Affordances and Gestural Interaction on Multi-touch Interface Systems: Building New Mental Models

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Abstract. This paper investigates users' gestural interaction mental models using touch screen technology for the first time. The research used Think-aloud Protocol technique for behavioral observation while performing tasks on two different Apps using an Ipad2 device. The tasks helped perceive users' recognition of functionality and gestural responses for each objective completion. The conclusions based on the observed results are discussed through mental model directives and Buxton and Spool theories of innovation and factors to achieve high acceptance of users on new technology.

Keywords: user experience, mental model, think-aloud protocol.

1 Introduction: Comparative Experiments with Mouse and Touch Screen Tablets

Shneiderman and Sears comparative research in 1989 regarding precision, cognitive learning and function perception on user's interaction with mouse and with touch screen technology presented results that implied an easier learning, higher precision and lesser error actions with a touch screen device. This easier interaction became evident specially when using icons with 16x16 pixels and 32x32 pixels.

The research was developed during the 80's, when just a few people had access to computer technology and personal computer were still far from being in every home. Some of the participants had their first time experience interacting with both touch screen pad and mouse devices. The affordance of both devices was based on users' mental model of how they would work, based on previous gesture experiences, which mostly were users' physical day-to-day life, apart from computer interaction.

From the late 80's to recent years, interactions with computer and mobile devices changed progressively. Our affordance perceptions, mental models and expectations changed with it. People's virtual and physical life belonged to two different domains, but have been merging together throughout years of technology advancement and new possibilities of digital interaction. Lately, it has been hard to consider the two worlds apart. Friends in restaurants, or cafés, talk about events in their mutual social networks, or check information online to add to the conversation. New words are being adopted, new jokes are emerging, new ways of acquiring knowledge are

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available. The perception of interactions are changing fast and physical life is no longer the primary reference to understanding features of innovative devices or systems. The perception of functionality and the learning process of how systems and artifacts work are related to the user's mental model. This mental model is a result of the users' primary and secondary references, knowledge and previous experiences with analogous interactions.

The users' mental model changes and develops according to their experiences, continuous learning and perceived affordances during their interaction with systems. The mental model of each person influences his perception of interaction and functionality of a new device (Renzi 2010). The term affordance, introduced by the psychologist James J. Gibson in 1977, refers to the cognitive perception of possibilities of actions that an object or system offers a person. This perception of possibilities implies directly on the creation of one's mental model regarding the functionality of the object or system. The better the affordance, the closest the mental model will be to the reality of usage.

This research proposes to observe user's perception of icons functionality and gestural interaction on a tablet multi-touch interface system based on each person's previous experiences and references. The participants chosen for this experiment were people who have never previously used any touch screen interaction artifact.

2 Online Questionnaire: Pre-selection of Participants

A previous online hybrid questionnaire was applied in undergraduate classes (design major) in order to select participants with no previous experience with touch screen devices. The questionnaire was created with the help of Google docs to easily reach the participants and quickly collect the results for analysis. The questionnaire had been open to participants for the period of two weeks.

Following Moura and Ferreira (2005) and Mucchielli (2004) recommendations on how to structure a survey to keep the answers without distortion, it started with broader topics and progressed to more specific subjects. Accordingly to the authors, all questions should be very clear to the participants, specially when being presented online and with no direct contact with the researcher to clarify any doubts (Renzi 2008).

Thirty six students participated, mostly with ages from seventeen to twenty two. The questionnaire had nine questions divided into two parts:

- three essay questions related to participants' personal information (name, e-mail, age)
- six multiple choice questions focused on participants' experience with web and touch screen devices

Based on the results collected through the questionnaire, thirteen students who had never previously used mobile multi-touch interface systems were pre-selected to be part of the second phase of the experiment. From this sample, five students accepted invitations to be in the second phase of the experiment.

3 Think-Aloud Protocol: Mapping User's Experience

Think-aloud Protocol Technique was applied to better understand user's interactions with mobile multi-touch interface systems. It was decided to use the Ipad2 (installed with the iOS 6 system) as the device for the observation.

According to Villanueva (2004) the technique consists of a researcher observing users doing specific tasks within a controlled environment. The users' actions and thoughts are to be described verbally aloud by themselves on real time. The researcher records the users' actions by written notifications, video shooting or voice recorder.

Filming and voice recording have the advantage of capturing the exact steps and descriptions of users, while written notifications depends on the researcher experience with observing reactions and quickness in writing down relevant actions of the experiment (Renzi 2010). However, the use of writing notes have the advantage of creating an informal observing environment, resulting in more flowing sessions with the participant. While the choice of filming captures every movement for future analysis, but could be considered intimidating. For this research the chosen direction was to use both voice recording and written notifications in order to keep the users in an informal environment and record all their spoken actions. The App Voice Recorder HD was used for this phase, where the participants could be recorded while doing the required tasks at the same time.

When noticing some reluctancy from the users in verbalizing actions and thoughts during the Think-aloud Protocol, questions related to the users' actions were placed to keep the flow of verbalization of their thoughts, based on Xiao's (2000) experiments: the researcher used general questions as users advanced on the proposed tasks for the session: “what do you think about the tool?”, “did you understand the steps?”, “any doubts regarding the tour?”, “do you have suggestions?”. According to Xiao, the insert of questions during the session helped to identify problems from the perspective of users of varying degrees of skill with the virtual system, as well as get constructive ideas for improving the tool.

3.1 Tasks for Gestural Interaction

Two tasks were established to help understand the interaction flow and to point out problems in functionality perception. The Apps used for the the tasks were Calendar, a built-in schedule agenda, and Starblitz, a spaceship one-person game. Both developed for the system iOS 6.2.

Although very different in nature, the two Apps require from the participants many and distinct types of touch interaction in order to fulfill the tasks proposed: touch and drag, lengthy touch, vertical spin, flip touch and indirect multitouch with both hands.

The proposed first task urged students to create a new event/appointment on the Calendar App and include detailed information regarding the planned schedule: beginning and ending hours, location of event and personal notes. As part of the same task, a second event had to be inserted one week later from the first event with similar

amount of information. The first task was considered finalized after users completed the registry or announced withdraw.

The Calendar App layout can be visualized on figure 1. The app simulate an open leather journal. One can choose the focus of the layout to Day, Week, Month, Year and List. All sessions recorded had the starting point on the Day layout. Participants explored all layout options, but preformed the task of inserting the two appointments using the Day layout.

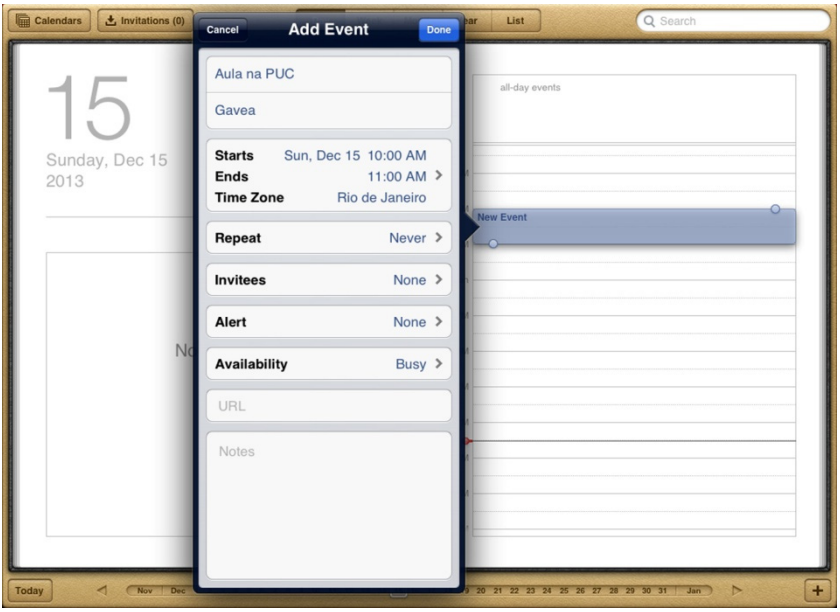

Fig. 1. On the top left corner is the current day and its relation to the month, while on the right top site the hour-by-hour schedule to insert appointment appears. On the bottom there is a timeline with a today button on the left and a plus button on the right. The registry of a new event creates a blue square that graphicaly indicate the beginning and ending of an appointment. It can be relocated, edited or deleted anytime by clicking on it.

The second task was directed for the game Starblitz, where each participant had to play the game and survive for as long as they could. In a spacial scenario (fig.2), the users had to pilot the spacecraft, defend themselves from alien ships and collect a green space mineral called Iridium to deposit it on proper space stations. The user's spacecraft also had an ally ship who helped protect the user. The ally ship was controlled automatically by the app. The ability to reach-on second features, such as change of weapons, were not compelled as part of the task, but was notified as part of observations and analysis.

Each participant started the task at first level. Users were free to navigate through the system scenario until they were forced to defend themselves.

The game layout (fig.2) presents an upper view of the user´s spaceship and a computer controlled ally ship. On the upper seccion of the screen, the system shows

the players´s money and level. On the bottom side, there are two circular controls, used for movement (left blue circle-controller) and for firing (right red circle-controller). It is necessary to use the index fingers from both hands at the same time to be able to control both features. In order to direct the controls to the desired direction, one needs to touch the circle-controller and drag it to the desired direction, to either move the ship and direct the firepower.

Other features on the bottom part of the screen are: circular arrows icon to change the type of weapon to use, exclamation icon to use items such as medical kit, and a central bar to indicate the player´s current amount of health.

All participants were presented with basic explanations about the objetives of the game, but in order to test their cognitive reactions and affordances, no explanations regarding the controls were given.

Fig. 2. Starblitz spacial scenario layout with centered player's spacecraft and ally space shuttle on the near top right. Alien enemy approaches from bottom. Circle-controllers on both lower sides.

4 Observed Interactions

On the first proposed task, there are two different ways to create a new event in the iOS6 Calendar: clicking on the + button, placed on the bottom right of the screen, or touching on the desired hour for the event with an extended touch. Either way, a new blue box will pop up to include title, notes, place and duration of the event.

During the observations, participants showed a hard time to figure out where to click, in order to start a new event. None had perceived the possibility of an extended touch interaction with the iPad. All participants tried all icons with a resemblance to a 3D button or an internet textual link. Users tried mostly to click (short and quick touch) directly on hours, dates or icons with a 3D button look. They also tried to interact with double-clicks and sequential clicking to achieve the objective. All observed users demonstrated frustration and surprise when not succeding with a one-short-click to create an event on the desired date.

During all observations, the use of the + button came as a last resource after testing all and every graphic that could resemble interactiveness. Two participants gave up and were able to complete the task only by reusing a previously existing event and changing it's information to their needs. These two opened the previous event by clicking directly on them.

After openning up a new event, users have to indicate the beginning and ending hours by spreading the edges of the blue box (representing the extension of the event) up to the desired time extent or by clicking on the hours' text-link. The event box increases its size vertically and the hours are presented as shown in fig. 3. To change the numbers, one has to vertically spin, simulating a rotative date rubber-stamp, and stop it on the desired hour. Four of the five participants tried without success to short-click directly on the numbers. Some (2) with increasing frustration while clicking repeatedly (and double-clicks). All users took a long time to find the correct gestural interaction to change the numbers. Four of the five participants understood the feature

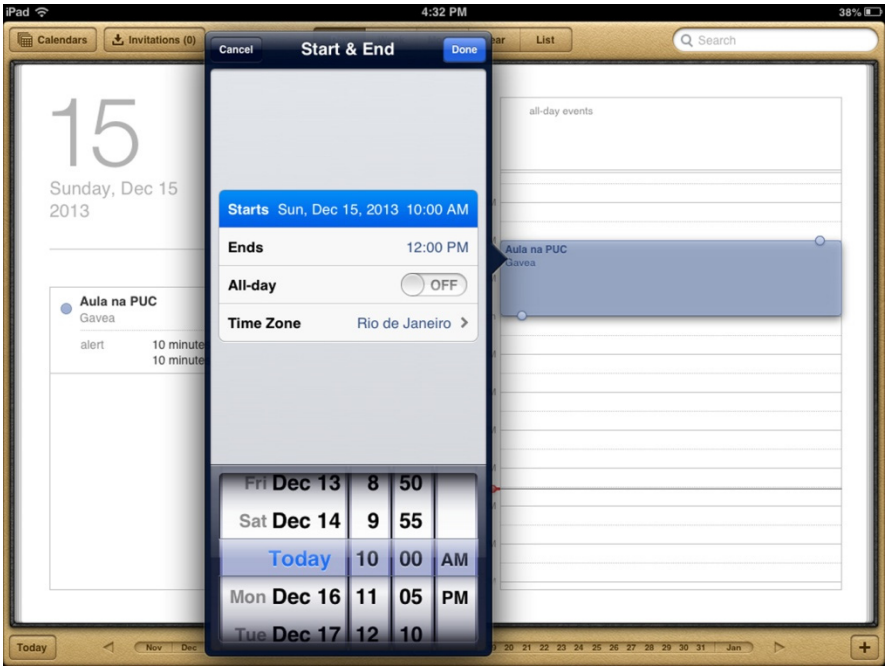

Fig. 3. Selecting the desired hour for the event simulate a rotative date rubber-stamp

by accidentally bumping onto the rotative artifact, making the numbers rotate. One participant quit. Even with the rounded perspective view illusion of the virtual rotative artifact, the participants could not relate the image with a vertical spin interaction to rotate the numbers.

After the discovery of the proceedings to create an event, the second event creation one week later came out with no difficulties. The flipping action to change pages in the calendar was perceived easily and users used the short-click-and-shift on the right corner rather than just clicking on the right edge. This action was used by the participants to advance one week and create the second event, part of the proposed task.

During the second task (survive as long as possible playing the game Starblitz), similar reactions regarding gestural interactions were noticed. As soon as the game started and the players' spacecraft appeared, all participants reacted instinctively short-clicking with one finger directly on the spacecraft to move it. A second instinctive action observed was click-and-drag the space vessel onto the direction desired to move it.

As in the previous task with the Calendar App, the frustration with the non-response of the ship eventually took the users to repeatedly touch (and drag) the spacecraft nervously. The users' choice of hand to interact followed their natural side: right-handed used the right index finger, while left-handed used the left one. Since the ally craft is similar to the player's spaceship, users tried the same touch-and-drag interaction with it. But with no success. Some of user's frustrations were recorded: “I am trying to move it but it's not working” and “I can't do it! I can't do it!”

With the proximity of firing enemy alien spaceships, all participants' immediate reactions were to click more strongly and more rapidly on their own spacecraft and on the alien enemies, hoping the action would point the target for automatic fire from their ship. These attempts, frequently resulted in repeatedly quick-strong touching on the iPad2.

The length of time that each user took to perceive the dual-touch possibility of the controllers influenced their survival duration. Four users died in less than three minutes (the quicker death took 2 minutes), but one player stood up with a faster control recognition and survived for 8 minutes and thirty seconds. He was the only player who also understood how to change the type of ammunition using the rotation icon. Players who took longer to recognize the functionality of the circle controls frenzied while enemy ships got closer and fired upon them. When understanding the controls, their health was not high enough to keep them alive for much longer.

During the open interview with the participants, after both tasks were performed, users confirmed being surprised with the many possibilities of gestural interaction with the iPad2 besides short-click and click-and-drag.

5 Conclusion and Discussion

The use of Think-aloud protocol made it possible to observe the participants' reactions, flow and perceptions of functionality. It was important to compare these observations with their previous experiences of interaction and technological references collected on the online survey. The comparisson brought the possibility of drafting characteristics of the students mental model regarding gestural interaction.

During the observation of participants trying to finish their tasks, it was possible to verify that users had difficulty to perceive and understand actions that needed indirect interaction. All users showed a tendency to interact with a direct short-click touch or click-and-drag actions, simulating their previous experiences and references with mouse interaction and desktop computers.

The users' choice of icons to interact or reach a desired function, demonstrate reference and similarity to dynamics with internet navigation, visual hierarchy and links. On the Calendar App, the + icon seemed imperceptible, partially caused by its hidden location in the bottom corner, partially caused by users' perception of its functionality. Users experimented to interact clicking the + icon only after exhausting experimenting with every graphic or texts with any resemblance to Internet links. The option of touching the desired date for 2 seconds to open a new event was never perceived or considered as a possibility by any participant, as later interviews confirmed.

Similar reactions were observed during the proceedings to mark the beginning and ending of events through vertical spinning interaction. Although the mechanism simulated graphically a rotative date rubber stamp, the possibility of rotating the numbers by vertically spinning the numbers never crossed any the participants's mind. Once more, the interactions attempts based on direct short-clicks and after repetitive touching, only finger slipping accidents showed the users how it worked.

The use of both hands to control the spaceship on the StarBlitz game seemed an alien concept to the users. All participants reacted naturally based on the web and mouse cultural convention of clicking one thing at a time. The possibility of interacting with two icons at the same time was declared as a complete surprise. Users perceived the circle-controllers as movement radars, as in computer games that use mouse and keyboard to play it.

On both proposed tasks, the easier gestural interaction affordances perceived by users for their first reaction were (1) direct short-clicks, (2) clicks-and-drag and (3) page flips. All choices to click on and experiment interactions, as well as response expectations, were similar to internet interaction models and links on websites, computer software icons and mouse actions. Their mental models, based on previous experiences with internet and desktop computers, influenced their functionality perception and affordances while interacting with a touch screen device. Users unconsciously reach for similarities of previous experiences, personal references and learning concepts from reference groups (Renzi 2010, p.37). The results observed indicate users' references based on commonly used devices, their related interactions and possibly online advertisings about touch screen features, mostly depicting direct short-clicks, click-and-drag gesture, image expansion-contraction and page flipping. These references seems to influence not only users' perception of affordances, but also their expectations of the iPad use and benefits.

From Schneiderman comparative tests on the late 80's to the recent use of touch screen mobile devices spreading around the world, references, user experiences, affordances and mental models are continuously being constructed. The evolution of mental models through new experiences builds cultural change and consequently new expectations and new cognitive readings, becoming base reference for innovations and new interaction concepts. All participants have absorbed new references after the

experiment and have new mental models regarding touch screen interaction. If contacted again for new tasks with Ipad2, the results would be very different, based on new mental models.

A brand new product bringing innovative concepts without building reference and mental models over the years could bring interactions too hard to understand or accept. Innovation is a result of a long period of research, tests and consumers' gradual familiarity to new concepts. Bill Buxton (2013), principal researcher at Microsoft Research and professor at Technical University of Eindhoven and Toronto University, shows a graphical representation of the “nose of innovation” with a length of 20 years, from concept and first testings to product's highest advancements.

Jared Spool (2013), founder of User Interface Engineering and working with user experience since 1978, shows that an innovative product has to be built on factors to achieve high acceptance and far spreading. One of these mentioned factors is Market Maturity,

As well as the use of mouse, computer and internet over the years has built up experiences, cultural conventions and references to help establish mental models and expectations to use touch screen devices and gestural interaction, future technology and concept innovations must consider the references and experiences being developed now in order to reach users' expectations in the next 5-10 years with easy cognitive affordances.

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