An Adaptive Turn-by-Turn Navigation System Using Passive Brain Input

Liat Litwin, Sam Hincks, Nikhil Shinday

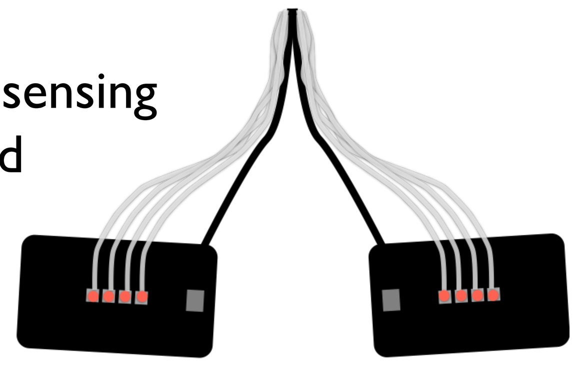
Human Computer Interaction Lab, Tufts University

OVERVIEW

We envision a future version of Google Glass that would display information to the user based on their personal context and tailor **when** information is delivered, **which** information is prioritized, and **how** information is presented using an unobtrusive, passive source of physiological input to update the system accordingly.

In this experiment, we prototype a Google Glass application that utilizes functional Near Infrared Spectroscopy (fNIRS) data to make intelligent adaptations to a Glass interface. We use a turn-by-turn navigation system, perhaps the most useful application of Glass, to test these extended functionalities in a pilot study.

fNIRS AND GOOGLE GLASS: A WEARABLE BRAIN MONITOR



Functional near-infrared spectroscopy (fNIRS) is a brain-sensing technology that shines near-infrared light at different wavelengths to determine changes in oxygenation level of the blood in the prefrontal cortex. Unobtrusive and light, it is placed on the user's forehead and calibrated to determined periods of low and high cognitive workload. The capacity of fNIRS to detect periods of short term cognitive workload has been demonstrated in several experiments, and, more recently, been applied in real-time physiological interfaces.

Google Glass is a wearable computer with an optical head mounted display. Located directly on the wearer's forehead, Glass affords the unique opportunity to measure the brain, the hotspot of intention, cognition, and emotion. As a result, any brain monitor that stands a chance to be integrated into Glass's sensor infrastructure needs to be light, small, cheap, durable, and resistant to noise, ruling out the traditional method of Electroencephalography.

As the brain monitor relies on simple, small, and inexpensive basic technology, a portable fNIRS-integrated Glass should be physically and economically possible.

STUDY GOALS:

- Learn about nature of adaptations
- Discover which types of Adaptations are most useful for integrating fNIRS and Google Glass

PILOT STUDY: EXPERIMENTAL DESIGN

Cognitive Workload

- Manipulated workload with n-Back task: participants repeat numbers either zero before, or one before what was just heard.
- 0-back → low cognitive workload
- 1-back → high cognitive workload

Four conditions:

1. Low cognitive workload + easy route
2. Low cognitive workload + complex route
3. High cognitive workload + easy route
4. High cognitive workload + complex route

Google Glass delivers information about the route depending on the cognitive workload of the participant. In an adaptive system, the route selection will allow for most efficiency (fewest number of mistakes) for the participant.

Hypothesis:

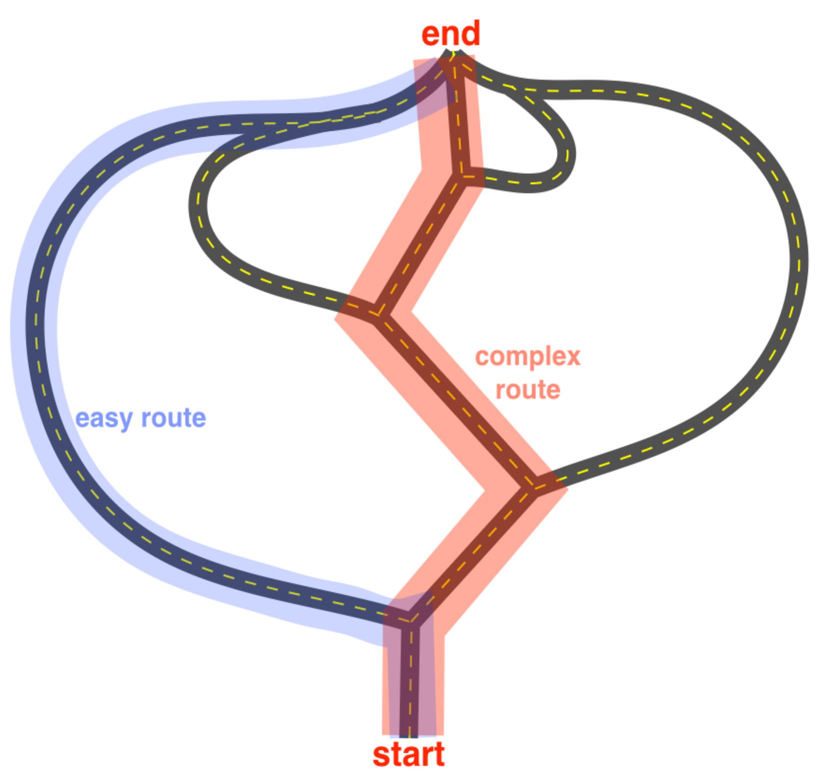
In low cognitive workload, the complex route will take less time to navigate; users will reach destination faster and with fewer errors.

In high cognitive workload, the easy route will take less time, and participants will have fewer errors. Adequate completion of complex route will be significantly more difficult.

Condition 1 > Condition 2
Condition 3 > Condition 4

Turn-by-turn navigation system

- Designed 3D road application in Unity
- Easy and complex routes that lead to the same point.
- The easy route takes longer, but has only one decision point.
- The complex route has 4 decision points and is narrower, but takes less time.

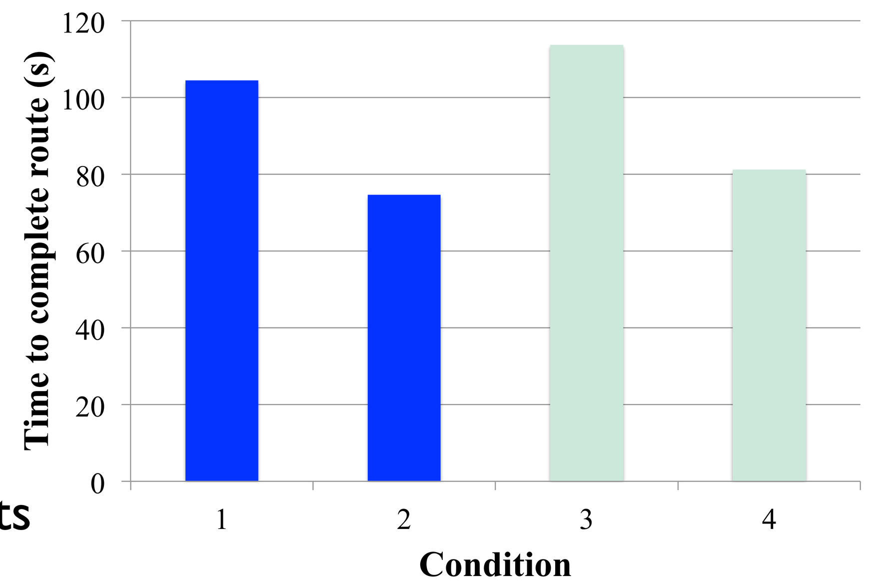


Sample map of easy vs. complex routes

3D game environment and Google Glass display

PRELIMINARY RESULTS

We ran a pilot study (N=8) to see how much high cognitive workload impedes the participant in making the correct turns. As expected, in low cognitive workload, the complex route (condition 2) results in better performance than the easy route (condition 1). Results for high cognitive workload were not as expected, and the complex, but shorter, route still resulted in faster finish times. However, data collection is not yet complete.



Participants reported the complex route in high cognitive workload to be a lot harder. We believe there may have been a learning effect that needs to be accounted for in future testing. More participants need to be tested to arrive at more conclusive results.

This study has a lot of potential in informing us about the nature of adaptations that a physiological brain sensor like fNIRS can implement on a wearable computer system like Google Glass.

FUTURE TESTING

In future testing, more conditions and road-maps will be considered:

- '**Attractions**': Capitalize on moments of cognitive inactivity by giving additional information when the user has the cognitive ability to learn. Measure success with a quiz after experiment.
- '**Break-up Directions**': In high cognitive workload, give directions one step at a time. In low cognitive workload, give multiple directions at once.
- '**Timing**': Capitalize on moments of cognitive inactivity and tell driver when to turn (adaptive condition) versus giving directions at a set, predetermined interval.

Nevertheless, these results suggest an important first-step in physiological-based notifications. Further experimentation is necessary in proving the system's value and the potential for integrating fNIRS with Google Glass.

REFERENCES

Afergan, D., Peck, E.M., Solovey, E.T., Jenkins, A., Hincks, S.W., Brown, E.T., Chang, R., and Jacob, R. J.K. Dynamic Difficulty Using Brain Metrics of Workload. *Proc. CHI 2014* (2014).

Peck, E.M., Afergan, D., and Jacob, R. J. K. Investigations of fNIRS brain sensing as input to information filtering systems. *Augmented Human 2013* (2013).

Villringer, A., and Chance, B. Non-invasive optical spectroscopy and imaging of human brain function. *Trends in Neurosciences 20*, 10 (Oct. 1997), 435-42.