

Coping Strategies of People with Low Vision for Touch Input: A Lead-in Study

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Abstract We present in this paper empirical findings from a lead-in study addressing the coping strategies adopted by people with low vision to increase the effectiveness of their touch input performance for standard target acquisition tasks on mobile devices. We evaluate the touch input performance of five people with various eye conditions by examining the accuracy and time duration of their touches and the coping strategies employed during touch input. Although our lead-in study already reveals many interesting strategies, such as specific adjustments of the mobile device or taking more time to touch targets, we also point to the need of more investigations to further understand and thoroughly catalogue the coping skills of people with low vision for touch input on mobile devices.

Keywords: low vision; coping strategy; touch input; mobile computing; e-Health; visual impairments; touch performance.

I. INTRODUCTION

The recent years have seen a proliferation of e-Health apps on various devices and for various user categories [1-11], accompanied by an increasing interest from people of all age groups to monitor their life style and daily activity patterns [12]. Besides constantly monitoring and delivering information about their users' health status and performance, e-Health apps also encourage positive changes in life style, such as engaging in more physical activities [16]. Among the "10 essential e's in e-Health" [13], efficiency, enhancing quality of care, empowerment, and equity characterize probably the best the accessibility requirements of e-Health applications to address users with all abilities. To this end, previous work has focused on applications and protocols to implement e-Health services for people with motor [1], cognitive [2,3], or visual impairments [4,5]. The prevalence of mobile devices has led to an even larger proliferation of and more interest for health apps [6,7], with over 100,000 applications currently available on the market to choose from [12]. While some apps target specific consumer and medical devices, such as smart bands [8-11], body-worn [14], or implantable devices [15], the large majority of mobile e-Health apps run on general-purpose smart devices, such as smartphones and smart watches. However, interacting with today's prevalent smart devices, *i.e.*, tablets, smartphones, and smart watches, is achieved with touch input which,

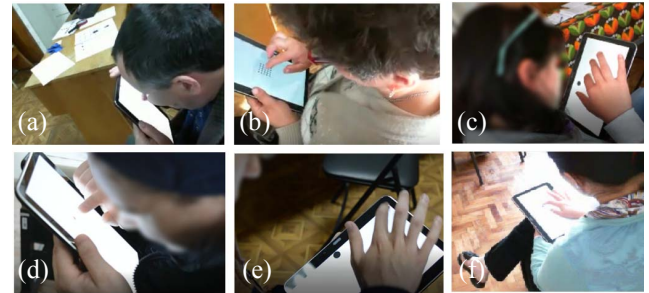


Figure 1. People with low vision (a-e) adopt various coping strategies to touch targets on mobile devices, compared to people without visual impairments (f). In this work, we discuss such strategies in relation to the specifics of several pathological eye conditions.

because of its strong reliance on visual and graphical elements, is little suited to people with low vision [17,18].

Effective touch input is the result of complex mechanisms orchestrated by processes running in the brain, which create a motor action plan to reach a target and then fine-tune the motor plan continuously with the help of visual information until the target is reached [19]. However, visual disturbances caused by low vision, such as blurred vision, blind spots in the visual field, incorrect perception of color, or eye fixation problems cause a poor quality of the visual information available to the brain to choreograph an efficient motor plan. After all, the quality of the experience of a visually-demanding interface cannot be separated from the extent to which it complies with the users' visual abilities [20]. In the lack of proper assistive solutions for touch input, people with low vision adopt various strategies to interact with mobile touchscreen devices [17,18].

In this work, we focus on the coping strategies that people with low vision develop to use mobile devices effectively. We discuss the results of a lead-in study, in which five people with various eye conditions performed repeated target acquisition tasks on a mobile device. Our results reveal many interesting findings, such as people with low vision perform various device adjustments or take more time to touch targets, and we show the need for more investigations to catalogue and understand coping skills for low vision and mobile touch input.

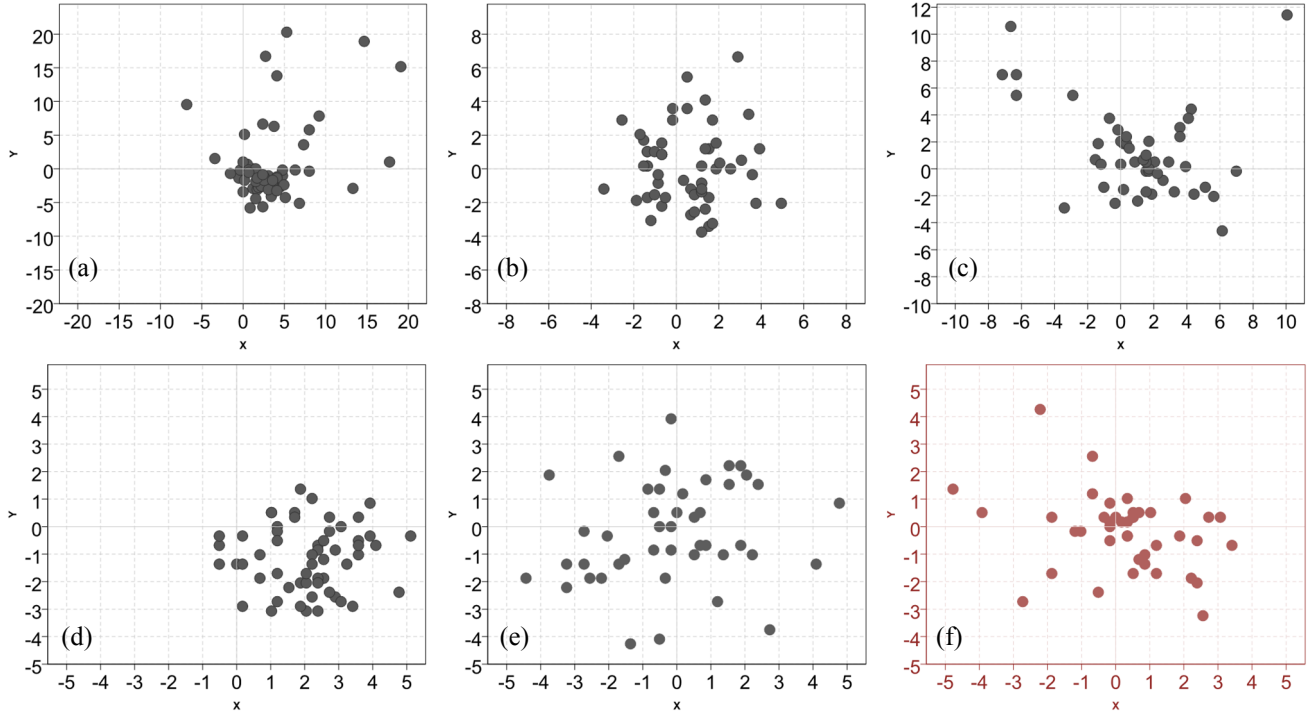


Figure 2. Touch points produced by five people with low vision (a-e) and one person without visual impairments (f) during several touch target acquisition trials. Note: the target is always centered at location (0, 0) in these graphs.

II. RELATED WORK

Two types of factors influence users' performance with touchscreen devices: the parameters of human vision and eye-hand coordination (*user-centric* factors) and the visual appearance of targets, such as target size, location, animation speed, and padding (*device-centric* factors).

From the user-centric perspective, touch performance is related to the capacity of the visual system to acquire a high quality image of the target and the ability of the motor system to precisely coordinate the hand and fingers toward the target. Three main approaches have emerged in studying human vision: neurobiological, cognitive, and neurocognitive. Following the neurobiological approach, Hubel and Wiesel [21] and Crick [22] described the process of transforming the visible spectrum of electromagnetic waves into a unified internal image with the anatomo-physiological components of the vision system. Cognitive researchers [23,24] have developed a computational view of the human vision system according to which visual perception is organized in modular stages that transform the 2D retinal matrix input into a 3D internal model of the visual reality. These two perspectives were connected by neurocognitive models that map the input-output cognitive process of vision on neurobiological structures. Kosllyn [25] proposed six neurocognitive structures that explain the bottom-up and top-down processes involved in human vision. Hand and finger coordination ability was conceptualized by the cybernetic model of eye-hand coordination of Helsen *et al.* [19]: the visual images obtained by the brain are used to fine-tune the finger muscles until the target is reached.

Prior work also addressed device-centric factors. For instance, Henze *et al.* [26] revealed that the accuracy of target acquisition is related to the size of the target. Also, the importance of target location was highlighted by Avrahami [27] and Henze *et al.* [26]. Avrahami [27] showed that targets near the edges of the screen take more time to acquire, while the empirical results of Henze *et al.* [26] showed that targets in the center of the screen are acquired more accurately by users.

III. OBSERVED TOUCH INPUT AND COPING SKILLS FOR PEOPLE WITH LOW VISION

In this section, we discuss the touch input behavior of five people with low vision during a touch target acquisition task on a mobile device. Participants' ages varied between 19 and 53 years ($M = 41.1$ years, $SD = 14.7$). Participants had various eye conditions, such as congenital nystagmus, macular degeneration, or optic nerve atrophy, which were accompanied by hyperopia and myopia; see Table 1 for an overview and the next section for a brief description of these conditions.

Participant	Eye condition
P ₁	Congenital nystagmus and high myopia
P ₂	Macular degeneration, optic nerve atrophy, hyperopia
P ₃	Chorioretinal degeneration and hyperopia
P ₄	Myopia, strabismus, and macular choroiditis
P ₅	Chorioretinal degeneration, cataract, and myopia

Table 1. Eye conditions of the five participants in our study.

Touch targets of various sizes (between 3 mm and 17 mm in diameter) were shown in the center of the tablet and participants were instructed to acquire them as accurately and fast as possible, knowing that a touch outside of a target's

	BRINGING THE SCREEN CLOSER TO THE EYES	HEAD PRONE TO SCREEN	DEVICE ADJUSTME NTS	SCANNING THE SCREEN	LONGER TOUCH TIME	LONGER SEARCH TIME	CHANGING HAND POSTURES	TENSE BODY POSTURE	RUBBING THE EYES	BODY NERVOUS NESS	TOTAL
A	1	1	1	1				1			5
B	2	2	2	1		1		1			9
C			1		1		1	1			4
D			1		1		1	1			4
E	1	1	2		1		1	1	1	1	9
F	1	1	1					1	1	1	6
G	1	1	1			1		1			5
H	1	1	1			1		1			5
I								1			1
TOTAL	7	7	10	2	3	3	3	9	2	2	

Table 2. Distribution of coping strategies function of the eye condition: **A.** Congenital nystagmus, **B.** Myopia, **C.** Macular degeneration, **D.** Optic nerve atrophy, **E.** Hiperopya, **F.** Chorioretinal degeneration, **G.** Strabismus, **H.** Macular chorioiditis, **I.** Cataract.

boundary would result in a failed trial. We used a 10.1-inch Samsung Galaxy Tab4 tablet with a display resolution of 1280×800 pixels and 149 ppi.

In the following, we detail our participants' eye conditions, present their coping strategies adopted during touch input, and we summarize their touch input performance reflected by the following three objective measures:

- Success Rate, the percent of targets successfully acquired with touches within their boundaries.
- Offset Distance, computed as the Euclidean distance, in millimeters, between the finger's (x, y) location at lift-off and the target's center.
- Touch Time, the duration of a touch trial, in milliseconds, while the finger was in contact with the screen.

To provide the reader with a comparison basis for the results that we report in this section, a person without visual impairments achieved a 95% success rate touching targets at 1.7 mm from their centers ($SD = 1.3$ mm), with an average touch time of 95.7 ms ($SD = 60.0$ ms); see Figure 2f.

A. Overview of eye conditions

Myopia is the difficulty in seeing clearly objects from a distance and *severe myopia* is defined as -6.00 diopters or more. *Nystagmus* represents rapid, involuntary movements of the eyes determining reduced visual acuity. *Hyperopia* is the difficulty in seeing clearly objects that are close. When *the optic nerve*, responsible for transmitting impulses from the retina to the brain, is affected, the result is vision loss that can manifest as acuity, color, contrast, or peripheral vision loss. *Age-related macular degeneration* (AMD) is a condition in which the macula suffered damages causing a blurred area near the center of vision. *Chorioretinal degeneration* refers to a pigment disruption on eye fundus leading to the blurring of the center of the vision field. *Strabismus* (abnormal alignment of the eyes) affects binocular vision because the eyes cannot be directed simultaneously to the same fixation point, which leads to symptoms of double vision and eye strain. *Cataract* is the general term used to denote the opacification of the eye's crystalline lens, which leads to decreased vision [20].

B. Summary of touch input performance

We found that offset distances for participants with low vision varied between 0.17 mm and 151.4 mm, with an (5%-trimmed) average of 7.61 mm ($SD = 25.3$ mm); see Figures 2a-e. This average value is 4.5 times larger than the one observed in our control condition (*i.e.*, the participant without visual impairments), who acquired targets at an offset distance of 1.7 mm on average. We observed that some participants with low vision were consistent in touching targets at specific locations relative to their centers (Figures 2a and 2d), while aiming for other locations caused larger offset distances (see Figure 1a). We also found that the average success rates varied between 42% and 84% with a (5%-trimmed) mean of 56% ($SD = 50\%$). This result is 41% smaller than the 95% success rate achieved by our participant without visual impairments. Touch times varied between 28 ms and 893 ms for participants with low vision, with an (5%-trimmed) average of 132.2 ms ($SD = 109.1$ ms), representing 38% more time than in our control condition.

C. Coping strategies for touch input

In the following, we discuss the most frequent coping strategies that we observed for our participants; see Table 2 for a summary of our results function of the eye condition.

Optimizing the physical distance between the eyes and the screen. One of the most frequent coping strategies used by our participants ($N = 3$) during touch input was to bring the screen at a comfortable distance close to their eyes, followed by adopting a prone position of the head with respect to the screen to stay focus especially for challenging (*i.e.*, small and very small) targets; see Figure 1a for an example. The goal of this strategy was to reduce the distance between the screen and the retina which, according to the neurobiological model, facilitates accommodative response for the eye [21].

Device adjustments. The "optimizing distance" strategy was integrated by $N = 4$ participants with specific device adjustments and maneuvering to bring targets in the center of their visual field in the so-called process of "fovealisation" [28]. For one of our participants, the "device adjustment"

strategy was implemented with device movements toward the finger to meet the finger halfway. We also noticed several head movements that served the fovealisation process in the form of continuous scanning of the screen in the search for the target ($N = 1$). Several hand postures were employed to foster a better, firm grasp of the device ($N = 1$); see Figure 1b.

Comfortable touch times for confident touch. We observed a visuomotor coping strategy employed by $N = 4$ participants that took more time during visual search and target acquisition, which served to unconsciously activate various compensatory strategies at different neurobiological levels, such as (1) the fovealisation process implemented with extra saccadic eye movements [25], (2) activating the look-up structure and top-down search processes [25], (3) running cognitive skills such as filtering and zooming [24], and (4) activating feedback to fine-tune the hand movement [19].

Maximizing the capacity to perceive visual information. We observed several direct consequences of participants' eye conditions on their body behavior, such as rubbing their eyes, which were accompanied by expressions of body nervousness, especially when participants had to acquire small targets or near the end of the study. In addition to these incidental body movements, the posture of the body was generally tense for all participants with low vision. We interpret these observations as the psychological signature of the conscious pathway of visual processing, acting on the effects of poor visual information or of the fatigue of the visual analyzer.

IV. CONCLUSION

In this work, we presented the results of a lead-in study regarding the coping strategies employed by five people with low vision during touch input on a mobile device. Our observations highlight tense body conditions adopted by people with low vision, numerous adjustments of the device, hand posture and head positions, and contour a time-based strategy to deal effectively with the task to accomplish. Future work will extend our observations on a larger sample of participants in the attempt to categorize a wider range of coping strategies for touch input and low vision.

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