Gaze Interaction Based on Smooth Pursuit Eye Movements

Gaze interaction is an innovative form of human computer interaction. But, despite its potential, it is still not a widely-used interaction concept. The need for calibration, strenuousness for the eyes and the high number of unintended selections (Midas touch problem) are limiting the practicability of gaze interaction for everyday human computer interaction.

A **novel form of gaze interaction** based on smooth pursuit eye movements performed on moving display buttons is presented, which has great potential to overcome these aforementioned barriers.

The novel interaction was tested in two experiments using an exemplary PIN code entry scenario.

Experiment 1

This experiment aimed to

a) identify a **user friendly** button movement for the novel interaction concept.

b) collect data to develop a specific and **robust algorithm** that matches the gaze path to the trajectory of the moving buttons (even when the eye tracking system is calibrated on a third person, "external calibration").

Sample: *N* = 18; Age: *M* = 27.3, *SD* = 4.9

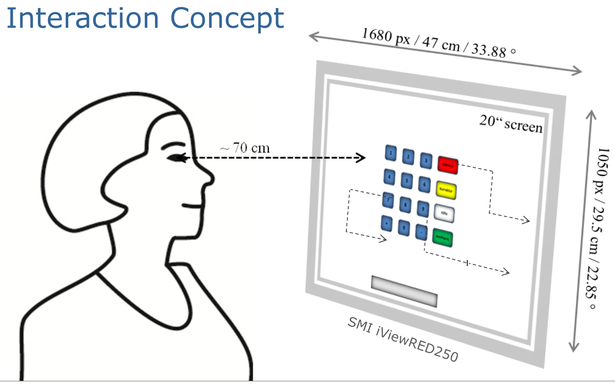
Design: within-subject design

IV: 1. Speed of moving buttons (slow, medium, fast)
2. Minimal button distance (small, large)
3. Calibration type (individual, external)

DV: 1. User friendliness
2. Gaze data (point of regard)

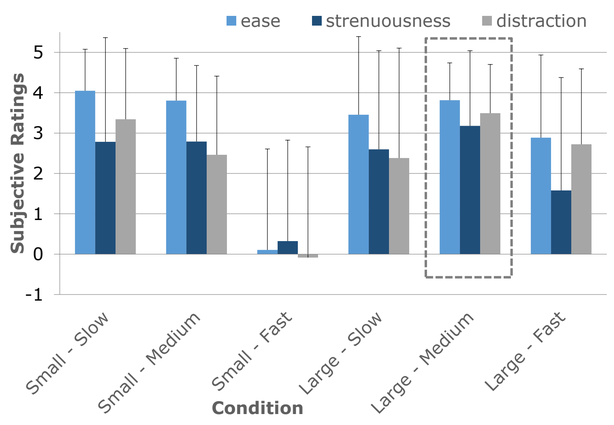
Task: Enter 1 PIN code per condition by visually following the movement of the numbers

Interaction Concept



Setup. The display shows the PIN interface with exemplary button movements (dashed lines) each composed of three single movements (up, down, left, right). Every object follows an unique path. The display was static for a moment so that participants could fixate the intended number before all objects started moving simultaneously.

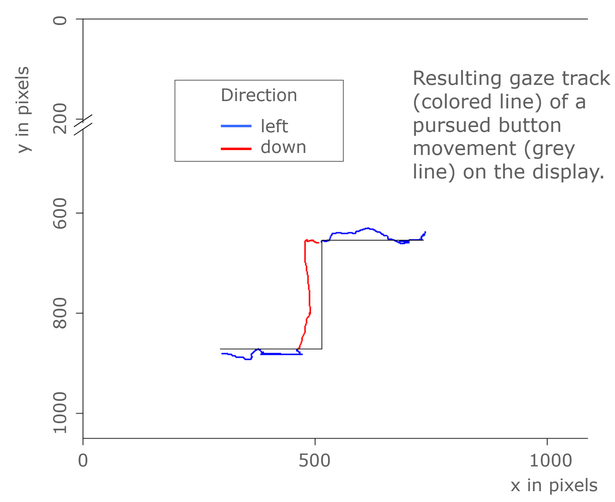
User Friendliness



Mean rating results of user friendliness. Slow speed was realized with 145 px/s, medium with 218 px/s, and fast with 436 px/s. Distance between the buttons was 4 px in the small and 39 px in the large distance condition. A -5 to +5 subjective rating scale was used, error bars indicate standard deviations, strenuousness and distraction are pictured with reversed polarity.

Overall ratings were highest in the medium speed (218 px/s) – large distance (39 px) condition.

Algorithmic Classification



Resulting gaze track (colored line) of a pursued button movement (grey line) on the display.

Only gaze data collected in the most user friendly condition was used for analysis and algorithm development.

The final classification is based on identifying the direction of each single eye movement first (up, down, left, right). Then, the pursued number is determined by combining the directions of 3 single eye movements and comparing them with the movement patterns of the numbers.

99.54% of all single eye movements (ind.: 99.31%; ext.: 100%) and accordingly 98.61% of all pursued numbers were correctly identified.

Experiment 2

This experiment aimed to

a) **validate** the developed **algorithm** in a truly interactive setup.

b) investigate the **user experience** of this novel way of interacting.

Sample: *N* = 24; Age: *M* = 30.3, *SD* = 7.2

Design: between-subject design

IV: 1. Calibration type (individual, external)

DV: 1. User experience questionnaire
2. Classification rate

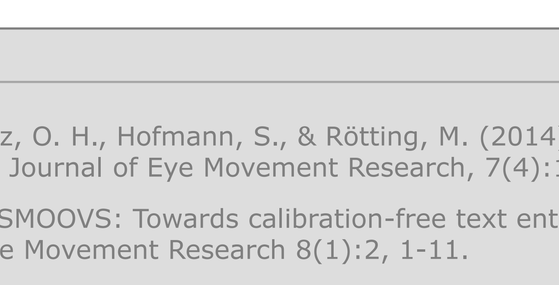
Task: Enter 3 PIN codes

Algorithm Validation

99.07% of all single eye movements (ind.: 99.54%; ext.: 98.61%) and accordingly 97.57% of all numbers were correctly classified on first input.

The remaining eye movements did not match a number movement pattern and therefore needed repeated input. In total, no false number was selected.

User Experience



Mean UEQ results for all subjects (-3 to 3 rating scale, error bars indicate standard deviations).

Efficiency was rated neutral (-0.8 to 0.8).

All other dimensions were rated positive (>0.8).

No group differences were found.

Classifying smooth pursuit eye movements for gaze interaction proved to be a **robust approach**. The implementation not only led to a **high percentage of correctly identified entries** and **eliminated** the typically high rate of **unintended selections** often associated with gaze interaction, but allows for the **omission of an individual calibration**. At the same time gaze interaction based on pursuing moving buttons is accompanied by **high user experience** ratings. With this intuitive, calibration free form of gaze interaction the often cited advantages of gaze interaction like freeing hands for other tasks and increasing hygiene due to contactless interaction are within reach. Therefore, e.g. surgeons in an operating theater may soon benefit from using their hands entirely for navigating instruments while controlling monitors by gaze.

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Cymek, D.H., Venjakob, A.C., Ruff, S., Lutz, O. H., Hofmann, S., & Rötting, M. (2014). Entering PIN codes by smooth pursuit eye movements. Journal of Eye Movement Research, 7(4):1, 1-11.

Lutz, O., Venjakob, A., & Ruff, S. (2015). SMOOVS: Towards calibration-free text entry by gaze using smooth pursuit movements. Journal of Eye Movement Research 8(1):2, 1-11.