Joystick Interaction Strategies of Individuals with Dexterity Impairments: Observations from the Smart Voting Joystick Usability Evaluation

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Abstract. In order to develop a joystick as a universal access device for accessible voting machines, it is necessary to observe and understand the strategies of users with disabilities when operating joysticks in this context. For this study, researchers analyzed video and audio recordings as well as written notes and user feedback from the usability evaluation of the Smart Voting Joystick to identify, document, and understand the interaction strategies individuals with motor or dexterity related disabilities employ when using a joystick to interact with a mock voting system.

Keywords: Assistive technology · Accessible voting · Joystick · Interaction strategies · Usability

1 Introduction

The Help America Vote Act of 2002 (or HAVA) was passed in order to reform the U.S. voting process, requiring polling places in all states to be physically accessible and to provide at least one accessible voting system for voters with disabilities, thereby allowing for independent and private voting [1]. However, although progress has been made, current electronic voting system equipment that is deemed "accessible" for persons with disabilities is inadequate and requires time and effort that can be prohibitive for these individuals to independently vote with confidence [2].

The U.S. Government Accountability Office found in 2013 that 46 % of polling locations still utilize voting systems that are not completely accessible, such as stations that do not accommodate wheelchairs [3]. In addition, the turnout rate in the November 2012 elections for voters with disabilities was 5.7 % less than the voter turnout rate for those without disabilities (if these voting rates had been the same, approximately 3 million more persons with disabilities would have voted), and 30.1 % of persons with disabilities reported encountering difficulties when voting in-person at a polling place

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(versus 8.4 % of voters with no disabilities) [4]. As a result, the right to independent and private voting is often not guaranteed for individuals with disabilities, as they are likely to need assistance at a polling place with current systems.

According to the Voluntary Voting System Guidelines (VVSG) 1.0 of the U.S. Election Assistance Commission, voters with disabilities should be provided with support that is built into voting equipment and should not be required to provide their own personal assistive technology to vote successfully [5]. Allowing voters with disabilities to connect personal assistive technology to voting equipment has been under consideration recently, but security concerns need to be addressed. Therefore, there is a need for universal access devices to allow persons with disabilities to easily and successfully vote at polling places.

Because the usefulness of joysticks as assistive technology for computers has been studied and discussed in previous research involving users with motor or dexterity impairments [6–10], we developed the Smart Voting Joystick [11] as a universal input device for accessible voting systems. A force feedback feature was also included in the design, as studies have shown that this force can enhance user performance and accelerate learning when using a joystick to control a computer [12] and a powered wheelchair [13].

1.1 Understanding Interaction Strategies for Joysticks and Other Input Devices

Usability evaluations of the Smart Voting Joystick made it apparent that individuals with motor and dexterity impairments use a variety of interaction strategies to manipulate a joystick and buttons to vote. These interaction strategies are not well documented in the existing literature, particularly in the context of voting and universal devices. For instance, hand poses and how various input devices are handled are briefly described in some studies [14–16], and some research has documented the interaction styles of individuals with motor and dexterity impairments when using touchscreen devices [17]. However, research on joysticks and other alternative input devices has primarily focused on the accuracy and success encountered when using these devices [8, 18, 19] and when using specific gestures in the case of touchscreens [20–22], and on developing adaptive interface systems that adjust based on the capability of the user [14, 23, 24].

Therefore, to address the need for a universal input device for voting systems that is accessible to the widest range of users and requires the least individual customization, it is essential to observe and better document the interaction strategies of users with motor and dexterity impairments when using joysticks in order to understand and appropriately accommodate voting for these users.

2 Methodology

Researchers analyzed video and audio recordings as well as written notes and user feedback from one-on-one usability evaluations of the Smart Voting Joystick [11].

2.1 Materials

The Smart Voting Joystick setup (see Fig. 1) included a dual-axis joystick (which allowed users to navigate in four directions) with haptic feedback and three external buttons (Enter, Review, and Help). For this study, the Smart Voting Joystick was connected to a desktop computer, via USB port.

Fig. 1. The Smart Voting Joystick with Enter, Review, and Help buttons

The Smart Voting Joystick has adjustable features which were kept consistent during evaluation to allow for comparison across users. The force feedback (felt as a "pulse" when the joystick is moved) was set to a 30 ms pulse of 2.5 N, and the return-to-center force (how much effort is required to move the joystick) was set at 0.6 N. The button repeat delay (minimum time between inputs that are accepted by the system; actions taken within this interval are ignored) was set at 100 ms to filter tremors and other unintentional actions.

For the purposes of the usability evaluation, a simple user interface was developed which allowed users to vote the NIST Test Ballot [5]. This interface was optimized for the joystick and allowed users to navigate between contests using the joystick in conjunction with the buttons (e.g., to move to the next contest, users could move the joystick to the right to select an arrow icon, then press the Enter button to move to the next contest) or to move between contests with the joystick alone (e.g., after moving the joystick to the arrow icon, users could move it to the right again to move to the next contest). To ensure consistency during the evaluation, participants were instructed to vote for specific candidates.

2.2 Participants

The usability evaluation included six participants (five male and one female) with a wide range of dexterity impairments. These participants clearly split into two groups:

four participants with moderate dexterity impairments, primarily muscular weakness (Group 1); and two participants with much more significant dexterity impairments, including functional limitations of spasticity and control (Group 2).

All participants had previously voted in a federal or state election. Three participants voted by absentee ballot/mail-in, two participants had another person assist them in filling out a paper ballot at a polling place, and one participant filled out a paper ballot at the polling place without assistance.

3 Results

3.1 Group 1: Participants with Moderate Dexterity Impairments

Three of the four participants in Group 1 were able to complete the ballot accurately using the Smart Voting Joystick, and one participant voted incorrectly on only a single contest. All of the participants indicated that they would recommend the joystick to those with similar needs as themselves. Participants were only given minimal guidance by the moderator to complete the task. For example, when one user accidentally went past a contest before voting and then became confused, the moderator directed the user to go back to the previously missed contest and continue voting.

Joystick Interaction Strategies. The majority of users in Group 1 pushed or pulled the joystick with one or more fingers (see Figs. 2 and 3). Two participants grasped the joystick at times while pushing or pulling, and one participant grasped the joystick for nearly the entire session (see Fig. 4). Three of the participants rested the side of their hand or their wrist on the joystick box while using the joystick.

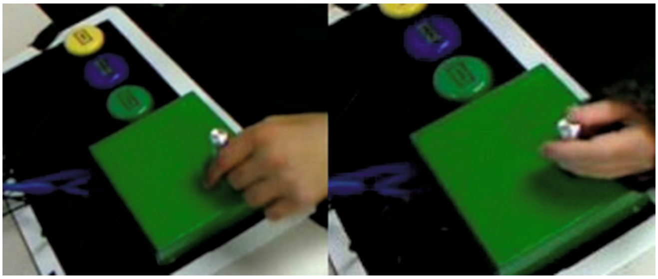

Fig. 2. Nudging with side of index finger (left) and thumb (right)

Pushing or Pulling. Pushing or pulling ranged from participants softly nudging the joystick (Fig. 2) to somewhat more forceful pushing or pulling (Fig. 3). Pushing or pulling of the joystick also varied from participants using one or two fingers (from the side or on top of the knob), a thumb, or all of their fingers or palm from the side. While pushing or pulling, participants rested their hand on the joystick box or hovered just above it.

Fig. 3. Pulling with all fingers (left) and pushing with two fingers (right)

Grasping. At times, participants grasped the joystick knob or stem with one or two fingers and their thumb, or used a hand resting on top of the joystick with one finger making most of the joystick movements (Fig. 4, left and center). One participant grasped the joystick for nearly the entire session, varying between grasping the joystick with the whole hand to move it (Fig. 4, right), or switching to a looser grip to nudge the joystick with only a thumb or fingers. This participant also switched to slightly wrapping their fingers around the stem of the joystick near the end of the session to scroll down, possibly due to fatigue. At times, when this participant was using a looser grip to move the joystick, they would pass a desired candidate or go on to the next contest before voting, accidentally moving the joystick more than intended while using this type of grip.

Fig. 4. Grasping knob and stem with two fingers and thumb (left), resting hand on top of joystick (center), and grasping with entire hand (right).

Button Interaction Strategies. Three of four participants in Group 1 used one hand for the joystick and the other hand for the buttons, and one participant used the same hand for both the joystick and the buttons. The three participants who used both hands rested their button hand on the table at times and occasionally hovered over the buttons. Two of the participants in Group 1 used one finger to press buttons, and two participants used their whole hand to press buttons.

Additional Observations. While participants in this group recommend improvements to the joystick design, they still indicated that they would recommend the joystick to those with similar needs. Participants in this group also expressed a preference for the dual-axis (four direction) joystick, as opposed to a single-axis (two direction) joystick.

The majority of participants in this group indicated that they would prefer less force feedback. Two participants were very surprised when they first moved the joystick and encountered the feedback, and one participant also thought that the feedback was a warning that they had pushed the joystick too far. One participant felt fatigue in their arm at the end of the session, and mentioned that they would prefer a joystick with less return-to-center force.

None of the four users in Group 1 held the joystick down to scroll through long candidate lists as expected, instead moving the joystick up or down one selection at a time. One participant specifically mentioned a preference for moving the joystick up or down one selection at a time, and noted that including page-up and page-down functions would be useful for long lists.

Two participants felt that a shorter and thicker joystick, more like those found on typical powered wheelchairs, would be easier to use and would allow more control. One participant indicated it was easier to move up and down with the joystick than left or right.

3.2 Group 2: Participants with Severe Dexterity Impairments

Both participants from Group 2 employed a wider variety of usage types and strategies than participants in Group 1, including operating the joystick with the forehead or chin. Because their impairments limited their ability to make fine movements, these users encountered a significant number of unintended actions and mistaken inputs that increased the time and effort required to vote.

One participant from Group 2 completed the ballot successfully with only minimal help (similar to participants in Group 1), and the second voted a portion of the ballot independently, then encountered difficulties and was unable to complete the voting tasks successfully. These difficulties primarily related to a lack of arm support, and problems with the size and shape of the joystick played a contributing role. This participant was given significant help with navigating the ballot throughout the session and, as a result, this session functioned more as an in-depth interview where researchers were able to collect important qualitative data.

Despite the fact that only one participant in Group 2 was able to vote successfully and that the testing demonstrated that the Smart Voting Joystick as it is currently configured does not cater to the needs of this user group specifically, both participants strongly endorsed a joystick in principle, and noted that adjusting specific features of the joystick, buttons, and user interface would improve its usability.

Joystick Interaction Strategies. The two participants in Group 2 used a variety of strategies (usually in conjunction with each other) to operate the joystick, including pushing, pulling, striking, and flicking, as well as grasping the joystick at times while making these movements. Neither of these participants rested their hands on the table, though one used the joystick box at times to stabilize or rest their hand when bringing it toward the joystick to make a movement.

Pushing or Pulling. Like Group 1, this group used pushing and pulling movements to interact with the system, ranging from nudges to more forceful movements. Movements were generally more forceful and were far more varied than in Group 1, including the use of a forehead (Fig. 5, left) or chin, closed fist, palm of hand (Fig. 5, right), knuckle of a finger or thumb (Fig. 6, left), a thumb, all fingers, fingertips over the top of the joystick, or a gap between fingers (Fig. 6, right).

Fig. 5. Pushing with forehead (left) and nudging with palm (right)

Fig. 6. Nudging with knuckle of index finger and thumb (left) and pushing with gap between index and middle finger (right).

Striking or Flicking. Unlike Group 1, this group also used striking and flicking, which are more forceful movements than pushing or pulling, to navigate and make selections. Participants used their hands to strike the joystick at times in order to move it or to grasp it (Fig. 7, left and center), and they also flicked the joystick with their palm, fingers, or fingertips to move it (Fig. 7, right).

Grasping. At times throughout the voting process, both participants in Group 2 grasped the joystick stem or knob with one or two fingers and a thumb to move the joystick (Fig. 8, left and center). Participants also grasped the joystick with their entire hand (Fig. 8, right), alternating between grasping from the left and right side of the joystick and with a hand or palm on top of the joystick. For these participants, grasping resulted in the most unintended actions (e.g., accidentally switching to a new contest) of any usage type. However, most of these errors were related to aspects of the test ballot's interface design and could be resolved with minor changes, such as requiring the use of multiple input devices to switch between contests (e.g., requiring the users to navigate to an arrow icon via the joystick and then pressing the Enter button to move between contests).

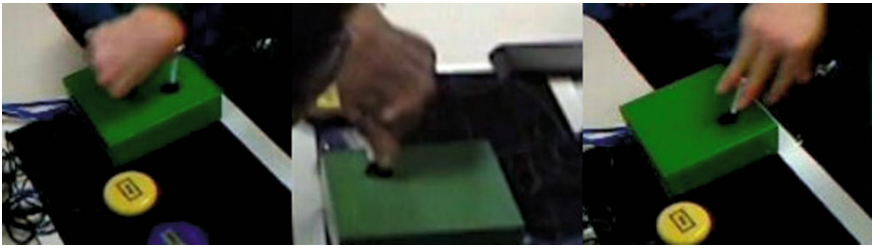

Fig. 7. Striking with back of hand (left), striking down with closed fist (center), and flicking with fingertips (right).

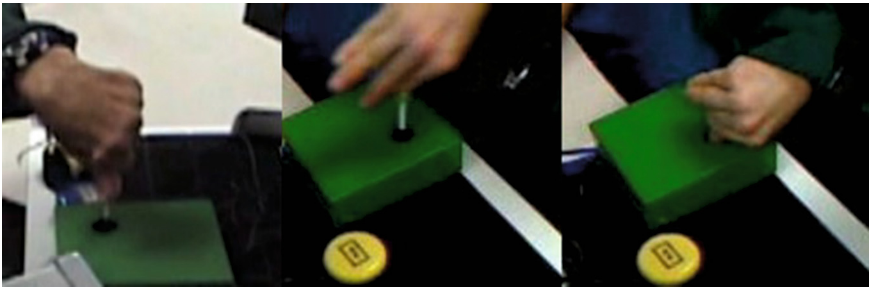

Fig. 8. Grasping stem of joystick with thumb and finger (left), grasping knob (center), grasping and holding with whole hand (right).

Button Interaction Strategies. When pressing the buttons, both of the participants in Group 2 used an entire hand, a fist, side of the hand, or fingertips. Neither of these participants rested their hands on the table (as Group 1 often did), but instead hovered over the joystick and buttons between movements.

Like the participants in Group 1, the participant who completed the ballot successfully used both hands to operate the joystick (one to press the buttons and one to operate the joystick). The second participant used one hand for both the joystick and the buttons (as well as their forehead and chin at times). This participant also used the foot pedal on their wheelchair as the Enter button, along with the other two tabletop buttons (Help and Review) to the left of the joystick.

Additional Observations. Both users in Group 2 were more successful when striking, flicking, or occasionally nudging the joystick, whereas grasping the joystick caused the most unintended actions, including unintentionally switching between contests and scrolling farther than intended. As a result, both users relied primarily on striking and flicking to vote the ballot, but also indicated they would have preferred a joystick they could hold without causing unintended inputs.

Although motions like striking and flicking were more successful, there were still a significant number of unintended inputs when participants employed this usage type. For instance, when one participant would move a hand toward the joystick to strike or flick it with an open palm, and when this participant would move a hand away after such an action, they would often accidentally hit the joystick with a thumb or finger. One participant indicated that moving the joystick away from their body was easier than moving it towards their body (presumably because moving the joystick to scroll down required either flicking or pulling, while moving it to scroll up allowed the use of nudging or striking motions). When asked, this participant said that the voting process would have been easier if the cursor had started at the bottom of the list of candidates instead of the top (so that they would need to scroll down less often).

For the participant who did not complete the voting process, many of the obstacles they experienced operating the joystick related to a lack of arm support. For instance, to operate their wheelchair joystick, this participant relied on the strong support provided by the wheelchair armrest to stabilize a forearm and then operate the joystick largely with wrist and fingers. However, because of the joystick position during the study, similar arm support was not possible, and the participant therefore needed to utilize their whole arm, unsupported, to operate the joystick. Furthermore, this participant was fully able to independently operate their wheelchair using a joystick (which was shorter, thicker, spherical joystick, and had substantial arm support via the armrest), indicating that their difficulties may be related to features of this specific joystick design.

While one participant experimented with scrolling quickly through the list of candidates while grasping and holding the joystick up or down, both participants preferred to scroll through candidates one by one like the participants in Group 1. Also similar to the other group, both participants in this group indicated that they would have preferred a joystick that was shorter and thicker, which would have been more consistent with joysticks these participants used previously for successfully interacting with information technology, and operating powered wheelchairs.

Unlike the participants in Group 1, one of the participants in this group expected the joystick to operate as a single-axis joystick, and felt that this would have been easier to use than a dual-axis joystick, and both participants in this group stated that they wanted a joystick that was "stiffer" (offering more return-to-center force) and provided stronger force feedback.

4 Discussion

From observing and analyzing the interaction strategies of individuals with dexterity and motor impairments while using the Smart Voting Joystick, we determined considerations which are critical for a universal access voting joystick and buttons. A variety of interaction strategies were used between and within the moderate and severe groups, and the majority of participants used more than one strategy throughout the voting task. Thus, it is necessary to accommodate a variety of joystick strategies, including both gentle and forceful movements (from pushing and pulling to striking and flicking). In addition, grasping is a potentially effective usage type that users will likely employ during the voting process, but joystick and interface designers need to ensure that grasping does not result in a high number of unintended inputs.

To meet the needs of a variety of users and support their preferred interaction strategies, the force feedback and return-to-center force levels of a voting joystick should be easily adjustable (by users and/or poll workers before voting begins). Both single-axis and dual-axis modes should also be offered.

As indicated by nearly all participants, a shorter and thicker (similar to the joysticks on powered wheelchairs) would facilitate a variety of interaction strategies, such as grasping or pulling the joystick. For example, a shorter, rounder joystick could prevent users with low motor control from "snagging" the joystick when moving their hand toward or away from the joystick.

Sufficient arm support needs to be provided to facilitate control and aid in reducing fatigue. For example, participants in Group 1 often rested their hands on the joystick or the table for support, and participants in Group 2 had difficulties using the Smart Voting Joystick because they could not stabilize their hand or arm as they could with their armrest while operating a wheelchair joystick.

The size and spacing of buttons used in conjunction with the joystick needs to accommodate the various interaction strategies of users, allowing the use of fingers and an entire hand without unintended inputs. Button sensitivity and careful timing of when buttons are active and inactive are crucial to preventing unintended inputs.

5 Conclusion

In order to further the development of a universal access voting joystick and buttons for the individuals, interaction strategies of individuals with motor and dexterity related disabilities were identified and documented during the usability evaluation of the Smart Voting Joystick. Further research and testing needs to be conducted in order to determine the range of feedback and default settings that need to be available to users, as well as to determine optimal joystick dimensions and button repeat delay. Arm support options for joysticks and buttons, such as universal access mounts, also need to be considered and researched to determine the best option to accommodate voters using wheelchairs.

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