set of instructions, the participants tried to manipulate the cube in all directions to try and discover the Cubicle’s range of movement. Some of the participants swung the cube from left to right, and right to left, and even in a circular motion.

Due to technical reasons, the rotation along the x-axis was not as smooth as the rest of the movements. The majority of the participants failed to make the virtual cube rotate on the screen. Only those who had used the Cubicle before the test knew how to properly rotate the cube, i.e. by rotating the cube abruptly, or with a little speed.

All participants successfully made any three sides of the cube visible on the screen and made one its side visible on the screen. It is worth pointing that miscalibration, however, occurred before and during the completion of these two tasks. Some participants seemed to be struggling in order to get the mapping right. It is also interesting to see that almost all participants did not know that the miscalibration was due to the wrong referent they used when manipulating the cube. For example, a participant who handled the cube by making referent to its top view (top alignment) had some difficulties to get the mapping right when the screen was showing the front view (front alignment) of the cube. This happened in both conditions: with numbers on the virtual cube, and without.

As participants had to go through the same instructions for all four sets, they often skipped steps (tasks) 2, 3 and 4.

Step 5-6

Due to the fact that we did not give them any extra information apart from the instruction sheet, the participants often at the beginning weren't sure how to select and did not know what to expect after displayed the Matrix image on the screen, i.e. the term used, 'select' was not so clear to the participants. Yet, they eventually discovered that the movie trailer would begin as long as the movie was on the front face.

The delay between selection and play caused participants some confusion. They weren't sure if the delay was a result of a mistake that they made or if there was a technical problem. This caused them to begin manipulating the cube before the intended action (play) commenced and so the trailer never played.

In situations where the participants were patient enough to wait whilst holding the cube steadily and evenly in their hands, the zoom effect was activated. If then the participant decided to place the cube on the table, the zoom effect got deactivated (zoom out) and started to zoom in again once the cube was securely placed on the table. As this scenario happened in many occasions, the investigators gathered that the instructions in steps 5, 6 and 9, 10 were not accurate that resulted to most of the participants did not know how exactly to select a trailer.

Miscalibration occurred quite often at this stage. Apart from the reason stated in the previous steps, miscalibration also occurred when participants wanted to rotate the cube along x-axis. The virtual cube did not act as the same way as the physical cube, i.e. either the virtual cube rotated slowly or did not rotate at all. This sometimes led to displaying a different image hence showing a different movie trailer. This unintended result caused frustrations to some of participants as we could tell from their expressions.

Step 7

Participants watched the movie trailer for few seconds as expected.

Step 8-10

As these steps were similar to previous performed steps 5 and 6, the experiences and issues rose were the same, i.e. problem in selecting, delays and miscalibration.

At this stage, the participants were informed about the alternative method to selecting, as stated in the instruction sheet. However, we observed that most participants continued comfortably with placing the cube on the table rather than hold it still in their hands.

Another occurrence that led participants to disappointment was when the selected movie image did not give any result, i.e. the picture did not zoom in hence the trailer did not play. For instance, when a participant chose to watch Love Actually after made the respective image displays on the screen, the picture did not zoom in. As this happened, we advised participants to continue with the test. We suspected the reason to this occurrence is due to the image being

displayed was tilted, which may cause by un-level surface of the physical cube (due to its lid that wasn't properly closed – see Figure 3) once it was placed on the table.

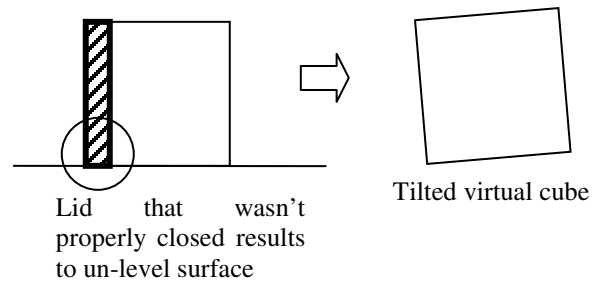


Figure 3. Un-level physical cube

Step 11

Participants watched the movie trailer for few seconds as expected.

Step 12-14

As these steps were similar to previous performed steps 5 and 6, the experiences and issues rose were the same, i.e. problem in selecting, delays and miscalibration.

For participants who had watched the Matrix trailer to the end in step 7 had nothing to watch when the image zoomed in. In this occasion, we advised participants to continue with the test.

Step 15

Very few participants viewed other trailers available.

Results from log files show that at some point during the test, the virtual cube didn't move as the same way as the physical cube. The movement of virtual cube didn't match the physical cube. The virtual cube movement from log files show that the cube sometimes jerked and sometimes delayed for few seconds although the physical cube was moving during the delay. We suspected that is due to the technical reasons, especially when the cube is rotated at x-axis.

Front aligned and top aligned cube

From the observations, it is very fascinating to discover that participants hardly looked at the physical cube in their hands when performing the tasks. They concentrated more on the virtual cube and used the physical cube just to get the virtual cube rotates without concerned about precision of mappings between the physical and virtual cubes.

In the case where the calibration was correct, there are also a number of interesting methods used to confirm their selection of movie images. One was by tapping the cube hard on the table. Second, was by placing the cube real slowly on the table when the movie image, for e.g. the Matrix, was visible (not yet fully) on the screen. As the cube was placed on the table, the cube was then rotated so

that the respective image on the screen faces to the front hence showed the full image of the movie.

Furthermore, we also observed the performance of each participant gets better and faster as they carried out all four sets, despite what type of alignment goes first. For e.g. the order of what background screen shown first had no effect on participants' performance. The following charts show the average time (of numbered and unnumbered) taken to complete the tasks.

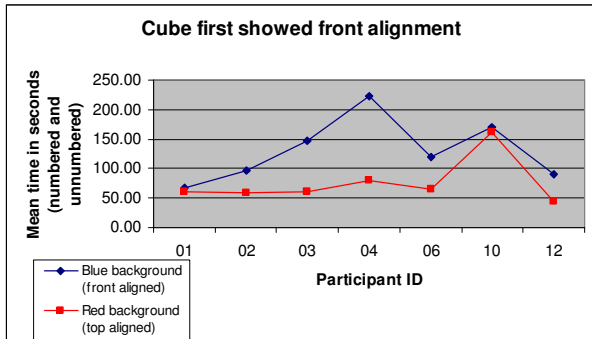


Figure 4. Participants performance when the cube's referent was first set to front alignment.

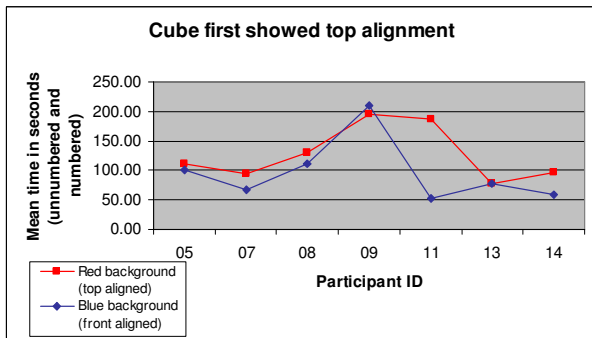


Figure 5. Participants' performance when the cube's referent was first set to top alignment.

Figure 4 illustrates performance where cube's referent (numbers) was first set to front aligned (blue line) and was followed with top aligned (red line), whilst Figure 5 shows conditions where cube's referent (numbers) was first set to top aligned (red line) and was followed with front aligned (blue line). Average time of numbered and unnumbered in each condition was plotted against participants.

From both charts illustrated above, we see that in most cases participants spent less time in the second alignment, despite which alignment was set first. Nonetheless, when the first alignment was front aligned (see Figure 4), the digression of mean time in the second alignment is quite significant compared to the one in Figure 5. This is true especially for participant 04, who very much preferred the red background (top aligned), attempted very hard to calibrate the Cubicle with the virtual cube when the referent was front aligned, hence spent a lot of time here.

Participants who first undergo the top aligned referent did slightly faster than the front aligned referent – except for participant 11. This participant who thought that there weren't any difference between the red and blue background did significantly quicker when referent was front aligned (blue background). Participant 09, who spent slightly more on the second condition admitted, "I had problem with the screen cube facing me..."

Despite proving which alignment is more significant, the results inform us that performances get better and faster as participants became familiar with the application. We observed from the videos and written checklists that participants spent more time in the first condition to overcome miscalibration. They became less concerned with calibration in the second condition, even when the condition was different, as their attentions were more attended to the virtual cube in the screen.

Numbered and unnumbered cube

In a glance, Figure 6 shows the number of participants who spent more time on numbered cube outnumbers those who spent more time on unnumbered cube. The ratio of numbered to unnumbered is 8:6. What would be ideal in making the Cubicle as an input device is to get the tasks completed as quickly and accurately as they can. The results somewhat proves the calibration as less important.

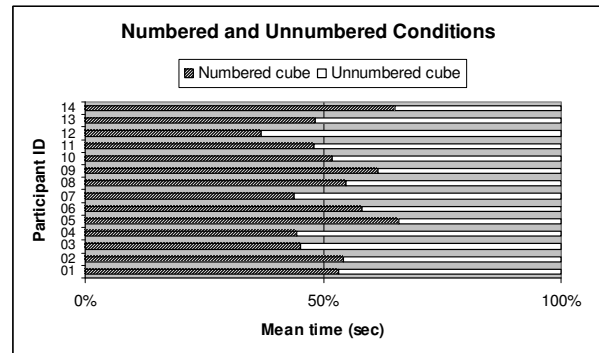


Figure 6. Participants' performances on numbered and unnumbered conditions.

Eight participants who spent more time on numbered cube are mostly female (4 from 5), and most of them do not come from the Computing Department. We observed that they only looked and concentrated on the virtual cube when manipulated the unnumbered cube, thus resulted to faster performance. They, on the other hand, spent quite some time when the cube was numbered as they were concerned with the mapping and tried to match numbers on the physical cube to numbers on the virtual cube.

It is fascinating to discover that six participants with strong computing background spent less time with numbered cube, and more time with unnumbered cube. Although there were few occasions where they didn't get the calibration correct in the condition where the cube was numbered, the time spent was still less than the one with unnumbered cube.

More time was spent with the unnumbered cube as they tried to figure out the movement of the virtual cube and how that mapped to the physical cube in their hands. The numbered cube can easily assist them in calibrating both of the physical and virtual cubes.

Overall Performance

We rated the overall performance based on the feedbacks received from the participants as they filled in the independent and dependent rating scales.

Independent rating scale

The independent rating scale was designed to provide us general information about users’ acceptance towards the Cubicle application as an input device. There are ten attributes that we wished the participants to evaluate on a scale 1 to 7, with 1 being poor and 7 being good. The following table (Table 3) gives an overview of the attributes and the items that were intended to test.

Smoothness	Wireless transmitting Speed of driver processing 3D rendering
Physical effort	Weight and measures of the Cubicle
Mental effort	Application usage Miscalibration
Reaction time	Wireless transmitting Speed of driver processing Usability of full screen toggling
Physical fatigue	Design of full screen toggling Weight and measure of cubicle
General comfort	Checking overall impression of the handling (comfort wise)
Overall operation	Checking overall impression of the handling (technology wise)
Fun	Playfulness of interaction
Frustration	Application design

Table 3. Attributes and their descriptions.

Although participants were not informed with the items that were intended to test, the sufficient captions provided underneath each attribute on each scale helped the participants to rate the attributes. Figure 7 illustrates the result.

Smoothness and *reaction time* have the average of 3.98 and 4.00 respectively. We suspected this was due to the reliable wireless link and the matrix smoothening algorithm that results to a smooth 3D rendering.

The scores for both *physical effort* and *physical fatigue* which are 2.07 and 1.36 respectively, and the high score of

4.93 for *general comfort* tell us that the application was quite comfortable that requires low physical effort and results less fatigue.

Nevertheless, it was found that participants required quite high *mental effort*, with average of 3.36, in relative to *physical effort*. The *reliability* of the application was thought to be not as good as it scores less than the average; 3.29.

With *frustration* scale rating describes 1 as the least and 7 as the most, the average score of 3.57 clearly shows some of the participants’ disappointment when encountered with the application.

The *overall operation* was rated 3.71 as its average which marks a positive performance. Of all attributes, *fun* scores highest with an average of 5.0. This shows those participants enjoyed interacting with the Cubicle.

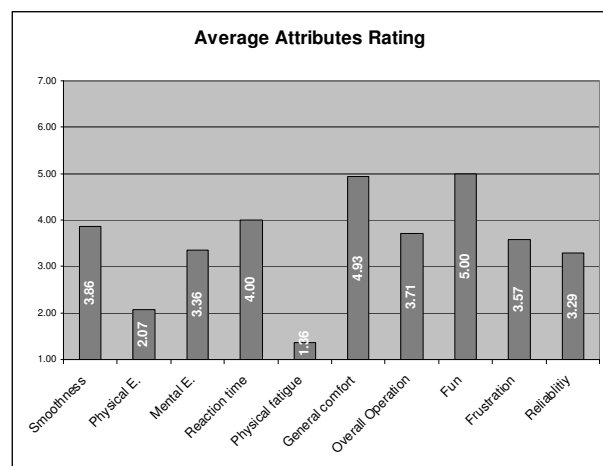


Figure 7. Average property rating.

Dependent rating scale

The dependent rating scale was supposed to provide us with information about the four conditions, by rating the four sets with the later three sets was rated against the first set. Meaning, after the first set was rated, participants need to rate the latter three sets by rating them more negative or more positive against the first set. The attributes given were the same as in the previous rating scale.

The scales of four sets were rated almost identical to one another (see Figure 8). This tells us the participants could not distinguish between the front and top view, and the conditions of the numbered and the unnumbered cube. Thus, from this particular result, we could not tell in which condition the attributes performed best.

We suspect that participants could not remember every little detail for comparison after having completed all four sets in one go. Nevertheless, from Figure 8, we can see that in overall, the blue screen background outnumbers the red screen background. Albeit informing us about participants’ preference of the front view to top view, this information actually informs us that participants prefer blue to red as

blue is much calmer than red. In addition, we can see that participants' preference on unnumbered cube to numbered cube.

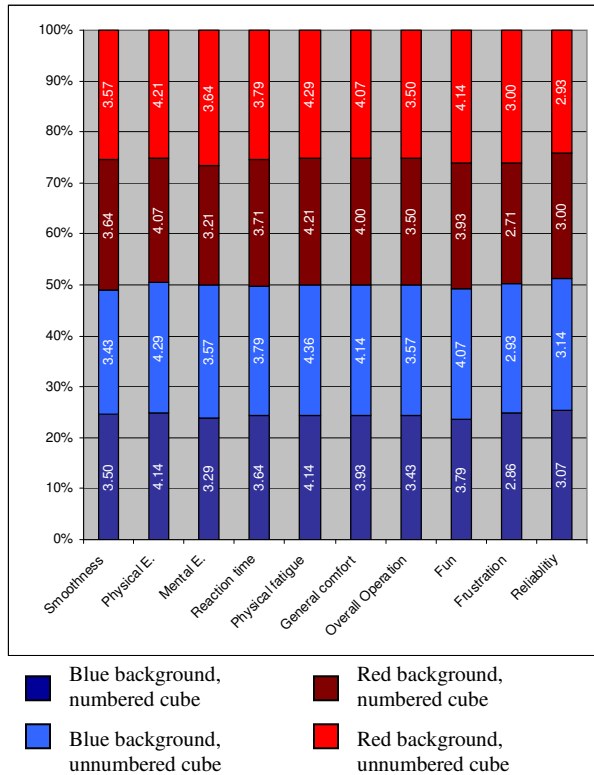


Figure 8. Dependent Rating, attributes against four sets

User Preference (participants' interaction)

User preference gathered from participant interaction is interaction or manipulation that takes place when participants handle a cube. In this section we observe the kinds of interactions that seemed most “natural” and intuitive to participants when they manipulated the Cubicle. We classified our results according to the task list outlined in Table 2.

Task 1: Play around with the cube

- Pick up, place, hold, flip, swing (left to right / right to left), twist, turn and rotate
- All except one participant manipulate the cube with two hands
- Attempts to calibrate the cube with its representation

Task 2: Make 3-sides visible on the screen

- Hold, rotate, twist, and turn
- Participants eyes were more on the screen rather than on the cube

Task 3: Turn one of the sides to the front

- Hold, rotate

- Participants eyes were more on the screen rather than on the cube

Task 4: Select another trailer

- Pick up, hold, rotate, turn, flip, place, hold evenly and steadily
- Participants eyes were more on the screen rather than on the cube

Task 5: Resume Matrix trailer

- Pick up, hold, rotate, turn, flip, place, hold evenly and steadily
- Participants eyes were more on the screen rather than on the cube

IS CALIBRATION VITAL IN PLAYFUL EXPERIENCE?

Having analyzed the results from the usability study, we have been able to answer the set of questions that was appeared in the beginning of the paper.

The answer to the first question, which asks whether numbered cube assist participants to detect miscalibration, has actually no clear answer. Those who come from strong computing background spent less time with numbered cube, as they found it easy to map the numbers on the screen with the numbers on the physical cube, whilst those who do not have strong computing background spent less time with unnumbered cube. To point out which condition is best is difficult as the between the two has only a very slight different. Nonetheless, we can say that the time taken to complete tasks in unnumbered condition is lower than the time taken in numbered condition.

From the results, participants couldn't distinguish the difference between the front aligned (red background) and the top aligned (blue background). The results, however, showed that in average, participants performed faster when they were in top aligned condition. The participants, surprisingly, hardly looked at the physical cube as they manipulating the Cubicle. Calibration barely occurred. The order of which alignment goes first didn't give any significant effects on the results.

We observed that those who tried very hard to calibrate the mappings between the physical cube and the virtual cube normally resulted to frustration. This scenario often took place when participants handled the numbered cube. Added with the fact that they didn't get the orientation correct, whether it was front aligned or top aligned, worsen the scenario. Thus, when dealt with unnumbered cube, participants were more freely to rotate and orientate the physical cube. Unnumbered cube has successfully brought smiles to their faces, especially after they failed to calibrate in with the numbered cube.

The physicality of the device, i.e. the Cubicle itself, and its weight, is vital matters *per se*. The study has determined that the size of the cube led the participants to hold the cube with two hands instead of using just one (only one

participant, who is expert in juggling, held the cube with one hand). By holding the Cubicle with two hands, the choices of manipulations are more in variety, i.e. the participants can rotate, flip, twist, and turn. There were few participants who started off with one hand, but changed to two hands shortly afterwards, as manipulation with one-hand could only allow them to rotate the cube along y-axis. The only participant, who manipulated the cube single-handedly with his right hand, used his left hand to rotate the cube along x-axis.

It is very interesting indeed to discover that what we thought of about correct physical-logical mapping (calibration) plays extremely important role when it comes to tangible devices, especially when one deals with the Cubicle as a medium to control media applications, was not exactly right. Although all participants initially attempted to calibrate the cube with the one on the screen, it just seemed to be an impossible thing to do.

So, is calibration vital in playful experience?

This study revealed that tasks completion didn't 100% rely on correct calibration between the physical cube and virtual cube. The more effort they put in to correct the miscalibration, the more frustrated they became. Without worrying about the mapping (calibration) resulted to more playful, fun experience, as it was more about intuitiveness rather than effectiveness of a device.

Other findings, from the comments received, highlighted the facts that aesthetic is such a salient feature in the design of a tangible device, for instance the texture of the cube, sounds, weight and lights, and how important it is to make it fun to use. In addition to this, it is fascinating to see how participants thought of the blue and red screens. The different background colours that were supposed to distinguish how the cube is controlled (by referring to its front or top views) have been misinterpreted. Instead of discovering the different ways to control the Cubicle, participants commented on their preferences on colours, i.e. which environment is more comfortable. In addition, it was suggested that the cube to be covered with different textures on the sides, incorporate sounds and has flashing lights. Textures and sounds would be highly significance for visually impaired. And to overcome the 'select' problem, they suggested some buttons on the cube to select once preference is made.

The whole experience of using the Cubicle as an input device for watching trailers could be more fun if we could reduce the amount of mental effort that participants put in. One way to do this is by making sure the jerkiness problem is solved. The experience would be more fun if the menu selection is more variety.

FUTURE CONSIDERATIONS

The Cubicle can be designed to its full potential, by making full use of all axes available to increase the number of states, and, to fulfill participants' nature of interaction with

the cube. The movements, hence, do not just limited to rotation at one point in time, but also include gestural movements. Thus, users can freely move the Cubicle in the air, and at the same time the virtual cube (application) corresponds to this movement.

CONCLUSION

In this paper, we presented the results from our investigation in the influence of calibration between physical-digital mappings on task performance and playful experience using the Cubicle.

We found that calibration is not vital in playful experience, and it is also not important when completing the tasks. If miscalibration occurs so frequent as they try to complete the tasks, the experience could only lead to frustration. Thus, playful experience can be achieved without the needs the worry much about calibration.

The results also revealed that there are still many more potential design features that can be considered, e.g. aesthetic values, and the Cubicle's movement's scope and alignment. Furthermore, these results inform ongoing work on understanding natural physical interaction as well as specific design features for Cubicle interfaces.

The work provides an important first step in the design of input device that focuses on playful experience rather than the effectiveness of a device.

ACKNOWLEDGMENTS

The presented research is part of the Equator IRC (GR/N15986/01 - "Technological Innovation in Physical and Digital Life"). We would like to thank the people who volunteered for our study.

REFERENCES

1. Block, F., Schmidt, A., Villar, N. and Gellersen, H.W., Towards a Playful User Interface for Home Entertainment Systems. Accepted paper for EUSAI 2004, the Netherlands.
2. Cubicle Application. <http://ubicomp.lancs.ac.uk/cubicle/applications.htm>
3. LucasArts Entertainment Company LLC, StarWars X-Wing Alliance, 1999.
4. Sheridan, J.G., Short B.W. Kortuem, G., Van-Laerhoven, K. and Villar, N., Exploring Cube Affordance: Towards A Classification of Non-Verbal Dynamics of Physical Interfaces for Wearable Computing. *Proceedings of EuroWearable 2003*, HP Labs, Bristol.
5. Smart-Its Project. <http://www.smart-its.com>
6. Van Laerhoven, K., Villar, N., Schmidt, A., Kortuem, G. and Gellersen H.W. Using an Autonomous Cube for Basic Navigation and Input. In *Proceedings of ICMI/PUI 2003*. ACM Press. Vancouver, Canada. 2003

The columns on the last page should be of approximately equal length.