CGS603: Methods and Tools in Cognitive Science
Project Report

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Group 1

1 Introduction

In the book 'Understanding Media', Marshall McLuhan introduced the idea that *"the medium is the message"*. He emphasized upon the idea that when a new medium is introduced to people, we tend to focus on the content that the medium carries, and not the medium itself. McLuhan argues that while the content influences our thoughts and beliefs and the way we go about our lives, the medium can affect our cognition itself. In 1882, the philosopher Friedrich Nietzsche bought a typewriter and started writing on the typewriter instead of by hand. And his friends and readers gradually noticed that changing the medium of writing had had a subtle effect on Nietzsche's writing style itself. The 20th and 21st centuries have seen the introduction and widespread use of many new media - telephones, television, computers, and the world wide web. In this study, we wanted to study if the internet as a medium has, in the process of making us read more and consume more information, changed something about our cognitive processes. The motivation for this came from Nicholas Carr's book 'The Shallows. In the book (and in an articled titled 'Is Google Making Us Stupid?'), Carr claimed that the internet has not only subsumed other technologies (like the camera, map, calculator, clock, etc.), but it has also caused our attention to become more scattered and diffused. By providing more information in shorter snippets and suggesting hyperlinks to jump from one piece of information to another, the internet is conditioning us into losing concentration quicker. Our aim was to test if internet exposure has made our reading habits shallower and increased distractibility. We did this through a between-subjects eye-tracking study, assuming ownership of a smartphone to be a proxy for internet exposure and usage.

The project involved conducting eye-tracking analyses on *internet-naive* and *internet-using* samples of participants, with the goal of finding evidence supporting or refuting the claim that the pervasive use of internet and the hyper-linked method of reading online has reduced people's attention spans and engendered shallow reading habits.

$$H_0 : \mu_1 = \mu_2$$

$$H_a : \mu_1 \neq \mu_2$$

where, μ_1 - Mean process noise of internet-naive participants
μ_2 - Mean process noise of internet-using participants
with significance level $\alpha = 0.05$ and power $\geq 80\%$ ($\beta < 0.2$).

2 Literature Review

Since before the dot-com bubble, scientists have been concerned about the ramifications of electronic media replacing literary reading. The rise of e-books and other forms of electronic media was seen as the decline of the literary culture. In "Perseus Unbound", an essay from his book "The Gutenberg Elegies: The Fate of Reading in an Electronic Age"(1994), Sven Birkerts presented reservations towards application of interactive technology to educational instruction, cautioning that "long-term cognitive effects of these new processes of data absorption" were unknown and that they could yield "an expansion of the short-term memory banks and a correlative atrophying of long-term memory". Developmental psychologist, Maryanne Wolf, also speculated that the ability to "deep read" and think deeply could be lost in future generations where children may be taught to "e-read" and not read, rendering them mere "decoders of information who have neither the time nor the motivation to think beneath or beyond their googled universes". She pointed to the need to scientifically study such speculations.

The argument that the internet affects cognition was popularized by Nicholas Carr through an article titled "Is Google making us stupid?"[1] and later expanded on in a book "The Shallows: What the Internet is doing to our brains"[2]. The book investigates the cognitive effects of technological advancements that relegate certain cognitive activities — namely, knowledge-searching — to external computational devices. He invokes the idea of sociologist Daniel Bell that technologies extend human cognition, arguing that humans unconsciously conform to the very qualities, or kinds of patterns, involved in these devices' function. The book received mainstream recognition for interrogating the assumptions people make about technological change and advocating for a component of personal accountability in our relationships to devices.

Carr also highlights the point that the Internet makes its money mainly by exploiting users' privacy or bombarding them with overstimulation, a vicious cycle where companies facilitate mindless browsing instead of rewarding sustained thinking. Similar concerns have led to the conception of movements like "Center for Humane Technology"[3] which tries to bring attention to how tech industry tries to monetize our attention and how it is "eroding the pillars of our society: mental health, democracy, social relationships, and our children". They advocate the need to address the problem at the level of corporations and tries to change to more "humane" technology.

It has long been hypothesised that encouraging young people to read more will help them to develop stronger reading skills[4]. The association between frequency of reading and higher attainment has been repeatedly demonstrated within the academic literature, with many studies exploring the role motivation plays in their interaction[5].

A 2008 study by University College London, titled "Information behavior of the researcher of the future"[6] looked at whether the 'Google generation' (a popular phrase that refers to a generation of young people, born after 1993, that grew up in a world dominated by the internet) are searching for and researching content in new ways and whether this is likely to shape their future behaviour as researchers. They provide a broad overview of how the digital transition and the vast range of information resources being digitally created affected behavior. They developed a methodology that tried to use, within the considerable limitations of the current evidence base, to recreate a longitudinal study from the literature (including previous survey materials) together with some new primary data. They caution that the evidence base relevant to the issues raised in this report were incomplete and, in some cases, contradictory, suggesting

the need for more thorough studies, ideally a longitudinal study.

More recent studies and meta reviews that also looked at reading comprehension and learning in digital versus other learning environments, also conclude that digital environments may not always be best suited to fostering deep comprehension and learning [7, 8]. Studies that have looked just at the preference of medium among university students have also shown a persistence for print media, with 92% reporting to being able to concentrate better when reading in print[9]. Practical suggestions like practice methods to overcome screen inferiority for people who prefer digital reading[10] have also been studied. People have also used eye tracking from the perspective of user experience design to try understand how users read content on webpages in order to deliver it better[11, 12].

3 Experiment Design

The experiment is based on a between-subjects design and requires two groups of subjects - one group of active internet using subjects and another group of internet naive subjects. The subjects in the two groups need to be matched on age, socio-economic status, education, and general intelligence. Finding matching subjects is one of the most difficult parts of conducting this experiment.

3.1 Participants

We decided to work with subjects for both groups from within a certain already delineated demographic, so as to control variations in socio-economic status and education. In order to get a sizeable number of participants who are internet naive, we decided to use working class individuals, or construction workers as our pool of participants. The internet naive subjects were chosen as those who did not own a smartphone, with the underlying assumption that individuals who do not own a smartphone do not have access to the internet via any other device, given the socio-economic status and profession. Hence the two groups were

1. Those who own a smartphone (active internet users)
2. Those who do not own a smartphone (internet naive).

Since the subjects were chosen from a common pool, we didn't have to explicitly match them on socio-economic status or education, since all the subjects hailed from similar backgrounds. The age and general intelligence were matched across the subjects. The general intelligence was matched across the participants using the Standard Raven's Progressive Matrices. All the participants were compensated monetarily.

3.2 Procedure

3.2.1 Raven's Progressive Matrices

The Raven's Progressive Matrices (RPM) is an IQ test that is free of language and culture confounds. It is a pictorial test and is used to measure general fluid intelligence. The Standard RPM is a 60-item test and takes 40 mins on average to complete. To reduce the time for the IQ test, we used an abbreviated 9-item form of RPM [14]. As the participants were never before exposed to such a test, they were given a couple of sample questions, so as to get familiar with the testing paradigm.

3.2.2 Eye tracking experiment

After the IQ test, the subject performs the Eye-Tracking experiment. Figure.1 shows the eye-tracker used. It is a screen-based eye-tracker by SR Research with a sampling rate of 1 kHz. The experiment was designed using their proprietary software. The subjects are given instructions first and then they proceed to do the eye-tracking experiment.

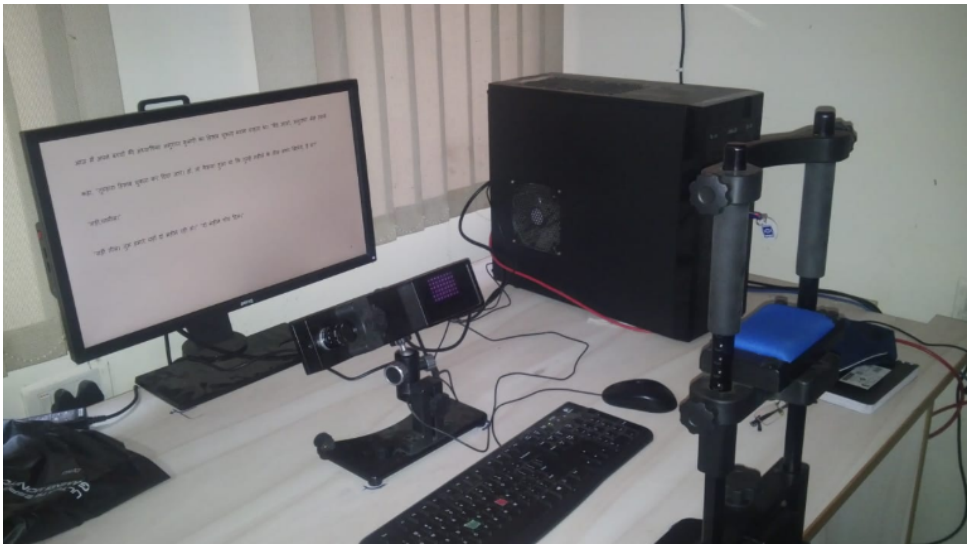

Figure 1: The eye tracking setup

A standard reading paradigm task was used. After calibration and validation, the subjects start off with a practice block. This familiarizes them with the task at hand. The practice block is followed by two blocks of the main experiment with a short break in between of around five minutes. The practice block contains three screens Hindi text followed by two questions. The main experiment blocks contain a story each that is split across 10 screens followed by two questions each. The stories are selected such that they are not too easy or too difficult to read and comprehend. Figure 2 shows the experimental procedure graphically.

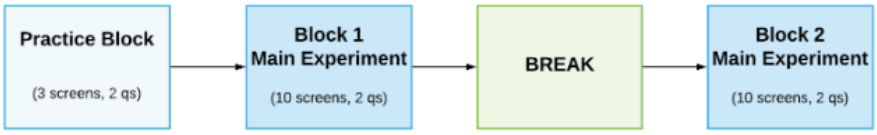

Figure 2: Timeline for the eye-tracking experiment

A sample screen of the experiment is shown in Figure 3. Each screen has a maximum of six lines of text. After the participant finishes reading the material on the screen, he/she looks at the black dot at the bottom right corner of the screen to move on to the next page. All lines in the text are triple spaced. The font type of the text is Mangal and the font size is 24. The distance between the eyes and the screen is 90 cm. Hence, the visual angle (the size of the image formed on the retina) is 1^o .[15]

$$VisualAngle = 2 * tan^{-1}(0.5A/D)$$

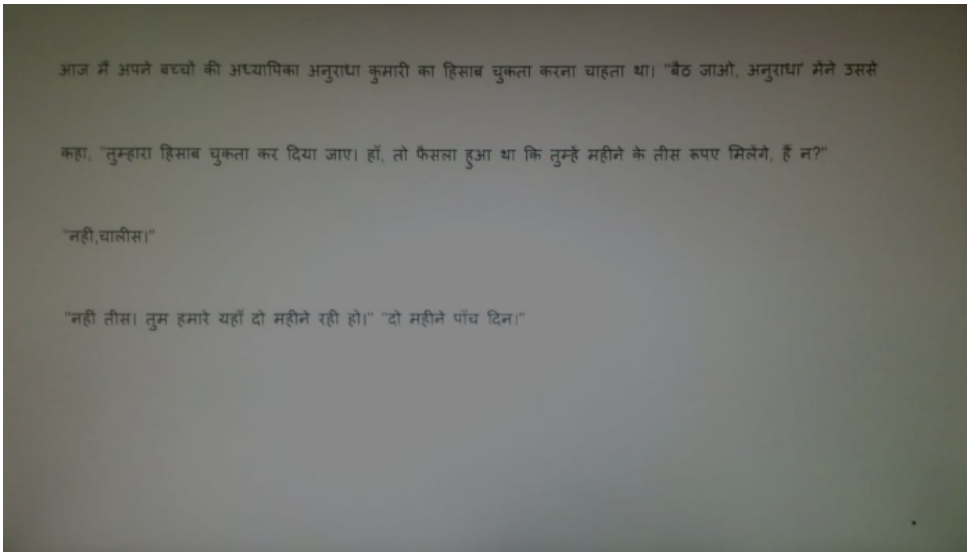

Figure 3: Timeline for the eye-tracking experiment

Figure 4 shows the interest areas along with the fixations. The interest areas are the red rectangles that encompass a word of Hindi text. The fixations are the blue circles in the figure. The size of the circle is proportional to the duration of the fixation. The readings were always binocular but the eye movements were recorded from the right eye.

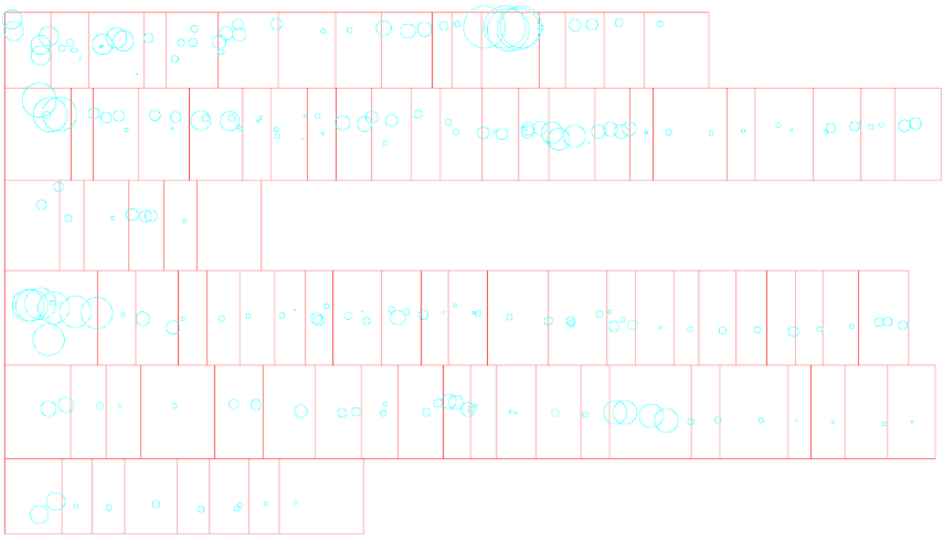

Figure 4: Interest areas and fixations

4 Data Collection

We collected data from 5 subjects belonging to the internet-naive sample. Out of the five, we were able to salvage 3 logs for further analysis.

5 Data Analysis

5.1 Pre-Processing

From the data collected, we use the fixation coordinates (x,y) as measurements to fit a linear state space model. Before passing this data we linearize it by shifting y-coordinates of each line and incrementing the x-coordinate such that y remains in [80,240] as x increases with each line, as show in Figure 5.

Figure 5: Linearising in the data

5.2 Kalman Filter State Estimates

We model our data as a linear dynamic system, with measurements at each time being the fixation coordinates at that time instant. We use Kalman filter for state estimation which is done over two steps - Prediction and Measurement.

5.2.1 Prediction Step

In this step, we start with a current estimate of state at time $k-1(x_{k-1})$, and predict the next state (x_k) using the transition matrix F_k, as the assumption here is that the transition from one state to another is linear. Note that x_k is the estimated mean of the state, and we'll also have the covariance matrix P_k which will be estimated with the addition of a gaussian noise Q_k, which is called the Process Noise of the Kalman filter. We use the determinant of the process noise as the quantifying measurement in our experiment.

$$x_k = F_k.x_{k-1}$$
$$P_k = F_k.P_{k-1}.F_k^T + Q_k$$

5.2.2 Measurement Step

Now we use our fixation data for the correction step of the Kalman filter. Here z_k is the fixation coordinates at time k, x_k is the state prediction from the last step, H_k is the measurement matrix which operates on state x_k to give the measurement z_k, and R_k is the measurement noise which is again modeled as a gaussian. K' is known as Kalman Gain, and acts as a weight for state correction using the measurement data.

$$x'_k = x_k + K'.(z_k - H_k.x_k)$$
$$P'_k = P_k.K'.H_k.P_k$$
$$K' = P_k.H_k^T.(H_k.P_k.J_k^T + R_k)^{-1}$$

We feed the corrected state estimate x'_k back into the prediction step and continue for the whole measurement data. Kalman filter schematic is shown in Figure 6. We estimate the various parameters of the Kalman Filter (F_k, H_k, Q_k, R_k) using the EM Algorithm

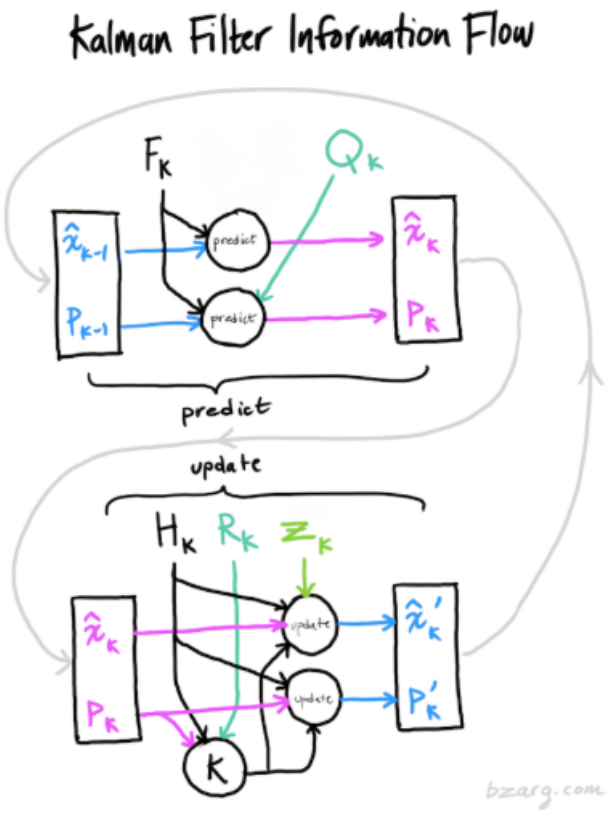

Figure 6: Schematic of Kalman filter

6 Results

We used the Kalman filtering toolbox for Matlab provided by Alex Blocker from Boston University[16]. The fixation data collected from 3 internet naive subjects were linearized and we estimated Process noise covariance for each. The determinant of the process noise is of the order of 10^{-5} for all the 3 subjects. Further inferences can be made with this after collecting data from subjects belonging to the internet proficient group.

7 Future Direction

We think that it is very important that we complete our data collection and analysis with choosing from a broader range of demographics over the summers. But based on any possible incongruencies that may come up from our analysis we are also thinking of asking and investigating the same question with different experimental design. Based on the trials, we think there is also a need to have a separate language reading proficiency test, as the variation among participants can be stark even though they belong to roughly the same demographic. We are also looking to research and design a study to explore if something like a change in reading pattern (distractibility, attention) is induced after priming a sample with hyperlinked internet-like reading over time and trials with a more sophisticated, yet simple and effectively designed

experiment. This would also help substantiate our study while providing more valuable insights. We are also considering to using other equipment such as the Tobii eye tracker setup which gives us an added advantage of the freedom of movement in a sitting position as well as maintenance of consistent accuracy throughout the duration of the experiment, both of which are very important considering the participants that we need to work with.

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