Abstract—This paper presents a study of multi-touch interactive surfaces based on the use of heat maps. The results of the study sheds light on two main issues that have not been researched formally thus far: User preferences between horizontal and vertical interactive surfaces, and preferred touch zones on both types of interactive surfaces. Our findings have implications for the design of user interfaces for multi-touch surfaces as well as for the use of vertical or horizontal surfaces in individual or collaborative settings.

I. INTRODUCTION

Applications over multi-touch screens are now a common research topic, but some authors have granted horizontal surfaces a preferred status over vertical ones, others say the opposite; truth is little effort has been put into formally experimenting about it. We focus our work on uncovering the truth and settling this debate.

A multi-touch surface is a computational device displaying visual information on a (usually flat) screen capable to receive input by human fingers and some other objects. Generally, multi-touch surfaces are transparent and/or integrated over the surface. This allows for the illusion of “touching” virtual objects with the fingers. These surfaces have been studied several decades but just recently they have become common and some of them have turned into commercially successful products.

Multi-touch surfaces in medium and large size allow for some useful applications either by a single user or in collaborative work. For instance, they can be used for design, planning, collaborative tasks and as a mechanism for information visualization or data mining tools. Other usages are being researched in the scientific community and also by industry leaders.

There is great effort in the academic field to find new applications and new interaction techniques using this kind of hardware. This effort is made because traditional interaction techniques are not directly translated into these new surfaces, so new mechanisms are needed in order to fully exploit their advantages. This is a difficult task, and some authors have even expressed some concerns and called for deeper studies to find out whether multi-touch surfaces actually enhance productivity or they, in fact, damage it [1].

Other authors have sidelined these assumptions and have directly used and studied horizontal surfaces. In the work of Muller-Tomfelde [2], maybe the first recollection on horizontal surfaces, some error and user frustration sources are listed, including lack of feedback, but also the lack of precision and “garbage” on the surface (generating noise) are noted as important. This compilation, however, focuses only on horizontal surfaces and never includes even a reference to vertical surfaces.

We conducted a study that compared the use of horizontal and vertical surfaces for which a group of people was selected to interact with the same application and the same surface but with differing orientations. This in order to understand the differences in the interaction when working on horizontal and vertical surfaces. The rest of the paper is organized as follows: in the next section, we describe some work related to this area of research. Next, we present the methodology used for our study. Then, we discuss the results along with an analysis of their implications. Finally we provide an overview of ongoing and future work.

II. RELATED WORK

One of the few items in the current literature focusing on orientation as an important factor to measure, is the work of Rogers and Lindley [3]. In their work, an interactive surface was analyzed, and both orientations were tested. However, their tactile surface was not multi-touch, but an interactive single-touch whiteboard placed horizontally. They found better collaborative work when using it as a horizontal surface. The lack of multi-touch capabilities severely affects the evaluation and its extension to multi-touch because users cannot collaborate when only one of them can touch or interact with the surface. This was more clear when the surface was placed
vertically, as a single user, the one with the stylus, became the leader of the interaction and another could only follow him. Rogers and Lindley found that horizontal was better for their purpose as users were more eager to exchange the stylus in horizontal mode, while gathering around the table. We can argue about the validity of this study when applied to multi-touch surfaces, but it is an important step towards a more objective assessment of this issue. Leadership appeared in Rogers and Lidley’s work as collateral effect of having to use a stylus, but if many users can interact, other aspects could appear and they might be related to social aspects and not forced by a token.

Potvin et. al [4] also compared horizontal and vertical surfaces. Their work aims to compare orientation effectiveness in collaborative scenarios while applied to design tasks. Factors about orientation, its influence on group inclusion, face-to-face contact are studied. They argue about horizontal and vertical surfaces but, in the end, they did not make any real tests, and restrict their study to traditional (non digital) whiteboard. Potvin et. al’s findings indicate vertical surfaces work better for promoting collaboration as users are face to face, while horizontal surfaces promote discussion. They found no clear preference among users, but they clearly state that more depth research is needed. Their work is interesting but must be validated with real multi-touch (digital) surfaces and must be tested both in group and single usage scenarios. In this work, we research these topics while doing individual work.

Inkpen et al. [5] also focused on factors affecting interaction. They studied group scenarios and not individual work. Several factors related to human interaction are discussed. Their conclusion suggests the superior benefits of horizontal surfaces mentioning they allow for a holistic vision. They also mention horizontal surfaces benefit the users by giving them the same perspective and more freedom. Inkpen et al finally make the remark that tilted surfaces present a wider field of view but are close to useless when the need for collaboration arises.

As mentioned earlier, the literature in the area aiming to determine an optimal orientation to work with multi-touch surfaces is scarce. Collaboration studies have justified their approach towards horizontal surfaces based on the work of Rogers and Lindley [3], which is not necessarily applicable to multi-touch surfaces. One of the works that justifies their study is discussed by Izadi [6].

Grudin [7], whose work focuses on collaboration, has long stressed the importance of bridging the enormous gap that often exists between those who design such systems and the people who actually use them. Because regularly, systems require substantial investment for their own development and they constantly cause disappointment among users. Grudin details several aspects that cause this to occur. In summary, system designers do not perform sufficient investigation, and therefore, they create complex systems that turn out to be difficult for ordinary users.

In the case of multi-touch interactive surfaces, several authors have begun to explore differing approaches to determine appropriate screen positions, for example, in collaborative systems.

To cite two cases, consider Shoemaker’s [8] and Apteds work [9]. Shoemaker [8] designed an interactive space using screens and large wall interaction techniques focusing on the body. Apted [9] presented a collaborative multi-touch interface for sharing digital photos, designed for the elderly. On the use of heat maps, the research conducted by Horak [6] implements this sort of graphical representation on a web application for a Geographical Information System (GIS) in order to understand the behavior and activity of users in relation to the user interface. For their study, they monitored the mouse clicks that users performed when using the application. User clicks data are stored in a database. They finally converted data to a two-dimensional vector to generate the heat map in which the set of values is associated with a color scale.

Atterer and Lorenzi [10] developed a tool that uses heat maps to visualize user activity while visiting a website. Their tool displays a summary by coloring parts of the site where the user spends more or less time, even controlling downtime on the site. This provides an overview of the history of personal interaction of a web page.

Fisher [11] used a heat map on a site map to represent a view about the geographical areas that users find interesting. It makes use of a range of colors to represent the number of times that a particular location is selected by users. Similarly, Cuthrell and Guan [12] use heat maps to visualize the number of fixations across three users on a page and investigate their strategies for web search.

III. METHODOLOGY

In our work, we measured proficiency on completing a task. To perform this experiment we designed scenarios in a way that allowed us to measure the total time needed to complete this task. At the same time, mechanisms were implemented in order to capture touch data; every touch and movement was recorded with a latency of 60 fps. In order to determine user preferences, a questionnaire was applied.

This experiment was performed in a laboratory under controlled conditions. In order to design the experiment, a variant of the method known as post-test control groups [13] was used. Two random groups were created, the first was asked to use the horizontal surface, and the other was asked to use the vertical one. Both groups used the same software1, the only variant was surface orientation. In this way, the different usage patterns were directly correlated to surface orientation. The user base had no previous experience using large sized multi-touch surfaces and users never experienced both orientations in order to avoid prejudice and collateral learning effects.

A. The two experiments

This was a guided study and two independent experiments were performed two times. The procedure was as follows: the guide was serving only as a director and helper in extreme circumstances. The experiments consisted of four tasks. Each

1The software used was PyMT: http://http://pymt.eu/.
user was asked to perform each of these tasks in a predefined order. Tasks had a predefined time lapse, but users were not informed about it, unless the time ran out.

Data collected from each participant were: (i) time to complete the activities, (ii) task completion status\(^2\), (iii) heat-maps about touch activity on the surface and (iv) final questionnaire.

B. Tasks and evaluation

The task list is shown below:

- The user takes a few minutes to know the interface, using a basic application showing only the touch points. The user uses an application where common gestures, such as pinch-zoom, are basic. When the user is comfortable, he should inform about it in order to continue.
- The user should use the photo application. In this application several photos with different sizes, angles and positions are shown. Then he defines a \(2 \times 2\) mosaic with specific rotation of the elements.
- The user opens an application emulating letters on a fridge. After that he arranges some letters to create the phrase “La ciguena tocaba el saxofon detras de la paja”.
- Finally, the user should play and solve the “entangled” game for 25 vertices.

Once the activities are done, the user answers a survey with three questions regarding comfort and physical aspects. A Likert scale was used and defined between 1 to 5.

Tactile activity was recorded using a software capture tool tailor made for this experiment. This tool acts as a proxy between the hardware input source and the software layer. It collected all information and recorded it before it was actually delivered to the application. By acting as a intermediary, this tool can log all information and transparently deliver the same information to the application, being a totally transparent and unobtrusive tool.

30 people aged between 18 to 27 years were selected for the study. They were randomly split into two groups. One of the groups, randomly chosen, was asked to interact with the surface in vertical position, the other in horizontal orientation.

The multi-touch surface was a 52 inch LCD, the same surface was used in horizontal and vertical mode. Pictures of the surface and users can be seen at figures 1 and 2. Also, the user has a training stage. This training stage was useful to ensure the users would not feel any pressure or anxiety when using the surface for the first time. Users were allowed to touch and make gestures and guided to discover by themselves the capabilities and limitations of the surface. Fig. 3 shows one of the users while performing an activity.

IV. RESULTS

Now we present the results obtained. The \(t\) Student test was used as a statistical method in order to find a significant relationship between the orientation and perceived comfort. The \(t\) test estimates the value of the statistical importance (or

\(^2\)If the maximum time was depleted it is considered “incomplete”. Almost every participant completed their tasks on time.
significance) difference between two data sets. The same test was used to determine the relationship of the orientation with the time required to complete the activities. This test did not give any significant result in any of the two experiments.

A. Evaluation of comfort

The 30 users evaluated each of the three activities in the final questionnaire, then the average was calculated. We did not find any statistical preference over any orientation.

B. Heat maps on the multi-touch surface

The input proxy captured samples for both orientations. Users of the horizontal surface frequently used center-right area (see Fig. 4). Instead, users of the vertical surface used mainly the center-left area (see Fig. 5). Fig. 6 shows the results of studies conducted for the second time.

V. DISCUSSION

We have presented a study to find out if there is any preferred interaction area when using vertical and horizontal surfaces. The test determined there is no clear user preference, but there is a clear difference on interaction areas. Heat maps were created based on interaction data gathered from users and they have clearly shown different interaction when using the same application.

This is different when compared with other findings, such as the work of Rogers & Lindley. However, the surfaces inspected were different from them. Roger & Lindley used single touch surfaces and a token (stylus) for interacting with the surface. Our surface was capable to detect two simultaneous touches. In addition, we were focused on individual rather than on collaborative work.

Our findings, however, seem to confirm some of the findings of Potvin et. al. We also found insignificant trace about user
preference of horizontal and vertical surfaces. But, unlike Potvin et. al we did test with real surfaces and not only with traditional paper and ink markers. We can assert that our results validate their insights for individual work. Nevertheless, more work is needed in order to fully understand user preference about surface orientation and preferred interaction areas, especially when group interaction is involved.

Even when some authors have assumed the horizontal orientation as their preferred way of interaction, these assumptions were not formally sustained. We, as Potvin can assure the validity of those assumptions cannot be sustained. It is possible that the preference for studying horizontal surfaces is related to the ease of build in amateur setups, so they can be readily available in academic research. This can also be conjectured because the first research surfaces were built by using projectors, cameras and other bulky equipment, which is easier to assemble when placed on the floor. Even the first commercial setups used these integration mechanisms. Conversely, larger surfaces are just beginning to appear as commercial products as an evolution of LCD panels. Maybe now, the academic community can study vertical surfaces against horizontal surfaces in a more equitable manner.

A. Factors to be considered in future studies

Before this experiments, we did not consider proximity of walls and other obstacles near the user to be significant noise generators. This experiment brought to the table the issue of walls being a discomfort for the user and creating artificial preference. Any object near the user might pose the threat of noisy results, so walls, chairs, sharp objects or even windows or other people should be taken into account in order to gather clean measurements.

Another important consideration is the inclusion of heat maps in multitouch setups. Effort-based usability tests are beginning to be taken seriously as they can measure more precisely the way users interact with touch surfaces and can give accurate results. We have discovered these heat maps can be important tools in order to measure user preference. These measurement tools can not only be used for orientation preference, but for finding preferred areas and to measure user’s effort when manipulating virtual objects.

Eye-tracking along heat maps have the potential to give great insight into what the user is manipulating and what the user wants to do. In future studies we are focusing on this important area.

VI. ONGOING WORK AND MULTITOUCHE HEATMAPS

In the first study we found users of vertical surfaces tend to prefer the central-left zone, while users of the surface in horizontal mode tend to prefer the central-right zone.

It is very important to have found these heat maps, as they can be used to better design user interfaces. Now, once we found preliminary usage patterns and we know some insights about preferred areas we can apply these to put special controls away from preferred areas and allow the user to have important work areas in their preferred zones.

The primary areas are the main working areas (for designing, writing or drawing) and the secondary usually contain toolbars, window control buttons, menus and sliders. In the case of multi-touch surfaces we now know that we can put the main GUI in the areas most used by users and placing other interface components in less used areas.

According to the obtained heat maps, horizontal surfaces should have the tools in the left, up or down areas, keeping the right central to major areas of interaction. On vertical surfaces the situation is different. The important area is the center, apparently to the left, and the other side can be used for controls. This is an interesting finding since there is not much information about it in the literature of the area. Further work is needed in order to obtain more data that can confirm these preliminary findings.

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