Task and the oculomotor system

Liya M

Yarbus, 1967

Free examination. 1

Estimate material circumstances of the family 2

Give the ages of the people. 3

Surmise what the family had been doing before the arrival of the unexpected visitor. 4

Remember the clothes worn by the people. 5

Remember positions of people and objects in the room. 6

Estimate how long the visitor had been away from the family. 7

3 min. recordings of the same subject

More recent works

also supports the conclusion that task set influences fixation location:)

eye movements during complex behaviors such as making tea or a sandwich have shown that observers tend to fixate task-relevant objects rather than the most visually salient objects (Land & Hayhoe, 2001; Land, Mennie, & Rusted, 1999).

when instructed to count the number of people in a scene, fixations tended to be directed toward scene regions likely to contain people (Torralba, Oliva, Castelhano, & Henderson, 2006).

Castelhano et al., 2009

instructed participants to either search for a specific object or memorize a scene.

Several measures were found to vary as a function of task:

- the spatial distribution and total number of fixations (memory > search)
- total scan path length (memory > search)
- average saccade amplitude for the first five saccades (search > memory)
- first saccade latency (memory > search).

Figure 1. Typical viewing patterns for two participants looking at a scene in the (A) Memorization and (B) Visual Search instruction conditions, respectively. The participants were asked to look for a bucket in the visual search task.

Issue:

(Castelhano et al., 2009) compared:

visual search tasks which specify the object to which gaze should be directed

and

memorization tasks which do not place direct constraints on which objects should be fixated

It could be called experimenter-directed and participant-directed tasks.

Mills, Hollingworth et al 2011

4 participant-directed tasks:

1. Scene memorization task
2. Pleasantness rating
3. Visual search task (participants were instructed to search through a scene for a small "N" or a small "Z." Importantly, the target letter could appear anywhere in the scene, meaning participants were free to determine which objects to select and fixate
4. Free-view task

Results: fixations

- fixation durations appeared longer in the free-view and memory conditions than in the pleasantness and search conditions.

- fixation duration increased across the length of the trial in each condition

The main effect of task accounted for 32% of the random intercept variance, the interaction of condition (time and task) for 3% of the random linear slope variance
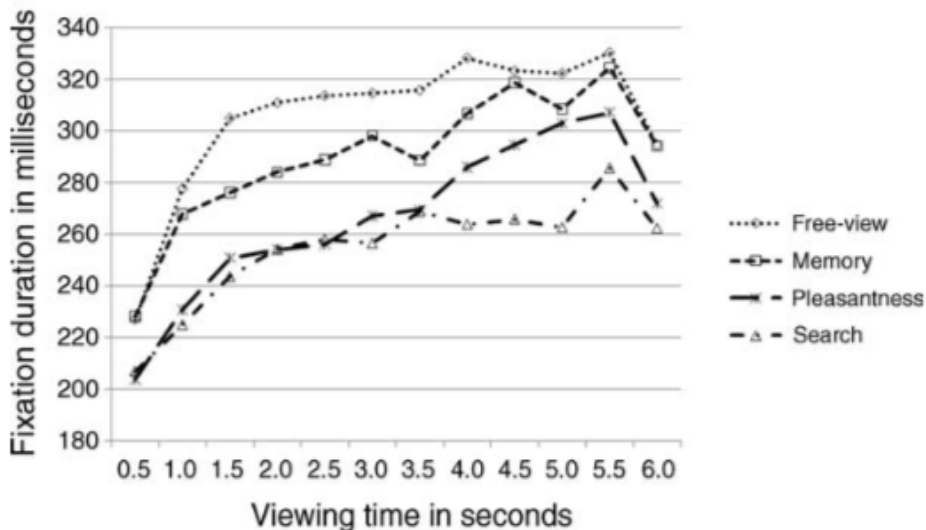
Results: saccades

- saccade amplitudes appeared smaller in the free-view condition than in others.

- in contrast to fixation duration, saccade amplitude appeared to increase only slightly across the length of the trial, with similar amounts of deceleration across conditions.
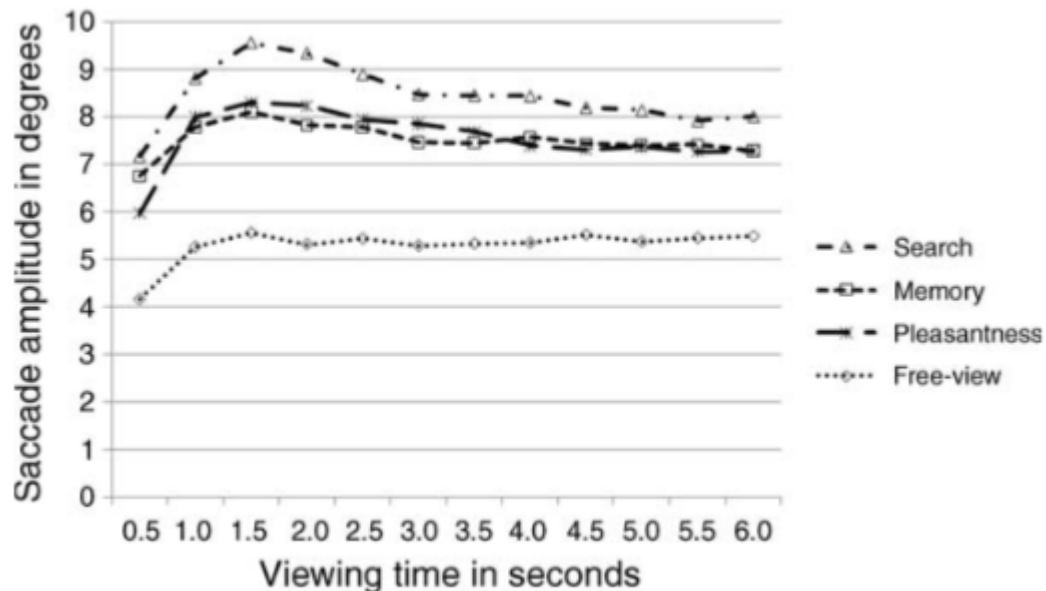
Task differences explain 57% of the random intercept variance, the interaction of condition (task and time, linear) 6% of the random slope variance, and the interaction of condition by quadratic viewing time accounted for 15% of the slope variance

To sum all above

According to (Castelhano et al., 2009) the task effects emerge immediately and generally influence "where" the eyes move as opposed to "when"

Consistent with that work (Mills, Hollingworth et al 2011) also found an early effect of task set on saccade amplitude.

In contrast to Castelhano et al.'s study where no effect of task was observed across the viewing period or during early viewing (first five fixations), the Mill's study did find that task set biased fixation duration.

Saccade amplitudes changed very little over the viewing period.

The pattern of change in fixation duration was influenced by task, whereas the pattern of change in saccade amplitude was not.

These results are inconsistent with the notion that fixation duration and saccade amplitude always function together systematically and imply distinct control mechanisms.

Dodd, Van der Stigchel, Hollingworth, 2009

Inhibition of Return and Facilitation of Return as a Function of Visual Task:

The study found that IOR is specific for search tasks. Other tasks (memorization, pleasantness rating, free view) induced facilitation

TABLE 1

Saccadic Reaction Times (SRTs; in Milliseconds) to Probes and Magnitude of Inhibition of Return (IOR) in the Four Task Conditions

	Probe location			
Task and measure	Novel	Two-back	Four-back	Six-back
Search				
SRT	254 (45)	324 (64)	336 (60)	256 (60)
IOR	—	−70	−82	−2
Memory				
SRT	293 (50)	261 (78)	280 (84)	289 (56)
IOR	—	32	13	4
Pleasantness				
SRT	291 (34)	231 (32)	231 (44)	223 (49)
IOR	—	60	60	68
Free viewing				
SRT	292 (64)	249 (38)	260 (44)	296 (69)
IOR	—	43	32	−4

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Curriculum Vitae

Research Interests

Scene perception
Visual memory: Visual short-term memory, long-term memory, episodic memory, change detection and change blindness
Eye movements: Gaze control; interactions among eye movements, attention, and memory
Attention: Top-down effects on attentional guidance, visual search, attention capture, object-based attention
Spatial cognition: Binding of objects to locations, the role of spatial memory in search
Object recognition and the effects of scene context on the identification of objects

Models

Classifiers can predict task from aggregate trial data (better than chance:))

Borji A, Itti L. Defending Yarbus: Eye movements reveal observers' task. J Vis. 2014
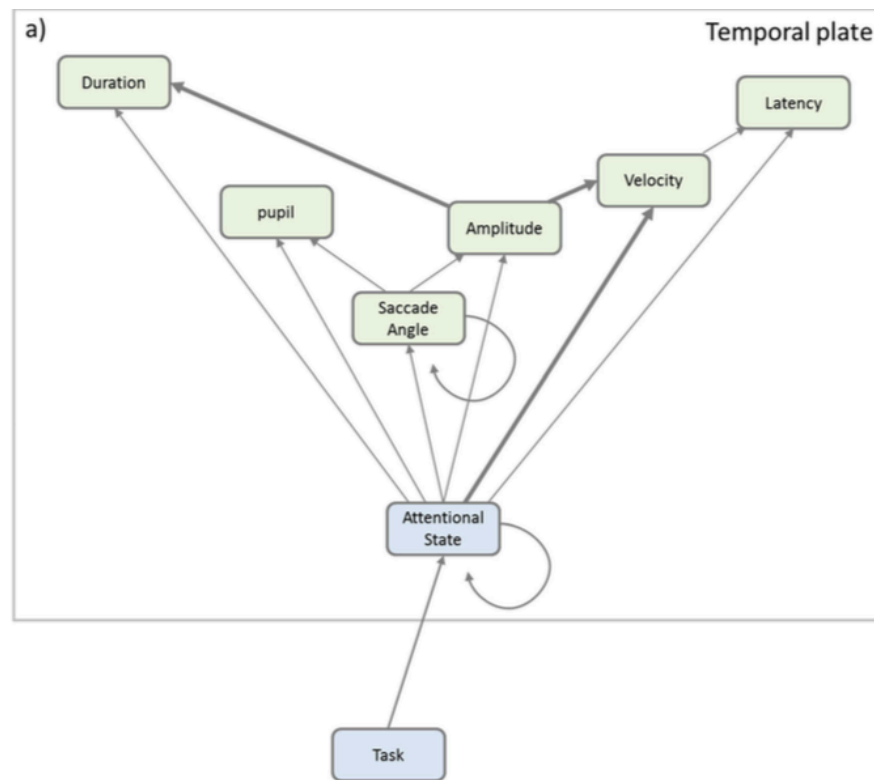
Henderson JM, Shinkareva SV, Wang J, Luke SG, Olejarczyk J. Predicting cognitive state from eye movements. PLoS One. 2013

MacInnes, Hunt, Clarke, Dodd. A Generative Model of Cognitive State from Task and Eye Movements 2018

MacInnes, Hunt, Clarke, Dodd, 2018

investigate the predictive value of task and eye movement properties by creating a model of saccade selection based on instructed task and internal cognitive state using a Dynamic Bayesian Network (DBN)

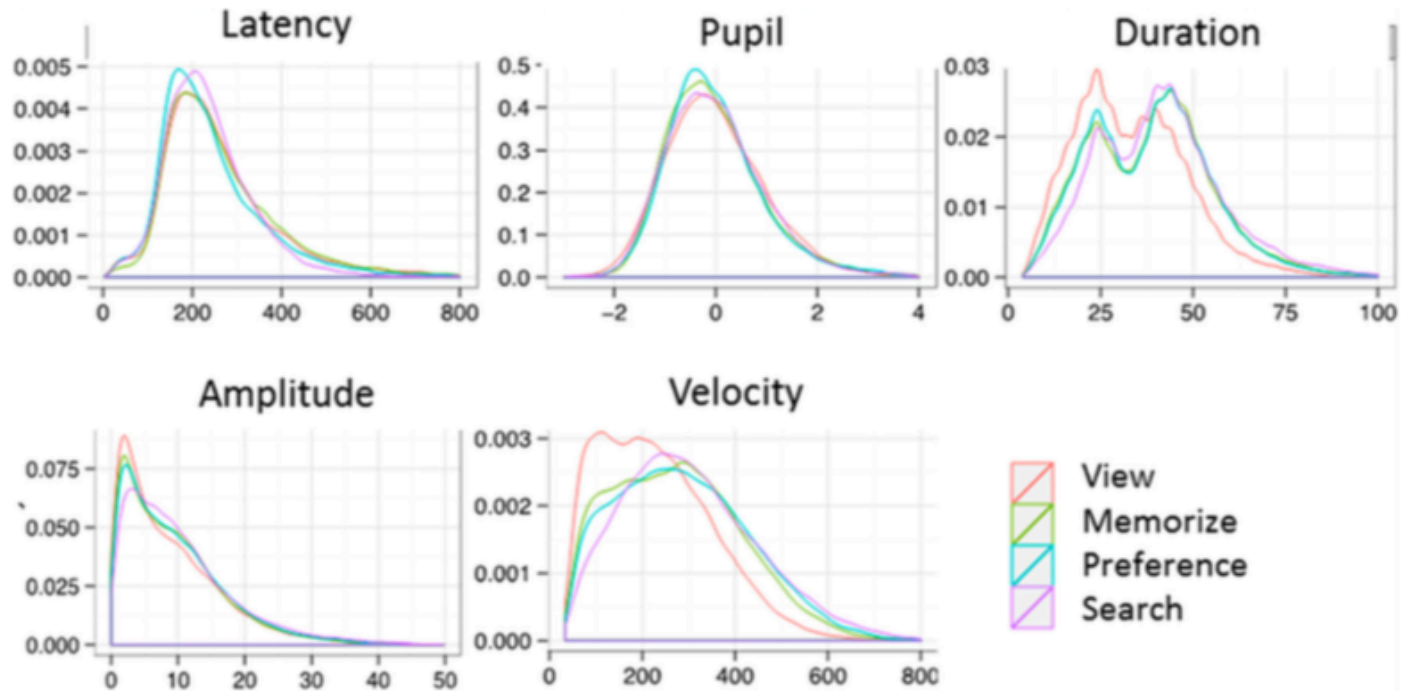The model consider only top-down influence: task and internal state

a) Temporal plate

Duration, pupil, Amplitude, Velocity, Latency, Saccade Angle, Attentional State, Task

Fig. 3 Density plots for saccadic features split by task. Saccadic features show potential for being diagnostic of task, in particular duration, amplitude, and velocity

The best accuracy was 36.4% (classification of individual saccades by tasks) and was better than chance (t = 3.45, p < .001)

Beyond attention. Oculomotor system and thinking

The cognitive goal of a task is distinct from the cognitive demands of a task. Variation in cognitive demand (or simply different visual environments) has been shown to influence fixation duration **(Andrews & Coppola, 1999; Pannasch et al., 2008; Unema et al., 2005).**

Knoblich, 2001. Eye movements related to problem solving and insight

Kahneman and Tversky. Pupil size as measure of cognitive load (if you are interested in, look here at Lena's talk for the Advanced Eyetracking Workshop https://social.hse.ru/en/vml/news/228855476.html)

Discussion

What this differences reflects?

- Papers associate fixations with retrieval of information from short and long-term memory
- Saccades amplitude could be considered as a marker of global/local processing in different tasks
- Increasing of fixation duration during trial could represent a progression toward a more complex representation of the scene
- What else?

Several measures in brain activity are related to attention. How they are related to the different tasks?

Thank you for your attention!