Usability Heuristics for Tabletop Systems Design

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Abstract: Tabletops are large interactive displays that enable many users to interact at the same time. These devices have different characteristics than other touchscreen devices, such as smartphones or tablets. They cannot be easily moved to bring the screen closer to the eyes or rotate interface elements, changing the screen to horizontal or vertical, for example. In this context, this paper presents a set of heuristics to be considered in tabletop interface design from the initial planning until validation. Nielsen's heuristics and others adapted or formalized from Nielsen, as well as researches about tabletop characteristics and user tests, were identified and analyzed to adapt and formalize heuristics to tabletop context. A set of twelve heuristics for tabletop context was created and they were considered to design simulator interfaces. Observing the militaries using them, we have gathered evidence that these heuristics can help designers to think about essential interface characteristics to support users to realize and understand the interface goal and how to interact with it.

1 INTRODUCTION

Different technological devices as laptops, smartphones, and tablets are changing people's behaviors and activities (Shneiderman, 2016). Then, systems for these devices must be designed to support people's use. On the other hand, this design can be a challenge because each device may have different characteristics and specificities to be considered.

Tabletops, large dimension devices, have been used in different contexts, and their use shows satisfactory results, e.g., with systems related to maps, because of the birds-eye view. In health, due to the number of elements that can be displayed on the screen, allowing to see more details about the medical image and supporting better analysis, among other contexts (Madni, 2016; Yang, 2014).

Tabletops size and weight represent different characteristics from other devices as smartphones, and this paper describes research that allowed noticing these characteristics to be considered, and they were useful to adapt Nielsen's heuristics for tabletop context.

According to Prates and Barbosa (2003), heuristic evaluation is one of the evaluation methods more widespread and better known by researchers and professionals from human-computer interaction. This evaluation examines the interface and judges its compliance with recognized usability principles, which are the heuristics (Nielsen, 1994).

Dourado (2016) says heuristics are easy to understand and useful to identify usability problems with low costs. In contrast, they can be very general, causing the recognition of specific problems a difficult task. The evaluators need much experience with these heuristics and device to judge the specific characteristics and needs of a device. Therefore, it is possible to improve the effectiveness of the method significantly using adapt heuristics with problems and examples related to a specific context (Rusu et al., 2011; Dourado 2016; Nielsen, 1994).

2 METHODOLOGY

The potential and use of Nielsen's heuristics, heuristics adapted from Nielsen or others formalized for different contexts, such as smartphone and tablet, are described in Chuan et al. (2014), Joyce et al. (2014), Neto et al. (2013), Humayoun et al. (2017), Shneiderman et al. (2016). However, these authors do not describe the process of adapting or formalizing heuristics. In this context, Rusu et al. (2011) report a six-step methodology for defining heuristics. Rusu's methodology was used in this work to adapt and formalize heuristics to tabletop context.

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2.1 Step 1 – Exploratory

It was intended to investigate works related to use, formalization, and adaptation of interface heuristics for multi-touch tabletop, but few works were found. Because of that, works related to any touchscreen devices were considered in this investigation.

Shneiderman (2016) formalized eight heuristics to be considered in any interactive technology. Neto et al. (2013) describe heuristics to mobile devices like smartphones and tablets. D'Carlo et al. (2017) present a set of heuristics to evaluate the usability of mobile educational devices. Humayoun et al. (2017), Inostroza et al. (2012), and Chuan et al. (2014) formalized heuristics to analyze multi-touch gestures in mobile devices. Rusu et al. (2011) defined a set of heuristics to evaluate grid computing systems. Joyse et al. (2014) formalized a set of heuristics based on touchscreen mobile devices.

Heuristics for tabletop context were not found, and then works about tabletop systems design were collected to observe important information and experience. Madni et al. (2016) reported the use of tabletop for supporting medical diagnostics based on images where a group of doctors could see and interact at the same time. Yang et al. (2014) describe a tabletop system design about GIS (Geographical Information System). Bortolaso et al. (2013) present a multi-display tabletop simulator to support military training.

2.2 Step 2 – Descriptive

Table 1 contains investigated heuristics and Nielsen's heuristics comparison to identify the most essential characteristics, interface elements discussed by these heuristics, among others. This comparison showed that Nielsen's heuristics are widely used in them.

For example, the first heuristic proposed by Nielsen is "Visibility of system status" which describes the system should always keep users informed about what is going on. Joyces et al., (2014), [P6] in Table 1, also describe that the system should show new users a welcome message, at their first heuristic (H1), as well as their second heuristic (H2) is related to show the status of system as soon as users interaction happens. It is important to highlight that this reasoning was considered with other heuristics from other studies.

Some heuristics describe specific contexts and examples not related to Nielsen's heuristics. In this case, a line was created with this information and which heuristics are related to this specific context.

Franceschi et al. (2018) describe the systematic review to identify these works, describing their names and more details about their content. Because of that, this paper aims to present the use of this information to formalize and adapt heuristics.

Works about tabletop were also analyzed and compared among them, as shown in Table 2. Each work designed system to be used in a different context, but there are many common characteristics among their works and the one presented in this paper as radial menu, geographic information at different angles as described in Yang (2014); route planning, geographical charts as described by Bortolaso (2013); and manipulating digital content and images as in the work of Mandi (2016).

Table 1: Heuristics Comparison.

Nielsen's heuristics	**[P1]**	**[P2]**	**[P3]**	**[P4]**	**[P5]**	**[P6]**	**[P7]**	**[P8]**
Visibility of system status	H1	H4	H2	H4	H1	H1, H2	H9, H3	H1
Match between system and the real world	H2	H1, H2	------	H5	H2	H3	H5	H2
User control and freedom	H3	H8, H9	------	------	H3	H4	H8	H3, H6
Consistency and standards	H4	H5	H3	H1	H4	H5	H2	H4
Error prevention	H5	H10	------	H6	H5	H6	H6	H5
Recognition rather than recall	H6	H7	H1	H8	H6	------	H11	H11, H13
Flexibility and efficiency of use	H7	H6	H4	H3, H9	H7	H7, H8	H7, H1	H9, H10
Aesthetic and minimalist design	H8	H3	------	------	-----	H9	------	H7
Help users recognize, diagnose, and recover from errors	H9	H11		H10	H8	------	H4	H13
Help and documentation	H10	H12	------	H14	-----	------	H10	H8
Cooperative/Collaborative Usability	H11	------	------	H11	-----	-----	------	------
View adaptation	------	------	------	------	-----	------	------	H15

Authors - [P1] Inostroza et al.; [P2] Rusu et al; [P3] Chuan et al.; [P4] D'Carlo et al.;[P5] Shneiderman et al.; [P6] Joyce et al.; [P7] Neto et al.; [P8] Humayoun et al.

Table 2: Tabletop Characteristics Comparison.

[Yang et al. 2014]	[Bortolaso et al. 2013]	[Madni et al. 2016]
• Simultaneous and collaborative interaction • Interactive table 40-inch • Blocks can be dynamically oriented • Radial menu • Can be used on multiple devices simultaneously • Works with geographic information at different angles and dimensions	• Shared interaction for multiple users • 55-inch 2D tabletop • Multi-touch inputs • Bifocal lenses (Zoom) • Route planning by drawing waypoints • Can be used on multiple devices simultaneously • Uses geographical charts • Allows future and past locations, tracking line, visibility, and range of a military unit	• Collaborative interaction • Samsung SUR40 (40-inch interactive tabletop) • Manipulation of digital content and images • 2D / 3D information display • Multi-touch interaction, tangible objects, pens, or mouse. • Zoom in/on objects

2.3 Step 3 – Correlational

This step is to identify the useful characteristics for tabletop usability heuristics based on other heuristics and observation analysis. The observation occurred in a military simulator project (Franceschi et al. 2018). This project means to develop a tactical virtual simulator for teaching military doctrines [1] related to recognition, choice, and position occupation of a missile and rocket battery for commanders from these areas. Figure 1 shows the tabletop where the simulator is working. It is TV 84-inch with a capacitive sensor to recognize users' interaction by touch on the screen.

Figure 1: Tabletop Tactical Virtual Simulator.

There were maps, cards, spatial/geographical information in this simulator where a group of five users interacted with during observation. According to Nielsen (2000), the best results come from testing no more than 5 users.

[1] Military doctrine is the expression of how military forces contribute to campaigns, battles, and engagements.

The users are military instructors who will use this simulator to support missile and rocket battery teaching. It is important to say that this simulator was developed by other professionals with no influence by the group of researchers of this paper.

Figure 2 shows one of the perceptions where users did not find where to click because after pressing a button with an icon, its name shows up in the middle of the radio button, and users tried to click on it, but the name is just an instruction, not a button, so users need to click on icon button again. The five users wrongly clicked on the name.

Interface element showed upside down considering user' view in some times because the interface of the simulator was programmed considering the proximity of the sides, that is, if the user is on one side but extends his hand to be closer to the other side, the tabletop will show the elements in this other side. The tabletop size also allows many users to interact at the same time, and some interaction conflicts happened, such as a user could cancel another user's action, even they were on opposite sides.

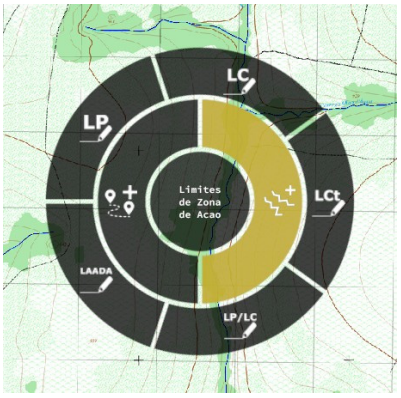

Figure 2: Radial Menu.

Considering characteristics from other heuristics, tabletop studies, and this observation, it was collected essential characteristics to be considered on tabletop design. Figure 3 shows them into two parts, elements and quantity.

Elements can be shown, taking into consideration where the user is, i.e., which side occurred touch on the screen. Through this information, tabletop recognizes users' place to show visual elements (proximity) to them and oriented (orientation) to them, facilitating the interaction.

The proximity of the sides is not a perfect criterion to identify where users are. Because of that, there is a necessity to allow rotating the visual elements 360 degrees. Zoom out and zoom in represent other useful strategies to consider design, allowing wider view, for example, to see a country, or detailed view, to see a street in a city. Moving elements is also another required to be thought because if an element appears over what users want to see, they can move it, as well as bring the element closer to where they are (zoom/move).

Tabletop sizes allow displaying a lot of information at the same time, so it is important to highlight which information can be clicked so that interactivity is highlighted, and the user does not have to look for options. Whenever items and sub-items exist, it is necessary to visually inform the user (highlighted interactivity).

The (quantity) is a tabletop characteristic that stands out from other types of smaller touchscreen devices, such as smartphones and tablets, which usually only one person uses at a time. In tabletop, it is important to identify how many users can use at the same time, and how many features can be performed at the same time, and the action of one user should not interfere with the action of another.

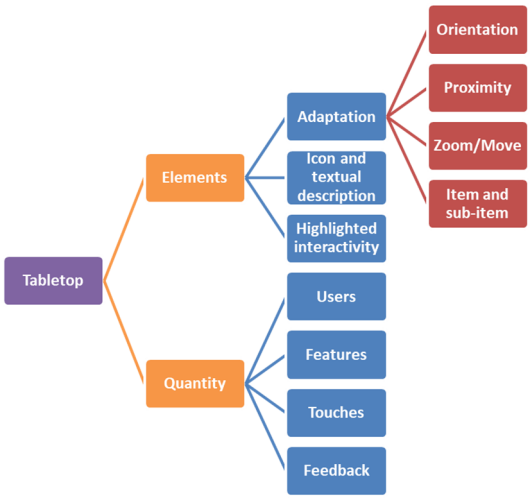

Figure 3: Characteristics of tabletop design.

The quantity of (touches) should also be considered, because users, with no intention to enter in an option, can unintentionally click on it, while they are explaining and just pointing with their fingers what they want to show. It is necessary to identify how to show the feedback for each system feature and possible click (highlighted interactivity) for each user who is interacting with, as well as always indicate when an item was selected and if there are other sub-items available (feedback).

2.4 Step 4 - Explicative

This step intends to specify the set of the proposed heuristics. Ten heuristics aimed by Nielsen for the tabletop, and two new heuristics (H11 and H12).

H1 - Visibility of System Status
Definition: System status visibility refers to how well system status is transmitted to users.
Adaptation: In a tabletop, there are interactive elements that blend in with non-interactive elements. Because of their size, the amount of these elements can make it difficult for the user to understand where on the screen to look for feedback, so it should be clear enough to indicate which feature is related to and be concerned with the location of the feedback. The location should be close to the clicked component because it is possibly the location the user is looking at. On a smaller device, the user can view what happens across the screen. On the other hand, on a tabletop, feedback may be outside the user's field of view. Also, items and sub-items, for example, in menus, need to be visually informed to users, indicating what items are, if they have sub-items, e.g., with arrow like dropdown, and whether they have been selected, e.g., changing the color.
Related Characteristics: Feedback, Item and sub-item.

H2 - Match between System and the Real World
Definition: The system should speak the user's language with familiar words.
Adaptation: Evaluate whether icons are self-explanatory regarding their function and application domain conventions. There may be a textual description to help users understanding the meaning of the icon, but it should always be close to and in the same visual element as the icon. For example, in a button design, the icon and description may be within the button area. Any distance between icon and description can make the user confused as to which one to click to confirm the interaction. Because tabletops are touch, some gestural

conventions of these devices should be used for sliding, dragging, and so on.
Related Characteristics: Icons and textual description.

H3 - User Control and Freedom
Definition: Users can choose system functions by mistake and need to undo and redo options without a lengthy process.
Adaptation: Enable the user to undo their actions even when using multiple users at the same time, ensuring that undoing one user's actions will not impact another user's actions. Undo and redo options should be easily understood by all users interacting at the table.
Related Characteristics: Quantity of Users, Quantity of Features.

H4 - Consistency and Standards
Definition: The device must follow established conventions, allowing the user to do things in a standardized and consistent manner.
Adaptation: Conventions established for other touchscreen devices should be followed, such as gestures to select, execute, zoom in/out, slide and drag used on smartphones, for example. It is emphasized that the proportion of the movement will not always be equal to the desired result. On the smartphone, the user can pinch the element and open their fingers to the desired size. In the case of the tabletop, the user may be interested in greatly enlarging an element, so with a little opening between fingers could allow enlarging the image to a much larger size than is between your fingers. Interactions throughout the system must be consistent.
Related Characteristics: Proximity Adaptation, Zoom/Move Adaptation.

H5 - Error Prevention
Definition: Verify that the interface contains only essential elements and eliminate error-prone conditions.
Adaptation: Context-associated menus can be used to reduce user choice options, disabling options not currently available. Depending on the outcome of the interaction, confirmations must be requested for the user to have the option to rethink an action. For example, the user may tap the screen only to point out an element during the explanation and not to activate a feature, so it is essential to question if the user wants to do the action. In case of just opening a feature or a menu option, no problem, since realizing that opened the option, the user can click the close or cancel icon. Besides, because of potential touch accuracy issues, it may be desirable to identify the user's intent.
Related Characteristics: Quantity of Touches.

H6 - Recognition Rather than Recall
Definition: The user should not have to remember information for system use.
Adaptation: The icons should be accompanied by textual descriptions making it easy for the user to understand the action that will be performed. When selecting an element, before executing, it is essential to make it clear which action the element will perform. It is also necessary to highlight the next actions to be performed. Interactive elements should be distinct from other elements, not requiring the user to remember. Because of their size, which allows many more elements to be displayed than other touch devices, the difficulty in identifying what can and cannot be clicked impairs interaction. User-tabletop interaction may occur similarly to smartphones. On these devices, users do not analyze the entire system to understand it before starting the interaction, but find clickable items and compare it with their intention of finding out where to click. On a smaller device, when the user does not identify what can be clicked, the user can click on what is being displayed to identify resources by trial and error. This possibility can also occur on a tabletop, but more clicks will be done. Therefore, the interactive components must be distinct from the other components. Icons and descriptions should be defined to clearly illustrate their goals.
Related characteristics: Icon and textual description, Highlighted interactivity.

H7 - Flexibility and Efficiency of Use
Definition: The device must be able to load and display information within a reasonable period and minimize the steps required to perform a task.
Adaptation: The interaction elements (menus) must be distributed considering each context and close to the respective feature. This enables fewer options in each menu and fewer interactions to perform the task because each feature will be close to its interface element. It is also necessary to ensure that the information is displayed in sufficient detail for the correct operation of the application, and zoom operations will perform satisfactorily.
Related Characteristics: Quantity of Features.

H8 - Aesthetic and Minimalist Design
Definition: The device should avoid displaying unwanted information by overloading the screen.

Adaptation: Tabletops allow users to view a large amount of content at the same time, but too much information can compromise the viewing of information. Whenever possible, enable the user to access information without overloading the interface. Swipe menus can be hidden whenever not in use, making it easy to access when needed. Also, the menus should be aesthetically simple and describe the features clearly. The buttons, text, and colors should be a contrast to the background and, when necessary, be transparent enough to see what is in the background, allowing the information to be viewed.
Related Characteristics: Icon and textual description, Highlighted interactivity.

H9 - Help Users Recognize, Diagnose, and Recover from Errors
Definition: Error messages should be expressed in plain language (no codes), accurately indicate the problem, and constructively suggest a solution.
Adaptation: Messages indicating errors should be clearly defined to assist the user in identifying and correcting them. The error may have been caused by another user's interaction with the tabletop so that it may be distant from the user's current interaction location. In this case, it is necessary to indicate the error information so that all users can view it.
Related characteristics: Quantity of Feedback.

H10 - Help and Documentation.
Definition: Provide user-friendly, task-focused help, and documentation mechanisms.
Adaptation: Assist the user in interacting with the system, providing relevant information. It is noteworthy that the use of instruction manual or any other option with a lot of content/text is not always the best way, because just like smartphones, users tend not to read all the help information to start the interaction. Therefore, help may be indicated according to the user's need and interaction. For example, by designing a symbol that represents the action that should be taken, such as a hand symbol with the finger-pointing at an item may indicate that it is clickable.
Related Characteristics: Quantity of Feedback, Highlighted interactivity.

H11 – View Adaptation
Definition: Whereas several people use the table at the same time, the system must identify each user's position and display interactive visuals oriented to it. If the guidance is not efficient or the user wishes to orient the visual element to another person, the system must be able to change this orientation simply. Because tabletops can be large, interactive elements should be displayed close to and oriented to the interacting user. For devices of this type, it is relevant to be able to zoom in on the viewer allowing users to display more detail or show more interface elements with less detail (multiresolution). These operations must be associated with conventions established by touchscreen devices.
Related Characteristics: Orientation Adaptation, Proximity Adaptation, Zoom/ Move Adaptation.

H12 - Cooperative/Collaborative Usability
Definition: Collaborative devices must allow multiple users to interact at the same time. It is essential to evaluate whether the tabletop allows more than one user to interact with the same or different elements at the same time. The execution of a feature by one user may not affect the execution of another user. Actions taken by one user must be visible to other users. The use of elements to explicitly express the user's intent is required. For example, a close button to close a feature or option. In this case, an explicit touch on close is required to close the feature. Another user interaction with other elements cannot close it.

It is crucial to verify that an action that a user is performing does not cancel another action that is being performed by another user. Therefore, if a user is choosing or has already chosen an option, the other options, which may cancel or directly affect it, must be blocked. If they become available, when chosen, there should be a warning that this option will influence another user's action. In this case, explicitly report which option will be influenced.
Related Characteristics: Quantity of Touches, Quantity of Users, Quantity of Features, Quantity of Feedback.

2.5 Step 5 – Validation

The validation of the proposed heuristic set was performed through a case study, in which a prototype was elaborated. The prototype was an instance of the simulator (Figure 4).

2.5.1 Prototype Design

This prototype was developed based on tabletop heuristics, as well as the characteristics are shown in Figure 3. The following is a brief description of how each characteristic was contemplated.

Orientation Adaptation: Icons are always displayed considering the proximity of the touch and oriented to the user's position (compared to center

and edges). If the click occurs between the center and the left edge, the elements are initially facing left; however, there is an arrow to rotate the view 360 degrees so that the user can adjust to the view.

Proximity Adaptation: Menus are displayed where the user clicks, but he can drag them on the screen with one tap. Feature-specific icons appear next to that feature, without the option to move it because, without the feature, the option could lose context, and the user might have difficulty recognizing its purpose later.

Zoom/Move Adaptation: There is a possibility to move the elements of the screen by dragging them with one touch. You can zoom in by zooming in on a specific area and showing more detail about the displayed scenario, as well as zooming out, showing less detail and more elements with multi-resolution rendering that performs well.

Icon and Textual Description: Each menu item contains the icon associated with its description, making it easy for the user to understand.

Highlighted Interactivity: When a radial menu item contains interaction sub-items, there is an indicator (arrow, as illustrated in Figure 5 - Embark option). Besides, there is a hand icon for all clickable options, as shown in Figure 4. We chose to have a visible hand, but not so prominent in color, so as not to detract from the background view.

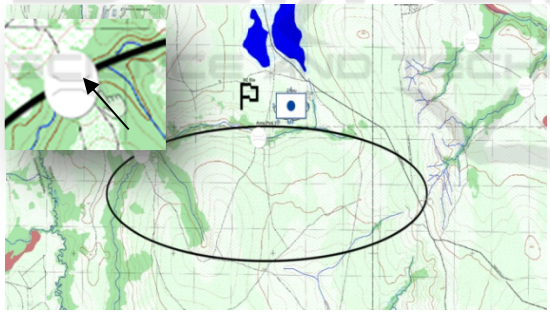

Figure 4: Simulator Interface.

Quantity of Users and Features: The simulator is intended for use by more than two people, so menus are closed only when explicit close commands are executed (click the X icon) and not the next click, which could interrupt or cancel another user's interaction. Therefore, more than one menu may be visible at a time, and commands may be entered into each menu by different users.

Quantity of Touches: The click hand icon (Figure 4) indicates that only one tap is required to open the options.

Quantity of Feedback: Feedbacks are always displayed next to the clicked items, and when an option is active, it turns a different color to stand out from the default background color.

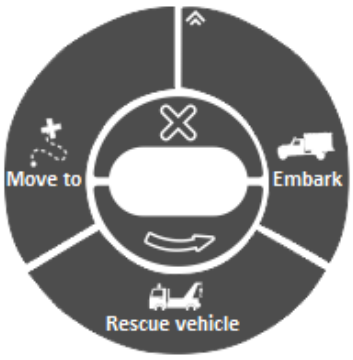

Figure 5: Radial Interaction Menus.

2.5.2 Case Study

It was performed with five users. All users have a military background and they frequently use touchscreen applications: three captains, two from Artillery (user 1 and 2), and one from Computer Engineer (user 3) and two Artillery sergeants (users 4 and 5). User 1 uses the simulator very easily and often; User 2 is familiar but does not use very often; User 3 is unfamiliar and uses infrequently. Users 4 and User 5 never interacted with the simulator.

During the study, the ease of completion of the tasks was assessed by observing the interaction and understanding of the user to perform the tasks, as well as the feedback provided. In the end, the users were asked about: Q1) It is easy to identify which interface elements are associated with some interaction; Q2: You can understand the content of each interface and what its purpose is.

Regarding Q1, 80% of users strongly agreed that it was easy to identify the interactive elements, while 20% partially agreed i.e., one user who had never used the simulator. He commented about some difficulty initially in finding the elements of interaction, but when he noticed the hand sign, the interaction became easier. All users agree that it was possible to understand the interface elements (Q2).

Later, other questions were asked: Q3: It is possible to verify the features and objectives of the menus; Q4: The menu icons correspond to the purpose itself. In Q3 and Q4, all users strongly agreed that the features, their names, objectives, and icons presented are consistent.

2.6 Step 6 – Refinement

By observing the use of the prototype, it was necessary to refine some information of the adapted

heuristics. It is noteworthy that all refinements have already been included in the description of heuristics in Section 2.4 so that each description already represents the final version for ease of understanding and use by other researchers, designers, among others.

A refinement occurred in H10, as users reported the hand drawing as a decisive factor to indicate clickable options, as the drawing somewhat illustrates the action they should take. Therefore, in this heuristic, it was explicitly described the possibility of using a symbol that represents the action that must be done.

The H12 was changed to reinforce that multiple users can interact at the same time, but one user's action cannot interfere with another user's action. The use of icon and textual description was rewritten on H2 because icons like arrows "menu rotate - arrow" can allow many interpretations such as returning an action or rotating, then a text can facilitate this interpretation.

3 CONCLUSIONS

In short, adapting usability heuristics for tabletop applications is relatively new compared to the proposed web and mobile heuristics. In this context, this research adapted usability heuristics and defined some observations that can be useful during the design of interactive interfaces for the tabletop context. As future work, it is proposed to use these heuristics for other systems contexts and to invite other researchers/developers to use these heuristics to develop and evaluate other systems.

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