Analyzing User-Generated YouTube Videos to Understand Touchscreen Use by People with Motor Impairments

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ABSTRACT

Most work on the usability of touchscreen interaction for people with motor impairments has focused on lab studies with relatively few participants and small cross-sections of the population. To develop a richer characterization of use, we turned to a previously untapped source of data: YouTube videos. We collected and analyzed 187 non-commercial videos uploaded to YouTube that depicted a person with a physical disability interacting with a mainstream mobile touchscreen device. We coded the videos along a range of dimensions to characterize the interaction, the challenges encountered, and the adaptations being adopted in daily use. To complement the video data, we also invited the video uploaders to complete a survey on their ongoing use of touchscreen technology. Our findings show that, while many people with motor impairments find these devices empowering, accessibility issues still exist. In addition to providing implications for more accessible touchscreen design, we reflect on the application of user-generated content to study user interface design.

Author Keywords

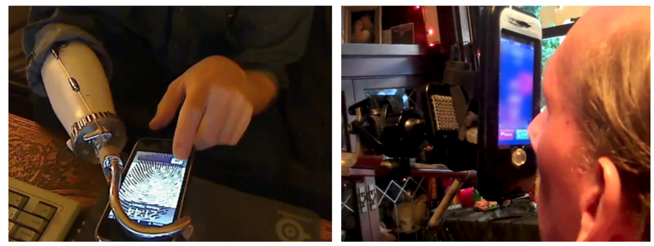
Touchscreen; motor impairments; physical disabilities; assistive technology; YouTube; iPad; iPhone.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (*e.g.*, HCI): Miscellaneous; K.4.2. Computers and society: Social issues – assistive technologies for persons with disabilities.

INTRODUCTION

Mainstream mobile devices are becoming an important means of daily technology interaction for many people with disabilities. Such devices are being used, for example, by users with visual impairments to navigate unfamiliar areas [24], by older adults with limited mobility as a communication channel to family and caregivers for greater independence [1], or by hearing-impaired users to communicate without expensive, specialized TTY (teletype) hardware [28]. Most newer mobile devices, however, offer touchscreen interaction that may be particularly problematic for people with physical disabilities. Research on touchscreen interface design for users with physical disabilities has been largely limited to lab studies with relatively few participants [3,6,10,16,31], or to small interview studies [20]. Moreover, even less attention has been paid to subpopulations such as children.



(a) (b)

Figure 1. Examples of unconventional touchscreen use being adopted by people with physical disabilities: (a) a user with a hand prosthesis demonstrates unlocking; (b) nose input with an iPhone.

To develop a richer characterization of how people with physical disabilities are adopting touchscreen devices, we turned to a previously untapped source of data: YouTube videos. We collected and analyzed 187 non-commercial videos uploaded to YouTube that depicted a person with a physical disability interacting with a mobile touchscreen device. In analyzing the videos, we asked questions such as: What are these touchscreen devices being used for on a daily basis? How well do they work out of the box, or how poorly? What adaptations are users making to improve accessibility? We coded the videos along a range of subjective and objective dimensions designed to characterize the interaction and to identify any challenges or adaptations we witnessed. To complement the videos themselves, we also invited the video uploaders to complete a survey on their opinions and use of touchscreen technology in their daily lives.

Our results show that, while many people with physical disabilities find touchscreen devices empowering, accessibility challenges still exist. We observed a range of interaction styles and use cases, from interaction with one's foot or nose or with a prosthesis (Figure 1) to interacting while lying down or, particularly with children, using arm or leg slings for support. Specific breakdowns were evident, such as challenges of multitouch interaction. We also observed a range of physical device adaptations, including both commercial and homemade solutions: physical guides and barriers to aid pointing, head and mouth sticks adapted for use with capacitive touchscreens, and screen protectors. Based on this synthesis, we identify potential means of improving touchscreen accessibility for users with physical disabilities through a set of design implications.

The contributions of this work include, first, a characterization of interaction styles, use cases, challenges, and (in some cases) homemade solutions that users with physical disabilities are adopting or encountering while using touchscreen mobile devices in daily life. Second, we derive a set of design implications from this data—implications based on a much broader sample of users than has been the case for prior work [3,6,10,16,20,31]. Finally, we build on the limited prior use of YouTube videos as a data source for HCI research, by extending this method to surveying content uploaders, and by demonstrating its effectiveness for studying user interface design and interaction in the wild. We close by discussing the challenges, benefits, and limitations of this methodology, to aid future researchers in applying it in their own work.

RELATED WORK

We survey related work on (1) touchscreen interaction for people with motor impairments, and (2) YouTube videos as a data source for human-computer interaction research.

Input for Users with Motor Impairments

Technologies to improve accessibility for users with motor impairments range from hardware devices like eye trackers and sip-and-puff input to software solutions such as voice recognition.[1] While several studies in the HCI literature have explored touchscreen accessibility for users who are blind or have visual impairments (*e.g.*, [19,25]), a smaller number—discussed here—have examined accessibility for people with physical disabilities. Our review focuses on studies of physical pointing and gestural interaction, since these are most applicable to our video dataset.

Studying basic touch interaction, Duff *et al.* [6] found that users with motor impairments were less accurate than non-disabled users in a tapping task. Follow-up work yielded a more nuanced understanding: participants with fine or gross motor control disabilities were slower than the non-disabled group, and those with gross motor control disabilities exhibited longer dwell times on touches [16]. Biswas and Langdon [3] found that touchscreens offered the fastest input compared to mouse, trackball and stylus for people with motor impairments, but 3 of 12 participants could not use the touchscreen at all. All three studies highlight the need for further work on touchscreen accessibility for users with motor impairments.

Several projects have resulted in design implications or proposed techniques to support touchscreen interaction for users with motor impairments. Guerreiro *et al.* [10] studied the performance of 15 participants with quadriplegia on touchscreens, concluding that targets should be at least 12 mm in size for this user group. Wacharamanotham *et al.* [31] compared tapping to a technique that allowed users with tremor to slide their finger on the screen, finding the latter reduced errors. Though not for direct touch interaction, *HandiGlyph* allows users to enter text on mobile devices [2]. Another touchscreen technique, meant for use with a pen, is *Barrier Pointing*, which improved target acquisition for people with motor impairments by utilizing the edge of the screen [8]. Also using hard edges to aid gestures on a touchscreen is *EdgeWrite*, a technique for stylus-based text entry [33]. Touch devices such as the iPhone do not have the built-in hard edges required for these latter techniques to transfer easily to finger pointing.

The challenges of more traditional computer setups have been well documented for people with motor impairments [15,30], as well as for older adults [34] and children [11], two other groups who have difficulty with mouse pointing. Novel techniques have been proposed to ease mouse pointing. Area cursors [18], for example, reduce the need for fine pointing and have been shown to be beneficial for older adults [34] and people with motor impairments [7]. Gravity wells provide force feedback when the user is over a target [14]. *Steady Clicks* reduces errors by briefly freezing the mouse at the button down location, but does not improve target acquisition time [29]. Methods that automatically adapt to an individual user's abilities have also been proposed, including solutions to reduce mouse speed [12,32], adapt user interface elements (*e.g.,* button size) [9], and predict useful accessible interaction techniques [13]. While this previous work has not focused on touchscreens, some of the solutions (*e.g.*, *Steady Clicks*) could be adapted for them.

YouTube as a Source of Data

Many research projects have examined YouTube, including an exploration of social networking on the site (*e.g.*, [23]), how people search for videos [5], and the appropriation of YouTube videos as a data source for the social sciences (see [17] for a summary) and health (*e.g.*, [22]). As a resource to inform user interface design, however, online videos have received little attention. To our knowledge, the most closely related work comes from Blythe and Cairns [4] and Paay *et al.* [26]. Blythe and Cairns [4] conducted a content analysis of 100 YouTube videos returned from a search for "iPhone" after the iPhone release in 2007. They categorized the videos into review, reportage, unboxing, demonstration, satire, advertisement, and commentaries, and conducted a qualitative analysis of comments from the single most popular video. While their study provides insight into reception and discourse around the iPhone launch, it does not discuss many of the challenges that exist in using YouTube videos to inform broader design. Our study is also deeper in that we focus on accessibility, with 480 searches (instead of 1). More recently, Paay *et al.* [26] analyzed 169 YouTube videos found on a search for "cooking together". All videos were coded on 13 categories (*e.g.*, cook

[1] For an overview see: http://webaim.org/articles/motor/assistive

Disability-Related Search Terms (*N* = 60)
AAC, accessibility, ALS, amputation, amputee, arthritis, assistive technology, ataxia, augmentative communication, brain injury, cerebral palsy, congenital amputation, congenital amputee, disabilities, disability, disease, dystonia, essential tremor, Friedreich ataxia, Friedreich's ataxia, handicap, hemiplegia, hemiplegic, hydrocephalus, hydrocephaly, Lou Gehrig's, Lou Gehrig's Disease, medical amputation, medical amputee, motor disabilities, motor impairment, MS -microsoft, multiple sclerosis, muscular, muscular dystrophy, myopathy, paralysis, paralyzed, paraplegia, paraplegic, Parkinson's, Parkinson's disease, physical disabilities, psychomotor agitation, quadriplegia, quadriplegic, rehabilitation, sclerosis, seizure disorder, SMA, special needs, spina bifida, spinal, spinal cord injury, spinal muscular atrophy, stroke, TBI, traumatic brain injury, tremor, wheelchair
Technology-Related Search Terms (*N* = 8)
touch screen, touchscreen, smartphone, tablet, app, iPad, iPhone, iPod

Table 1. Final set of search terms used. Each disability-related search term was combined with each technology-related search term for a total of 480 search term combinations.

expertise); 6 were analyzed in more depth to map out spatial relationships among objects in the kitchen. Their study did not focus on technology, but was meant to inform the design of systems to support the experience of cooking together remotely. We further reflect on methodological differences between our work and these examples [4,26] in the discussion section.

METHODOLOGY

This study included three main phases: (1) video searching—finding user-generated videos of mobile touchscreen device use by individuals with motor impairments on YouTube; (2) video coding—developing a coding scheme that focuses on user interaction with the touchscreen devices and any challenges or opportunities that are evident, applying it to the videos, and analyzing the results for patterns; and (3) an online survey—soliciting responses from the YouTube video uploaders on the continued use of touchscreen devices in their daily lives.

Constructing a Dataset from Public Videos

Because there are many terms used to describe physical disabilities and motor impairments, a single search would not be sufficient. Instead, we followed a systematic approach. We generated a list of disability-related search terms (60) and a list of technology-related search terms (8), then exhaustively searched for every combination of terms from the two lists (Table 1). This resulted in 480 unique searches. The terms were informed by an extensive exploration of YouTube's search capabilities and the descriptions we found people using for their videos. For example, non-Apple brand terms such as "Android" yielded no useful results in these explorations, and thus were not explicitly included our final set. When an item included more than one word, we searched for it in quotes. For example, the terms *accessibility* and *touch screen* resulted in the combination: *accessibility "touch screen"*. For each combination, we looked at *all* results returned or *the first ten pages* of results (*i.e.*, 200 results), whichever came first. By the tenth page, relevant results were generally sparse. Many very specific searches returned only a few new results or none at all. Some similar terms, such as "Parkinson's" and "Parkinson's disease," were both included in our searches because the 10-page cut-off for the first (more general) one sometimes led to the second (more specific) one finding new videos. Finally, YouTube's "Suggestions" list and users' "channels" also provided a small number of relevant videos.

Video Analysis

Our primary analysis comprised of coding the videos along the 21 dimensions shown in Table 2. To ensure the code set was reliable, we refined the codes in a four-phase process. The first two phases involved three researchers independently coding two separate sets of 15 randomly selected videos along 15 dimensions, followed by discussion of disagreements and refinement of the coding dimensions. In the third phase, two researchers independently coded 12% of the video set (23 videos), and a third researcher computed inter-rater reliability on this "spot-check" set using Cohen's kappa. We removed three dimensions due to low agreement: number of people off-screen, relationship between main subject and other people, and commercial *vs.* DIY adaptation. We then iterated on a small number of remaining problematic codes, including collapsing some in *Category of Application(s) Used*, where we had too much detail (*e.g.,* all children's apps became a

Video characteristics:
• Video Purpose • Video Emotion (valence): negative or not • Context: *e.g.,* home, office, vehicle • Number of other people onscreen • Interaction of cameraperson w/ subject: yes or no • Language (either in video or in description)
Device usage in video:
• Number of application(s) used • Category of application(s) used • Type of device(s) • Physical position of device(s): *e.g.,* lying flat, standing upright • Physical position of user: *e.g.,* sitting, lying down
User characteristics:
• Age group: *e.g.*, small child (~1–5 years), child (~6–12), etc. • Gender • Type of disability/disabilities • Other assistive/accessible technology (unrelated to touch device): *e.g.*, wheelchair • Frequency of use: First time or not
Type of interaction:
• Direct *vs.* indirect interaction • Number of hands (if direct and hands) • Direct touch detail (if direct): *e.g.*, index finger + thumb • Indirect interaction detail (if indirect) • Use of external objects with touch device: *e.g.*, head pointer

Table 2. The final 21 dimensions used to code videos. Many dimensions also included a code of "unable to tell" or "NA".

single code: "kids apps"), and collapsing codes of the form "unable to tell" and "none". Cohen's kappa across the remaining 21 dimensions was on average 0.73 (*SD* = 0.24). Finally, one researcher coded all remaining videos using the refined coding scheme.

Following the coding, we qualitatively analyzed subsets of videos identified by the codes as being interesting in some way, such as showing a particular type of interaction. These richer descriptions complement the coded data. For each subset, one or two researchers identified themes and commonalities across videos. Additionally, we recorded objective information about the video, such as length.

Survey

To complement the snapshot of use offered by the video analysis, we developed an online survey to elicit more detail on users' daily use, opinions, and experiences with the device(s) shown in their video. Through YouTube's messaging functionality, we contacted 90 unique YouTube users whose videos were in our dataset and who appeared to be individuals rather than larger entities (*e.g.*, non-profit organizations). The survey included 20 questions divided into: (1) demographics—age, gender, disability, *etc.*, (2) daily use of the device—activities, frequency, motivation, *etc.*, and (3) adaptations of the device—special setup, difficult actions, *etc*. Users who completed the survey (and voluntarily disclosed their email address for compensation) received a $10 Amazon online gift card. Fifteen respondents completed the survey. We characterize the survey participants in more detail in the Dataset section.

DATASET AND PARTICIPANTS

In total we found 187 videos that depicted users with physical impairments interacting with a mobile touchscreen device. The videos were uploaded by 101 unique YouTube users. In this section, we characterize the videos and survey respondents before presenting additional findings in the next section. Overall, our data represents a broader range of use cases than past human-computer interaction work on the use of mobile devices by users with motor impairments [8,10,20,31]. The diversity of our dataset also highlights that YouTube can be a rich source of data for similar work.

Video Characteristics

The videos ranged in length, from only a few seconds to much longer, covering multiple episodes of interaction (*M* = 127s; *Mdn* (median) = 78s; range = 6–680s; *SD* = 128s). Most videos were all or partly in English (95%). Video upload dates ranged from August 2007 to August 2012[2] (time since upload: *M* = 1.38 years prior to September 2012; *Mdn* = 1.48 yrs; *SD* = 0.84 yrs).

We subjectively coded the environment or context in which the video was recorded, based on cues in the video itself. The most common setting appeared to be the home (82%), followed by office settings (6%), school settings (4%), hospital settings (3%), or outdoor settings (2%). The prevalence of home-like environments reflects the personal nature of these user-generated videos.

[2] YouTube launched in February 2005. The Apple iPhone was released in 2007, the iPad in 2010. Only 13 videos were uploaded prior to the Apple iPad launch in 2010.

Primary Disability	No. Videos (% of 187)	No. Users (% of 101)
Cerebral palsy	46 (25%)	22 (22%)
Spinal muscular atrophy	31 (17%)	16 (16%)
Quadriplegia / hemiplegia	14 (7%)	7 (7%)
Seizure disorder	9 (5%)	2 (2%)
Hydrocephaly	6 (3%)	3 (3%)
Spinal cord injury	6 (3%)	3 (3%)
Other (*e.g.*, congenital/medical amputation, multiple sclerosis, muscular dystrophy, etc.)	62 (33%)	32 (32%)
Unable to determine	39 (21%)	31 (31%)

Table 3. Frequency of physical disabilities observed in our video dataset. (Multiple disabilities possible for 1 video.)

User Characteristics

Typically, each of the 101 users only uploaded one video in our dataset (*M* = 1.85, *Mdn* = 1, *SD* = 2.61). At the extreme, one user was a physical therapist who had uploaded 25 videos of various clients (all children). The uploader of the video was not always the primary subject of the video, that is, the individual with a physical disability interacting with a touchscreen device. For the remainder of this paper, we use the word "user" to refer to the primary subject. Our codes resulted in the following demographic breakdown:

(1) **Gender.** 43% female and 57% male.

(2) **Age Group.** 47% small children (~1–5 yrs old), 26% adults (~18–64 yrs), 19% children (~6–12 yrs), 6% teens (~13–17 yrs), and 2% older adults (~65 yrs and up).

We also recorded diagnosed medical conditions where possible. Typically this information was available in the video title, description, or comments, or in some cases, on the uploader's YouTube profile page or external website (linked from their profile page). Table 3 shows the frequencies of disabilities in the dataset. Since users may have more than one co-occurring disability, the numbers sum to greater than 187. In 21% of cases, we were unable to determine the exact disability, but watching the video made it clear that some type of motor impairment existed. These data reflect the diversity of users in our study.

The videos included a variety of assistive technology devices, such as wheelchairs (30%), arm and leg slings (13%), chest harnesses (11%), or assistive breathing equipment (9%). Other equipment included adaptive seating systems, stander systems, neck braces, and limb prostheses. In about a third of videos (30%), more than one assistive device was present; 24% of videos showed none.

Touchscreen Device Characteristics

Perhaps reflecting the rapid adoption of the iPad after its release in 2010, and the recent nature of the videos in the dataset (*i.e.*, average of less than 1.5 years since upload), the iPad dominated the videos in the dataset (78%). The

Direct Interaction Method	Number of Videos (% of 187)
Index finger	55 (29%)
Fingertips (*i.e.*, multiple at once)	31 (17%)
Thumb	30 (16%)
Hand (*e.g.*, whole palm)	29 (16%)
Knuckles	24 (13%)
Middle finger	13 (7%)
Fist	10 (5%)
Nose	5 (3%)
Other (*e.g.*, feet, ring finger, little finger)	23 (12%)

Table 4. Direct interaction styles observed; a single video could include more than one interaction style. *N* = 187 videos.

iPhone was a distant second (17%), and the other videos included such mainstream touchscreen devices as the iPod Touch, Android tablets, and touchscreen Tablet PCs.

A wide variety of applications were in use in the videos. Each video typically showed interaction with a single app (82%). The *specific* app was not always apparent, so we instead coded the app purpose. The most common apps were either kids' apps (*e.g.*, educational software or games for children), in 26% of videos, or entertainment apps (*e.g.*, music or art apps), also in 26% of videos. Other common apps were augmentative and alternative communication (AAC) apps (15%) and other games (12%).

Survey Respondents

Fifteen participants responded to our survey (response rate 17%). Of these, two were not members of our target population and were removed from analysis (one was a minor and one was an older adult without a medical disability[3]). We additionally received a response from a therapist who works with iPads and people with disabilities. Of the 12 remaining respondents, 3 were the user from the video themselves, while the other 9 were caregivers or relatives answering for the main user. We report the demographics of the users (not available in one case) rather than the person filling out the survey. Of these 11 participants (6 female), 4 were adults and 7 were children under 18 years of age (M = 15.6 years, range = 2–39 yrs, SD = 13.8 yrs). Respondents reported a range of disabilities, including myotubular myopathy, spinal muscular atrophy (SMA), cerebral palsy, quadriplegia, and traumatic brain injury. Half (6) reported only one disability, while the other half had 2 or more. For 8 users, the disability had been present since birth, for 2 before age 5, and for 1 since adulthood. These respondents were relatively technology-savvy, as might be expected of those uploading YouTube videos. Most (9) indicated they used the touchscreen device once or more a day, and the others noted less frequent use.

FINDINGS

We report on overall trends within the video set, while highlighting interaction styles, challenges and successes that we observed with smaller sets of users who shared similar abilities. We find a rich set of use cases and interaction styles that emphasize users' diversity of abilities, needs, and accessibility concerns.

Interaction Styles

Nearly all videos (91%) showed *direct* interaction, *e.g.*, using fingers, hands, or feet. Only 15 videos (8%) showed *indirect* interaction through use of an intermediate device (*e.g.*, head pointer). One video showed both touch and an intermediate device.

Direct Touch Interaction Methods

Interaction with the fingers was by far the most common direct interaction method, appearing in 56% of all videos. Also, one-handed interaction (58% of all videos) was more common than two-handed interaction (29%). Frequency of direct interaction methods is shown in Table 4.

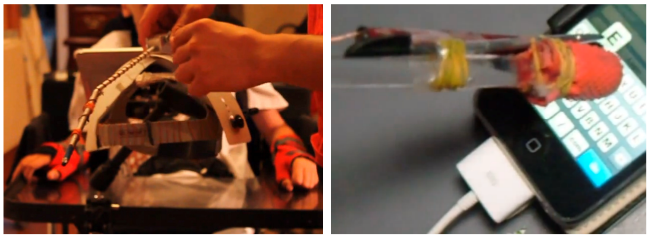
Fingers. Although many users were able to successfully use finger-based interaction, we observed several types of difficulties. In some cases, users' motor impairments interfered with their ability to perform the necessary touch or gesture that the app was expecting. For example, users unable to fully control finger extension sometimes made contact with the device surface with their fingernail. The capacitive touchscreens on iPads and iPhones do not recognize a tap by a fingernail because it is not conductive (enough). One mother commented on a video about her son: "*[He] has been doing a much better job of touching the screen with the pad of his finger, instead of his nail.*" (V8).

We also observed users holding their finger on the screen too long, which the device recognizes differently than a short tap. Similarly, dragging or sliding motions presented challenges for some users with limited muscle control or tremor. One small child with mixed developmental delays changed how he was holding his iPhone several times and used different fingers to enable him to drag his finger along the path an app required (a letter tracing app called I Write Words, V144). In other cases, the user was unable to reach all areas of the screen due to limited range of motion. In many videos (15%), a third party helped the user in some way to recover from these errors.

Hands. We coded interactions in which the palm or side of the hand was used to contact the screen as 'hands'. Most users who interacted in this way (83%) were small children with limited mobility due to their disability and/or young age. Although the size of the contact point is larger than for the (typically expected) finger, any part of the skin can be recognized as contact by these devices. An app can take this potential interaction style into account by using larger interactive widgets onscreen that do not require precise targeting. One caregiver of a child with Wolf-Hirschhorn Syndrome alluded to a need to develop precise motor control: "*You have to actually touch on the…object to make it move, …so it works on…fine motor skills.*" (V56).

Fists and knuckles. Uses of fists and knuckles were similar in our videos. We coded any interaction with a closed fist as

[3] This user's video (originally included because he mentioned arthritis) was subsequently removed from our dataset as well.



(a) (b)

Figure 2. Examples of indirect interaction methods. (a) Homemade head stick using copper wiring to conduct electrical signals from the head. (b) Typing with a mouth stick also adapted with a piece of copper wire.

'fist,' whereas 'knuckles' typically meant that the fingers were only partially bent, with the back of the knuckles as the contact point with the touchscreen. Most users who used fists or knuckles were babies or young children using a simple app that only involved touching the screen (*e.g.*, taps, no swipes or flicks). As with hands, fists and knuckles can be recognized equivalently well to fingers, as long as precise aim is not required by the app.

Nose. In 5 videos (4 unique users), direct touch with the nose was used as the primary interaction. In one comment, a mother remarked on her daughter's use of the iPod Touch with her nose: "*She can play almost any game out there! It is really quite a great accessible tool that Apple has created.*" (V58). The videos depicted a range of tasks, including typing, creating music, and playing games. In all cases, the touchscreen devices were mounted to a wheelchair so that they could be easily reached by the user (Figure 1b).

Feet. Two videos showed people interacting with the touch device using their feet. One of these users, an adult, commented regarding the iPhone and iPad that: "*I used to have other phones with the little buttons but since I use my feet, it's easier to do things on the screen*" (V72). During the video he tended to use his big toe and second toe the most, typing and interacting with different apps.

Indirect Interaction Methods

Head sticks. Four videos (3 unique users) included head stick interaction. In all cases, the users were seated in wheelchairs, with the touchscreen device either mounted to the chair or on a nearby surface. The intention of one of these videos was to communicate that a standard head stick does not work on the capacitive touchscreen of the iPhone, while the remaining videos demonstrated use of head sticks that had been custom-adapted to work with such a screen (Figure 2a). In one of the latter videos (V3), the user achieved some success tapping app icons and the physical home button on the iPad, but encountered problems because it was difficult for him to tap quickly enough with the head stick. The narrator expresses that: "*One thing that would be nice about the iPad is if you could adjust the sensitivity or the delay time for clicking on it.*" (V3).

(a) (b)

Figure 3. Two examples of slings used to support (a) an arm and (b) legs. The setup in (a) allows for horizontal movement but limited vertical access to the screen.

Mouth sticks. Adapted mouth sticks were used in 7 videos (3 unique users). In one case, the user had attached a commercial capacitive stylus to her mouth stick, while the other two examples were homemade (*e.g.*, Figure 2b). The videos demonstrate a range of interactions with both iPhones and iPads: tapping, dragging and scrolling. One user was quite pleased with the combination of mouth stick and iPad, noting that: "*There's just a couple of limitations for me personally. That's a couple of…2-finger, 3-finger gestures, but other than that…I can do so much.*" (V22).

Stylus. Finally, a stylus was held in the hand in four videos (3 unique users). Two users held the stylus like a regular pen with the iPad positioned at a slight vertical angle. The third user interacted with the iPad mounted to the front of her power chair and used an extra long stylus that appeared to extend her reach to be able to tap on the iPad screen.

Other Interaction Context

Arm and leg slings. In 13% of videos, children with severely limited motor control used slings to stabilize their arms or legs and enable direct touch interaction (Figure 3). Most often the device was set up vertically, allowing the user to approach it from the side. While this setup allows for horizontal movement, the child cannot reach higher or lower; correspondingly, the apps used in these videos tended to be children's games that did not require precise touches. One mom told her young daughter with SMA: "*Stretch [your finger] out! ... You gotta stretch it out really far so it works, all right now swing it.*" (V27), indicating therapeutic use of the touch device to improve reach.

User Posture. People in the videos used the touchscreen devices while they themselves were in a range of positions, including seated (71% of videos), lying down (17%), and reclining, *e.g.*, in an adjustable wheelchair (8%). All users who were fully lying down were babies or small children who may have had trouble sitting up either due to their age or their disability. However, they were still able to interact with the touchscreen device if it was propped up vertically.

The range of interaction methods that we observed points to the diversity of this user group in terms of abilities and accessibility needs. While we observed many successful interactions, challenges still exist. We return to potential improvements in the Discussion section.

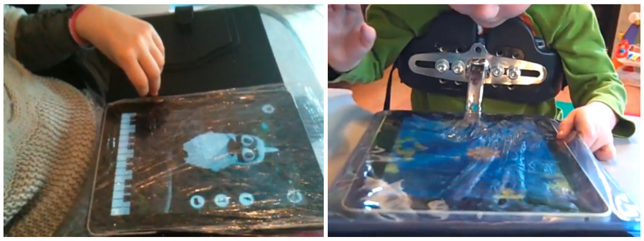


Figure 4. Examples of plastic bags being as screen protectors.

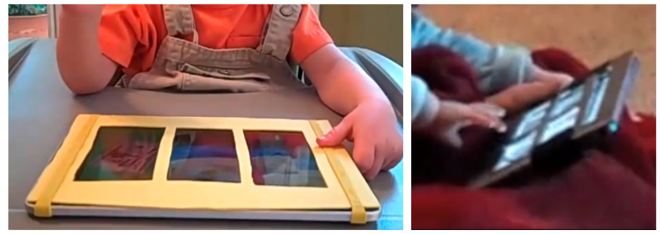


Figure 5. Examples of homemade physical barriers to guide accurate pointing. The left one uses foam and rubber bracelets.

Physical Device Adaptations

We were interested in how users had adapted the touchscreen device to accommodate their own abilities. In addition to commercial adaptations such as using a stand for the device, we observed a smaller number of do-it-yourself modifications (DIY). We discuss these DIY adaptations in detail, as well as device positioning methods.

Device position. The videos showed devices oriented in a variety of positions. Most often, the device was either lying flat on a surface (42% of videos), typically a table, a wheelchair tray, the floor, or the user's lap, or it was standing vertically (41%), typically leaning against something or held by another user. In 11 videos (6%), the touchscreen device was hard-mounted to an arm or stand that was affixed to the user's wheelchair. Handheld use was seen in only 15 videos (8%), perhaps unsurprising given users' physical disabilities and the fact that the iPad, the most common device type in our videos, is not necessarily intended for handheld use. Touchscreen device position was related to user position, and both were related to disability and interaction method, pointing to a concrete set of use cases that users with motor impairments find successful.

Screen protectors. Plastic zip-top baggies used as screen protectors (Figure 4) were seen in 8 videos, 7 of which were uploaded by the same user, a physical therapist who used the iPad with multiple children. One child licked the screen, demonstrating the need for such a protector. The plastic bag does not interrupt the conductivity of the screen, so users can still interact successfully.

Physical barriers. We also observed DIY physical barriers. Previous work on stylus-based touchscreen interaction for people with motor impairments has demonstrated the value of hard physical edges in guiding users [8,33]. However, the bezels of modern touchscreen devices are flush with the screen, leaving no physical edges for stabilizing the touch point. Interestingly, two YouTube users uploaded a total of four videos that showed homemade physical guides for the iPad (Figure 5). These guides were designed to be paired with specific apps, and, as such, included openings to match the layout of buttons in the app. While these examples support direct touch interaction for children, they could also be useful for intermediate devices such as head sticks.

Positive and Negative Sentiment

While a sense of empowerment permeated many of the videos and the survey responses, a small number of videos and responses included either extremely positive or consistently negative sentiment toward the touchscreen device. One user, an adult female with a spinal cord injury resulting in quadriplegia, stated in her video, "*My main concern was if I would be able to use it given the fact that-it's designed to be used with your hands.*" (V22). After describing how she uses a special capacitive stylus attached to her mouth stick, she says, "*It gives me the freedom and independence to…do a lot of things on my own, which is great.*" (V22). The user we mentioned who uses the iPhone and iPad with his feet cited these technologies as enabling his own independence: "*I'm running the company and basically being independent.*" (V72).

Positive sentiment was also expressed in many videos (and surveys) by parents of children with severe physical impairments who are growing up using these devices. The iPad especially was seen as an affordable tool that gives their children the ability to communicate and play, in some cases expressing that this was occurring for the first time and in ways not previously possible. The uploader of one video wrote of her child in the video description: "*He may not be able to talk yet, or walk, but this little guy…loves playing his piano and he loves musical apps on the iPad.*" (V34). Another mom stated in the video description, "*When [I] saw this [I] was so amazed never in my life did [I] think she could ever be as good as she is.*" (V124). One of our survey participants indicated that her child has "*no other way to communicate…*" (P4), and another wrote that the iPad enabled her daughter to "*verbalize things others had to guess at previously.*" (P2). Another indicated "*the iPad gives [my son] the ability for voice*." (P6). Dedicated AAC devices are often expensive and inflexible, so these parents used the iPad as an affordable, multi-purpose AAC device.

In contrast to these positive examples, six videos seemed to have been recorded for the purpose of demonstrating how a touchscreen device was *not* accessible for that user. For example, one user, a teen male with cerebral palsy, made a video entitled "Why Touchscreens Scare Me." In the video, he comments that touchscreens require interaction via hands, and he is unable to control his hands enough to even touch the device (V250). Another user, an adult male with a congenital amputation, uploaded 4 videos, all of which primarily showcase how it is difficult or impossible for him to use the iPad or iPhone. The hand prosthesis he wears does not have a conductive contact point, and unlocking the device with his left hand is difficult because of the awkward left-to-right swipe required (Figure 1a).

Survey Data

Survey respondents told us they are using mainstream touchscreen devices for a variety of applications, such as books, music, entertainment, games, and education. Interestingly, 6 users who responded to our survey had never heard of the iOS feature known as AssistiveTouch, which allows entry of multitouch gestures with one finger. Only 3 indicated they used it "sometimes" or "often". (We saw no one using this feature in our video dataset.)

A strong theme in our survey responses was that touchscreen technology is perceived as being particularly advantageous or suited for people with physical impairments. Seven of the 12 survey participants indicated that they had initially tried the device in their video because they had "heard it was useful for people with disabilities or with my disability." One reason touchscreens may be helpful to users with motor impairments is that the amount of physical strength needed to interact is less than with physical objects. One respondent mentioned: "*I don't need the physical strength to press down each of the keys that I would on a physical piano*" (P6). Another indicated that:

> "*Due to severe and pervasive physical weakness …, [my son] is not able to interact with most of the typical age appropriate toys. The iPad allows him to play stimulating games and fun learning apps, which he otherwise would not be able to do.*" (P1).

Survey respondents indicated that the technology still needs to improve before it can meet all of their needs. For example, all but one of the survey respondents customized the device in some way for their own use. Only one (P1) of the survey participants was able to use the device by holding it; 7 indicated they had to lay it flat on a table and use it that way, and 6 indicated they used a stand or mounting rack with the device. One respondent stated: "*Correct positioning of [the user's] hand and arm were key.*" (P3). Confirming our observations from the videos, limited arm mobility, finger control, and muscle control created challenges for users to interact with a touchscreen device like an iPad without accidentally activating the screen, as one respondent mentioned: "*This [an arm sleeve] lets me slide my hand around the touchscreen surface without activating it. Then I can use my index finger and thumb for interacting with the screen.*" (P8). However, one respondent indicated that she hasn't "*found a really good set up for when I am using the iPad on my own*" (P6).

The survey respondents indicated that many of the basic functions of the touchscreen devices were quite challenging. Nine people noted that using the device's hardware buttons is difficult, 6 people indicated typing or entering text was difficult, and 5 people indicated that both selecting text and onscreen items or browsing the web and other documents were difficult. Survey participants indicated that all such difficulties were caused by a lack of fine or gross motor control of one's arms or fingers. In fact, one user (P9) specifically stated that he preferred using the iPhone to the iPad because it was smaller and easier to reach the whole screen. Every respondent except P9 had continued to use the touchscreen device since the video.

DISCUSSION

Our study found evidence that users with motor impairments are frequently using mobile touchscreen devices in their daily lives. Many users were able to interact with direct touch, using their fingers or hands with varying degrees of success. Users frequently customized the devices or their configurations to work better for their particular needs. For example, we saw a range of physical device adaptations such as homemade guides and barriers, pointing devices, or screen protectors. We also saw a range of use cases, from interaction with one's feet or nose to interacting while lying down or using arm or leg slings for support.

Rather than finding a touch-oriented interaction completely inaccessible, motor-impaired users in our videos and in our survey responses commented that these devices empower them to be more independent and do things they otherwise could not. Still, there is significant room for improvement in accessibility, ranging from tailored interaction styles for those with limited mobility, to support for indirect interaction methods, to personalization of interaction that can adapt over time. We discuss the design implications we believe emerge from this work in the following section.

Design Implications

Several design suggestions came directly from user comments in videos and survey responses. For example, one user (a head stick user) suggested supporting *adaptations for the sensitivity of the device*, because he had difficulty tapping as quickly as needed by the device. A settings option or even a feature that could learn this over time would be helpful for users with motor impairments.

Alternative support for multitouch interaction for motor impaired users is also required. One user (a mouth stick user) specifically mentioned being unable to perform 2-finger and 3-finger gestures. We did not see any instances of pinch-to-zoom or other multitouch gestures in the videos. The built-in accessibility feature on iOS devices called AssistiveTouch could support these interactions. However, this feature was not used in a single video and only 3 survey respondents had ever used it. One survey respondent stated that "*It's not too intuitive.*" (P12), whereas another simply stated that it was "*not necessary so far*" (P11). More work is needed to understand why this feature does not succeed and how we might design improved multitouch support.

We suggest support for *constant touch habituation*, in which long duration touches that do not change or move for a period of time would be ignored by the system. Highlighting this need, one user's arm was continuously activating objects onscreen as she attempted to interact with the device, while another mentioned that he used an arm sleeve to mitigate the problem of accidental interactions.

The DIY *physical guides* we saw in some of the videos were inspiring. Users had made them out of different materials to keep from hitting other buttons on the screen, but these materials were often not very sturdy (*e.g.*, paper, cardboard). Commercial products such as the TouchFire[4] physical keyboard overlay for the iPad are available for touchscreen text entry; perhaps similar products would be useful if standardized for various apps.

Many of the videos in our dataset involved children with disabilities, some of whom had severely limited mobility and were unable to lift their head to focus on the screen. In one video, a young child diagnosed with Krabbe disease was using a xylophone app without looking, moving her fingers slightly over the screen to make sounds and music. The narrator says with clear pride, "*You gonna play music? Yeah! Good job!...Do it again…play more music.*" (V149). This population presents an interesting design opportunity: how can we design apps that engage these children's minds but do not necessarily require fine motor control?

Reflecting on the Study Method

We found user-generated YouTube videos combined with uploader surveys to be a rich source of data on interaction in the wild. While our focus has been YouTube, our approach could be applied to other sources of user-generated content, such as blogs or photo websites. To guide future work, we summarize lessons learned.

A primary challenge was to develop an effective search strategy. The goal of our work was to look through users' own lenses on their daily interactions with technology, and, as such, many videos that fit this profile were labeled with generic labels denoting daily activities, such as "Dane and his iPad". We had initially attempted (and failed) to search with only a small number of keywords as other studies have done [4,26]. Thus, we adopted the systematic approach described in the paper, resulting in 480 search term combinations. It was also difficult to find videos for every type of motor impairment that we explored. For example, we found no hits for the search term "Parkinson's touchscreen" even though Parkinson's disease is a fairly common condition causing motor impairment. Inability to find these videos could have been due to a combination of factors: poor labeling, disinterest in making videos by Parkinson's users, or an actual lack of use of touchscreen devices by them.

Our method also has a sampling bias, in that it only includes users and/or caregivers who are willing and able to record and upload videos to YouTube. As such, there was little representation from users who cannot use a touchscreen at all. The method is also limited to use cases and activities that users actually wish to record. For example, users may not want to record themselves in bed with the device or using social networking apps due to privacy reasons. We cannot know the frequency of such use cases in users' overall behavior, nor the adaptations required to support them.

Soliciting survey responses from people who had uploaded videos worked well to complement the video data. We were reasonably successful, with a 17% response rate. Still, as with most survey-based research, self-selection and response bias due to the minority sample could have impacted our findings. An additional challenge relevant to future work in this area was that, in many cases, a third person completed the survey on the user's behalf, either because the primary user was a child or because it was difficult for the primary user to do. As such, there were instances where the responses ambiguously referred to "I". Careful survey design is critical for mitigating this issue.

Using video data as the primary source of data meant that we had very little context with which to resolve uncertainty. For many dimensions, we included an "unable to determine" code, to prevent overconfidence in the findings. This work represents one slice of interaction styles, physical adaptations, and attitudes toward touchscreen devices. Ideally, we would triangulate the data we obtained here with data from other methods, such as in-person interviews, diary studies, ethnographies, and so on. We had also hoped to include a systematic analysis of text comments for each video as was done in prior work [4], but a majority of videos in our sample had few or no comments.

Finally, we aggregated the data based on videos rather than on individual users, an approach that could bias results toward users who had uploaded many videos. Mitigating this issue, the median number of videos uploaded per user was 1, and the 25 videos uploaded by the most prolific user actually showed many different individuals. We attempted to make clear cases where one or a few uploaders had a substantial effect on the counts (*e.g.*, screen protectors). Moreover, multiple videos by the same user were sometimes individually valuable in depicting different issues due to increased experience with the device.

CONCLUSION

We presented an analysis of 187 non-commercial videos uploaded to YouTube that depicted a person with a physical disability interacting with a mobile touchscreen device. Our method included (1) coding the videos along a range of subjective and objective dimensions, and (2) inviting the YouTube users to complete a survey on their opinions and use of touchscreen technology in their daily lives. Our study builds on previous work [4,26] to demonstrate the effectiveness of using publicly available, user-generated content to inform input and interaction design. We found evidence that users with a range of physical disabilities are adopting touchscreen devices, but often in unexpected or customized configurations. Based on this data, we presented design implications to improve touchscreen usability for people with physical impairments. Despite existing accessibility challenges, mainstream touchscreen

[4] http://www.touchfire.com/

devices have enormous potential as a primary means of technology interaction for people with physical disabilities.

ACKNOWLEDGMENTS

This research was funded by a Google Faculty Research Award. We also thank Jon Froehlich for his comments.

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