Lying through the Eyes: Detecting Lies through Eye Movements

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ABSTRACT
In this pilot study, we investigated if it is possible to detect lies through eye gaze behavior. Earlier research suggests that lying increases the cognitive load, resulting in less eye-movements and shorter saccade amplitudes. To investigate these findings further, a structured interview was conducted with three subjects. During the interview, subjects were supposed to lie in half of their answers. The subjects' eye gazes were tracked during the interview session. We hypothesized that people show shorter saccade amplitudes and tend to engage in less eye-movements when lying. A significant difference could be observed for saccade amplitudes between the truth telling and lie telling situations. The overall results support the theory that cognitive load decreases the number of eye movements, but our analysis also revealed significant individual differences. This raised the question whether different individuals have different ways of handling deception and whether different viewing behavior patterns could be found for different groups of individuals.

Categories and Subject Descriptors
J.4 [**Social and Behavioral Sciences**]: Psychology

Keywords
Lie detection; eye tracking

1. Introduction
Lying has been an intricate aspect of human interaction that has always garnered interest from different fields of research. The first incidence of this social behavior often takes place early in our childhood in the form of bluffing, and eventually becomes a natural aspect of human interaction. Despite lying being a natural ability, most people could only correctly distinguish truth from lies with an accuracy of 54% (Bond & DePaulo, 2006).

GazeIn'13, December 13, 2013, Sydney, Australia.

At present, the literature examining lying and its associated behaviors, is divided between two theoretical frameworks. The emotional framework of lie detection purports that when people lie, the emotions associated with the concerns of their lie being discovered raises their arousal levels. This elicits physiological or behavioral responses which could be interpreted as deception cues. An instance of the application of the emotional framework of lie detection is the polygraph test. A polygraph test continually assesses a participant's physiological responses for deception cues during a questioning paradigm. These include pulse rate, blood pressure, respiration rate, and skin conductivity.

Although initial findings by Raskin and Hare (1978) revealed that polygraph tests had an accuracy of 95.5% in discriminating truth tellers from liars, the reliability of polygraph test results has received a lot of criticism from the field. Among the most serious criticism of the test is its validity (National Research Council, 2003). Physiological responses displayed by liars in polygraph tests were not discriminable from general arousal responses to stress, fear or guilt (Ekman & O'Sullivan, 1991; Gross, 1998; Lykken, 1988; Richards & Gross, 1999). In addition, the central assumption of polygraph testing, that lying results in more sympathetic nervous system arousal than truth telling, has not been validated (National Research Council, 2003). This limits the effectiveness of the polygraph test as a lie detector, and reduces the credibility of the test results as evidence of lying.

An alternative approach to lie detection is the cognitive load framework. The cognitive load framework of lie detection assumes that lying is more cognitively demanding than truth telling (Burgoon et al., 1989; Goldman-Eisler, 1968; Kohnken, 1989). Firstly, formulating a lie is cognitively demanding as the liar needs to fabricate a story and remember the details of the story to ensure its consistency. Secondly, retrieval of the truth is often automatic but activating a lie is more intentional and deliberate, and thus requires mental effort. Thirdly, liars need to suppress the truth while fabricating a lie, which places cognitive demands on the liar. Fourthly, when lying, individuals also tend to be preoccupied with controlling and monitoring their demeanor to appear honest. In addition, liars may also tend to monitor the interviewer's reactions more carefully to evaluate the successes of their lies. These controlling and careful monitoring of behaviors also imposes cognitive load on the liar. As a result of the increased cognitive load due to lying, the cognitive load approach to lying predicts that the maintenance of natural behaviours become increasing difficult for liars. This results in a neglect of body language amongst liars which leads to deception cues leakage.

Recent developments in lie detection techniques employing the induction of cognitive load have provided evidence that liars and truth tellers can be classified beyond chance. Cognitive load inducing methods like time restricted integrity confirmation (Walczyk et al., 2005) and recounting events in reverse chronological order (Vrij et al., 2008) exploits the increase in cognitive load brought about by lying to generate more pronounced differences between liars and truth tellers. This is reflected in an increase in deception cue leakage such as eye movement, pupil dilation, answer inconsistency and response time (Ekman & Friesen, 1971; Harrigan & O'Connell, 1996; Walczyk et al., 2005; Vrij et al., 2008; Zuckerman et al., 1981).

While the cognitive load inducing approach identifies gaze behavior as a deception cue, it only surfaces when cognitive load due to lying is further amplified. Thus, is gaze behavior sensitive enough to be used as a direct measure of cognitive load due to lying?

Our review of the literature on gaze behavior suggests that eye-tracking technology can potentially allow us to measure a person's cognitive load. These measures include fixation durations and saccade amplitudes. Fixations are stationary points in eye movement. Early studies by Just and Carpenter (1976) and Rayner (1978) have linked fixation durations to processing time applied to the object of fixation. Longer fixation durations indicated greater difficulty extracting or interpreting the visual information. The amount of processing required could thus reflect the amount of cognitive load placed on the individual by the visual information.

Saccades are eye movement between fixations which shifts the eyes to the next viewing position. Saccade amplitude which measures the distance of eye movements is influenced by different cognitive processing demands. In a study by Tatler and Vincent (2008) it was found that large saccade amplitude represented movement to new visual areas where new information is presented to the visual system while short saccades were connected with the examination of details. Besides the influence of the nature of cognitive processes, saccade amplitudes were also found to vary with the amount of information processing. A review of eye movement studies on the cognitive processes of reading (Rayner, 1998) revealed that with increased processing demands, saccade amplitudes decreased. With the above evidences suggesting top down cognitive processes influencing saccade amplitudes, saccade amplitudes could thus be used as a measurement of the amount of load faced by the cognitive system.

In this pilot study, we wanted to investigate whether gaze behavior could be used to distinguish lying from truth telling. We defined lying as the assertion a false belief with either the intention that the statement is believed to be true or with the intention that it is believed to be true by the other person, or both (Mahon, 2008). A within subject study was conducted for conditions of truth telling and lying. If telling a lie is cognitively demanding, we can expect a decrease in saccade amplitude and an increase in fixation duration as direct compensatory behaviors for the increase in cognitive load.

We hypothesized that people tend to have shorter saccades when they lie as compared to when telling the truth. This is a compensatory behavior that results from the cognitive demands of lying. Shorter saccades would help reduce the amount of new information picked up by the visual system and hence reducing the cognitive load imposed. We also hypothesized that the duration of fixation is longer when people lie as compared to telling the truth. This is because, when people lie, they tend to be preoccupied with monitoring and controlling behavior. We predicted that this exertion of cognitive control would extend to the eyes, resulting in longer fixations. Thus, we came up with the following hypotheses:

H_1: "Saccades are longer during truth telling."

H_2: "When people lie, they tend to engage in less eye movements, which results in longer fixation durations."

2. Method

2.1 Participants

For this pilot study we tested three subjects, two males and one female. They were 23, 39 and 24 years of age and their mother tongues were German, Finnish and Hungarian. The subjects were recruited through related course participation.

2.2 Setup

The subjects were seated in a room, facing the interviewer. A stimulus-poor background was chosen in order not to distract the subjects. A free standing eye tracking device (Tobii X120) and a web camera with microphone to record the subject's face and conversation were situated about 60 cm in front of the participant, at a low level that did not obstruct the participant's view of the interviewer. The use of the Tobii X120 free standing eye tracker allowed eye tracking to take place without any equipment attached to the participants. The eye tracker had an accuracy of 0.5 degrees and a data rate of 120 Hz. However, the accuracy of the eye tracker was somewhat lower for the interview setting the participants were engaged in, because even if the observers were instructed to stay in one place, during the natural conversation they moved their head. A calibration of the eye tracker was done with each participant with a five-point calibration grid prior to the commencement of each of their interview. The interviewer was seated within the calibration grid throughout the interview.

The experiment was recorded with a video camera (Sony SuperSteadyShot HDR-SR12), situated behind the participant, at a height that was above the participant's head. The data from the video camera and eye tracking device were imported to the computer and put together using the software Tobii Studio 2.3.1. The final product of the video captures the area within the calibration grid that participants were watching, with red dots indicating the direction of their gaze (see Figure 1).

Figure 1. Experimental setting. The dots indicate the subject's gaze direction.

2.3 Procedure

Prior to the experiment, subjects were briefed on the purpose of the experiment and given the instructions listed in Table 1.

Table 1 Instructions

You will be interviewed on a series of six different topics on your personal life:
1. Your favorite movie *2. Your favorite subject in school* *3. Your most unforgettable experience in school* *4. Your most disgusting experience with food* *5. Your favorite country to live in* *6. Your most embarrassing experience with the Finnish/foreign language*
Select any three out of the six topics and lie about them. In the remaining three topics, relate the truth to the interviewer. Your task in this experiment would be to make it difficult for the interviewer to spot your lies.

Subjects were given two minutes to prepare for the interview. The eye tracker was calibrated with the subject and interviewer seated in his position. The interview was a structured interview involving a two-party interaction between the subject and one interviewer. Two additional instructors were also present in the room. One instructor operated the eye-tracking-device during the experiment, the other one gave the instructions in the beginning and stayed in the background to help out, when additional help was needed.

The interview started with basic questions about the subject's name, age, nationality and mother tongue. Subjects were then asked questions regarding to the six different topics in Table 1. Each topic was prompted with an open ended question asking subjects to describe their experiences related to the topic. Additional follow-up questions were asked to prompt subjects to provide reasons for their answers and to describe their feelings regarding the topic. Questions were fixed across all subjects to control for influences from the interviewer. And beyond the additional follow-up questions, the interviewer's verbal responses were also limited to simple acknowledgements like "okay" and "aha".

While subjects provided their responses to the questions, the interviewer scored whether he felt subjects were lying or telling the truth for each of the topics. The interviewer had no prior knowledge of the topics that subjects chose to lie or tell the truth in. And at the end of the interview, a survey was handed out to subjects, to find out on which topics subjects told the truth and to assess the relevance and task difficulty for each topic. The average duration of each interview was about 5 minutes long.

2.4 Dependent variables

Saccade lengths in pixels were used to measure the amplitude of eye- movements, which were needed for the second hypothesis (Hypothesis 1: *Saccades are longer during truth telling*.). The fixation durations in milliseconds (ms) were obtained as the dependent variable (DV) with regard to the frequency of eye-movements (Hypothesis 2: *When people lie, they tend to engage in less eye movements, which results in longer fixation times.*). The DVs are summarized in Table 3.

2.5 Outliers

Fixation durations below 90 ms and above 2500 ms were treated as outliers and were deleted from the dataset.

3. Results

3.1 Analysis of the whole dataset

Analysis of the data revealed that none of the data were distributed normally, thus nonparametric tests were used. The Mann-Whitney U Test (Mann & Whitney, 1947) was used to compare the saccade amplitudes and fixation durations between truth-telling and lie-telling situations. Saccade amplitudes were longer in truth telling situation than when telling lies ($p= .007$) (Figure 2). No significant effect could be obtained for the fixation durations between truth telling and lying ($p= .979$) (Figure 3).

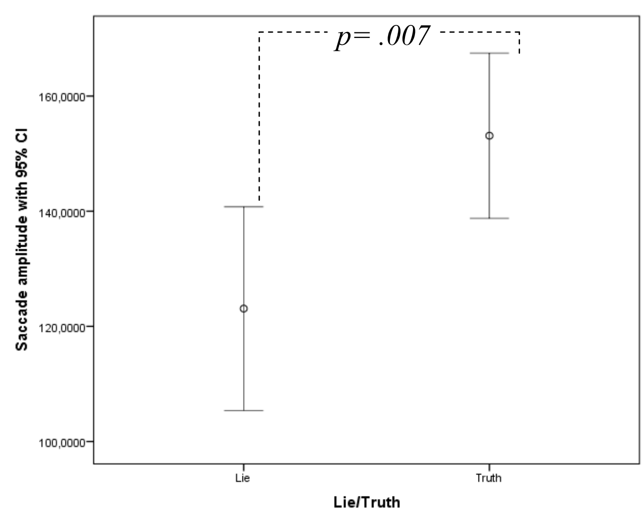

Figure 2. The average saccade amplitudes for *Lying* and *Truth telling with 95 % confidence intervals. The saccade amplitudes are given in pixels of the camera screen recording the scene.*

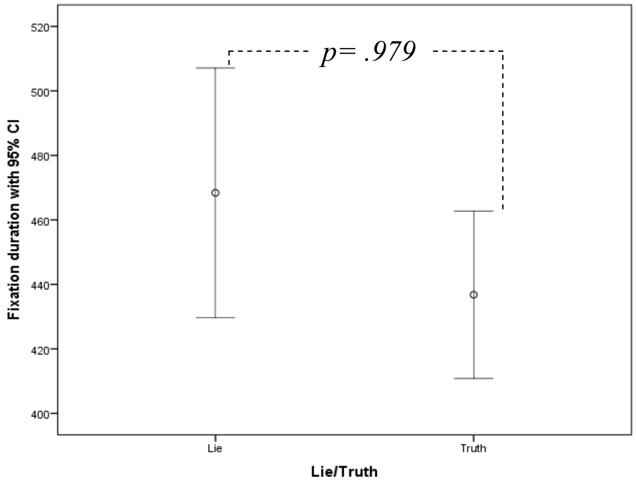

Figure 3. The average fixation durations in milliseconds for *Lying* and *Truth telling with 95 % confidence intervals*

3.2 Analysis of individual differences

Individual differences could be observed from the data. Figure 4 shows the individual differences for saccade amplitudes and Figure 5 for fixation durations for the lying and the truth-telling situations. Table 4 and 5 show the results of Mann-Whitney-U-Tests for saccade amplitudes and fixation durations for each subject separately.

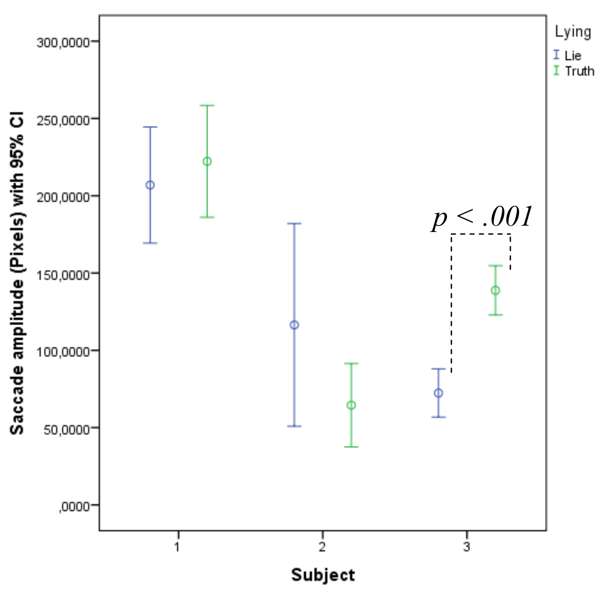

Figure 2. Individual differences in saccade amplitudes by *Lie* and *Truth*

Table-2. Results of the Mann-Whitney-U-Test for saccade amplitude for each subject individually

Subject	Mean rank Truth	Mean rank Lie	p-value
1	169.70	162.09	*p = .469*
2	49.34	49.69	*p = .639*
3	417,56	350,53	*p < .001*

As can be observed from Table 4, the difference in saccade amplitudes is only significant for subject 3 and not for the other subjects.

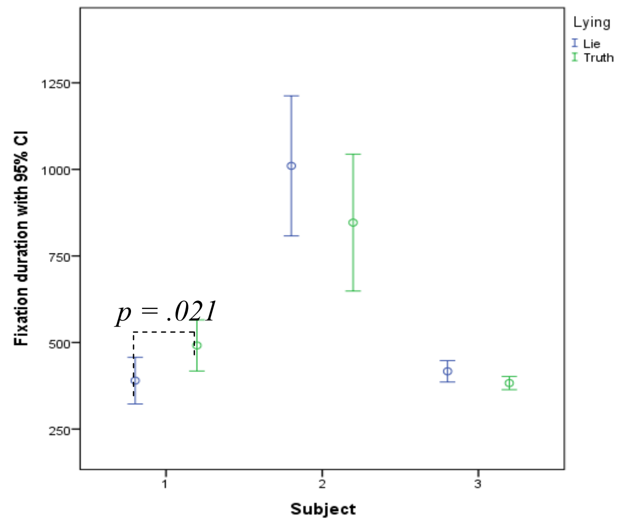

Figure 3. Individual differences in fixation durations by *Lie* and *Truth*.

Table3. Results of the Mann-Whitney-U-Test for fixation duration for each subject individually

Subject	Mean rank Truth	Mean rank Lie	p-value
1	177.77	153.57	*p = .021*
2	44.84	51.09	*p = .269*
3	387.05	412.73	*p = .137*

The results in Table 5 show that the difference in fixation duration was significantly shorter during lie telling for subject 1. However, we could not find any differences in fixation durations for the other two subjects.

Table4. Results of the Kruskal-Wallis-Test to test the significance of individual differences

Dependent Variable	Kruskal-Wallis-Test
Saccade amplitude	$\chi^2_{(2)} = 46.588$, p. < .001
Fixation duration	$\chi^2_{(2)} = 70.457$, p. < .001

A Kruskal-Wallis-Test was conducted to investigate if the subjects differ significantly from each other, with respect to their saccade amplitudes and fixation durations. Table 6 above, summarizes the results of the test, showing that the differences between individuals are statistically significant

4. Discussion

While the present pilot study has found differences in saccades amplitudes during lying, the results seemed to be explained by gaze behavior from one subject. This finding of individual differences in gaze behavior during lying questions the homogeneity of behavioral and cognitive antecedents of lying across individuals. In other words, could lying have different cognitive and behavioral implications for different individuals? And to what extent were individual differences involved in the findings reported by Walczky et al. (2012) that liars had less eye movements. Different individuals may have resorted to different deception strategies in a bid to avoid detection and to cope with the increased cognitive load while lying. Therefore, deceptive behaviours that unfold may vary across individuals depending on the strategies they adopt. At this juncture, further investigations into the individual differenes would be needed to determine whether gaze behaviour and lying can truly be associated across different groups of individuals.

The lack of significant effects for fixation durations highlights the possibility that factors other than the psychological attribute of cognitive load might be influencing fixation duration. Findings by Levitski, Radun, Jokinen (2011) during a three-party interaction suggests that the speaker's fixation durations reflect the elicitation of feedback on whether the other party follows and understands the conversation. And in our case, eliciting feedback during lie telling could have also played an important role in helping subjects determine if their attempts at lying had been successful. Hence, the lack of difference in subjects' fixation durations during truth telling and lying could have been due to the additional representation of subjects' efforts at monitoring how well the interviewer follows their presentation of the topics during the interview, rather than portraying solely the psychological attribute of cognitive load.

Although the small sample size of our pilot study limits the extendibility of our findings to the larger population, we conducted an analysis of individual differences in order to understand the strength of our findings. Looking at the differences in saccade amplitude and fixation duration between truth telling and lying situations in each subject, we also found influences of individual differences on the overall results. For the findings on saccade amplitudes, the significant differences in the saccade amplitudes between *Truth* and *Lie* could be explained solely by the data from subject 3. Although the data with regards to subjects 1 and 2 did not achieve significance, the data from subject 3 was able to contribute significance on the overall data because subject 3's interview lasted 478 seconds, which was longer than the average interview duration of 369 seconds. This resulted subject 3 contributing more saccade amplitude and fixation duration data compared to the other two subjects. Thus, allowing the data from subject 3 to have a greater influence on the overall results.

No significant difference could be found for the fixation durations. Only subject 1 showed longer fixation times when telling the truth, which was contrary to the hypothesized difference. Furthermore, the Kruskal-Wallis-Test was also significant, indicating that individual scores differed from each other. Thus, the findings of individual differences suggest a reduced power of the statistical analyses and that more studies are needed to determine whether the results are solely due to individual differences or a difference in gaze behavior when people are lying. Future studies should repeat the experiment with a bigger sample size to rule out the influence of individual differences and for the study to be representative.

One limitation of the current study was the extent to which the controlled experimental setting was able to emulate real world scenarios of lying. Factors such as the consequences of discovery of the lie by the interviewer and the intent of the lie could influence the motivation for lying, and the extent to which the lie deviates from the truth. As these factors could possibly impact the individual's behavior when lying, the study's set up attempts to control for these influences by informing subjects that they would be constantly evaluated by the interviewer to detect instances of lying. Information on the additional role of the interviewer introduced a common motivation for lying among subjects; to minimize detection of their lies by the interviewer. While this information may also result in a change in subject's behavior, it adds realism to the experimental setup; akin to interrogation scenarios where subjects are closely monitored for leakage of deception cues.

Another limitation faced by the study was due to the eye-tracking device. The eye tracking device required subjects to keep their heads stationary throughout the interview. At times, this proved to be challenging for the subjects. This had two implications for the study's findings. Firstly, the accuracy of the eye tracking device depended on subjects' ability to keep their heads stationary. Head movements generated during the interview could decrease the accuracy of the eye tracking device, increasing the amount of error in the saccade amplitude and fixation duration extracted from the device. Secondly, requiring subjects to keep their heads stationary constrains natural behaviors elicited during the interview process, decreasing the study's representativeness of a real interview. Thus, future studies could explore the use of mobile eye-tracking devices to measure gaze behavior and avoid inconsistencies in instrument accuracy and behavioral constraints.

Another aspect to consider is that English was not the mother tongue of the subjects even though they all were fluent with the English language, This presents a potential confound as the high cognitive load reflected in lying could also be attributed to the cognitive demands of translating subject's thoughts into English. However, the use of a within subject's design allowed us to control for these additional cognitive demands faced by subjects when relating the truth or when telling a lie. For future experiments, it would be useful to conduct the interview in the subject's own mother tongue.

5. Conclusion

The main conclusion from the present pilot study is that there seems to be a need to examine whether gaze behavior and lying are truly associated across individuals. Further studies on individual differences would be needed before we can consider the use of gaze behavior as a direct measurement of increase in cognitive load when lying.

6. Acknowledgements
This study was conducted as part of an exchange program with the University of Helsinki. Our thanks to the University of Helsinki, for hosting us and giving us the permission to use their facilities for the purpose of this study. Also, special thanks to our fellow course participants for taking part in the study.

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