Excerpt from

LABORATORY MANUAL

# PRINCIPLES OF PSYCHOLOGY: EXPERIMENTAL FOUNDATIONS

# PSYCHOLOGY 122
# 2001


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**Experiment 9**

## Eyeblinks and Eye Movements in Cognition

### Investigations in Thinking and Language

Howard Thorsheim, Mike Mensink, and Sarah Strand

**begins on the next page and constitutes pp. 103-118 of the full manual**


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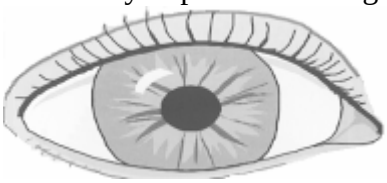
# Eyeblinks and Eye Movements in Cognition

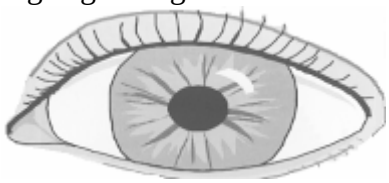
## Investigations in Thinking and Language

Howard Thorsheim, Mike Mensink, and Sarah Strand

## Introduction

Eyeblinks and eye movements provide "windows" through which we can understand many aspects of thought as well as language usage.





### Eyeblinks

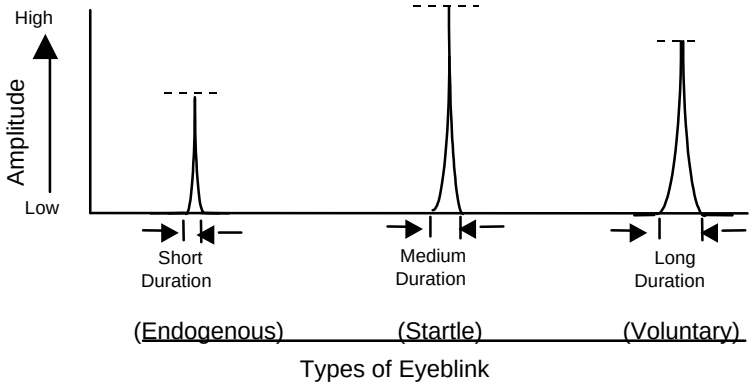
Eyeblinking is achieved through the contraction of sets of muscles called the orbicularis oculi and levator palpebrae superioris (See any anatomy resource). The electrical signal from those muscles, known as the ***electromyogram***, produces a "pulse envelope" that may last for a fraction of a second. Orchard & Stern (1991) identify three types of eyeblinks: (a) ***reflex blinks*** (in response to something invading in the eye), (b) ***voluntary blinks*** (as a result of a decision to blink), and (c) ***endogenous blinks*** (due to perception and information processing). These eyeblinks **{**xe "eyeblinks "**}**are the focus of interesting psychological research.

Reflex blinks are instinctive responses that guard the eyes against airpuffs and dust; they are also part of the startle response to loud noises. The blink reflex can be classically conditioned to a neutral stimulus such as a tone. After several pairings of a tone and airpuff, the tone itself will generate the blink. This has been shown in class demonstrations.

Voluntary blinks include squinting and winking; they are under conscious control. Applications of voluntary blinking include their use as signals for communicating when diseases (such as AIDS, Multiple Sclerosis, Muscular Dystrophy, or Alzheimer's) have made other forms of communication impossible.

Endogenous (meaning "originating from or due to internal causes") blinks occur during reading or speaking and reflect changes of attention and changes in thought processes. The more attention required by a task, the fewer endogenous blinks occur.

The typical duration of eye closure during blinks is 40 to 200 milliseconds (msec.). Useful and important information for distinguishing among the various forms of eyeblinks is provided by the fact that their “pulse envelopes” reliably differ in both duration and amplitude. The pulse envelope is the outer border of the pulse.




**Summary**

| **Amplitude** | **Type of Blink** |
|---|---|
| Highest: | Startle blinks |
| Next highest: | Voluntary blinks |
| Lowest: | Endogenous blinks |

| **Duration** | **Type of Blink** |
|---|---|
| Short: | Endogenous blinks |
| Medium: | Startle blinks |
| Long: | Voluntary blinks |

Figure 1. Eyeblink amplitudes and durations

An interesting issue to investigate is the specific instant at which blinks occur during thought and language processing. Research is quite clear that blinks do not occur randomly during reading. Thus, an important and useful question of interest relates to when eyeblinks occur during reading and conversation.

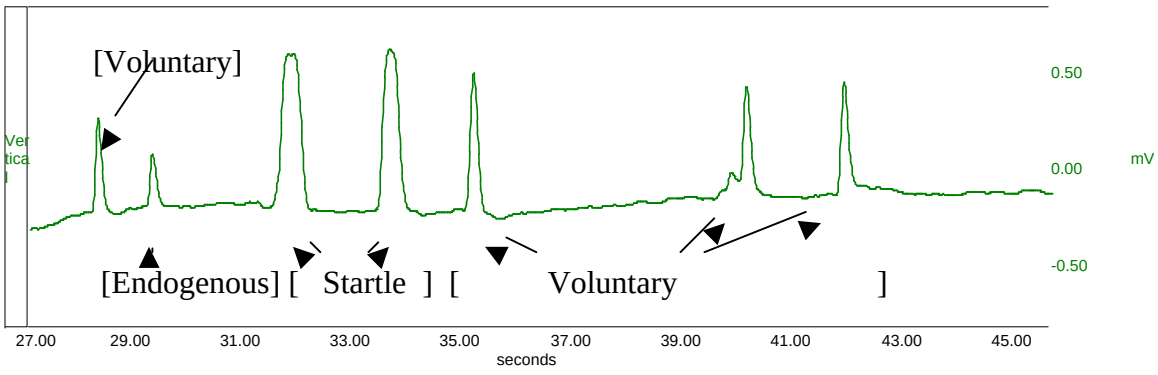



Figure 2. Actual Electrooculogram (EOG) for eyeblinks. . 2. Actual analog EOG for eyeblinks ;. 2. Actual analog EOG for eyeblinks ;{tc "Fig. 2. Actual analog EOG for eyeblinks " \l 1}Sample contains voluntary, endogenous and startle eyeblinks.

| | |
|---|---|
| **CT** | How could you investigate whether, through their eyeblinks, listeners might reveal something to speakers about their level of attention to what the speaker is saying? For example, how might the blink rate (blinks / minute) serve as a way to monitor the amount of attention someone is paying to a product or to a salesperson? Conversely, how could you use what you know to investigate whether a speaker may signal listeners something about his / her attention level by his / her blink rate? How could this be useful in analyzing the information "tipped off" by TV personalities you see talking or listening? What would you look for? How could you make use of listeners' blink rates? |

**Eye Movements**

The fact that both eyes move and work together is a remarkable achievement, particularly since the two eyes are not connected mechanically in any way! This is in great contrast to the eyes of a toy doll. The doll's eyes are wired together and, thus, move up and down together.

Eye movements are controlled by the brain in conjunction with cranial nerves and eye muscles attached to the exterior of the eyeball called extra-ocular muscles. (Extra in extra-ocular it means "outside of the eye")**{**xe "extra-ocular muscles"**}**. There are three pairs of extra-ocular muscles that control each eyeball, and the two eyeballs together operate in tandem. More than artifacts of the human neuro-muscular system, current theory and empirical research suggest a key role in cognition for both eye movement and eye blinking. They are implicated in significant ways in the processing of information by the brain. At issue is how they play a role in providing coding information for the brain itself.

Eye movements are produced by extra-ocular muscles that contract, pulling the eye first one way and then another way.

The superior rectus (above the eye) and inferior rectus (below the eye) are extra-ocular muscles that control the up-and-down movement of the eye. The lateral rectus and medial rectus control side-to-side movement. The superior and inferior oblique muscles control the rolling of the eyes.

Efficient readers move their eyes in a rather complex way; they do not simply move their eyes at a constant speed across the page. **Saccades** (see Figure 3) are horizontal (back and forth) or vertical (up and down) movements of the eye that occur when looking out at the world--or when reading; for example, when readers

move their eyes from one point of fixation to the next, these movements are called saccades. Movement back to reread a selection on the same line is known as a ***regressive saccade.*** A variation of the regressive saccade is when a person sweeps his or her eyes back to begin reading the next line. When readers stop because they wish to pay attention to a certain portion of the text, this is called a ***fixation pause.*** These saccadic (pronounced sah-cad'-ick) movements and eye pauses can be used to measure many kinds of interesting cognitive processing.

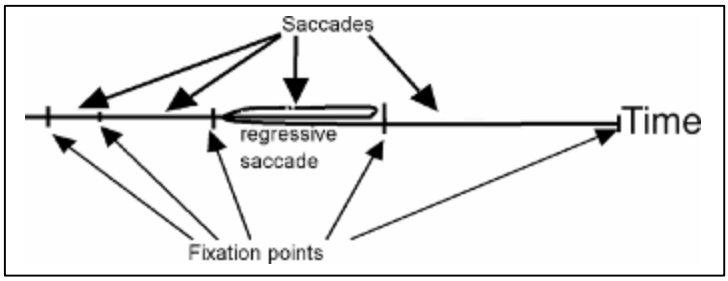



Figure 3. Terms for eye movement during reading

The measurement of eyeball movement during reading and the visual tracking of a target is called *electro-oculography* (EOG)**{**xe "electro-oculography (EOG)"**}**. These EOG signals are created by the fact that the front (anterior) of the eyeball is positive relative to the rear (posterior) of the eyeball, setting up a dipole**{**xe "dipole"**}**, as shown in Figure 4.

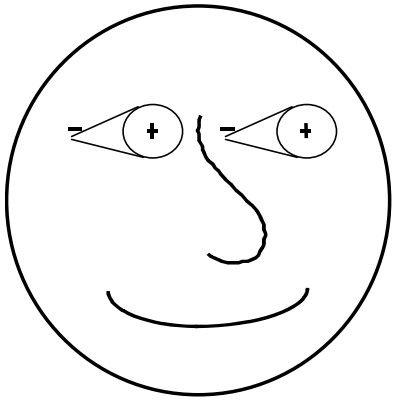



Figure 5. Stylized sketch of typical eye movements during reading three lines of text, as they would be depicted on the electrooculogram (EOG). See if you can identify the other unlabeled parts of the EOG.

Figure 6 shows how to place electrodes above and below the eye to provide information about up and down movement of the eyeball, in addition to eyeblink information.

Figure 6. Electrode Placement

Figure 6 also shows how electrodes placed on the right and left external canthi of the eyes{xe "external canthi of the eyes"} (i.e., the outside or *lateral* location, just next to each eye) will pick up the change in orientation of the +/- dipole of each eye. These electrodes will provide information about saccades, line changes, and fixation points.

In combination, the electrodes provide information about where the eyeball is oriented (direction of gaze) in an X-Y Cartesian coordinate system, as well as about eyeblinks. Electrodes on the sides of the eyes provide information about lateral movement (X-axis) and electrodes placed above and below the eyes provide information about up and down movement (Y-axis) and eyeblinks.

For investigating a number of interesting psychological questions, the EOG may be used as a general research tool to measure direction of gaze, as well as the length of fixation. The typical kind of response one finds is illustrated in Figure 7.

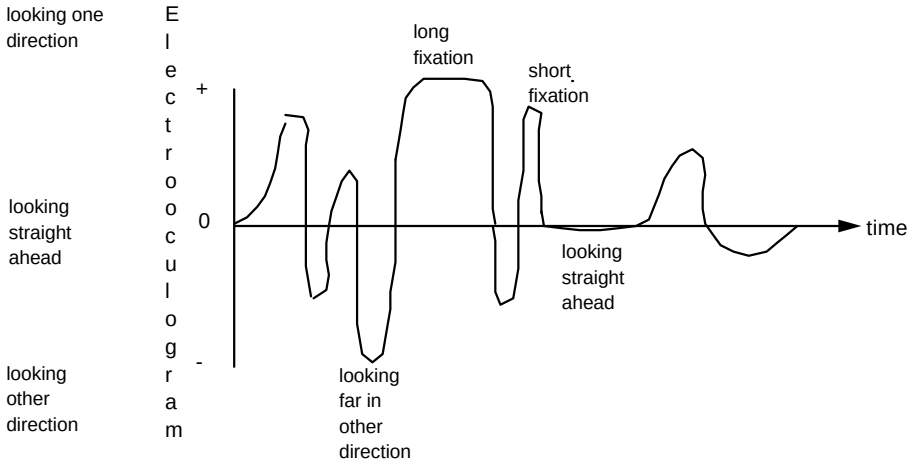



Figure 7. Typical EOG recordings during casual eye movements

| | |
|---|---|
| **CT** | Initial observations in our laboratory suggest that just prior to sleep onset, the extra-ocular muscles of the eyes relax. We hypothesize that eyes under closed eyelids diverge to an infinite focus when a person is asleep. A next step to test whether eye divergence is a reliable indicator of sleep onset would be special EOG measurement accompanying sleep onset. Given what you now know, where would you place electrodes to measure eye divergence? |

**Eyeblinks and Eye Movements--Working Together**

Certain kinds of eyeblinks may occur at times when a reader does not need to be taking in information, for example, when moving from one point of fixation to the next (***saccades***), at ***line changes***, or when moving back to reread a selection on the same line (***regressive saccades***). These movements may inhibit certain kinds of blinking when the reader needs to pay attention, such as during ***fixation pauses***. On the other hand, other kinds of eyeblinks may occur because they are associated with various kinds of cognitive processing.

## Objectives

- To investigate the relationship among eye behavior (specifically, eyeblinks and eye movement), thought, and language
- To investigate eyeblinks and eye movements, using ordinary visual observation as well as sophisticated instrumentation
- To investigate the relationship between types of eyeblinks and eye movements, and the time at which they occur during the reading various kinds of material
- To stimulate your ideas for future independent investigative research

## Terms

Canthus (plural = canthi)
Dipole
Electrode
Electro-oculogram
Empirical
Endogenous
(EOG)
Extra-ocular
Fixation pause
Fixation point
Frequency
Line change
Operational definition
Rectus Inferior
Rectus Lateral
Rectus Medial
Rectus Superior
Reflex
Saccades
Sample
Saccadic
Superior

Impedance
Inferior (below)
Lateral vs. Medial

## Method

### Participants

Lab participants will work in two-person teams. One person will be the source of data, while the other person will be engaged in conducting the investigations and recording observations. Then roles will be switched. Both members of the team will share their observations, notes, and data with each other. Bring your lab notebook, handout for the lab, and citation skeleton (which will be collected at the beginning of the period) to the lab. All other belongings (coats, backpacks, heavy sweaters, etc.) should be stored in another room. (To be specified)

Logging your Work:

Good research practice includes keeping track of every time you use your equipment. Find the lab log in the top drawer of your workstation. Find the next blank log sheet and write down today's date, your names as researchers, and what you will be doing. For example, "we will be doing the 'attention and brain behavior' labs." Then, during your labs make notes about how the labs went for you, difficulties you figured out how to overcome, tips you might have for others, any problems with the equipment, etc.

PART 1

*Visual Observation of Eye Movement*

*(Saccadic Movements, Fixation Points, and Regressive Saccades)*

### Materials

Paper and pencil
Reading selections
Table and chairs

### Procedure

Seat yourselves as illustrated in Figure 8 so you can collect your data while keeping eye contact with your partner's eyes over the paper he/she is reading and is holding up.

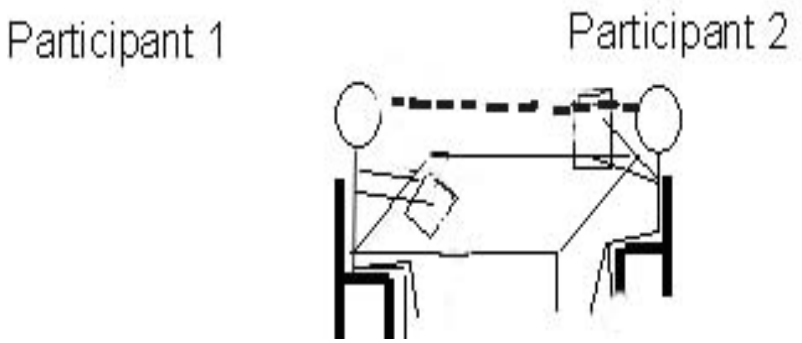



Figure 8. Positions for visual observation of eye movements during reading.

Participant 1 views Participant 2's eye movements as Participant 2 reads three samples of text material provided: (a) silently and then (b) orally as summarized in Table 1.

Table 1: Procedure Summary

| *Participant 2 reads* | *Participant 1 counts* |
|---|---|
| 1. A sample of text<br>a. silently<br>b. orally | 1. <u>The number of blinks</u><br>During the silent and oral readings, make tally marks / / / / with your pencil each time you see a blink. |
| 2. A second sample of text<br>a. silently<br>b. orally | 2. <u>The number of fixation points</u><br>Make a tally mark for each fixation point you observe (which is only somewhat related to the number of saccades because regressive saccades will influence your count). |
| 3. A third sample of text<br>a. silently<br>b. orally | 3. <u>The number of regressive saccades</u><br>*Count the number of regressive saccades that occur.* |

Note: For writing up your results later, it will be important to measure and record the length of the line read and to count the number of characters per line (including spaces) so you can calculate the number of eye movements per character.

PART 2

*Electronic Observation of Eye Movement*

*(Saccadic Movements, Fixation Points, and Regressive Saccades)*

Lab participants will work in two-person teams. Participant 2 will be the source of data, while Participant 1 will be engaged in conducting the investigations and recording observations. Then roles will be switched. Both members of the team will share their observations, notes, and data with each other.

**Apparatus and Materials**

BioPac Workstation
Psychophysiological measure called the electro-oculogram
Alcohol-acetone Prep Pads
Rubber gloves (Latex- free gloves are an option)
Printed copies of text material to be read from previous section.
BioPac Lesson 10 EOG 1
BioPac Electrode Lead Set (SS2L), Quantity-2
Disposable Vinyl Electrodes, Quantity- 6
Adhesive tape if necessary

**Objective**

You will explore eye movements and eye blinks while reading the same paper copy you read in Part 1. In addition, you will use the information from the physiograph to calculate your results. Before you start making recordings, discuss with your team what you are going to be looking for. Bring your lab notebook, handout for the lab, and citation skeleton (which will be collected at the beginning of the period) to the lab. All other belongings (coats, backpacks, heavy sweaters, etc.) should be stored in another room (To be specified). Remember to put on a lab coat.

## Procedure

1. Make sure BioPac MP30 unit is OFF, that is no green lights are on, in the front of the MP30 box.
2. Plug in the electrode leads (SS2L) into the MP30. Horizontal is in channel 1 and vertical is in channel 2.
3. Turn on MP30 using the switch at the rear of the box.
4. Wear Gloves if you are Participant 1.
5. Clean the skin with alcohol pads where the electrodes will be placed.

Figure 9. Shows Participant 2 cleaning one of the electrode locations. **Important:** make sure you squeeze out 3 drops of alcohol from the prep pads before using them to prevent alcohol running into participant's eyes!!

6. Place 6 electrodes on the subject as shown in figure 10. For accurate recordings, attach the electrodes so they are horizontally and vertically aligned.

Figure 10. The typical placement of Electro-oculogram (EOG) electrodes for BioPac Lab 10.

7. Attach the vertical electrode lead set (SS2L) channel 2 to electrodes.
8. Attach the horizontal electrode lead set (SS2l) from channel 1 to electrodes

Table 2: Important Instructions for where to connect each color electrode lead. (The electrodes attach with the metal facing down.)

| Lead color | Channel 1 (Horizontal) | Channel 2 (Vertical) |
|---|---|---|
| ***Black*** | Connect the electrode above Left eye | Connect the electrode to the middle of forehead |
| ***Red*** | Connect the electrode lateral to Right eye | Connect the electrode above Right eye |
| ***White*** | Connect the electrode lateral to Left eye | Connect the electrode Below Right eye |

Electrode Lead

Figure 11. The typical hook up of Electro-oculogram (EOG) electrodes for BioPac Lab 10.

9. Have subject adjust the seating position such that his/her eyes are in line with the center of the computer screen. Be sure to note the distance from the eyes to the screen.

Figure 12. Participant 2 measuring the distance subject is away from the screen.

10. Start BioPac Student Lab Program. Choose Lesson L10-EOG-1. Type in a file name that both team members will be able to remember. Click on OK.
11. Click on Calibrate. You will be instructed to follow the dot on the screen with eyes only. The subject should try not to move his/her head.
12. Person 1 should be facing Person 2. Person 2 should hold a pen about 10" from person 1. Important: Person 1 should pick a focal point on the pen so that the eyes remain horizontal.
13. Click on Record
14. Participant 2 holds the pen still and in the center of the subject's visual field. Then person 2 moves the pen laterally 10 inches and back to center in about 3 seconds. Person 2 should also insert a marker (F9 Key) and type "L" for moving the pen left and "R" for moving the pen right. Participant 1 fixates on the pen, tracks it, and tries not to blink.

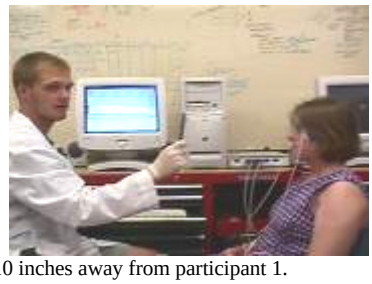


Figure 13. Participant 2 holds the pen about 10 inches away from participant 1.

15. Click on suspend. Review the Data

16. Now participant 2 should hold the pen stationary and in the center of participant 1's visual field. But this time participant 2 should move the object up for about 1 sec., down for about 1 sec., and return to the center.
17. Click on Suspend. Review data.
18. Click on Resume when the subject is ready
19. Participant 1 should read the materials from the preceding section .
20. Place the reading material on the table. Place the subject about 10" from the table. The material should still be in the center of the subject's visual field.
21. Participant 2 should insert marker (F9 Key) and label it "reading." Be sure to mark (with F9) anything you think would be important to note about the reading.
22. Click on Suspend.
23. Review data. If correct, click on Stop. If not click on Redo.
24. Partners will rotate, testing one participant at a time, and collect their data.
25. Finally, when each participant's data have been recorded, print out part of the data from steps 15, 17, and 20. To print the graphs follow these steps:
    a. File menu
    b. Print and then print graph
    c. Click ok.
26. Print out part of the EOG recordings and paste them into your lab Notebook using rubber cement.

**Reminder about Lab Logs**

Take out the lab log once again and add any comments you can. Be sure to note any problems with the equipment. (Review the earlier part of this lab write-up to see what kinds of things to enter in the log)

## Discussion Questions

### Topic 1: Cognitive Processing

What might you have learned from this "Eyeblink and Eye Movement" lab that could be used for study of various kinds of cognitive processing tasks? Think together with your lab partner about possible ideas (e.g., learning, problem solving, reading, visual search to find a certain word in the text transparency, or imagery). For example, how could you study whether the eyeblink is some kind of marker or index of cognitive activity; e.g., when a person is {xe "parsing"} *parsing* (i.e., "chunking") information into meaningful units? How might other variables--such as text difficulty, distractions, and presence of an audience, noise, divided attention language--influence your observations?

### Topic 2: Videotaping Eyeblinks and Eye Movements

How could you use videotape to study some interesting psychophysiological research questions relating to eyelid movement (i.e., blinking) during reading and conversation? For example, how could you design a procedure in which you select

a sample of text for a participant to read aloud, videotape his/her eyes during reading, and count the participant's eye movements while the participant follows your instructions? (What procedural steps might you follow, including replaying and stopping a videotape, so each eyeblink may be marked on a transcribed copy of the material to be read aloud and silently by the participant? How might you repeat the process with each participant? One issue to explore could be the extent of correspondence in the positioning of eyeblinks relative to the text, within-participant and between-participants, of material read orally and read silently. What other issues might be explored?

**Topic 3: Eye Focal Length during View of "Magic Eye" Figures**

A popular visual experience is known as viewing "magic eye figures." The magic eye figures popular in print require eye divergence in order to control focal length.

When one's eyes are allowed to diverge (effectively increasing their focal length to about twice the distance between them and the page, as though "looking through" the page), a three-dimensional image appears.

Learning to allow the image to emerge requires more or less practice. For some the task is easy; for others, it is very difficult unless tips are provided. How could you use what you know to provide a viewer with tips on what it feels like when the image is coming into focus. Remember, any such "feeling" would be coming from the relaxation of the extra-ocular muscles; this normally results in divergence and focus. How could you empirically observe what is going on when a person all of a sudden "feels" the image coming? Where would you place EOG electrodes to learn more about this conscious control of focus in vision?

**Topic 4: Conversation Analysis**

How might you apply what you know to provide new insights into conversation analysis?

**Topic 5: Visually-Controlled Mouse**

In our lab we have been working on a visually controlled computer mouse. The signals from the electro-oculogram have been used to provide information for sideways and vertical cursor movement, and eyeblinks have been used to serve as the mouse "click." How might this be achieved, given what you know? See http://www.cs.sunysb.edu/~vislab/projects/eye/Reports/report/index.html

## Topic 6: Uses in Advertising

"Show the subject an advertising poster and determine how the subject's eyes move to the most important features of the image. Advertisers use EOG devises in poster design. Show the subject a map and ask them to find a particular city, or group of cities with certain characteristics (e.g. population size). How effective is the legend of the map in helping the subject? How often is the legend consulted? Does the subject scan the map in a specific pattern or more irregularly?"

(from http://www.qubitsystems.com/electro.html )

# References


**Required Lab Reading to Learn More About Eye Movements and Cognition**

Orchard, L. N. & Stern, J. A. (1991). Blinks as an index of cognitive activity during reading. *Integrative Physiological and Behavioral Science, 26 (2),* 108-116.

**Suggested Readings**

Blanchard, H. E., & Iran-Nejad, A. (1987). Comprehension processes and eye movement patterns in the reading of surprise ending stories. *Discourse Processes, 10,* 127-138. [This article is a good example of an interesting cross-disciplinary connections. Here the impact of stories that have surprise endings, like O'Henry stories, is related to what happens to the eyes at the end of such stories.]

Glenn, F.A., Iavecchia, H. P., Ross, L. V., Stokes, J. M., Weiland, W. J., Weiss, D., & Zaklad, A. L. (1986). Eye-controlled interface. *Proceedings of the 30th Annual Meeting of the Human Factors Society*. [What practical use might eye movements have? Here is an article that describes how eye movements might someday be used to replace the mouse in controlling your computer.]

Goldstein, R., Bauer, L. O., & Stern, J. A. (1992). Effect of task difficulty and interstimulus interval on blink parameters. *International Journal of Psychophysiology, 13,* 111-117. [Do people blink more or less when reading hard materials? Read this article to find out.]

Just, M. A., & Carpenter, P. A. (1980). A theory of reading: From eye fixations to comprehension. *Psychological Review, 87(*4), 329-354. [If you look at something for a long time, will you understand it better? How does your guess compare to what these folks found?]

Thorsheim, H. I., Rice, C. D., Harner, A., & Sjulstad, M. (1997*). Psychophysiology: Study of mental or emotional processes illuminated by involuntary physiological reactions.* Unpublished manuscript, St. Olaf College, Northfield, MN. [Also look at the website on physiological responses.]

Williams, P. L., Warwick, R., Dyson , M., & Bannister, L. H. (Eds.). (1989*). Gray's anatomy* (p. 1208). Edinburgh: Churchill Livingstone. [This reference is cited to give credit for the illustration borrowed from the book. By the way, it is a terrific resource for answering all kinds of questions about physiology.]

**Web links**

Electro-oculography research
http://www.cs.sunysb.edu/~vislab/projects/eye/index.html

[A moving eye appears on this page, which describes using eye movements for an EyeMouse to control a computer, instead of hand-held mouse]

Eye Movement mailing list
http://listserv.spc.edu/archives/eyemov-l.html
[A wide range of current issues in eye movement research]

Eyelink Gaze Tracking
http://www.smi.de/el/elintro.htm
[Good example of EyeMouse equipment]

St. Olaf Research Projects
http://www.stolaf.edu/depts/psych/psychophysiology/
[For St. Olaf student projects in psychophysiology underway here]