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Usability Study and Heuristic Evaluation of the Applied Robotics for Installations and Base Operations (ARIBO) Driverless Vehicle Reservation Application ARIBO Mobile

by Kristin E Schaefer and Edward R Straub

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14. ABSTRACT

This study addresses the usability of the Applied Robotics for Installations and Base Operations (ARIBO) Autonomous Warrior Transport On-base (AWTO) rider reservation and reminder system mobile application, called ARIBO Mobile. ARIBO is an on-demand transportation system that will allow Soldiers to reserve a vehicle for a specified time and at predefined pick-up and drop-off locations throughout the medical campus at Ft Bragg, North Carolina. The mobile application allows riders to request transport reservations, modify or view existing reservations, and receive reminders for upcoming reservations. A usability assessment was conducted with 7 subject matter experts to provide a heuristic evaluation of the application, feedback on the design of the application, and an objective assessment of the tool. Direct measurements including time to complete task, number of steps to complete task, errors, and requests for assistance were recorded. The usability assessment of ARIBO Mobile provides the designers with feedback that may be used to update or change the design prior to wide distribution to the Soldiers.

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1. Summary

This study addresses the usability of the Applied Robotics for Installations and Base Operations (ARIBO) Autonomous Warrior Transport On-base (AWTO) rider reservation and reminder system mobile application, called ARIBO Mobile. This mobile application is used to interface with the ARIBO driverless vehicle transportation system, allowing Soldiers with the Warrior Transition Battalion, Ft Bragg, North Carolina, to request transport reservations, modify or view existing reservations, and receive reminders for upcoming reservations. ARIBO is an on-demand transportation system, which will allow Soldiers to reserve a vehicle for a specified time and at predefined pick-up and drop-off locations throughout the medical campus at Ft Bragg.

A usability assessment was conducted with 7 subject matter experts to provide a heuristic evaluation of the application, feedback on the design of the application, and an objective assessment of the tool. Direct measurements including time to complete task, number of steps to complete task, errors, and requests for assistance were recorded. The usability assessment of ARIBO Mobile provides the designers with feedback that may be used to update or change the design prior to wide distribution to the Soldiers.

2. Introduction: ARIBO-AWTO Program

The US Army Tank Automotive Research, Development and Engineering Center (TARDEC) Applied Robotics for Installations and Base Operations (ARIBO) program is a series of pilot programs using federal installations and universities as test beds for developing guidelines for operating autonomous vehicles in public, noncombat environments. The strategic objectives include socializing users and nonusers with autonomous systems, identifying operational issues and developing mitigation strategies to increase trust and use, and generating empirical data (e.g., performance, reliability, maintenance). The goal is to produce technical and social-behavioral value through a cycle of data collection, reliability analysis, and technical and behavioral improvement. One specific research focus has been on the prototype development of autonomy-enabled on-demand transit vehicles, called the Autonomous Warrior Transport On-base (AWTO) project located at Ft Bragg, North Carolina (see also Mottern et al. 2015).

The goal of the AWTO research project is to build knowledge around how autonomy-enabled vehicles perform in and impact real-world environments. The prototype driverless shuttle vehicle (Fig. 1) was designed to address the specific needs of the Warrior Transition Battalion (WTB) at Ft Bragg. Soldiers in this

battalion may have mobility difficulties and require transportation assistance from the medical barracks to Womack Army Medical Center (Fig. 2). TARDEC funded an effort from Robotic Research, LLC, to develop robotic technology to provide the driverless transport system and the associated reservation/reminder system, ARIBO Mobile, for these Soldiers and caretakers. The modular technologies are compatible with other TARDEC Warfighter-focused autonomy projects.

(a) (b)

Fig. 1 Base AWTO platform (a) and wheelchair accessible version (b)

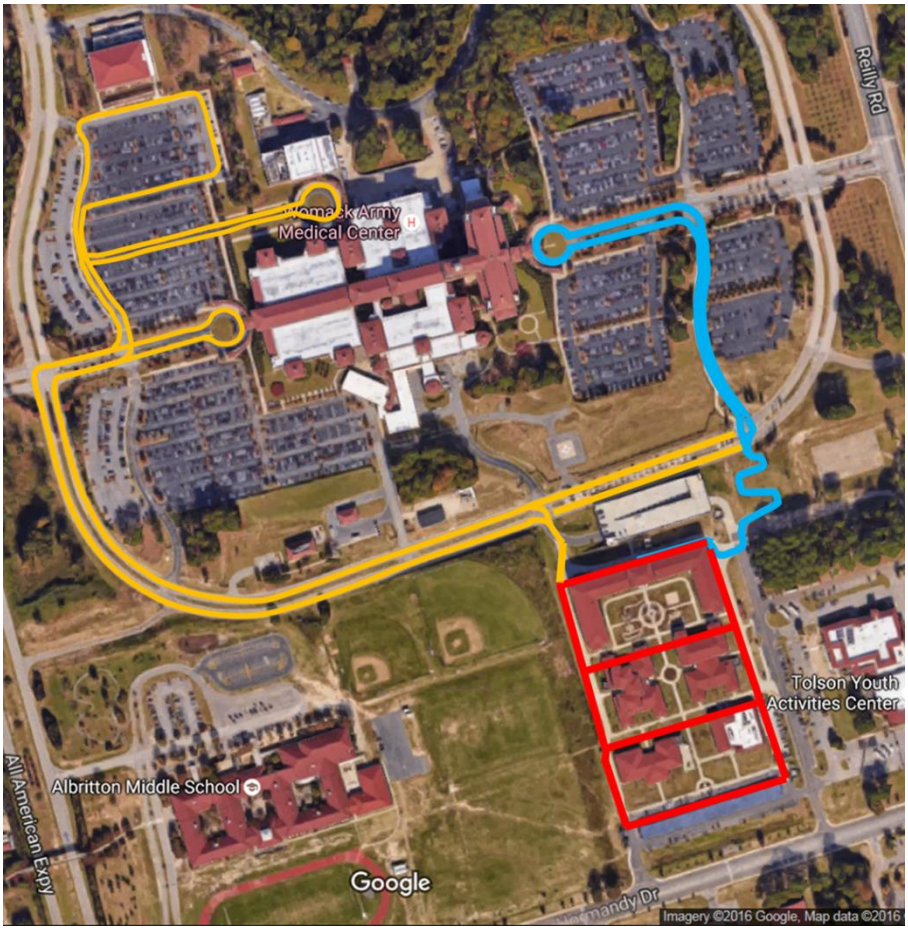

Fig. 2 Example routes between the medical barracks and Womack Army Medical Center, Ft Bragg

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3. ARIBO Mobile

Initial trust begins to develop before the first interaction with the real-world system. Expectations, attitudes toward technology, cultural and societal views, individual differences such as personality and the propensity to trust, even the physical appearance of the system, can impact individuals' initial perceptions about the trustworthiness of the robotic system (Schaefer et al. 2012; Schaefer 2013; Burgoon et al. 2016). For the ARIBO-AWTO driverless vehicles, the first interaction is not with the vehicle itself but with the reservation and reminder application, called ARIBO Mobile. The design of this user interface can have a direct and potentially lasting effect on a rider's trust and future use of the vehicle.

3.1 Current Design of the Application

The design and development of ARIBO Mobile was a combined effort between Robotic Research, LLC, and the University of Texas at Arlington Research Institute (UTARI). The reservation component of the application was designed around 3 main types of transportation requirements: on-demand, reservation-based, and optimized ride-sharing transportation services. The reminder system was designed to send mobile application notifications, emails, or SMS messages to the rider to remind them of their appointment. Reminders are particularly important for AWTO, because some passengers may be affected with traumatic brain injuries that can affect memory recall. Specific customizations were made to accommodate riders' needs. To make this system available to the maximum number of potential riders, the application was designed to run on Android-powered smartphone platforms and publically available kiosks (Fig. 3). Tablet computers are secured in the kiosks located at the primary rider pick-up and drop-off locations. The 3-in-1 kiosks, dedicated to the ARIBO Mobile application, allow for maximum flexibility for placement around the site and are American Disabilities Act–compliant to accommodate wheelchair users. An Android application was developed to provide mobile phone access, and a web application is currently in development.

Fig. 3 The application is designed to run on both mobile platforms as well as a publically available kiosk

3.2 Usability Considerations

Subject matter expert (SME) review was used to assess the initial design of the application and identify potential challenges to ongoing application development. The first challenge for ARIBO Mobile development was scaling a display for use on both a smartphone and a larger tablet interface. The second challenge was to develop an application that can be easily used by individuals with a wide range of technological acuity or skill, as well as mental and physical limitations due to injury. Consideration of these challenges and previous research during the design of the user interface should reduce stress and cognitive load to maximize ease-of-use of the system and acceptance by a wider range of riders. Usability guidelines suggest that to reduce cognitive load, similar items should be placed in close spatial proximity taking into account symmetry, unity, and cohesion of items (Endsley 1988). The design should also include traditional Windows-type interaction to link the new application to similar known systems such as a back arrow, clickable buttons, and markers for drop-downs (Goodrich and Schultz 2007). In addition, the number of items per page, spacing between items, and the reduction of "dead space" or nonfunctioning buttons affect perception, acceptance, and ease of use (Baker et al. 2004). Poor usability of ARIBO Mobile could affect ridership, trust, and appropriate use of the driverless transport vehicles.

4. Methods

Usability testing is "an approach that emphasizes the property of being usable, i.e. it is the product that is being tested rather than the user" (Sharp et al. 2007, p. 646). A 3-part procedure was used to guide the design process, including an objective assessment, a heuristic evaluation, and verbal feedback (Ericsson and Simon 1980;

Nielsen 1993; Lamming and Newman 1995). This procedure addressed the following items:

- Recommendations for reducing ambiguity in design elements
- Identification of possible individual differences or accessibility limitations due to vision, hearing, dexterity, or mental acuity
- Frequency and clarity of scheduling reminders

4.1 Participants

Seven SMEs were selected per their expertise in the field of usability assessment or mobile interface design. This is in line with previous research that recommends between 5 and 12 SMEs (Nielsen and Landauer 1993; Dumas and Redish 1999; Baxter et al. 2015). All 7 SMEs provided a heuristic evaluation and verbal feedback; however, because of an internet accessibility issue, only 6 SMEs completed the objective assessment. The objective assessment is Part 1 of the procedure.

4.2 Procedure

This assessment included 3 types of usability assessments.

1) The first type of assessment objectively measured the capabilities of the system. SMEs completed 5 different tasks using ARIBO Mobile. The time to complete each task, the number of steps to complete each task, errors, and the number/type of requests for assistance were recorded. The 7 tasks included the following:
    a) Log into the application
    b) Navigate the main menu screen
    c) Request a new ride
    d) View current appointments
    e) Cancel an appointment
    f) Modify a current appointment
    g) Identify a failed request
2) Following the objective assessment, participants completed a heuristic evaluation (Nielsen 1993). The SMEs walked through each task again and provided comments and feedback on the design for Nielsen's 10 heuristics

(Appendix A). General comments and specific design recommendations were recorded. SMEs also provided information to rate the importance, or priority, of each recommendation based on the scale below (Nielsen 1994):

0 - not a usability problem at all

1 - cosmetic problem only (need not be fixed unless extra time is available on the project)

2 - minor usability problem (fixing this should be given low priority)

3 - major usability problem (important to fix, so should be given high priority)

4 - usability catastrophe (imperative to fix this before product can be released)

3) After review of the entire task, in Part 3 of the assessment procedure participants were asked to provide feedback on the following points:

- Amount and type of training recommendations to use the application
- Identification of design recommendations for riders that may have limitations due to vision, hearing, dexterity, or mental acuity

5. Usability Assessment and Heuristic Evaluation

This section outlines the usability findings associated with the following 7 tasks: log into the application, navigate the main menu screen, request a ride, view current appointments, cancel an appointment, modify an appointment, and identify a failed appointment.

5.1 Log into the Application

Five out of 6 of the SMEs who performed the objective assessment required assistance in locating the ARIBO icon to load the ARIBO Mobile application (Fig. 4). Search time ranged between 7 and 32 s before requesting assistance to complete the action.

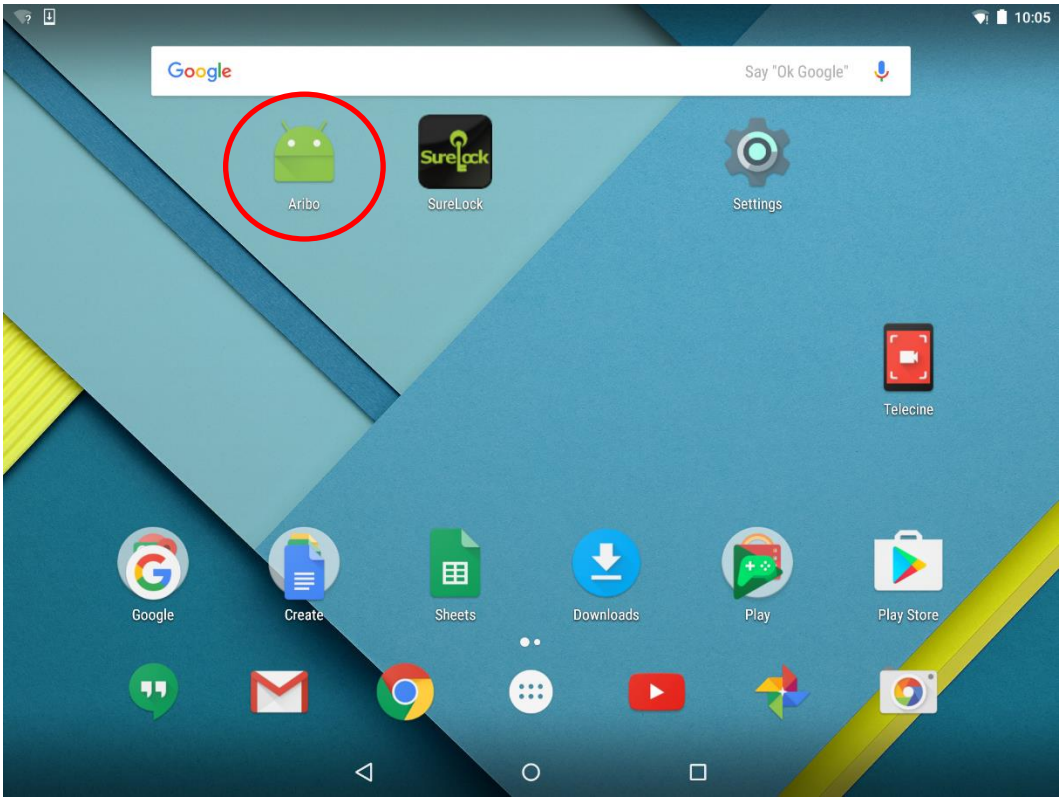

Fig. 4 Main Android tablet screen with the current ARIBO Mobile icon circled in red

After locating the ARIBO icon, the average total login time was 22.833 s (range of 16–39 s). This process included accessing the keyboard, entering the username and password, and pressing the login button (Fig. 5). No additional button presses, errors, or requests for assistance were reported. A table of the timing information is provided in Appendix B.

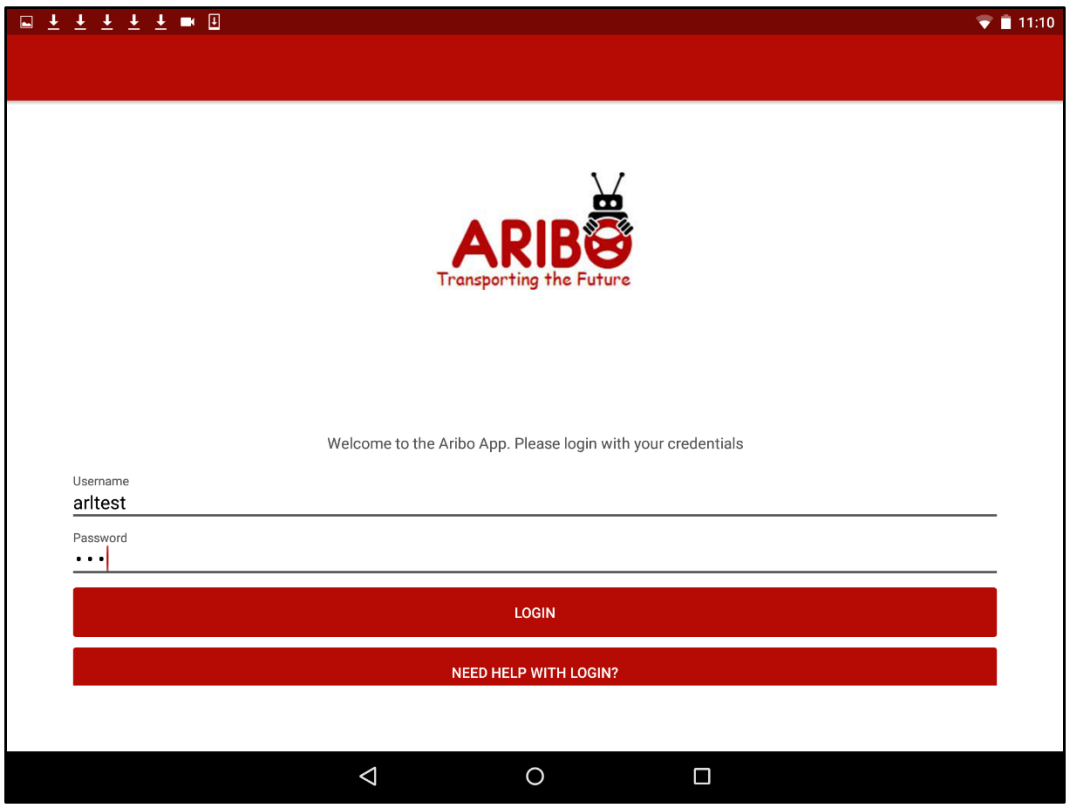

Fig. 5 ARIBO Mobile login screen

Overall, SMEs felt that the login design and process, once they were able to open the application, was user friendly and self-explanatory. The high-priority recommendation was to change the green icon to the ARIBO icon (Fig. 6) to increase recognition of the system and remind users of the available service. Additional cosmetic and low-priority comments were made about the choice in keyboard, case sensitivity of login information, and request for help logging in to ARIBO Mobile. The heuristic evaluation in Table 1 provides some additional recommendations for the login process.

Fig. 6 ARIBO logo

Table 1 Heuristic evaluation of login procedures

Heuristic	SME recommendation	No. of SMEs	Priority
Aesthetic and minimalist design	No recommendations.	. . .	0
Match between system and real world	No recommendations.	. . .	0
Recognition rather than recall	**ARIBO Mobile Icon:** The ARIBO Mobile icon should represent the ARIBO program (Fig. 4). It is important for users to make the connection to the application to increase recognition and use.	7	3
Consistency and standards	**Virtual Keyboard:** No clearly marked open/close keyboard buttons. The current Android keyboard uses a check mark in place of "Enter". This may not be apparent to all users.	2	1
Visibility of system status/ Feedback	**Keyboard Feedback:** Update kiosk tablets with Android update for high-frequency vibrations on keypad. This improves typing accuracy and is good for individuals with vision-related limitations or physical limitations such as tremors.	1	1
User control and freedom/ Clearly marked exits	No recommendations.	. . .	0
Shortcuts/ Flexibility and efficiency of use	No recommendations.	. . .	0
Help users recognize, diagnose, and recover from errors	**Login Error Messages:** The usernames and passwords are case sensitive. An error message stating "Invalid Username or Password" will appear. Recommend adding a statement or updating error message.	1	1
Error prevention	No recommendations.	. . .	0
Help and documentation	**Login Help:** A button "Need Help with Login?" appears on main login screen. However, when it opens, the keyboard is opened automatically and covers up the directions and additional help information.	1	2

5.2 Navigate the Main Menu Screen

The login procedures for ARIBO Mobile directly open the main menu screen (Fig. 7). As this happens automatically, there are no objective data for this section. Overall, SMEs felt that the main menu screen was intuitive and user friendly. Recommendations for this section highlight primarily cosmetic problems. The only point of confusion was the terminology of "resync" (described in more detail in Section 5.3). It was not clear as to what this term meant or the implications for users. The heuristic evaluation is provided in Table 2.

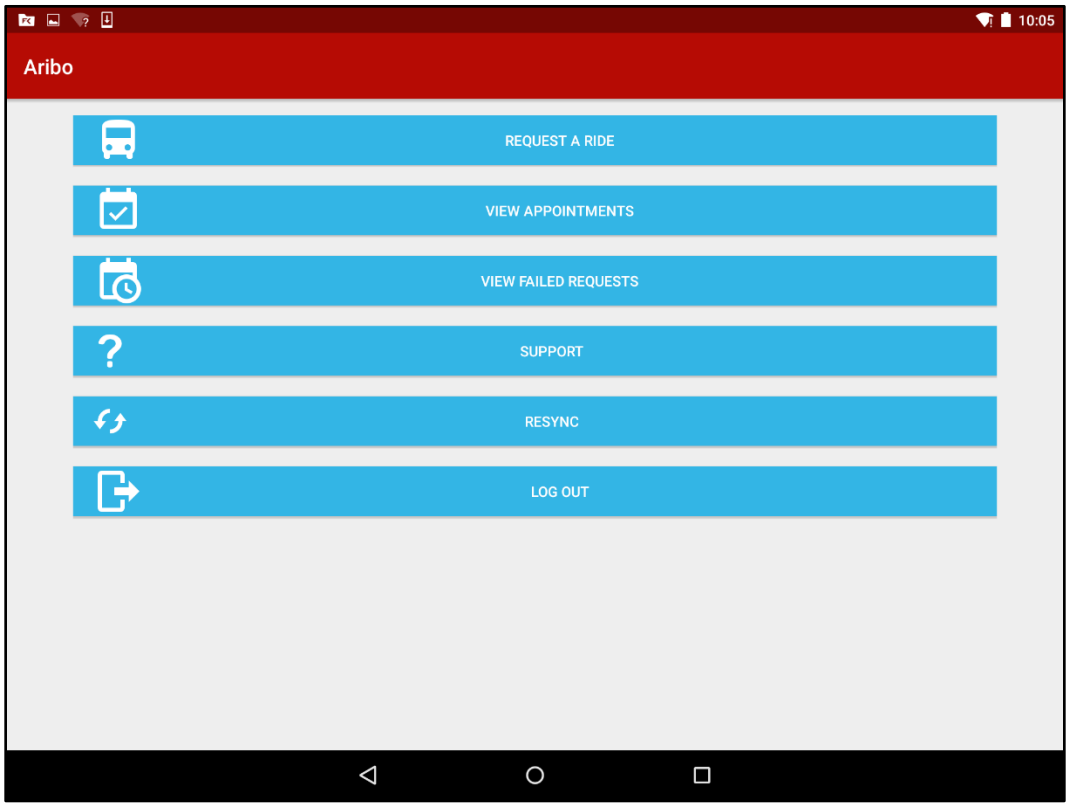

Fig. 7 Main menu screen

Table 2 Heuristic evaluation of main menu

Heuristic	SME recommendation	No. of SMEs	Priority
Aesthetic and minimalist design	**Menu Layout:** Current menu layout is ideal for mobile phone application and vertical orientation. Recommend autoadjusting for screen size to increase font size in proportion to button size and reduce "white space" to fill the screen.	3	1
Match between system and real world	No recommendations.	. . .	0
Recognition rather than recall	**Icons:** Icons are intuitive and match description for 5 out of 6 items. Recommendation to change "view failed requests" icon to a crossed out calendar.	7	1
Consistency and standards	**Menu Items:** Clarity needed for menu item "Resync" and when it will/should be used.	5	2
Visibility of system status/ Feedback	**Indicators:** Recommendation for indicators for number of appointments and number of failed requests on the associated buttons to increase clarity.	1	1
User control and freedom/ Clearly marked exits	No recommendations.	. . .	0
Shortcuts/ Flexibility and efficiency of use	No recommendations.	. . .	0
Help users recognize, diagnose, and recover from errors	No recommendations.	. . .	0
Error prevention	No recommendations.	. . .	0
Help and documentation	**Help Options:** Help documentation are provided under the "Support" menu item. Recommend changing name to increase clarity (e.g., "Help" or "Contact Information").	1	1

5.3 Request a New Ride

One of the key requirements for the ARIBO Mobile application is the capability to schedule a ride. All SMEs were able to quickly and accurately locate and select the "Request a Ride" button from main menu (M = 10 s). This menu option opened the "Request transportation" screen (Fig. 8). Both objective assessment and heuristic evaluation are provided below.

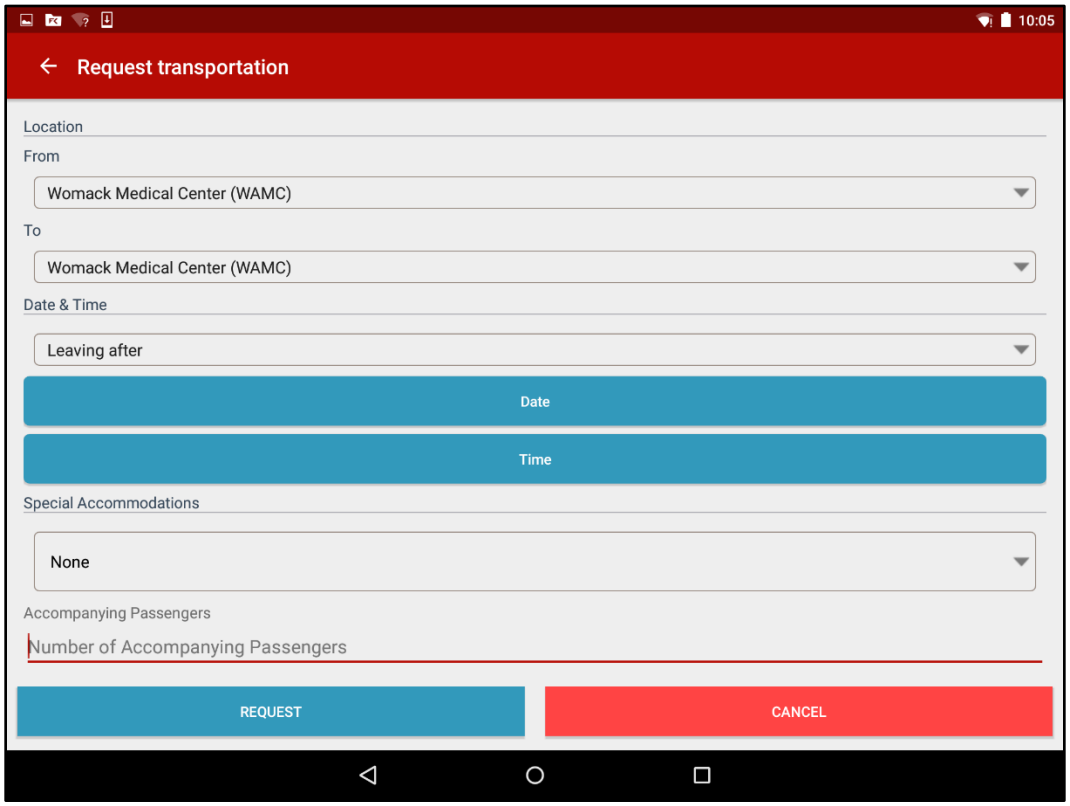

Fig. 8 Request transportation screen

The minimum number of button presses required to successfully schedule a vehicle with only 2 location options, no special accommodations, or passengers is 8 button presses. If every box is checked, it takes 16 total actions to make a complete request, specifically: Location (2), Dates/Times (10), Special Accommodations (2), Accompanying Passengers (3), Request (1), Passenger Accommodations (2), and Request (1). Screenshots of all the different features for creating a new reservation can be found in Appendix C. The average number of button presses for the SMEs to successfully schedule a ride was 23 button presses for a total average scheduling time of 91.833 s (Table 3). The design of this part of the application (e.g., 10 button presses to set date and time) and system errors may account for some of the issues with scheduling ARIBO vehicle service.

Table 3 Time and number of button presses to make a reservation

SME	Time to get to new reservation	Time to schedule new reservation	Number of button presses
1	21	157	26
2	10	55	19
3	4	34	16
4	5	84	14
5	10	69	25
6	10	152	38
Min	**4**	**34**	**14**
Max	**21**	**157**	**38**
Range	**17**	**123**	**24**
Average	**10.000**	**91.833**	**23**

Note: Time is in seconds.

A few errors occurred while making new reservations. Only one SME (SME 6) had an error making a reservation by leaving the date blank. The system provided an error through a "toast" (i.e., a small popup that provides simple feedback and disappears after a short amount of time), and the user was able to correct the error with an additional 4 button presses. More significantly, a system error occurred between the mobile application and the server during objective measurement on SMEs 1, 5, and 6, requiring the SMEs to "resync" the application. No error messages were provided, meaning the SME needed advance knowledge about the application to go back to the Resync menu option to update the application. This resulted in extra time (50 s, 30 s, and 58 s, respectively) and button presses (6, 6, and 14 button presses, respectively). This error resulted in substantial user frustration and significant time increase. One SME started to reschedule the whole ride before realizing there may be a connectivity issue.

A heuristic evaluation is provided in Table 4. Overall, SMEs felt that this menu was streamlined and clear. The major usability concerns were related to connectivity issues and the amount of button presses tied to specific features (e.g., clock). SMEs also made recommendations for changes to the design that could minimize potential errors in the future (e.g., addition of confirmation screens, or constraining the number of passengers).

Table 4 Heuristic evaluation of scheduling portion of the application

Heuristic	SME recommendation	No. of SMEs	Priority
Aesthetic and minimalist design	**Design:** The overall design is relatively streamlined. However, red on red coloration for titles is confusing. Red is traditionally a color reserved for errors. Recommendation for banner to be a different color.	1	1
	Special Accommodations: Section is bigger than rest of items in menu.	1	1
Match between system and real world	**"Leaving After":** Designers added a "leaving after/arriving by" scheduling option to match real world transportation systems. SMEs were confused by this option. Recommended changing autofill to "Arriving by" to work more closely with military operations and avoid most confusion.	4	1
	Extra leg room: Why would user select/not select extra leg room as an option? Consider changing terminology.	3	1
Recognition rather than recall	**Smart Kiosk:** The kiosk tablets should autofill the start location to reduce the number of button presses and working memory load of user.	1	1
Consistency and standards	**Calendar:** Mobile optimized and intuitive.	1	0
	Clock: Clock appears to be mobile optimized. Clock options may not be familiar to all users (e.g., scrolling clock). Appearance and functionality may also vary per Android device.	7	2
	SMEs unsure of need for minute accuracy. Recommendation: could reduce number of button presses by autodefaulting the minute or setting to the next available pick-up time.	2	1
	Clock am/pm: Users are Soldiers and used to working in military time. Scaling issue with am/pm button leads to difficulty pressing button.	2	2
Visibility of system status/ Feedback	**What to do:** The application never tells the user what to do; however, it is relatively intuitive.	1	0

Table 4 Heuristic evaluation of scheduling portion of the application (continued)

Heuristic	SME recommendation	No. of SMEs	Priority
User control and freedom/ Clearly marked exits	**Back Arrow:** A "back" arrow is present in the upper left hand corner of the screen, but the text next to it is the page heading. Recommendation to link the correct terminology with back button.	4	1
Shortcuts/ Flexibility and efficiency of use	**Shortcut:** Recommend adding a "pick me up now" button with most of the menus autofilled.	5	2
Help users recognize, diagnose, and recover from errors	**System Connectivity Error:** A toast appeared stating that the ride was successfully scheduled; however, the ride did not appear in the View Appointments menu. Recommendation would be to add a refresh button in the Appointments window to reduce confusion, increased steps, and potential disuse of the application.	3	3
Error prevention	**Need Confirmation Screens:** Recommend adding confirmation screens for most major actions to avoid errors at the end of scheduling.	6	2
	Need appointment time verification and confirmation prior. This does not appear when there is a connectivity issue.	3	2
	Constrain Number of Passengers: Current design looks like a number (even if it is 0) should be added. Recommendation to limit to either max number of passengers or available number of seats. One SME was able to reserve a vehicle for 32 passengers. Number keypad has a lot of unusable buttons. Recommend reducing the number of options available to user.	4	2
	Special Accommodations: "Extra Leg Room" is unclear terminology and is not an option for passengers.	2	2
Help and documentation	No help or documentation available.	1	0

5.4 View Current Appointments

All SMEs were able to quickly (M = 8.833 s) and accurately locate previously scheduled appointments through the main menu (Fig. 9). Users of this system may have a number of scheduled rides per day. Therefore, the organization and disambiguation of the information on the View Appointments menu is a high priority. All SMEs found the extended information on the Transport menu to be helpful, but 4 of the SMEs made a specific note to increase the visibility of the button to be easily identified as a selectable button.

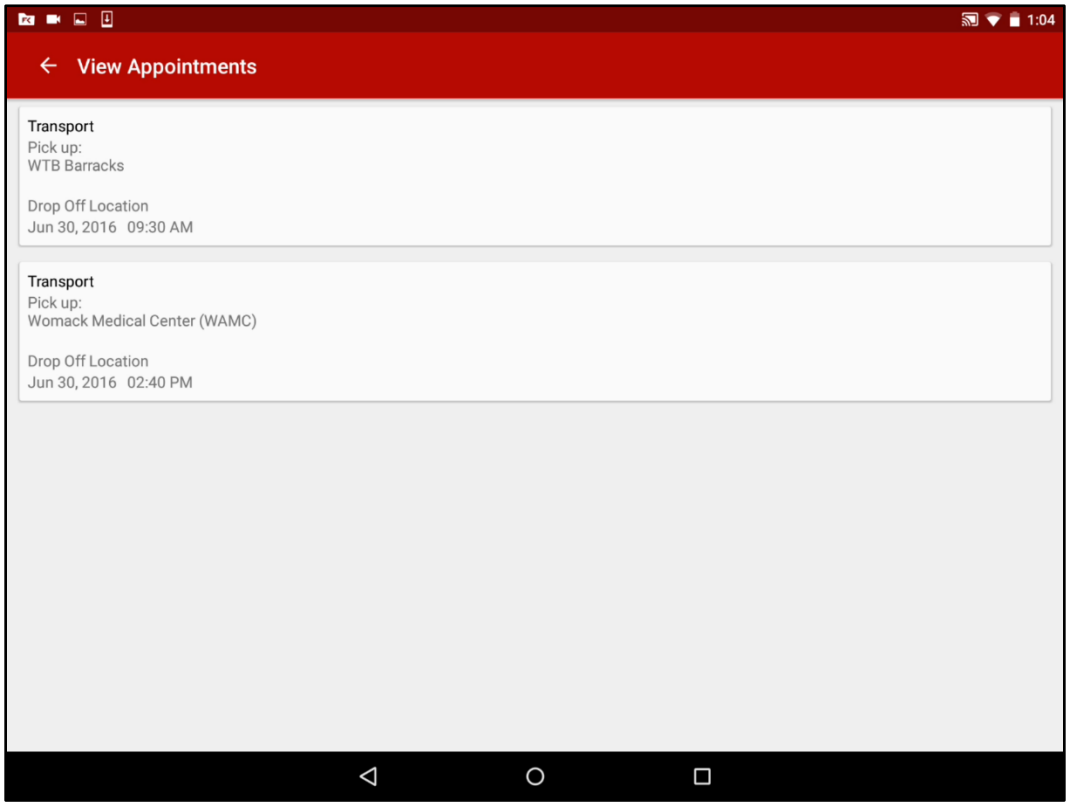

Fig. 9 View Appointments menu

There were 2 primary recommendations for this window (Table 5). First was to update the organization of the information for each reservation so that it was clear where the vehicle was going and what time it would arrive for service. Second was to make clickable items more recognizable (e.g., 3-D formatting, gradients, 3 vertical dots, long press option, or add buttons for more info, modify, and cancel on this screen). This would allow users to realize they could access more information by clicking on a reservation.

Table 5 Heuristic evaluation of View Appointments menu

Heuristic	SME recommendation	No. of SMEs	Priority
Aesthetic and minimalist design	**Buttons:** Not clear that the reservations are selectable. Recommendation to make the selectable options look more like selectable buttons (e.g., 3-D formatting, gradients, 3 vertical dots, long press option, or add buttons for more info, modify, and cancel on this screen).	4	2
Match between system and real world	No recommendations.	. . .	0
Recognition rather than recall	**Custom Name Appointments:** Recommend the capability to be able to provide a custom name to their appointments to help reduce confusion, memory issues, and cognitive load.	1	1
	Custom Order Appointments: Recommendation to customized ordering of appointments. Examples include making the "next" appointment more salient, add the capability to collapse/expand by day, or have selections for "just created".	1	1
Consistency and standards	No recommendations.	. . .	0
Visibility of system status/ Feedback	**Feedback:** Recommendation to show the vehicle's status (on time, late, etc.).	2	1
User control and freedom/ Clearly marked exits	No recommendations.	. . .	0
Shortcuts/ Flexibility and efficiency of use	No recommendations.	. . .	0
Help users recognize, diagnose, and recover from errors	**Ambiguous Appointment Information:** Need to list drop-off location on the View Appointments window.	7	3
	Need to move time under pick-up location so users know when the vehicle should arrive.	7	3
	Highlight or Bold the important information.	2	1
Error prevention	No recommendations.	7	0
Help and documentation	**Buttons:** Nothing to tell user to touch the reservation for more details (see recommendations in Aesthetics).	. . .	0

5.5 Cancel an Appointment

The options to cancel or modify existing appointments was included in the design and development of the system to account for users' schedule changes. From the main menu screen, the option to cancel or modify an appointment should take 3 button presses, one to open the View Appointments window (Fig. 9), one to click on the appointment for more information (Fig. 10), and one to click on the cancel button (Fig. 11). However, because of an error in design, none of the SMEs could figure out how to cancel an appointment. The OK, Reschedule Transport, and the Cancel buttons were only visible if the tablet computer was held in portrait mode. This problem was considered to be between a major usability problem and a usability catastrophe as the application is not usable without access to this functionality. SMEs also suggested that designers consider Soldiers that may have an injury that may not allow them to hold the tablet in the portrait position or may have their personal device stationary on a desk.

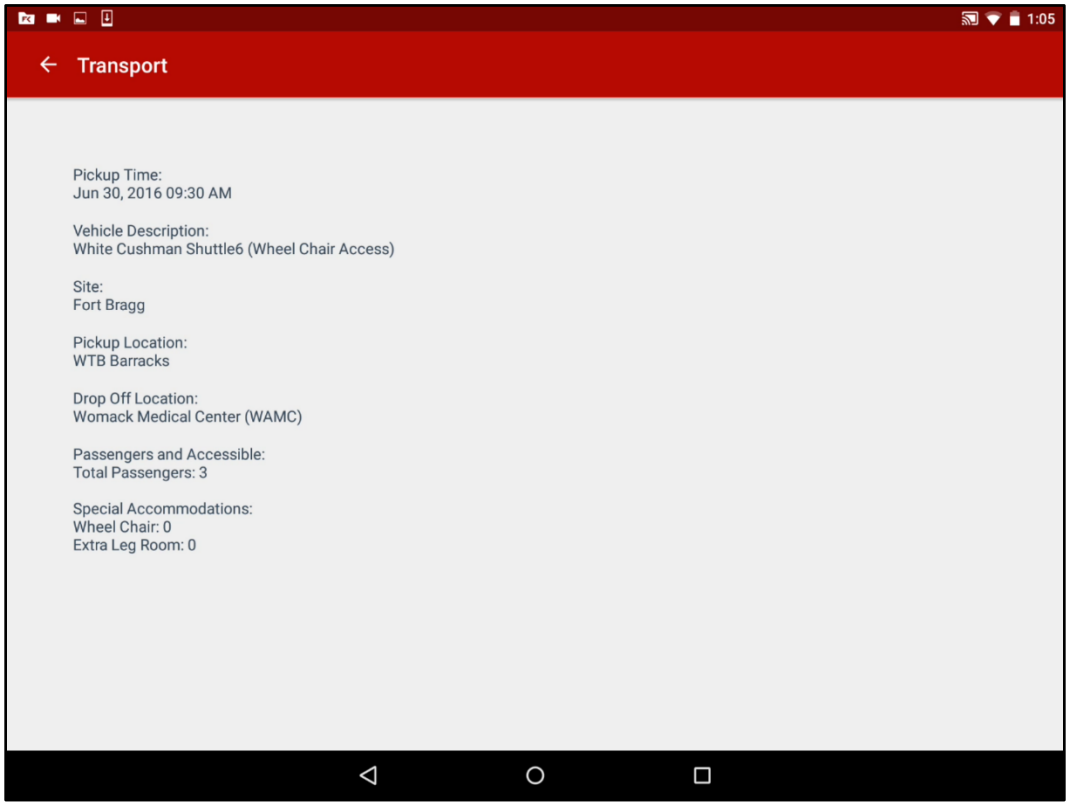

Fig. 10 The Transport Screen provides more information about scheduled transportation

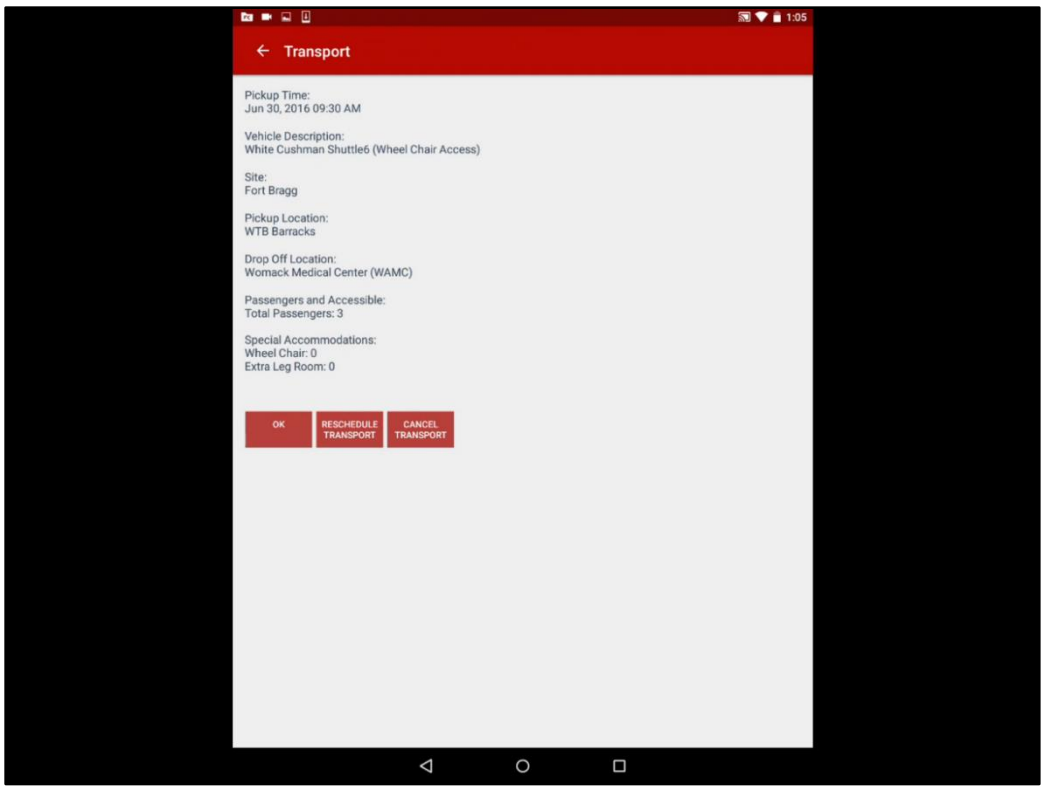

Fig. 11 Users needed to turn the screen 90° to access the OK, Reschedule Transport, and Cancel Transport options

Objective assessment of the application found that it took on average an extra 12 button presses before SMEs gave up and asked for help locating the Cancel button (Table 6). The total average time from the View Appointments screen to complete the action of cancelling a request took almost 2 min, with a minimum time of 82 s. In addition to the design issue, there was also a connectivity issue accessing the server for SMEs 4, 5, and 6, which added an additional 36 s and 7 button presses, 81 s and 12 button presses, and 71 s and 9 button presses, respectively.

Table 6 Number of button press and time to cancel an existing appointment

SME	Extra number of button presses	Total time
1	5	107
2	15	83
3	8	82
4	18	159
5	14	106
6	14	179
Min	**5**	**82**
Max	**18**	**179**
Range	**13**	**97**
Mean	**12.33**	**119.333**

Note: Time is in seconds.

The heuristic evaluation (Table 7) identified the critical screen orientation issue. SMEs also provided 2 low-priority recommendations to address the issue of blank space (Fig. 12) and to consider adding the cancel option to the View Appointments screen. This would increase recognition and decrease the number of button presses needed to make the action.

Table 7 Heuristic evaluation of canceling an appointment

Heuristic	SME recommendation	No. of SMEs	Priority
Aesthetic and minimalist design	**Font Size:** Removal of blank space would allow the font size to be larger and easier to read.	6	1
Match between system and real world	No recommendations.	. . .	. . .
Recognition rather than recall	**Cancel Appointment:** A lot of steps were needed to cancel the appointment. Recommended moving the Cancel option into the View Appointments screen to reduce the number of button presses and increase recognition.	4	1
Consistency and standards	No recommendations.	. . .	0
Visibility of system status/ Feedback	No recommendations.	. . .	0
User control and freedom/ Clearly marked exits	No recommendations.	. . .	0
Shortcuts/ Flexibility and efficiency of use	No recommendations.	. . .	0
Help users recognize, diagnose, and recover from errors	No recommendations.	. . .	0
Error prevention	**Orientation:** Landscape screen orientation hid essential buttons to modify/cancel an appointment. This led to increased frustration and loss of confidence in the system. Recommendation to make screen fluid rather than extended so it automatically adjusts to new screen orientation, allowing user to see all options on screen.	6	3–4
Help and documentation	**Help Documentation:** No help documentation. Required assistance to figure out how to cancel the appointment.	6	0

5.6 Modify a Current Appointment

ARIBO Mobile provides the option to modify an existing appointment. It follows the same process as canceling an appointment: select "View Appointments" from the main menu (Fig. 7), select the appointment from the View Appointments screen (Fig. 9), and select "Reschedule Transport" (Fig. 11) to update or modify the appointment. Once SMEs were aware of the need to rotate the Transport screen, they were able to quickly and accurately locate the "Reschedule Transport" button to modify the appointment without any errors. The time to get to the modify appointment screen took an average of 21 s compared to the 119.333 s to cancel the appointment (Table 8).

Table 8 Time, button presses, and errors in modifying a current appointment

SME	Time to access modify appt.	Time to modify appt.	No. of extra button presses	No. of errors
1	19	68	5	2
2	17	34	20	4
3	20	42	8	2
4	17	56	16	2
5	26	45	7	0
6	27	30	11	1
Min	**17**	**30**	**5**	**0**
Max	**27**	**68**	**20**	**4**
Range	**10**	**38**	**15**	**4**
Mean	**21.000**	**45.833**	**11.17**	**1.83**

Note: Time is in seconds.

SMEs were asked to change their appointment time from the previously scheduled 10:00 am to 2:15 pm. This should have required 6 button presses to complete this action with the current design of the clock. However, because of a design flaw in the application, no information was retained from the original reservation. SMEs had to reschedule the entire reservation. Since SMEs were familiar with the application at this point, the number of extra button presses (M = 11) and time (M = 45.833 s) were reduced from the total button presses (M = 23) and time (M = 91.833 s) it took to make the original appointment.

Even though the number of button presses and time were reduced overall, a number of errors were recorded. The errors for SMEs 1, 3, 4, and 6 occurred because they assumed that the form was autofilled from the original appointment. The technical capability to autofill a form is standard in Android development with a few lines of code. The potential benefit of incorporating an autofill feature for modifying requests is essential for this population who have multiple appointments, some in a single day, as well as those with traumatic brain injury or memory

impairment. Users may not realize items have been cleared out. This can lead to an increase in errors and frustration. People tend to rely on calendar information and may not remember the appointment date or time if it clears out. SME 2 also had errors related to this issue but also had a major error by not changing the clock time from am/pm. This error led to a failed request that required the SME to completely reschedule the appointment a second time, resulting in 11 extra button presses. Table 9 identifies 3 major usability issues relating to retaining original reservation information and responding to errors. These should be addressed prior to wide distribution of this application.

Table 9 Heuristic evaluation of modifying an appointment

Heuristic	SME recommendation	No. of SMEs	Priority
Aesthetic and minimalist design	No recommendations.	. . .	0
Match between system and real world	No recommendations.	. . .	0
Recognition rather than recall	**Autofill:** When modifying an appointment, the system should retain (autofill) original information.	6	3
Consistency and standards	No recommendations.	. . .	0
Visibility of system status/ Feedback	No recommendations.	. . .	0
User control and freedom/ Clearly marked exits	No recommendations.	. . .	0
Shortcuts/ Flexibility and efficiency of use	No recommendations.	. . .	0
Help users recognize, diagnose, and recover from errors	**Error messages:** Error messages should be salient and clearly explain issue (e.g., pop out, location, do not use toast).	4	3
Error prevention	**Warnings:** Warnings should be provided at the time of the error. Users should never get to a failed reservation screen.	4	3
Help and documentation	Addition of confirmation screens for all major actions assist the user in knowing if system accepted action or not.	4	1

When errors do occur, error messages should be salient. Currently, the design of the system uses a toast at the bottom of the screen to communicate certain errors. The concern with using a toast is that it is small, only present for a short time (even though Android offers options for longer toasts), and is located at the bottom of the screen, which may be covered by the hand of the user. Traditionally, toasts are used for immediate feedback, not for error messages. The second type of error message occurs at the end of the reservation. Users are taken to the Failed Reservation screen (described in Section 5.7) and are required to reenter all reservation information. From a usability perspective, design should be modified to avoid the opportunity for failure when possible.

5.7 Identify a Failed Request

Once a user presses the "Request" button (Fig. 8) when scheduling an appointment, ARIBO Mobile is currently designed to take the user to the Transport screen (Fig. 11) to confirm the reservation or to a Failed Request screen (Fig. 12) to inform the user of a reason for the failure.

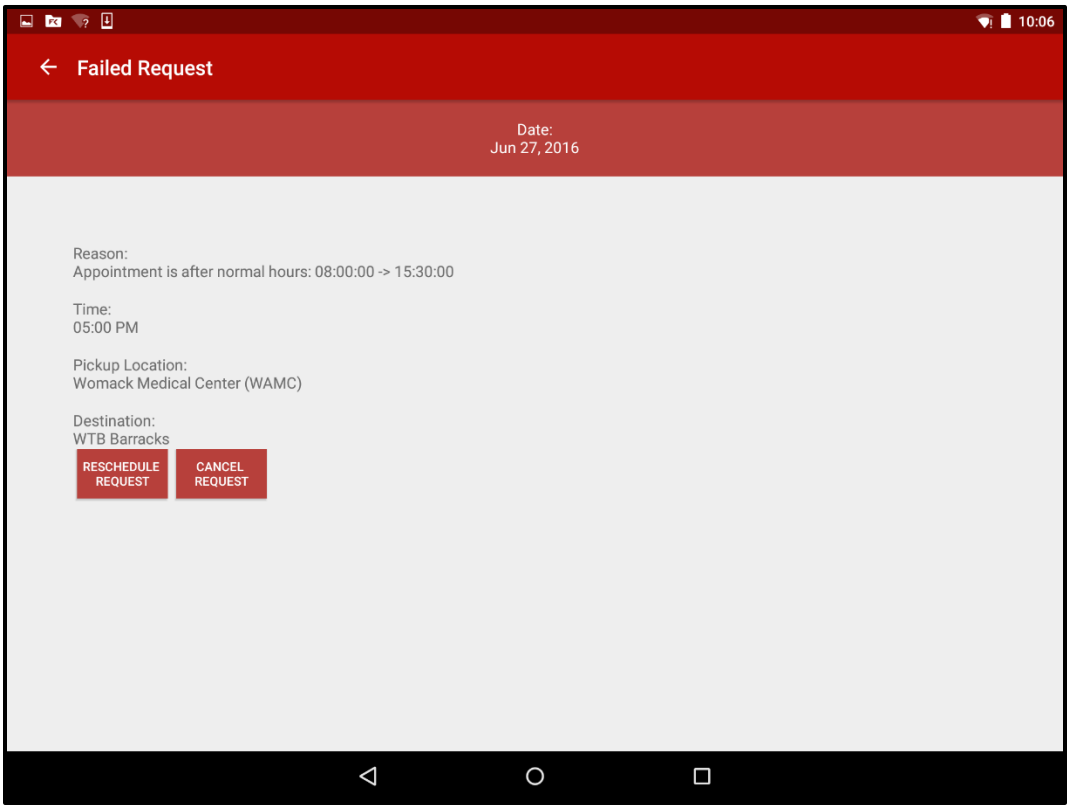

Fig. 12 Example of a Failed Request screen

When a connectivity error occurs, users are provided a toast stating the reservation is successfully scheduled, even when a failure ensued. Since there is a separate window for Failed Requests on the main menu, users need to be aware of how to access the failed requests on the View Failed Requests screen (Fig. 13). On this screen the failure is not clearly displayed.

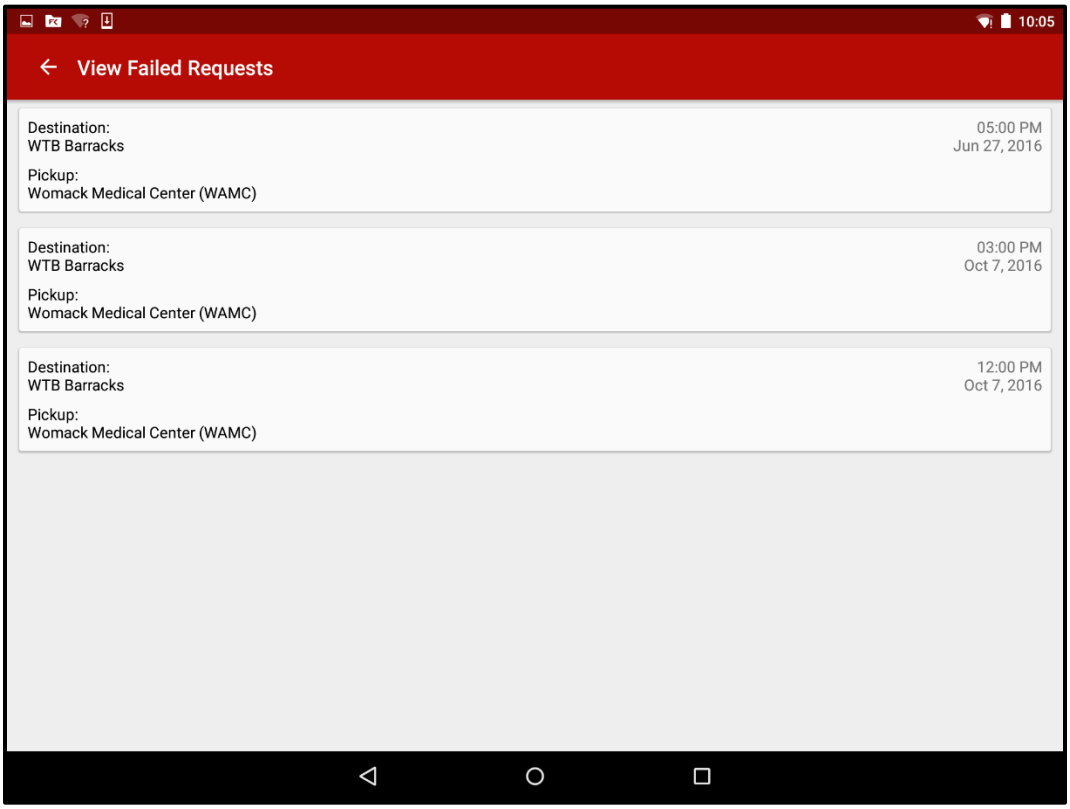

Fig. 13 Example of View Failed Requests screen

A connectivity error occurred for 4 out of the 6 SMEs who completed the objective assessment. With being previously aware of the connectivity issue and how to resolve this issue, results still demonstrated an average of 3.5 extra button presses to determine that a failure had occurred. The 2 participants who did not have a connectivity issue were sent to the Failed Request screen automatically (Table 10). On average it took 63.5 s for SMEs to fix the failed request since previously selected options were cleared out.

Table 10 Identifying and correcting a failed request

SME	Time to fix failed request	Number of button presses to identify a failed request
1	93	4
2	45	3
3	65	0
4	114	0
5	32	10
6	32	4
Min	**32**	**0**
Max	**114**	**10**
Range	**82**	**10**
Mean	**63.500**	**3.5**

Note: Time is in seconds.

A heuristic evaluation was provided for assessing the process for identifying and resolving a failed reservation (Table 11). SMEs agreed that errors should be provided to the user immediately at the time of an error. A failure that requires the user to exit the current window should not occur.

Table 11 Heuristic evaluation of reservation failures

Heuristic	SME recommendation	No. of SMEs	Priority
Aesthetic and minimalist design	**Failed Request Window:** The font size for the reason for failed request (Fig. 12) is too small. Recommend adding clear design to "pop out" the text from the rest of the information (e.g., font size, color, bold).	4	1
	View Failed Request Window: The buttons of the failed request (Fig. 13) are the same color as the successful requests in the View Requests window. Recommend moving all trip reservations to the same place (View Requests window) and change the color of failed request button to red.	1	1
Match between system and real world	No recommendations.	. . .	0
Recognition rather than recall	**Recognition of failed request:** Buttons (Fig. 13) and content (Fig. 12) should easily be recognized as a failure. Currently, the only defining marker is the page title.	6	1
Consistency and standards	No recommendations.	. . .	0
Visibility of system status/ Feedback	No recommendations.	. . .	0

Table 11 Heuristic evaluation of reservation failures (continued)

Heuristic	SME recommendation	No. of SMEs	Priority
User control and freedom/ Clearly marked exits	**Connectivity Issue:** When there is a connectivity issue, the Failed Request screen does not open. Users assume success and are not provided instructions.	3	3
Shortcuts/ Flexibility and efficiency of use	No recommendations.	. . .	0
Help users recognize, diagnose, and recover from errors	No recommendations.	. . .	0
Error prevention	**Failed Request Menu Item**: This window is more of a developer debug list and should not be available to the user.	1	3
	User should receive a "retry" option or be notified of an error before it goes into a separate window.	6	3
	Possible failures: Users are not aware of potential failures (e.g., number of riders per vehicle, times the vehicle operates). Add some text or a pop-up message that states when something is incorrect.	4	1
Help and documentation	No recommendations.	. . .	0

6. Discussion

Overall, SMEs felt the application was user friendly and self-explanatory. A majority of the feedback involved cosmetic or minor usability problems. A few findings should be addressed prior to wide distribution of this application.

1) **ARIBO Mobile Icon:** The ARIBO Mobile icon should represent the ARIBO program rather than using the generic Android icon. It is important for users to make the connection to the application to increase recognition and use. Based on the findings of this evaluation, the mobile icon has already been updated (Fig. 14).

Fig. 14 The change in application logo from the original (left) to the ARIBO (right) logo

2) **Connectivity Issues:** Wireless connections may not be stable at all locations leading to the potential for a connectivity issue. While this is not something the designers can control, it is possible to control how the system updates and informs the user. If a screen needs to be updated or refreshed, the option to do so should be on that particular page. It is also essential that the system not send conflicting messages—for example, a toast that states a ride was scheduled successfully, but then it does not appear in the appointments list.

As a result of this evaluation, the resync option on the main menu was removed, and software was updated to account for any reservation errors due to a loss in signal (Fig. 15). Additional modifications are currently underway.

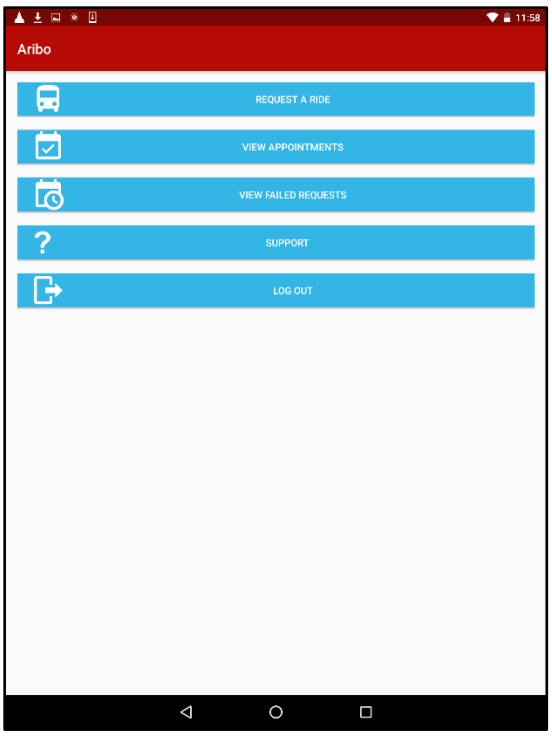

Fig. 15 The Resync option was removed from the main menu screen

3) **Screen Orientation:** All buttons and options should be available despite screen orientation (i.e., make the screen fluid rather than extended to adjust to new screen orientation). As a result of this evaluation, changes were made to the software to account for screen orientation issues (Fig. 16).

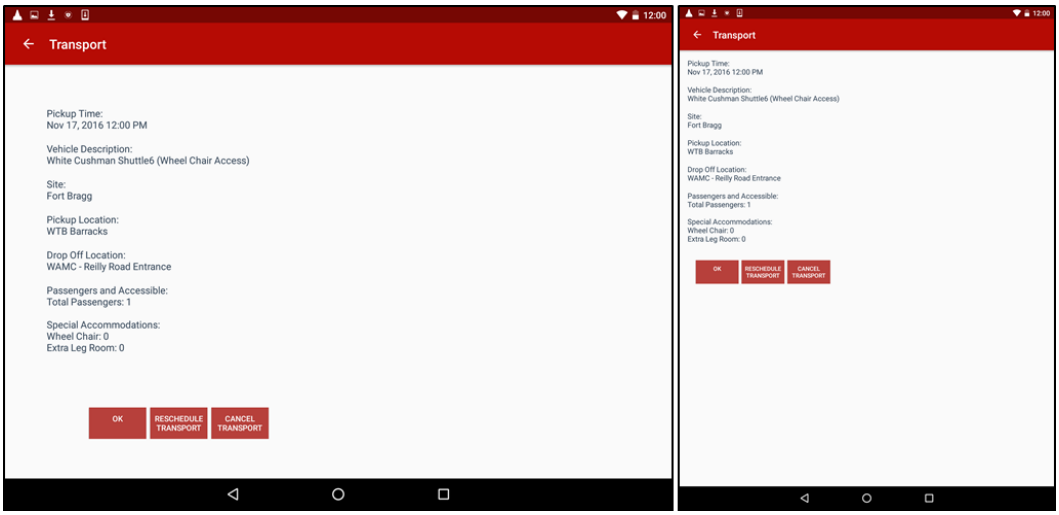

Fig. 16 Software changes were made so that all buttons (e.g., OK, reschedule transport, cancel transport) were available in both landscape (left) and portrait (right) views

4) **Reduce Ambiguity of Appointment Times:** When listing scheduled appointments, it is important to reduce any ambiguity. For example, it is important to list both the pick-up and drop-off locations. The time that the vehicle will arrive to pick up the passenger should also be positioned under the pick-up location. Therefore, changes were made in the design to clearly mark pick-up and drop-off locations (Fig. 17).

Fig. 17 Changes were made to increase clarity of scheduled appointments

5) **Autofill Appointment Modifications:** When modifying an appointment, the system should retain original reservation information. This item is currently on the developers' task list to be completed by January 2017.

6) **Add Salient Error Messages and Warnings:** Users should never get to a separate failed reservation screen. Errors should be salient and clearly explain an issue. They should also occur at the time of the error, not following completion of an appointment reservation. To date, some advancements were made, including to the current Failed Request screen. Overall, errors are more salient and clearly identified in bold red text, as shown in Fig. 18. After pressing the "request" button on the Ride Request page, the user is now always taken to either a Successful Request page that details all the information of the ride, or a Request FAILED page (in red font) informing them of the reason why the request failed.

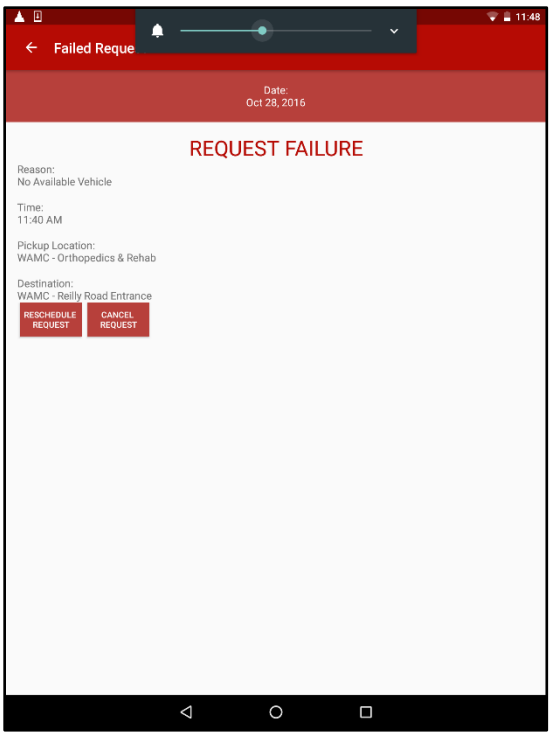

Fig. 18 Text delineating a Request Failure was added to increase clarity of the display to the user

The following is a list of minor usability problems. These are items that are low priority but may improve ease of use for the users.

1) **Login Help:** The button "Need Help with Login?" is available on the main login screen. However, when a user selects this option, the keyboard is opened automatically and covers up the directions and help information. Following the results of this evaluation, this feature has been updated so that the keyboard no longer covers up important text.

2) **Clarity of Menu Items:** The developers need to increase the clarity of the "Resync" menu item to communicate to the user what it is and when it should be used. In response to this evaluation, the "Resync" button has been removed completely. Its functionality has been automated and users have no need for this.

3) **Clock:** While the clock appears to be mobile optimized, the options may not be familiar to all users. The appearance and functionality may also vary per Android device. The developers should also consider that Soldiers are used to working with a 24-h clock, not a 12-h clock. The am/pm button is also small and difficult to press. The developers are currently looking into options.

4) **"Pick Me Up Now" Button:** The addition of a "Pick Me Up Now" button could increase on-demand ridership and ease of use. This option should autofill date, time, and potentially even current location (from kiosk devices). This would greatly reduce the amount of information the user would need to enter. The developers are currently looking into options to determine how to best address this issue.

5) **Add in Error Prevention Options:** Certain documentation or information could help prevent users from making errors during the reservation process. For example, constrain the number of passengers, update terminology (e.g., "extra leg room" is unclear), and add confirmation screens for appointment time verification. A change in the software was made to address potential errors by changing "extra leg room" to "extra leg room (for leg/foot injury)".

6) **Make Selectable Options More Salient:** Selectable buttons should look like buttons. Options could include 3-D formatting, gradients, 3 vertical dots, or text stating "more info". The developers are currently looking into options to determine how to best address this issue.

7. Conclusion

The ARIBO Mobile application has the power to shape users' initial perceptions about the ARIBO AWTO system before they ever board the vehicle. Because of the ubiquity of smartphones and other mobile devices, when users log in to the ARIBO Mobile application to schedule, check, edit, or cancel a ride, they will have certain expectations about the usability of the tool. The manner and degree to which the tool meets or violates user expectations can influence their trust in the overall system's ability to reliably transport them to where they need to be, when they need to be there.

With one notable (see Section 6, "Screen Orientation") and a few minor exceptions, the developers of the ARIBO Mobile application met their first challenge by scaling a display for use on both a smartphone and a larger tablet interface. The second challenge, to develop an application easily used by individuals with a wide range of technological acuity or skill, as well as mental and physical limitations due to injury, was largely met with a few notable exceptions. Enabling autofill options, improving error messages, and implementing other recommendations (see Section 6) will reduce stress and cognitive load of users improving ease-of-use and system acceptance. Future work will include end-user evaluations using actual Soldiers of various ability levels to help capture any accessibility issues or additional problems that may not have come up during the SME evaluation.

Approved for public release; distribution is unlimited.

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Appendix A. Nielsen's Usability Heuristics

Nielsen Heuristics

Aesthetic and minimalist design

Dialogues should not contain information that is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility. Less is often more. There should be a balance between graphic design, color, and information.

Match between system and the real world

The system should speak the users' language, with words, phrases, and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

Recognition rather than recall

Minimize the user's memory load by making objects, actions, and menu options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

Consistency and standards

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

Visibility of system status / Feedback

The system should always keep users informed about what is going on through appropriate feedback within reasonable time.

User control and freedom / Clearly Marked Exits

Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

Shortcuts / Flexibility and efficiency of use

Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user, such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

Help users recognize, diagnose, and recover from errors

Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

Error prevention

Even better than good error messages is a careful design, which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action. Avoid insert and edit modes.

Help and documentation

Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

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Appendix B. Table of Times to Log into ARIBO Mobile

Table B-1 Login time for subject matter experts (SMEs)

SME	Locate icon	Access keyboard	Enter username	Enter password	Total login time	Total login time w/o icon
1	11	14	14	11	**50**	**39**
2	7	7	6	8	**28**	**21**
3	12	3	8	8	**31**	**19**
4	20	3	13	10	**46**	**26**
5	9	3	5	8	**25**	**16**
6	32	4	6	6	**48**	**16**
Min	**7**	**3**	**5**	**6**	**25**	**16**
Max	**32**	**14**	**14**	**11**	**50**	**39**
Range	**25**	**11**	**9**	**5**	**25**	**23**
Mean	**15.167**	**5.667**	**8.667**	**8.500**	**38.000**	**22.833**

Note: Time is in seconds.

Appendix C. Making a New Reservation Screenshots

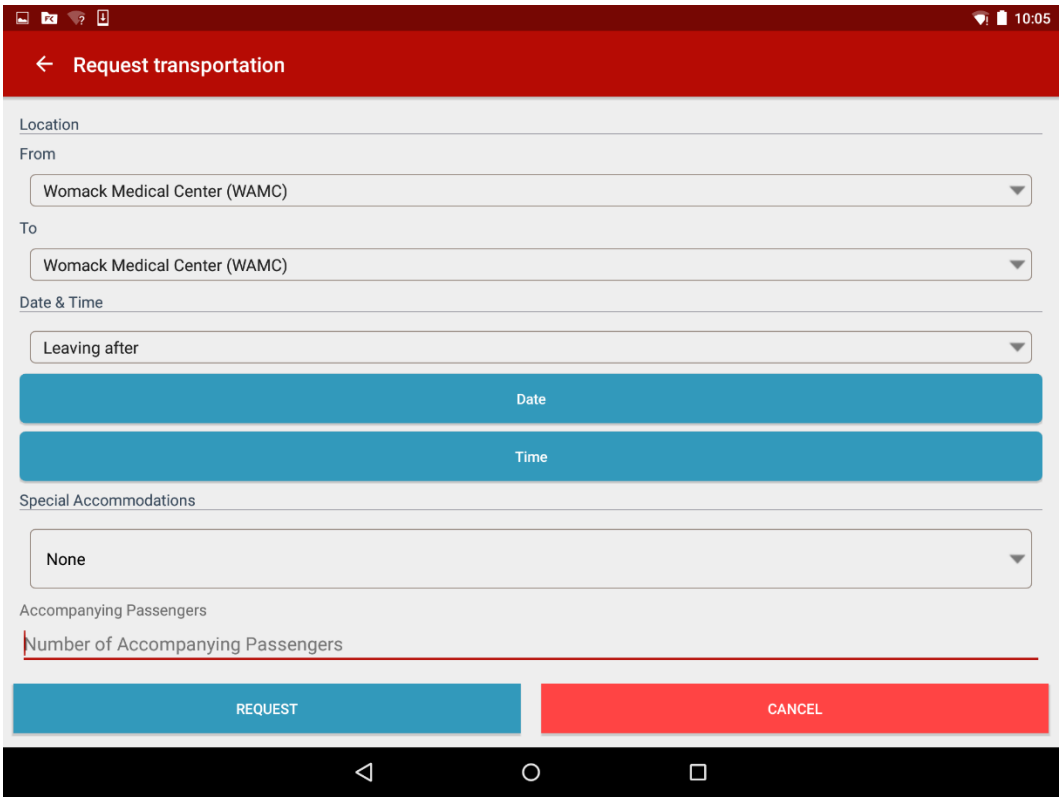

Fig. C-1 Screenshot of the main Request Transportation screen

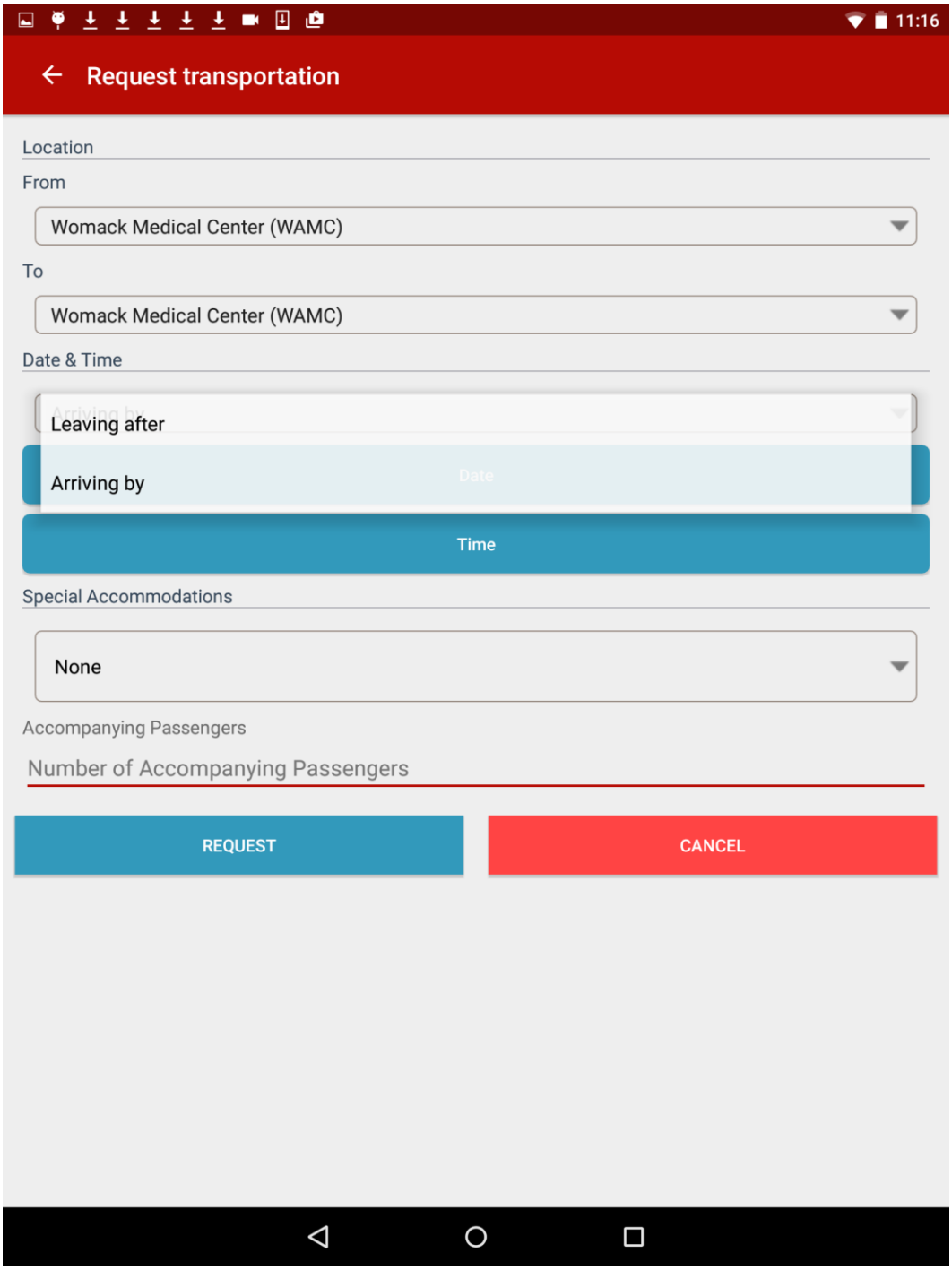

Fig. C-2 Screenshot of options for selecting specific criteria related to pick-up time

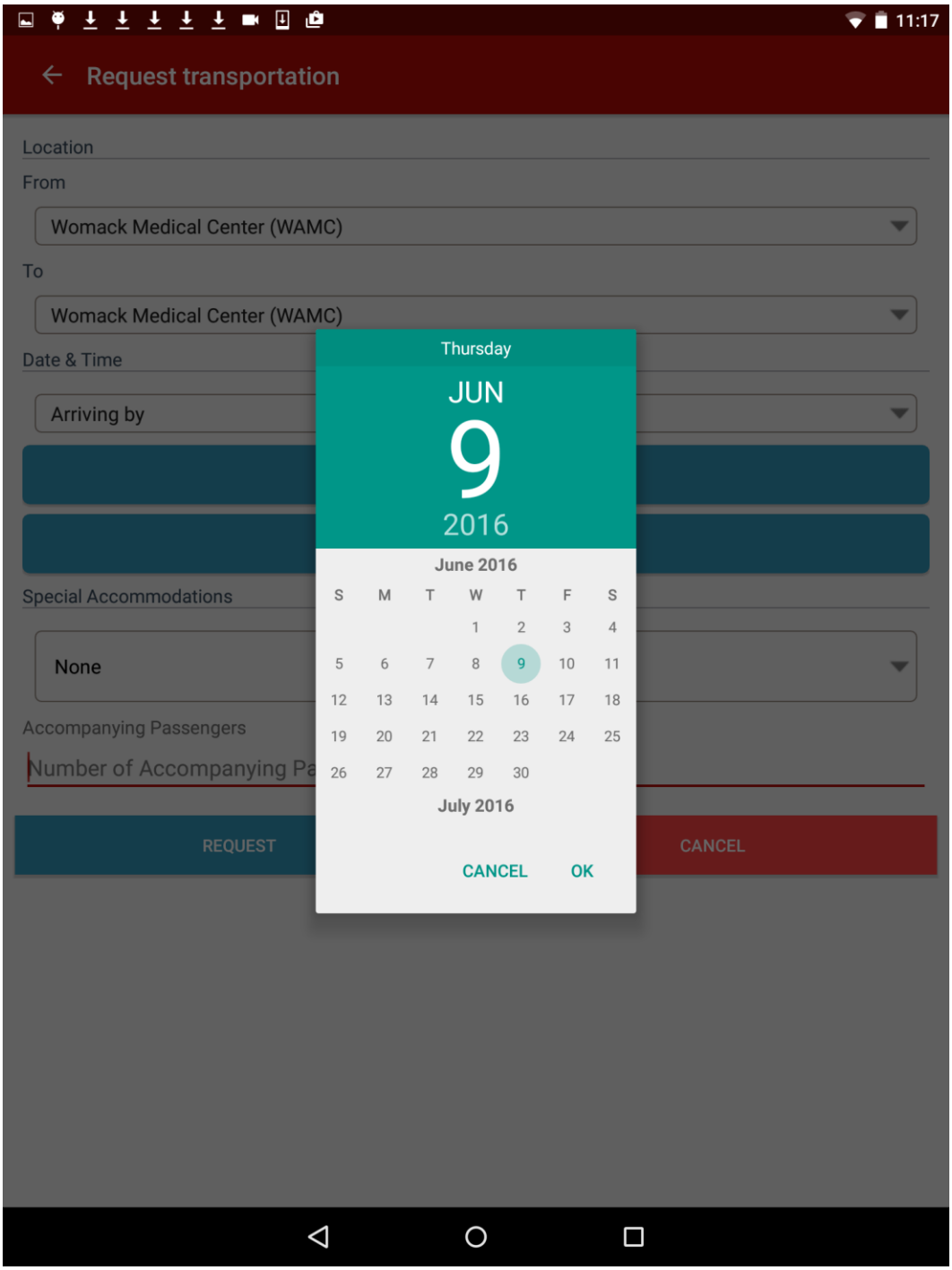

Fig. C-3 Screenshot of calendar feature

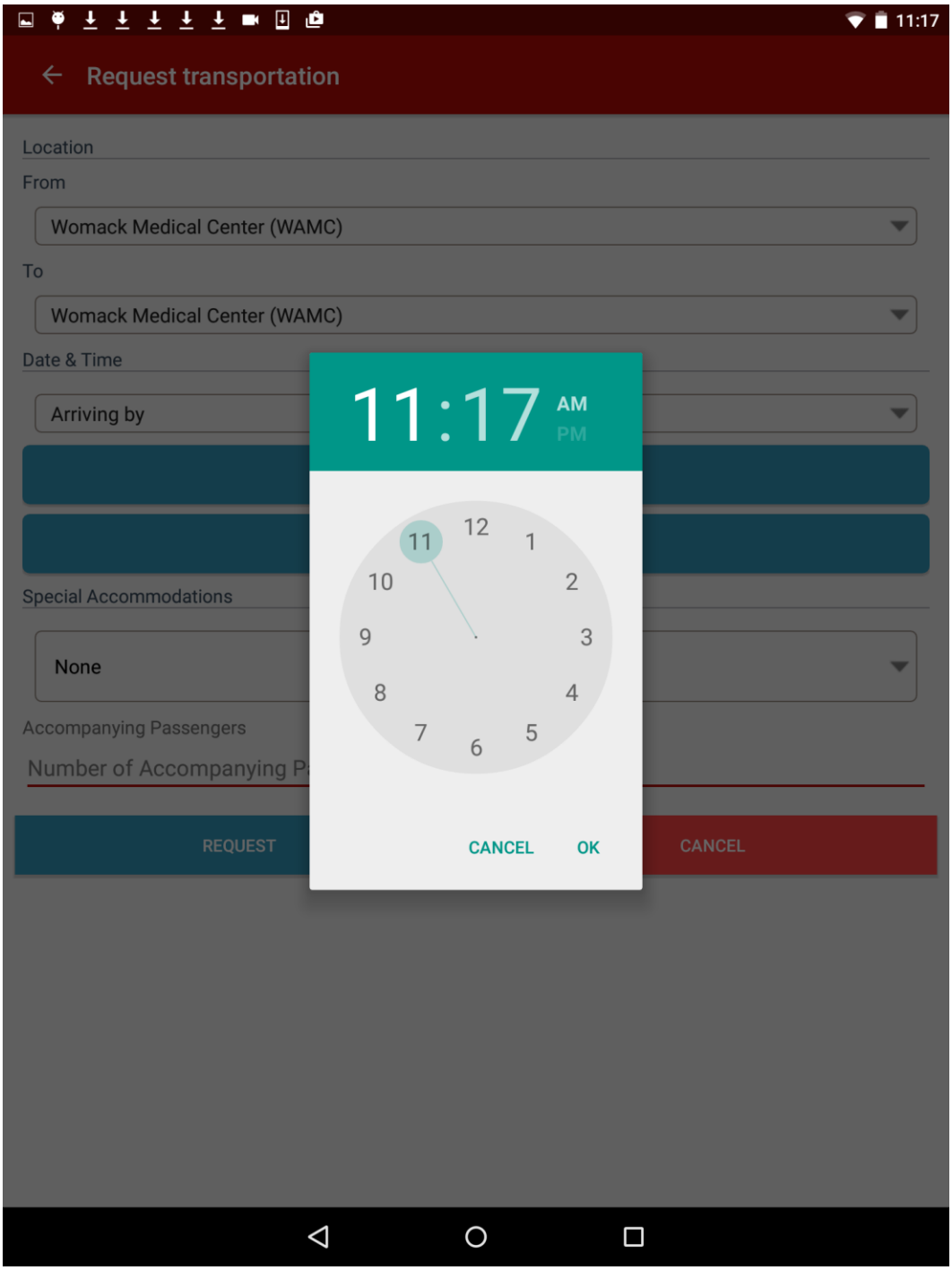

Fig. C-4 Screenshot of clock function

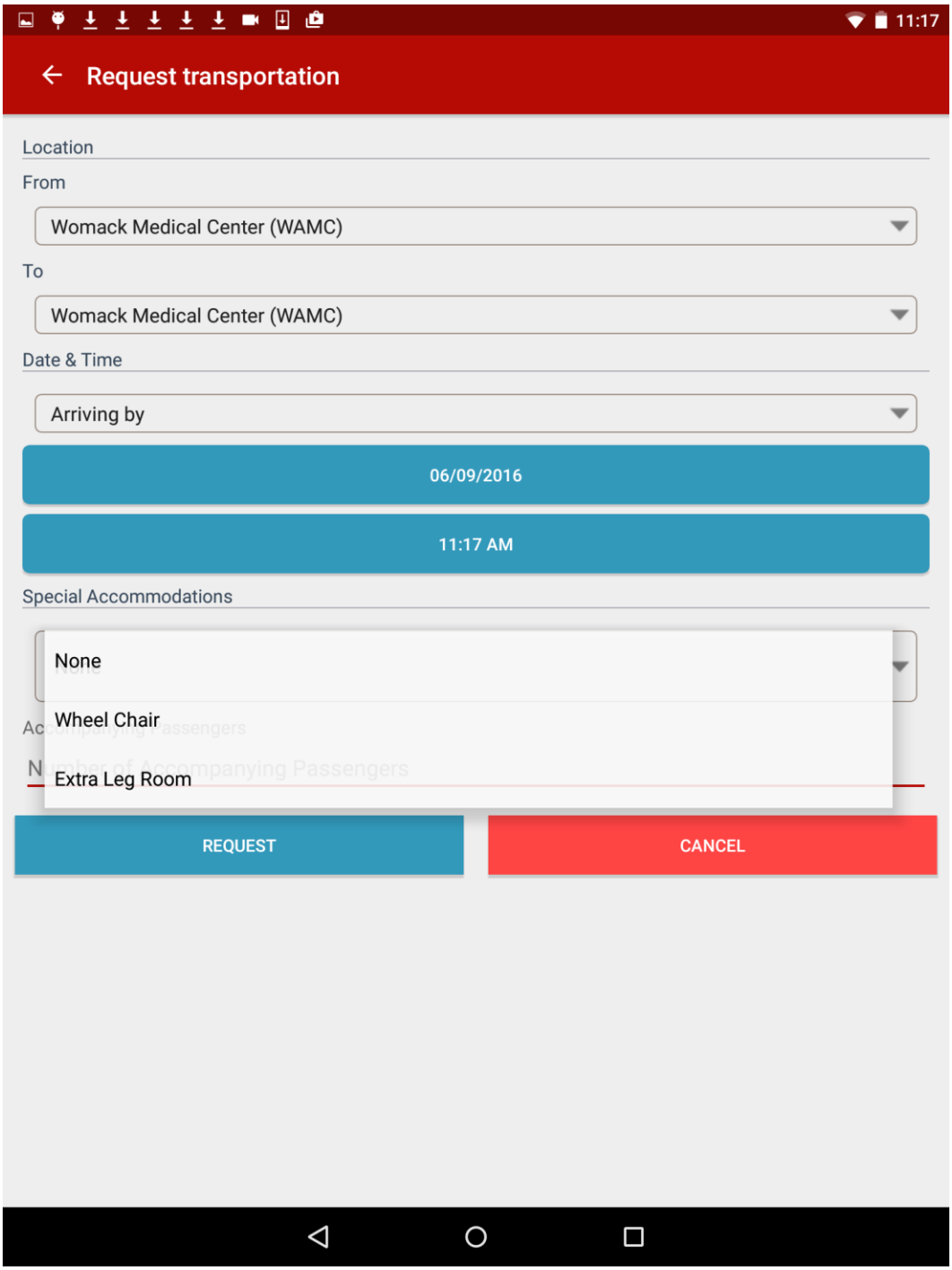

Fig. C-5 Screenshot of special accommodations options

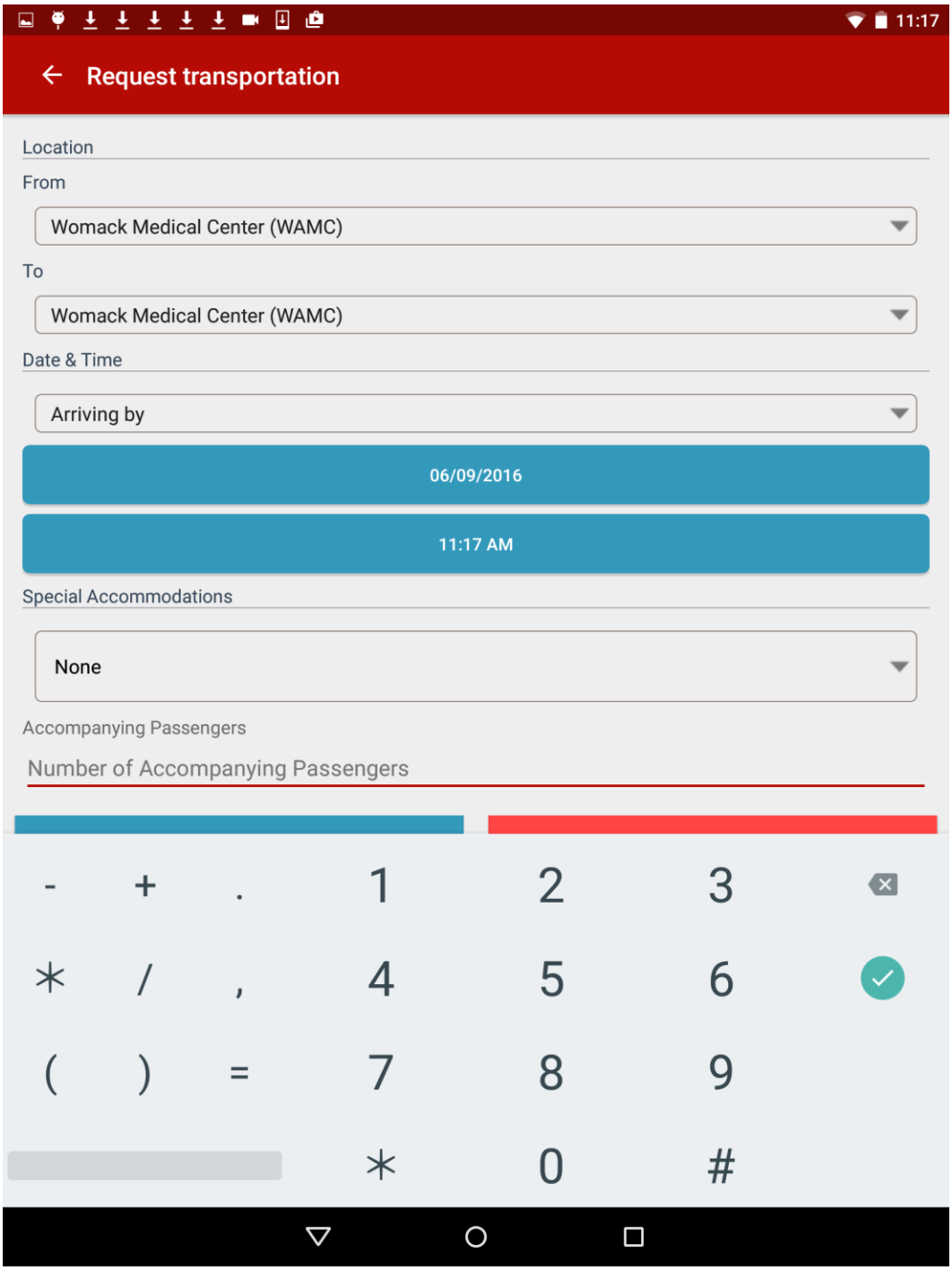

Fig. C-6 Screenshot of pop-up menu to set the number of accompanying passengers

List of Symbols, Abbreviations, and Acronyms

ARIBO	Applied Robotics for Installations and Base Operations
AWTO	Autonomous Warrior Transport On-base
SME	subject matter expert
TARDEC	US Army Tank Automotive Research, Development and Engineering Center
WTB	Warrior Transition Battalion

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