Tampere University

Vision for Augmented Humans

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TAUCHI research center
Tampere University

My background

Eye Tracking Research at TAUCHI

1996

1999

2002

2004

2014

2015

2007

2017

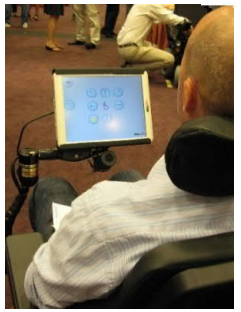
2019

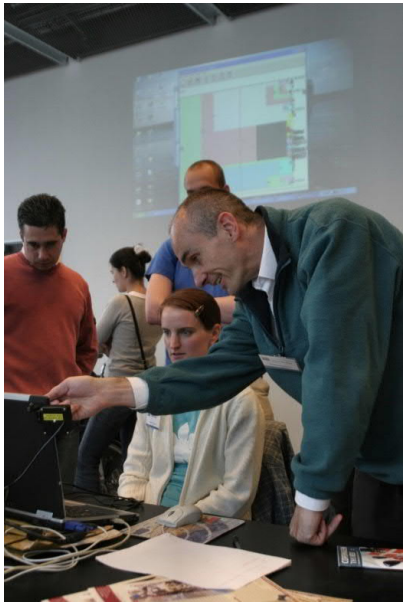
https://research.tuni.fi/virg/research/

My background

Gaze Interaction Work in COGAIN

www.cogain.org





Vision for Augmented Humans

https://en.wikipedia.org/wiki/Hugh_of_Saint-Cher

Human Augmentation

Human augmentation is an interdisciplinary field that addresses methods, technologies and their applications for enhancing sensing, action and/or cognitive abilities of a human. This is achieved through sensing and actuation technologies, fusion and fission of information, and artificial intelligence (AI) methods.

- *Augmented senses*
  (aka enhanced senses, extended senses)
- *Augmented action*
- *Augmented cognition*
  (aka enhanced cognition)

Raisamo et al. (IJHCS 2019)

Benefits of Gaze – Some Scenarios

Gaze indicates visual attention – e.g., Enhanced or extended viewing

Gaze conveys targets of interest – e.g., Gaze-aware life-logging

Gaze is natural for pointing – e.g., Enhanced hearing with selective mic

Gaze anticipates action – e.g., Indicating the target for augmented action

Gaze helps interpreting the user's state – e.g., Support for cognitive tasks

…

Human Augmentation by Gaze Interaction

TOPICS

- Application areas
- Eye movements in HCI
- Challenges and example solutions
- Lessons learned from Gaze in HCI and Assistive Technology
- Lessons learned from Gaze in Attentive Interfaces

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KEY DESIGN ISSUES

- Match the task with suitable eye movement type & technology
- Controllability & non-interfering design
- Feedback & visibility of system status
- Customizability & user-centered design
- Acceptability, social norms, and user experience

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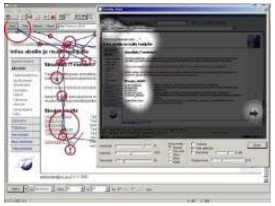
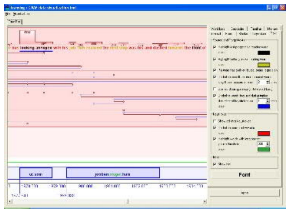
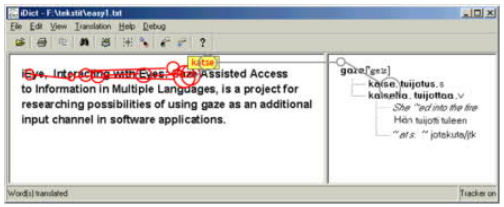
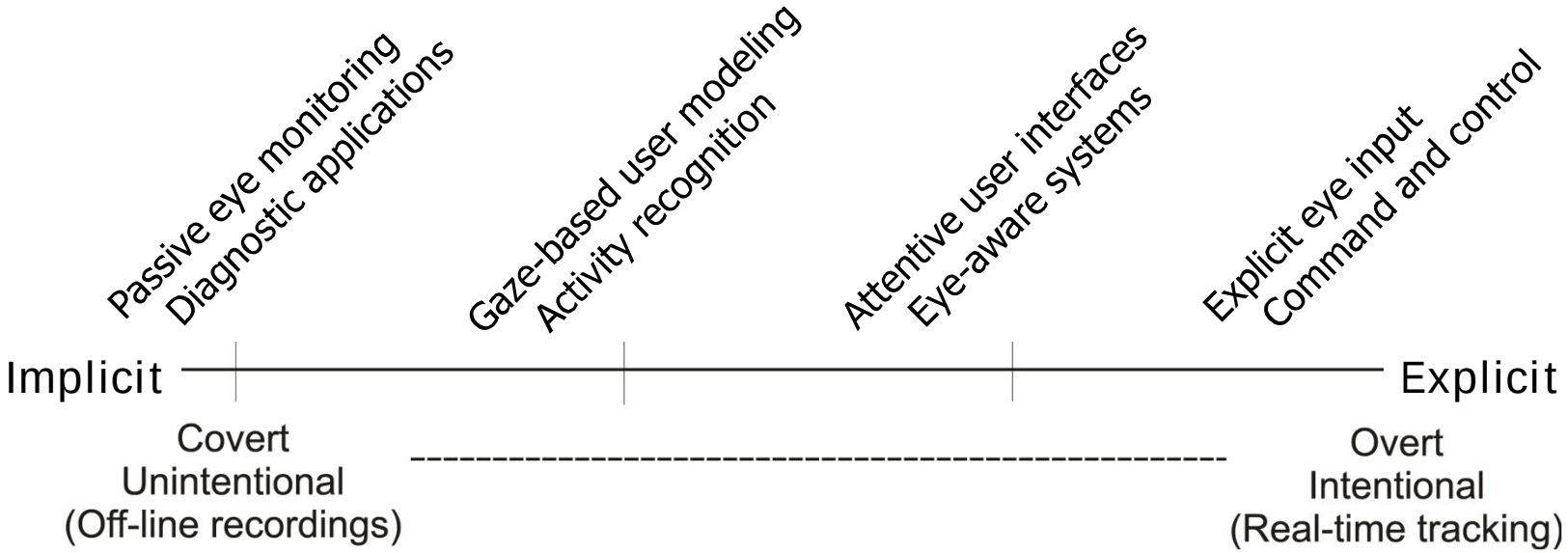
Application areas

Continuum of Eye Tracking Applications



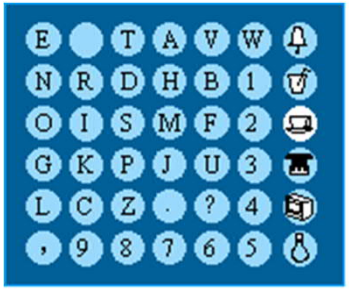






Majaranta & Bulling, 2014

Eye-Letter-Selector (1979)

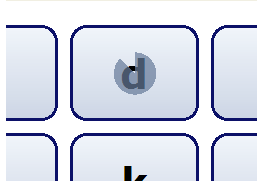


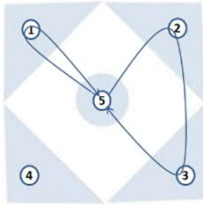
ten Kate et al. 1979

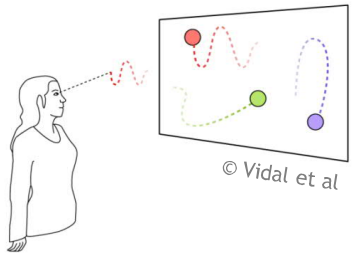
Eye Movements in HCI

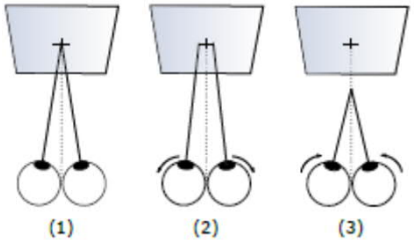
- Fixations and dwell time
- Saccades and gaze gestures
- Smooth pursuits for interaction

- Voluntary vergence
- Voluntary blinks and winks
- (Voluntary) pupil dilation
- Gaze with head movements
- … and in various combinations with other methods









© Kirst & Bulling

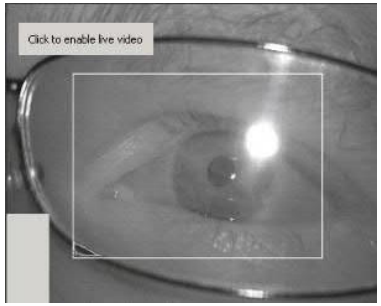
Majaranta et al (2019), Istance et al. (ETRA 2010), Møllenbach et al. (UIAS 2013), Vidal et al (UbiComp 2013)

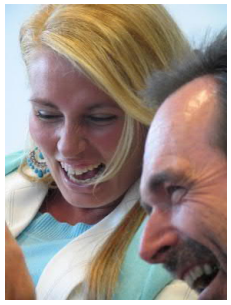
Technical Challenges

- Reflections, ambient light, droopy eyelids
- Squint, laughing
- (Involuntary) body or eye movements
- Inaccuracy and tracking reliability
- Implementation challenges
  - System delays, synchronization of inputs & user's actions
- …

Challenges for HCI

- Characteristics of eye movements
  - Easily distracted, largely unconscious
  - Size of fovea, covert attention
  - Inability to eye-draw smooth curves
- Ambiguous Interpretation
- Midas touch: Looking vs. gaze control
- User experience
  - Usability, social acceptability





Human Augmentation by Gaze Interaction

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Mouse Emulation

Gaze bound to cursor

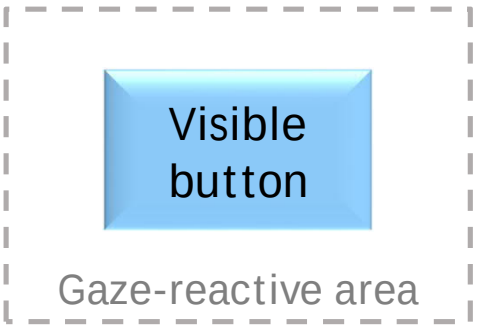
Here lying position
reduces body movements
enabling accurate control

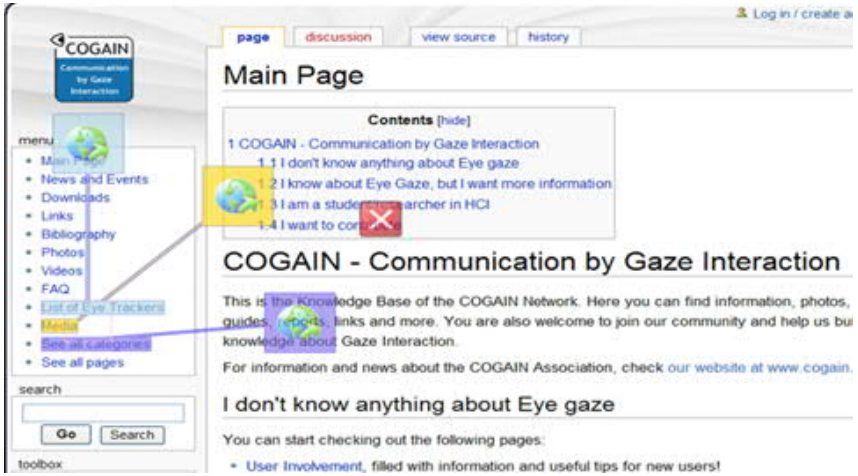
Donegan et al. (2009; 2011) , Holmqvist & Buchholz (2007), More information: COGAIN website (www.cogain.org)

Zooming

- Zooming glass
- Invisible zooming
  - Expanded selection area

  → *Good perceived accuracy!*
- Semantic zooming
- Probabilities
  - E.g., word prediction





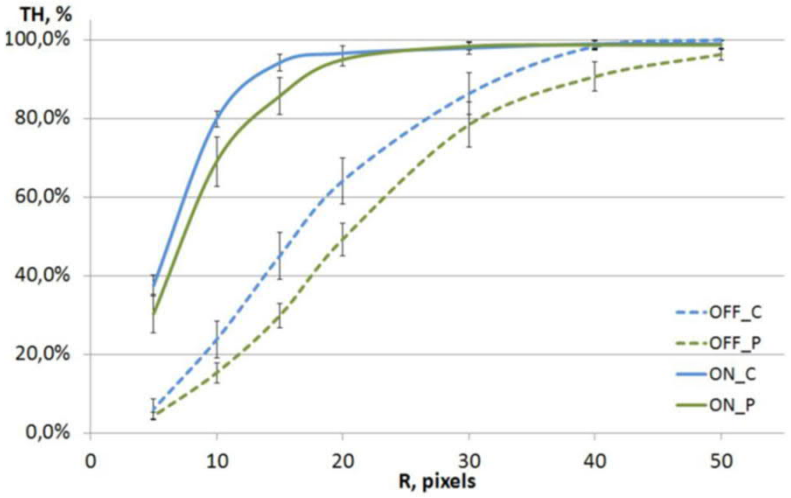
MyTobii browser

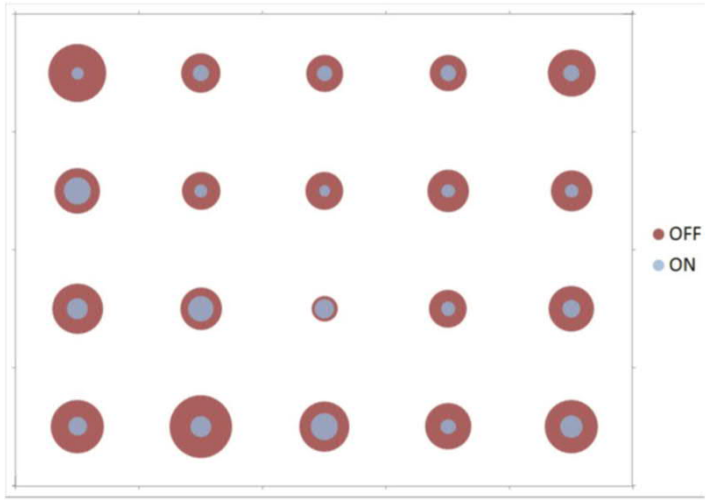
Špakov & Miniotas (ICMI 2005), Skovsgaard et al., (2011), See also COGAIN book (Majaranta et al. (eds) 2011

Head-assisted Eye Pointing

- Inspired by Magic pointing (Zhai et al., CHI 1999) & observed behavior by some users

- Quick pointing by gaze + fine-tuning with head movements

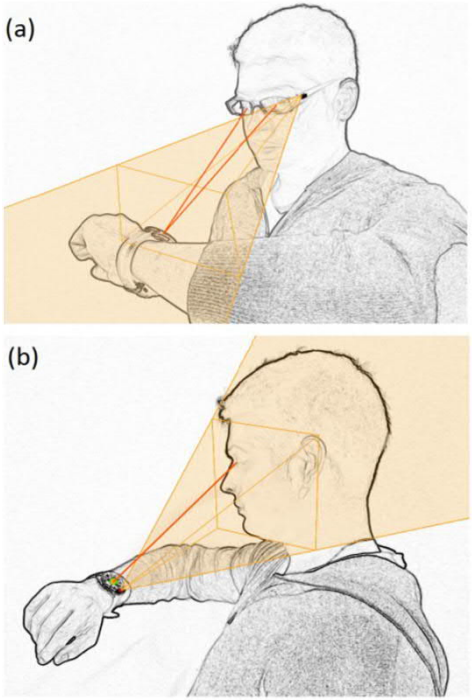




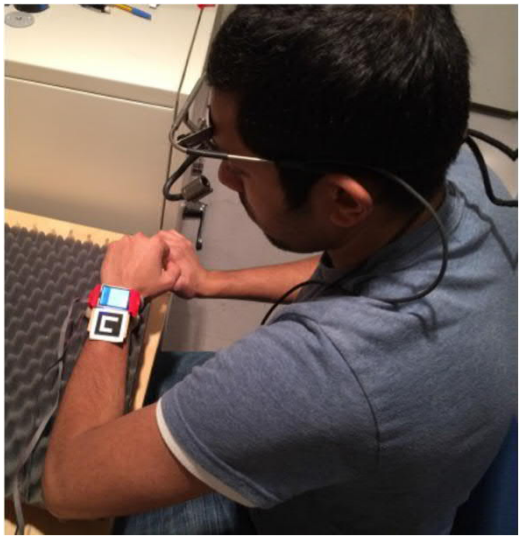
Špakov, Isokoski & Majaranta (ETRA 2014)

Eye-aware, Gaze-reactive Smartwatch

Concepts



Experiments

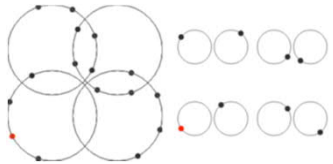


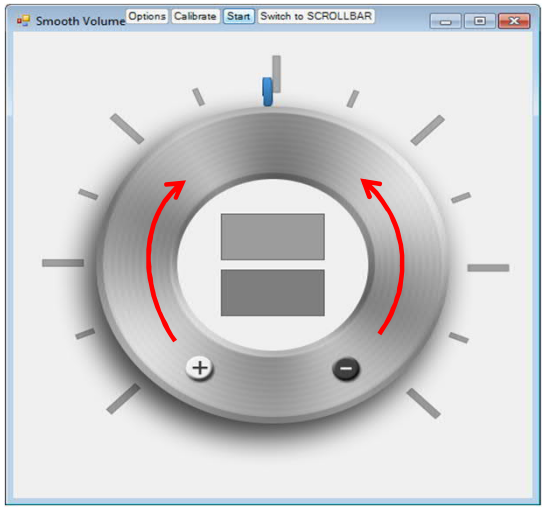
Akkil et al. (CHI 2015)

PursuitAdjuster

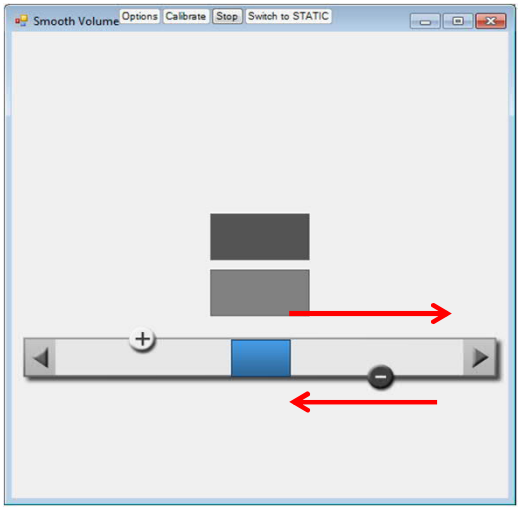
Inspired by the work by Vidal et al (2013)

See also “Orbits” by Esteves et al (UIST 2015)

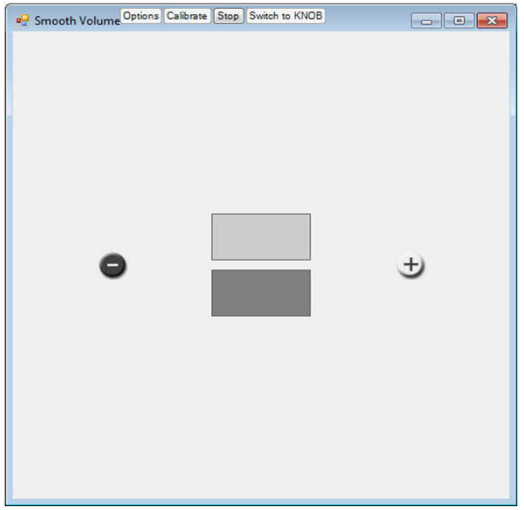




Rotary control



Scroll bar



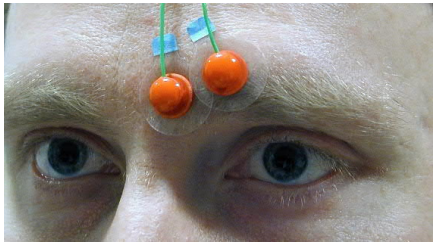
vs. Dwell time

Spakov et al. (ETRA 2016)

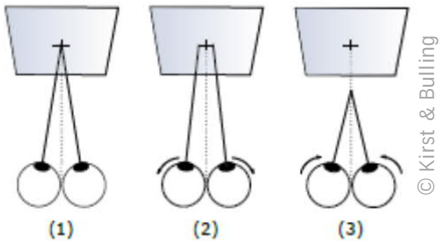
Gaze Pointing with Other Selection Methods

Activation by e.g.

- Separate switches
- Blink, wink
- Wrinkle, smiling, or any muscle activity
- Voluntary converge
- Special selection area
- Gaze gesture



© Ohno



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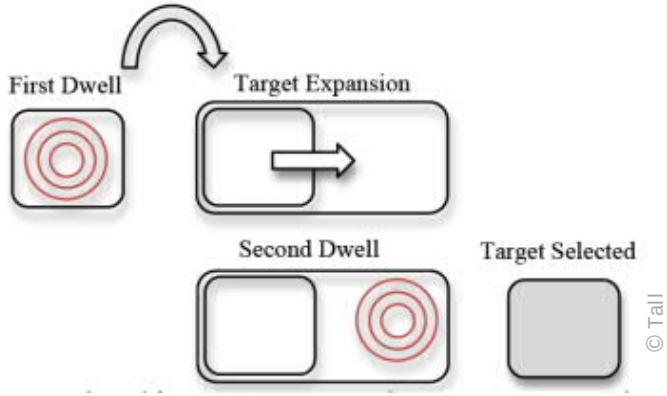
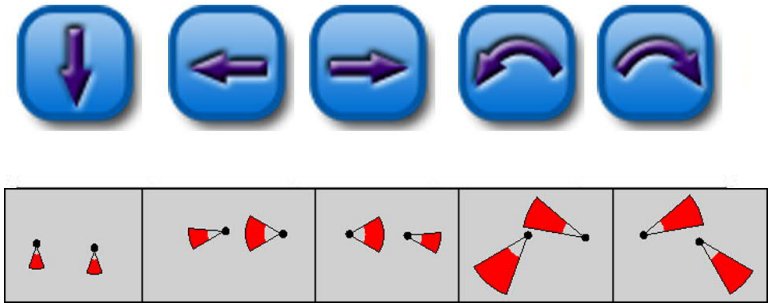


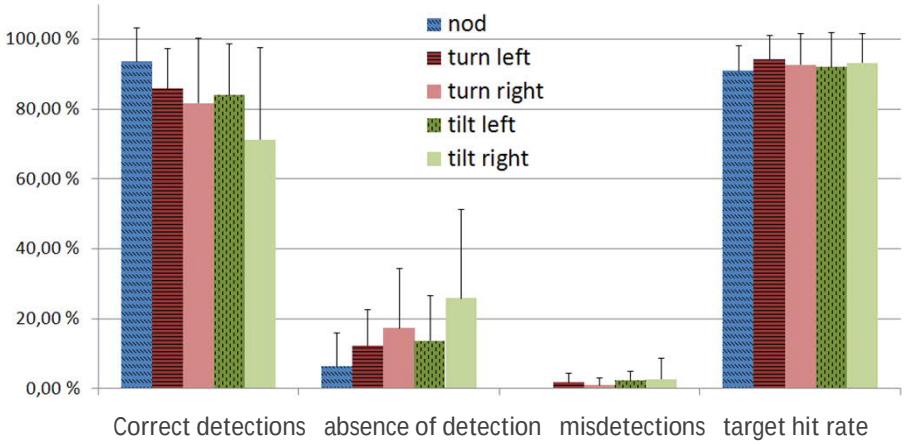
© Tall

Donegan et al. 2005, 2006; Ohno 2003; Grauman et al. 2003; Surakka et al. 2004; Tall 2008; Tuisku et al. 2013; Kirst & Bulling 2016;

Enhanced Gaze Interaction Using Simple Head Gestures

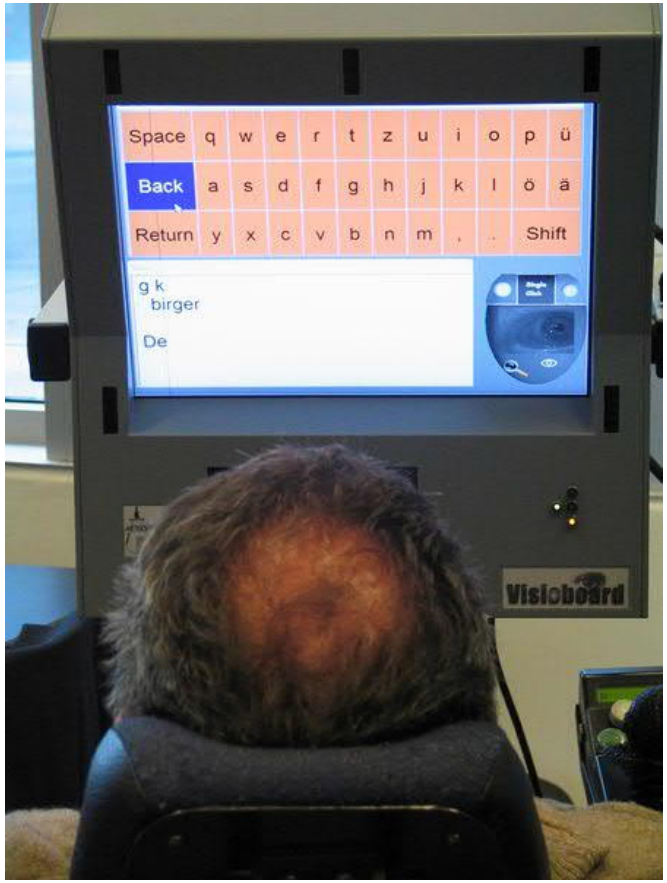


See also “Eye-based head gestures” by Mardanbegi et al (ETRA ’12)



Spakov & Majaranta 2012

Example of Dwell Selection: Typing



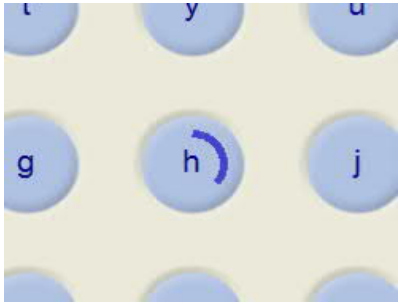
versus

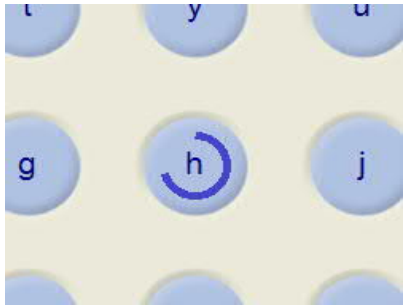
Majaranta et al (UIAS 2006), Majaranta et al (JEMR 2016)

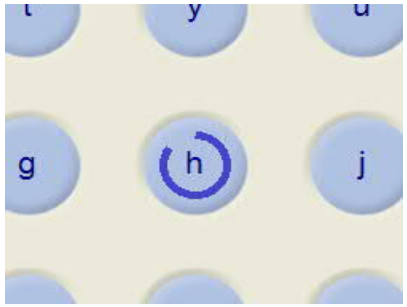
Feedback

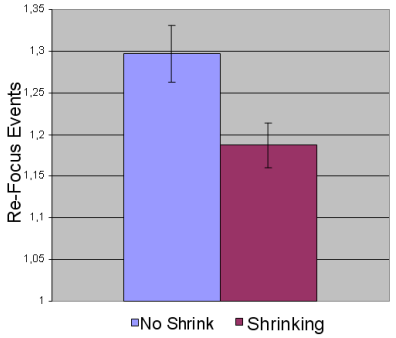
- Is the tracker following my gaze?
- Currently focused item? (Perceived accuracy)
- How long do I need to dwell?
- Was a correct item selected?

→ Effects on performance and user experience





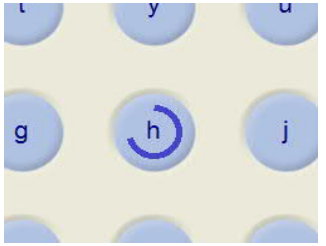


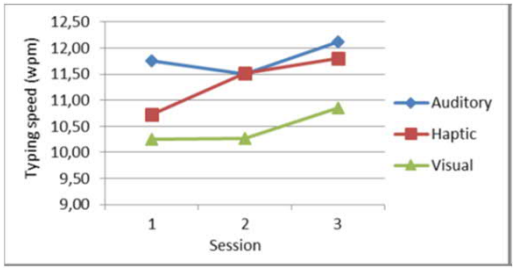


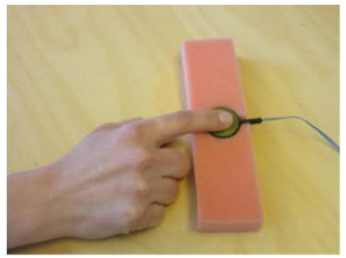
Majaranta et al. (UAIS 2006); Majaranta et al. (2011), Rantala et al. (2020), Majaranta et al. (2019)

Visual, Auditory or Haptic Feedback

- Visual feedback given on the location of action
  - Added auditory or haptic ‘click’ helps to confirm the selection
- Auditory or Haptic feedback
  - Available even if there is nothing to look at!
  - Not bound to gaze location
  - Can be heard or felt even during saccades or blinks
- Haptics provides privacy
  - Felt only by user touching or wearing the device
- Note! User preferences and needs vary
  - Context, abilities, availability

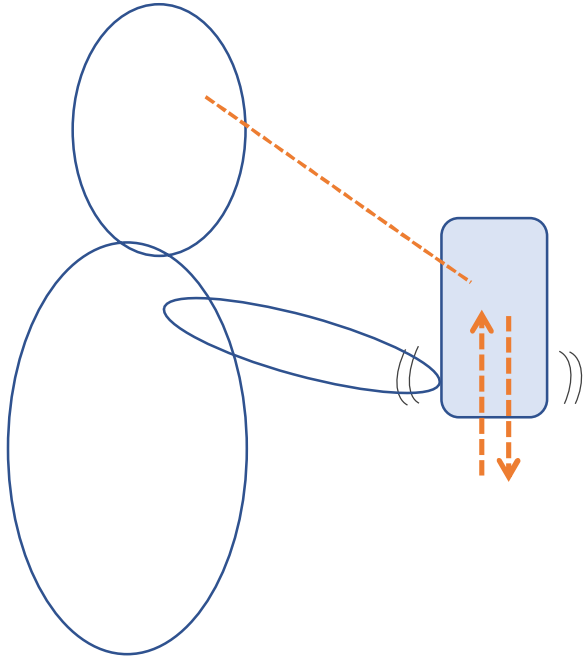


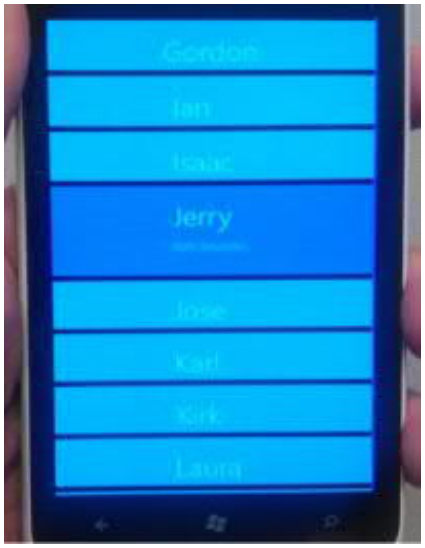




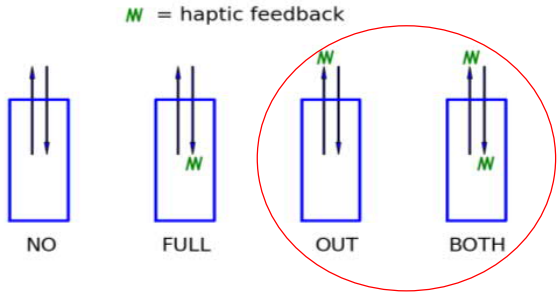
Majaranta et al (UIAS 2006); Kangas et al. (AH 2016), Majaranta et al. (JEMR 2016), Majaranta et al.(2011), Rantala et al. (2020)

Example of Gaze Gesture Interaction with Haptic Feedback: Controlling a Mobile Phone



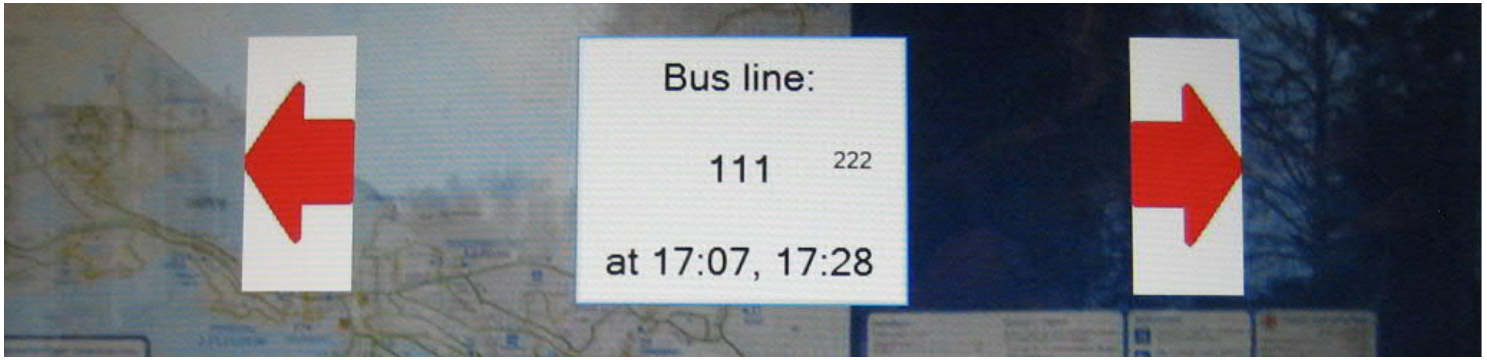


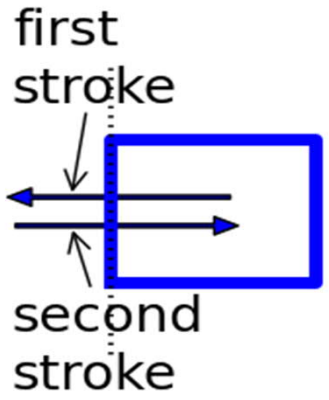
- Relative gestures – no need for accurate calibration
- Don't take space / affect the screen
- Haptic feedback improves interaction



Kangas et al. (CHI 2014)

Another Example: Gaze Gestures with Haptic Feedback on Glasses



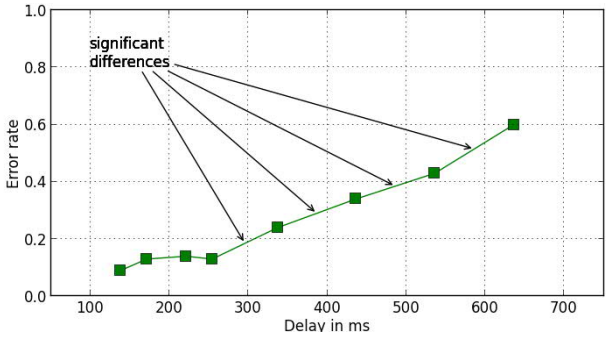


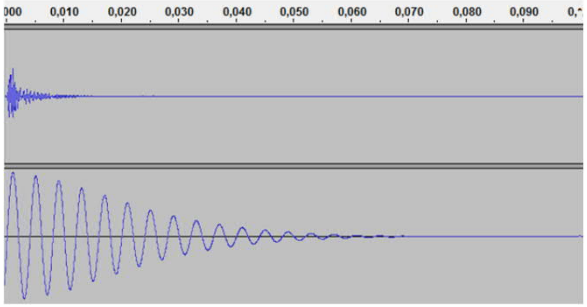
Kangas et al. (NordiCHI 2014), Kangas et al. (EuroHaptics 2016), Kangas et al. (2017)

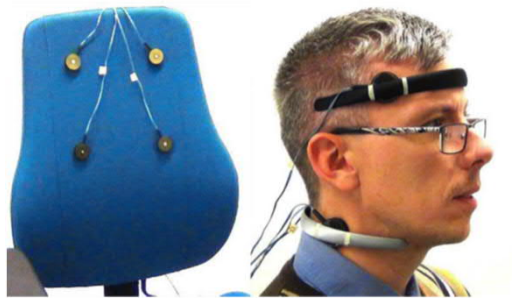
Feedback Properties

- Onset timing & feedback delay
  - Depending on eye movement type, feedback modality and task
- Duration (depending on modality & context)
  - E.g., brief 30 ms auditory *easily perceived* vs. ensuring visual perception (e.g. 100 ms)
- Location or body area
  - Note also: spatial congruence
- Amplitude, frequency, waveform, rhythm
  - E.g. 250 Hz vibration easiest to perceive, 150 Hz upper limit for head (due to comfort issues)
- Coding (color, meaning, complexity)
- Competing feedbacks

All these little implementation issues can make it or break it

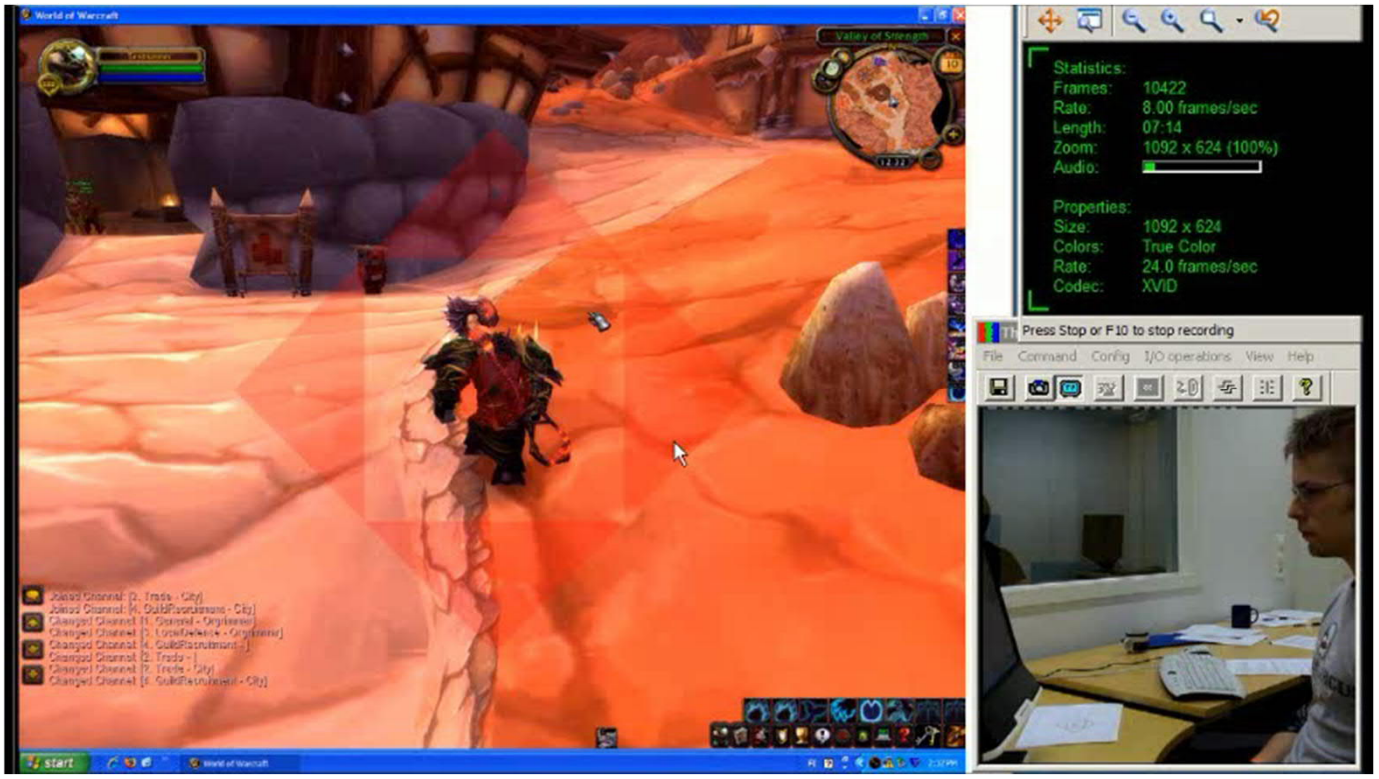






Kangas et al. (ETRA 2014), Kangas et al (EuroHaptics 2014), Spakov et al. (WHC 2015), Majaranta et al. (JEMR 2016), Kangas et al. (2017), Rantala et al. (2020)

Gaze pointing, Dwelling & Gestures
Example: Gameplay by Gaze



Istance et al. (ETRA 2008, INTERACT 2009, ETRA 2010)

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Ambiguous Interpretation

Gaze position

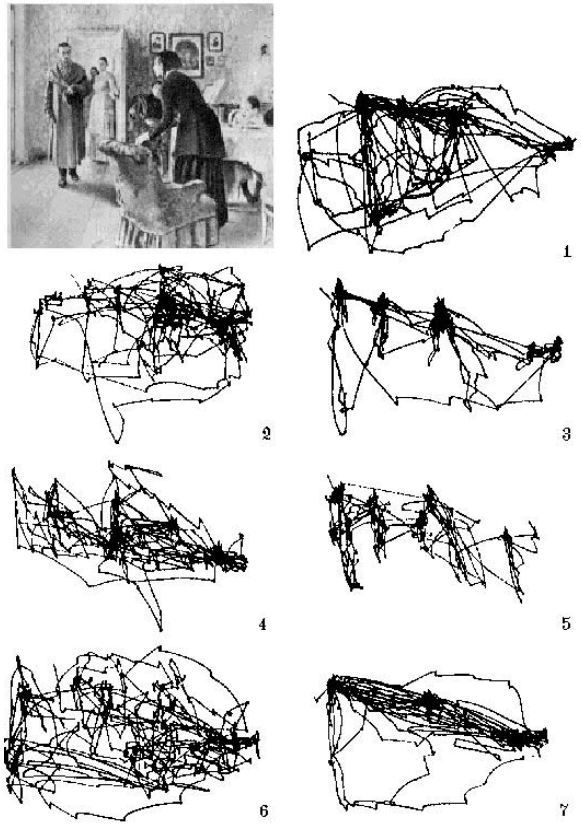
- Looking but not seeing?
- Recognizing or using, even if not visually attending?
- Ignored accidentally or intentionally?

Gazing time

- Confused or engaged?

Scan path

- Spontaneous or task-driven?

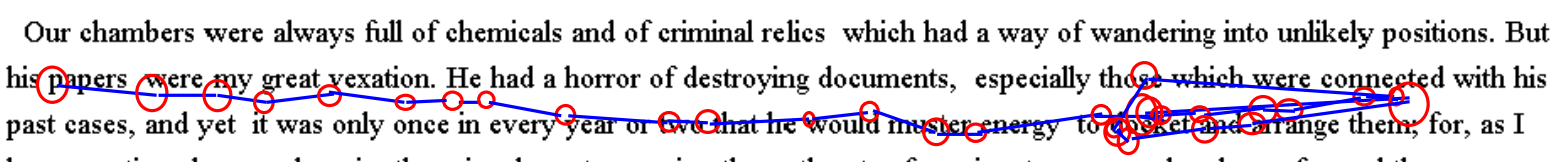


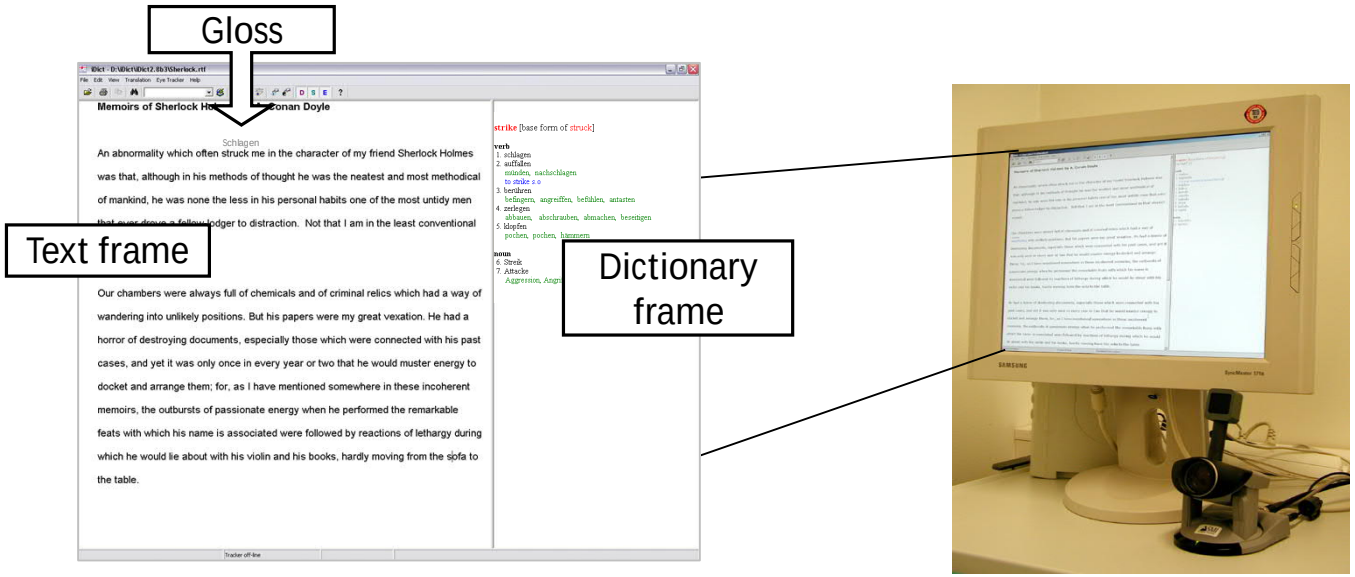
Yarbus (1967)

Same user,
same target image,
7 different gaze recordings

→ Problem of implicit selection

Example: Gaze-aware iDict Reading Aid

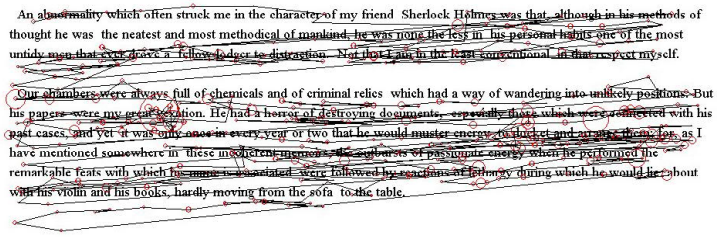


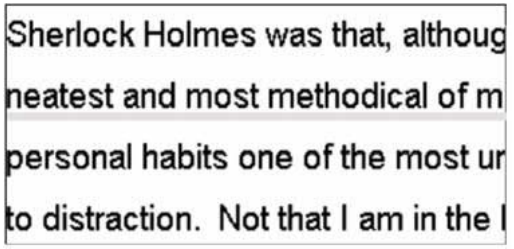


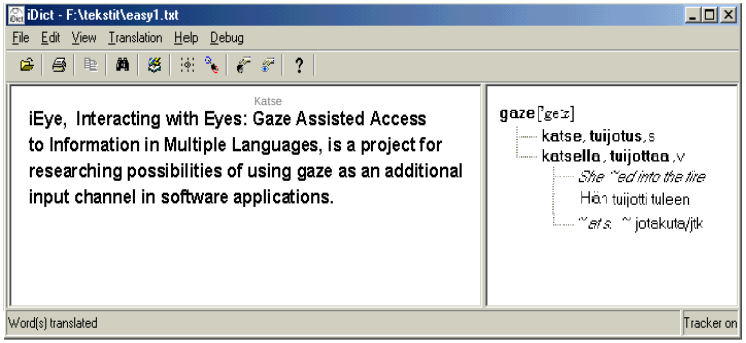
Hyrskykari et al. (ETRA 2000, INTERACT 2003). See also: http://urn.fi/urn:isbn:951-44-6643-8 For further ideas: https://text20.net/

Accuracy Challenges

1. Spatial accuracy
   - mapping the point of gaze to the right word
2. Timing accuracy
   - recognizing the need of help
   - When to offer help?
3. Linguistic accuracy
   - quality of given translation







Hyrskykari et al (INTERACT 2003); See also: Hyrskykari 2006 http://urn.fi/urn:isbn:951-44-6643-8

Key Design Issues

- Feedback
  - System state should be visible to the user
- Controllability
  - Possible to make manual adjustments
- Non-interfering design
  - Automatic actions done with extra *discretion*
  - User feedback after experiments: *“unnecessary glosses went often unnoticed”*

User Experience

- Usability
- Customizability
- Social norms
  - ability to maintain gaze contact
  - dwelling on people might be rude
- Acceptability
  - abnormal eye movements in public
  - self-consciousness
  - privacy, safety, etc.

More research on the UX aspects is needed!

Akkil et al. (NordiCHI 2016), Majaranta et al. (2011), Majaranta et al. (2019), Mele & Federici (2012)

Learn more: www.cc.gatech.edu/fac/Thad.Starner

Human Augmentation by Gaze Interaction

TOPICS

- Application areas
- Eye movements in HCI
- Challenges and example solutions
- Lessons learned from Gaze in HCI and Assistive Technology
- Lessons learned from Gaze in Attentive Interfaces

KEY DESIGN ISSUES

- Match the task with suitable eye movement type & technology
- Controllability & non-interfering design
- Feedback & visibility of system status
- Customizability & user-centered design
- Acceptability, social norms, and user experience

Conclusions

- Match the task with suitable eye movement type & technology
  - E.g., required accuracy, interaction methods, EOG vs. camera-based tracking
- Controllability and non-interfering design
- Feedback and visibility of system status
- Customizability and user-centered design
- Acceptability, social norms, and user experience

If it doesn’t work at first, it doesn’t mean there isn’t a way to make it a success

→ Lots of small things to adjust

→ Test and iterate!

Learn more: Majaranta et al. 2019

Gaze in Interfaces

- Multimodal interfaces
- Eye-controlled games & toys
- Mobile eye tracking
- Activity tracking
- Health tracking
- Intervention user interfaces
- Internet of things
- Pervasive tracking
- Gaze-reactive environment
- Gaze in VR
- Augmented reality
- Augmented human

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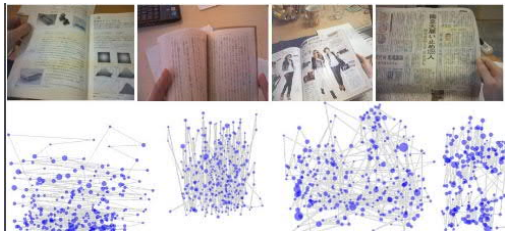
Esteves et al 2015



Kunze et al. 2015

jins-meme.com

© Zhang et al. 2013

Ajanki et al. 2011

Ajanki et al. 2011; Kandemir & Kaski 2012; Tuisku et al. 2016, Esteves et al 2015, Kunze et al. 2015, Jacob & Stellmach 2016, Schmidt & Herrmann 2017, …

Vision for Augmented Humans

Call for Research

"Any sufficiently advanced technology is indistinguishable from magic"
Arthur C. Clarke

Realizing the vision will require research at least in the following areas:

Paradigm: Define an overall interaction paradigm and metaphors that enable to benefit from augmented senses, action and cognitive abilities.

→ From interaction with technology to augmented abilities

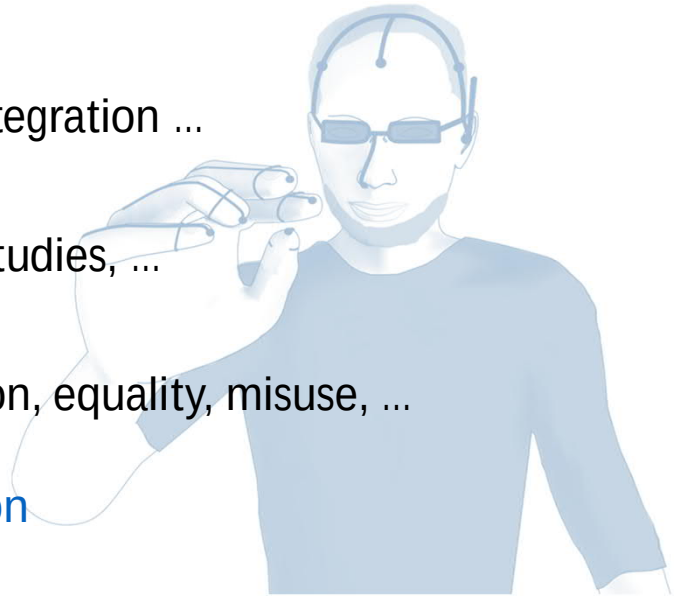
Technology: sensing and actuation technologies, AI, context modeling, integration …

Experimental research: basic research, validation, …

Applied research: utilization in everyday systems and applications, field studies, …

Theory and models: build a basis for theory, model augmentation, …

Ethics and societal research: effects on augmentation on human evolution, equality, misuse, …



Research on gaze interaction is required to realize the vision

Raisamo et al. (IJHCS 2019)

Main References & More Information

The “COGAIN book”: Majaranta, P. et al. (Eds.). (2011). *Gaze Interaction and Applications of Eye Tracking: Advances in Assistive Technologies*. IGI Global.

Majaranta, P., & Bulling, A. (2014). Eye tracking and eye-based human–computer interaction. In *Advances in physiological computing* (pp. 39-65). Springer, London.

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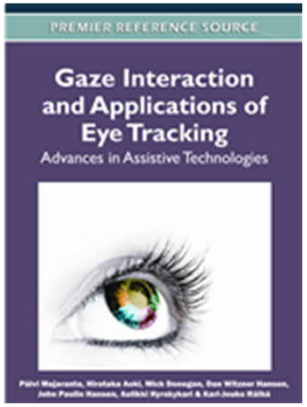
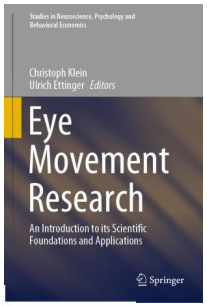
Rantala, J., Majaranta, P., Kangas, J., Isokoski, P., Akkil, D., Špakov, O., & Raisamo, R. (2020). Gaze interaction with vibrotactile feedback: Review and design guidelines. *Human–Computer Interaction*, *35*(1), 1-39.

COGAIN website: http://www.cogain.org

TAUCHI / Visual Interaction Research Group: https://research.tuni.fi/virg/research/





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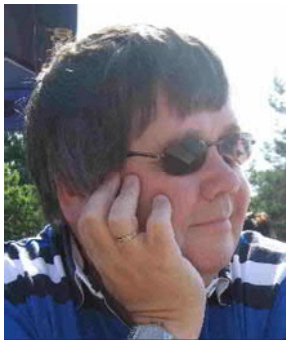

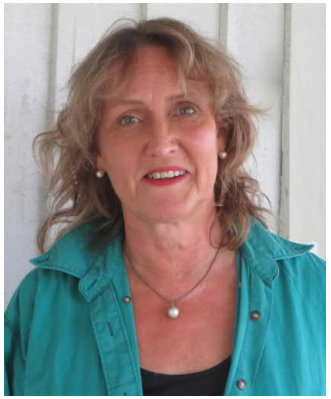

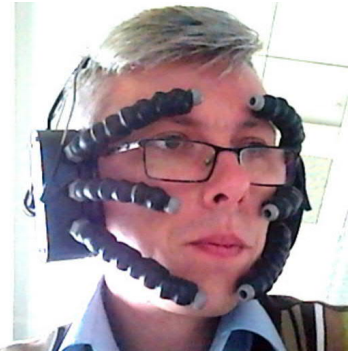

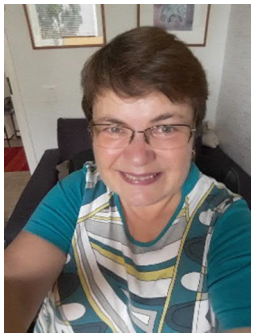

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Pupil labs tracker's image of the eye. More info: pupil-labs.com

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