Eye Movements and Lie Detection

Yulia V. Bessonova(✉) and Alexander A. Oboznov

Institute of Psychology, Russian Academy of Sciences, Yaroslavskaya 13,
129366 Moscow, Russia
farandi@mail.ru

Abstract. Accurate value-driven attention and lie detection are crucial for psychodiagnostics. Eye-tracking could be a way to improve the reliability and validity of psychological research. Benefits of eye-tracking are its non-invasive, speed recording, consciousness control proof. The first aim was to search for markers of attention to meaningful stimuli. Specifics markers and gaze patterns of value driven attention were found in contrast to the attention of neutral or composed-indented stimulus. The second aim was to find eye movements' markers of deception. We found a stable complex of markers for reliably lie detection which is stimulus' and deception' type free. Also, specific markers allow differentiate any kinds of deception. Selected deception markers together with "value-driven" markers formed the basis of truth-or-lie detection technology for psychological testing. The special software has been developed what measure background of an individual response rate and allow to set flexible criteria for identifying false responses.

Keywords: Eye tracking · Eye movement · Lie detection · Types of deception
Software

1 Introduction

The polygraph testing technique remains a widespread instrumental method for lie detection despite the accumulated list of critical remarks and problems, but so far, no solutions have been found or difficult to achieve. There have been critiques of the polygraph techniques from several perspectives. Arguments include that it based on a number of outstanding issues, including, first of all, the low validity of polygraph testing; the high variability of individual responses; the subjectivity of the polygraph examiner affecting testing process and test interpreting, and these cannot be eradicated; the differential impact of attitudes, described in detail by Ekman [1]; the complexity of testing in an altered state of consciousness, for example, a generalized fear, mood disorders, any form of intoxication etc. [2]; a widespread resistance to testing, as well as difficulties in defining reasons can be given for psycho-physiological changes (the observed reaction is caused by exam situation or significant stimulus?). Moreover, in 2012, Jarrett noted that the scientific community does not have any theoretical evidence to substantiate the reliability of polygraph testing, which would be published in serious peer-reviewed sources [3].

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These shortcomings call for either increasing validity and reliability of polygraph test or searching for other techniques of lie detection. The action within the scope of the first approach are geared towards the combination of verbal, non-verbal and physiological markers of deception [4] implemented together with improved technology of questioning [5]. In the second area, the researchers concentrated on seeking another psychophysiological correlates of deception that would not be volitionally controlled, but rapidly changing and useful for differentiating between the changes owing to the functional state of the individuals or intention to hide true information. The eye movements as another perspective psychophysiological markers of deception are attracting greater attention.

Improvement of equipment for eye movements recording had led the way by using eye-tracking in psychological research more frequently in recent years. Eye-tracking has significant advantages. Firstly, the eye movement registration demands little in terms of examiner's skill requirements. Secondly, the eye-tracking technology allows remote, non-invasive diagnostics, while at the same time delivering extremely precise results with less time spent calibration, testing and data processing. Thirdly, many psychophysiological indices are too often inert responding with great latency and, for that reason, uninformative. Eye-tracking has high measuring accuracy; high-speed calibration, survey and processing of results, as well as high-frequency data recording that enable us to capture more thin changes in eye movements, such as, saccade velocity etc. Fourthly, eye-tracking is based on the measurement of cognitive responses instead of an emotional response that is considered unreliable, dependent on the respondent's status and testing situations.

The main idea of eye-tracking is the "value-driven attention" - the searching and focusing more on a subjective significant and/or emotional stimulus. Therefore, the eye-tracking hasn't limitations of polygraph and makes it technically possible to differentiate true and false answers regardless of the emotion reaction of the testing situation, the functional state of the respondent, etc. The eye-tracking is increasingly being used for lie detection for security reasons - EyeDetect; The Automated Virtual Agent for Truth Assessments in Real-Time (AVATAR); Saitama Police detecting system; The detecting technique by Luniakova, etc. Available data confirm the validity of the method (the accuracy of lie detection is comparable to the polygraph testing and is, according to various estimates, from 86 to 95%), but set of markers of deception and their variability in lying are highly controversial. For example, technologies are based on a different stimulus (text, image, face recognition, interaction) and different marker of deception: pupil diameter [6], microsaccades [7], fixation count and duration [8], consolidated changes in the eyes, voice, gestures and posture using BigData in AVATAR. Pupil diameter increases at crime-relation stimulus [9], but also it increases at deception [6] or at fright [1]. Fixation count and duration depend on nature of the tasks - lying and attention to simple task are uncorrelated, lying and attention to complicated task are highly correlated [10], age (decrease at the age 7–9, increase at the later age, [11]), stimulus emotional valence - increase at positive stimuli, decrease at negative one [6, 12] etc. Some inconsistencies have been observed both in the set of eye movements as markers of lie, and their degree of shift, which makes it possible to distinguish between true and false answers. Thus, the purpose of this study is to differentiate true and false

answers in various testing situations and to identify constant set of eye movement markers of deception.

2 Method

Eye-tracking testing encompasses the goals: (1) An assertion that gaze represents a focus of attention is the core idea of eye-tracking. But the question remains: what caused this attention? The external characteristics of image or its relevance for respondent? The first goal is to search for eye movement markers that distinguish value-driven attention from attention to a neutral stimulus or stimulus selected with the composition (size, color, etc.). Results have been published [13]. (2) The second problem is a selection of true/false answers. The second task is to study eye movement markers of deception. The experiment reflects a view of main types of lying including a concealment, a passive lying in terms of Ekman [1], and an active deception, in turn, takes two broad forms [14]: "false descriptions" (an imaginary event) and "false denial" (a negation of a real event).

The procedure included four series: (1) Text stimulus (neutral questions) contained 2 or 4 choices to answer. Total 32 slides. Instruction: (a) true answer, (b) false answer. (2) The second area of research is comparing eye movements response to text or image stimulus yielded with a view to identifying meaningful patterns. The pictures were previously selected by experts (10 people) as emotionally neutral. According to the theory of P. Kavanakh, these pictures were a closed circuit, black on a white background to reduce the cognitive processing complexity. Image stimulus contained 2 or 4 choices to answer. Total 32 slides. Instruction: (a) true answer, (b) false answer. (3) Projective images of the Social Motivation Test [15]. One image has gained a positive relevance, another one – negative relevance Instructions: (a) presentation stimuli in pairs on condition true answer, (b) false answer. (4) Projective images of TSM presented in pairs. Instructions: freely viewing; random choice of picture; a socially desirable answer; avoiding some answers.

Presentation time of each stimuli – 10000 ms. The stimuli were counterbalanced according to latin square. The stimuli were separated by a mask (25% gray, duration – 500 ms). Hardware: eye-tracker SMI iView Red 250 Hz. Participants: N = 108, mean age = 27, all of them employed full-time, 52% female and 48% male.

3 Results and Discussion

3.1 Eye Movements Lie Markers According to The Type of Stimulus

The discriminant analysis of eye movements in case of a true and false answers to text or image stimuli had provided valuable evidence for revealing a complex of informative markers. These markers are essentially the same and authentically identify a false answer irrespective of stimulus' type.

The comparative analysis hasn't shown differences between complex of eye movement markers of deception and their discriminating fineness when using text or image stimulus. Regardless of the stimulus material (text or image), a similar set of interrelated

eye movements markers of a false answer was identified. The true answer is accompanied by a predominance of focal attention: it's characterized by fewer repeated fixations and revisits, slower motor response, greater amount of fixation on the selected stimulus, combined with high-speed low-amplitude saccades (Table 1).

Table 1. Eye movements' markers of true and false answers.

Eye movements parameters	Text stimulus		p-level	Image stimulus		
	True	False		True	False	
Average fixation duration (ms)	411.78	344.02	0.000010	277.77	284.60	0.012199
Fixation count	4.18	3.08	0.002237	44.19	40.75	0.036894
First fixation duration (ms)	183.79	186.94	0.000000	228.64	226.11	0.014742
Saccade count	No differences			45.35	42.19	0.047710
Saccade amp. (°)	56.91	58.16	0.000145	5.76	7.45	0.044094
Saccade velocity average (°/s)	96.94	99.90	0.000003	111.23	128.21	0.043987
Saccade velocity peak (°/s)	180.44	186.55	0.021107	No differences		
Dwell time (ms)	1620.52	1027.16	0.000374	1527.17	1504.39	0.018698
Glances count	2.52	1.88	0.006091	2.01	1.90	0.029720
Revisits	2.67	4.77	0.019976	21.96	27.59	0.051900
Time to first mouse click (ms)	3586.37	2854.98	0.001830	539.71	522.32	0.039038

Selection of false answer is manifested in a change in the sequence of viewing, increasing amplitude and speed of saccades, growth in the number of repeated fixations with a decline in the number of fixations on selected false answer and less duration of fixation on it, decreasing in the total time of reviewing all slide. The choice of a false answer, especially with the number of alternatives more than two, reflects the process of an additional cognitive task, which is consistent with the findings of a study conducted by Cook et al. [6].

3.2 Eye Movements and Different Types of Deception

The type of deception has a direct impact on the list of specific lie markers and the expression of differences. The passive deception (as random choice of answer) were reflected in an orientation viewing (lengthening the overall gaze trajectory, growth in the number of revisits, the greater amplitude and velocity of the saccades) and an accelerated motoric response as taking the additional cognitive load off. Chosen false answer doesn't meet to the previously identified markers of value-driven attention, it is chosen spontaneously. A random choice does not correspond to the previously identified "value-driven" eye-movement markers, that can be seen as a measure of "passive lying" without additional cognitive burden.

Any type of active deception has a sharp decrease in the number of eyeblinks and pupil diameter. Temporal and speed data are increasingly important for active deception detecting. Quantitative indicators are also significantly increased, because active deception assumes additional cognitive task – inclusion or exclusion of the choices of answers. In addition to the general criteria for deception, the false description is characterized by an increase in the number and duration of fixations, an increase in number of saccades while reducing saccade velocity, which reflected chosen stimulus placement in the canvas of a false response and thus, gaining its relevance. The false denial (concealment of information) doesn't differ from another type of deception in fixation number on hiding stimulus, but total dwell time, saccade duration and velocity were decreased. The key difference of the false denial is a sharp reduction in time to motoric response (mouse click). The analysis of the pattern of viewing carries information about areas of the stimulus field that have subjectively value. In case of image stimulus, the time and speed rates of eye movements are increasingly important than quantitative rates. Quantitative measures (the number of revisits, fixations, saccades, etc.) reflect the characteristics of viewing and depend on complexity of image, as well as the average duration of the first fixation. When the density of the stimulus field is increased, they could not be regarded as markers of deception, because active lying integrates the secondary objective to, in the process, construct a story with inclusion and hidden some context (Table 2).

Table 2. Eye movements' markers of different types of deception.

Heading level	Type of deception			p-level
	Random choice	False description	False denial	
Fixation count	98.15	106.25	90.07	0.000000
Pupil diameter (mm)	4.12	4.04	4.03	0.000000
Saccade count	108.06	113.52	93.34	0.000000
Saccade total duration	25875.47	22491.72	24066.30	0.000000
Saccade amplitude average (°)	4.77	3.71	3.60	0.002733
Saccade velocity peak (°/s)	303.30	292.34	256.99	0.000000
Saccade velocity average (°/s)	136.35	123.04	107.68	0.000000
Saccade acceleration peak (°/s)	11270.56	9555.72	8904.75	0.000000
Revisits	33.97	38.95	39.82	0.051900
Dwell time (ms)	1527.17	1504.39	1425.27	0.018698
First fixation duration (ms)	282.32	200.05	185.81	0.014742
Average fixation duration (ms)	329.50	311.48	305.95	0.012199
Glances count	2.51	1.65	1.62	0.029720

3.3 Special Software HawkEye

Selected deception markers together with the previously identified "value-driven" eye-movement markers formed the basis of truth- and lie-detection technology for psychological testing. The results of the research project were implemented in the technology

of detection of true answers in psychological testing. Special software HawkEye have been developed by ErgoLab LLC (2016) for measure the background individual reaction norm and compared it to shift in complex of lie markers for each AOI (e.g., chosen answers). Software recorded 2 types of answers – chosen with the click and areas of increased attention, corresponding value-driven attention criteria. Their convergence reflects answer consistency. In case of conflict chosen answer will be verified with complex of lie markers and selected with color. The software allows to set flexible criteria for identifying false responses according individual rate. Complex of eye movements shifts are compared to the rate during replies to each question in psychological testing process. Areas of increased value-driven attention and criteria for differentiation false and true answers can be used in applied research to reveal an true measure, even respondents try to hide it, for example in underlying motivation testing. Eye-tracking testing data was a significantly higher correlation with in-blank test results ("Motivation-to-work Profile" by Martin, Ritchie, N = 108) and multichannel polygraph recording data.

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