Applicability of Smooth-Pursuit Based Gaze Interaction for Older Users

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In an experiment with 75 older users (55-79 years), the applicability of smooth-pursuit based gaze interaction was investigated. Three different velocities of object movement were tested regarding two different interfaces: one for entering digits and one for entering letters. Participants were presented with an audio sequence of numbers or words, respectively. The sequence was first read in full, and then with each number or word separately, to allow for direct input after each piece of given information. The results showed that entering digits was reliable and relatively quick (v1 = 1.2% errors & 6.6 s/number, v2 = 6.6% errors & 8.5 s/number, v3: 5.5% errors & 9.8s/number), while entering sentences was slower and more prone to error (v1 = 5.0% errors & 8.1s/letter, v2 = 6.6% errors & 26.9 s/letter, v3 = 30.4% errors & 11.8 s/letter). The results suggest that older users are capable of using smooth pursuits for gaze interaction. The number of elements involved in the selection process should be limited to allow for robust selection. Furthermore, the participants stated that the technology was easy to learn and comfortable to use, thus indicating a general acceptance for this interaction-based technology.

Keywords: smooth pursuit, eye tracking, older users, gaze speller, gaze interaction

Introduction

For a long time, gaze interaction applications were primarily designed to support people with severe motor impairment. In recent years, efforts were made to introduce the use of eye movements as a novel input modality to a broader spectrum of the public. Due to the availability of low cost eye tracking systems, reduced calibration requirements and methodological advances, gaze interaction has become an alternative to traditional interaction techniques. However, current applications are most often tested with a young and healthy sample of a population. With respect to demographic changes, it is necessary to include older users in the design and testing of gaze interaction applications.

Aging is associated with physiological and anatomical changes of the eye that often result in functional deteriorations of eyesight and is reflected in e.g. contrast sensitivity, visual acuity and the ability to differentiate color (Holz et al., 1996). Additionally, age related changes are often accompanied with the use of glasses. In Germany, 73% of 45-59 year olds and 92% of seniors aged 60 years and older wear corrective glasses (Allensbach, 2014), which can distort the visual image of the eye and result in inaccuracies regarding positional tracking. Smooth pursuit approaches provide a relatively robust option for planned or spontaneous gaze interaction in varying settings (Holmqvist et al., 2011, Vidal et al., 2013). This study was designed as a 'proof of concept' to see if smooth-pursuit based gaze interaction was feasible (e.g. Lutz, et al., 2014; Cymek, et al., 2014) with participants of older age. Further optimal speeds of interaction as well as a maximum number of items were explored; this was done by testing three speed levels in two designs, each with different numbers of items from which to select.

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Materials

Based on designs by Blankertz et al. (2006) and the SMOOVS speller introduced by Lutz et al. (2014), an arrangement that displayed either ten digits or 36 characters in a hexagonal layout was implemented in Python. Groups of items were programmed to move from the center of the screen to the peripheral of the hexagonal shape, where they are to be split up to move individually. The detection algorithm was based on two criteria: the length of the eye movement had to lie within an interval of one half and double the length of the current objects' movement while, simultaneously, an angle criterion for the gaze vector had to be met. The size of the angle criterion during the second movement phase depended on the number of items shown and was thus smaller in the text condition (60° - α) compared to the digit condition (180° – α). A hysteresis ("resting area") area with a diameter of 75px around the midpoint of the screen prevented permanent initiation of group movement. A remote eye-tracker sampling at 30Hz was used.

Methods

Overall 75 participants were recruited for the experiment (39 female) ranging from 54 to 80 years of age. A six-point calibration was performed. Participants were asked to enter a

ten digit PIN and a 46-letter text in form of a holoalphabetic sentence, using a smooth pursuit based gaze interaction interface on a 24" display. All participants interacted with both spellers. Half the participants were randomly assigned to begin with the PIN speller and the other half started with the text speller. For each speller, a training trial with an intermediate speed was initiated, followed by three trials with different object movement speeds (slow (~7.5°/s), medium (~8.7°/s), fast (~9.9°/s)) in a randomized trial order and with pauses in between. Dependent variables were the number of errors, number of corrections, input duration as well as subjective measures of the comfort of use and the learnability. The experiment lasted for two hours and participants were compensated with 40 euros.

Results

Due to tracking problems discussed below, only 51 participants completed the entire experiment. 63% of these participants wore corrective eyeglasses.

PIN Speller: Overall the error rate for the PIN speller was low (low speed 1.2%, medium speed 0.8% and high speed 5.5%). The mean number of corrections per single digit was similar for the low and medium speed condition but almost doubled in the high speed condition (Table 1). A one-factorial ANOVA revealed a significant effect of object movement speed on the number of corrections, $F(2, 100)= 3.4$, $p> .05$. On average, the input of a number took 6.6s in the low speed, 8.5s in the medium speed and 9.8s in the high speed condition. Every input of a number consisted of two consecutive smooth pursuit movements. Questionnaire data suggested that the PIN entry was easy to learn and comfortable to use, but both measures decreased with increasing object movement speed.

Text Speller: The averaged error rates for the text speller were higher compared to the PIN speller (low speed: 5.0%, medium speed 6.6% and high speed 26.9%). The mean number of corrections per single letter increased with higher object movement speed (Table 1) resulting in a significant main effect, $F(1.68, 82.38)= 33.74$, $p< .01$. On average, the input of a character took 8.1s in the low speed, 9.5s in the medium speed and 11.8s in the high speed condition. Questionnaire results showed that the text speller was slightly more difficult to learn than the PIN speller. The comfort of use decreased as a function of increasing object movement speed.

Table 1. Mean number of corrections per single item try

Speed	Speller condition	
	PIN *M (SD)*	Text *M (SD)*
Slow (7.5°/s)	.02 (.06)	.11 (.11)
Medium (8.7°/s)	.02 (.05)	.17 (.14)
Fast (9.9°/s)	.05 (.08)	.30 (.21)

Discussion

The experiment and its results suggest that smooth-pursuit based gaze interaction is feasible for older users if speeds do not exceed ~8.7°/s and the number of items on the screen is limited. This conclusion can be made as the number of errors increased considerably in the highest speed condition and even more so for the text speller-- which employs 36 items as compared to the PIN entry, which features only 10 items.

The smooth-pursuit based approach as implemented here is relatively slow in comparison to spelling techniques that are intended to be used as a primary means of spelling, such as the Dasher (Ward et al., 2006). As this was a proof of concept, reliable detection was made a priority rather than speed of interaction.

For the text input test, more errors were made in comparison to the PIN entry test, which led to frequent corrections. This was expected, as the algorithm required the use of a large amount of items, resulting in a smaller angle deviation to detect the corresponding item.

The high number of incomplete data sets resulted from several reasons. First, some users had recently had surgical corrections regarding their vision in which case their eye movements could not be tracked correctly. The majority of incomplete data sets resulted from aborts initiated by subjects due to fatigue, as well as high error rates in the fastest speed-resulting in the highest speed condition being identified as not feasible for the use of gaze interaction in the context of older users.

Conclusion

The results confirm that people of higher age are able to use a smooth pursuit based interaction interface without prior knowledge or extensive training. However, speeds should not surpass ~8.7°/s and the number of items shown should be limited to benefit the older users' orientation as well as the robustness of the detection. Despite the comparative high number of corrections, participants perceived the interaction as pleasant to use, easy to learn and showed a general interest in using such input modalities either in public spaces or for recreational purposes.

Ethics and Conflict of Interest

The authors declare that the contents of the article are in agreement with the ethics described in http://biblio.unibe.ch/portale/elibrary/BOP/jemr/ethics.html and that there is no conflict of interest regarding the publication of this paper.

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