Perinasal Indicators of Malevolence

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***Abstract*— Several decades of research into detecting lies has resulted in a large number of available of techniques among both behavioral and physiological channels. However only in the recent past, have researchers started to focus more on ways to detect ill-intent. Persons lying under high stakes situations show detectable changes in behavior. Similarly while lying to conceal ones true intent, one exhibits similar characteristics. This work presents a fast, convenient and discrete way of monitoring facial physiology using thermal imaging to detect when a person is lying about their intentions. Its application is suitable for screening in airports, border crossing and other venues with large transit volumes.**

I. Introduction

Observational methods to detect malicious behavior are being used by various law enforcement authorities. It is the first step among a series of screening procedures that leads to detaining or arrest of suspected individuals. One such venue where active vigilance is needed is in air travel safety. The TSA in 2007 has deployed Behavior Detection Officers (BDO) who are on the look out for behavioral indicators of mal-intent. It is estimated that about 1.8 million people fly within the U.S. daily. Those who peak the suspicion of the BDOs are refereed for secondary screening which needs to take place in under 3 to 4 minutes and without raising much awareness within the concourse. In this paper, we present a complimentary, discreet, physiology based screening method whose outcome will aid the interrogator at arriving at a decision about the individual/passengers intent.

The human face displays a variety of non-verbal and verbal cues to lying. Non-verbal cues include gaze duration [1], pupil dilation [2], blinking rate [3], exhibiting involuntary micro expressions [4] etc, while verbal indicators include change in pitch and tone of voice, producing contradictory responses, correcting a previous response [5] etc. These methods to spot a lier have been found to be very effective, since they are involuntary responses brought about under stressful situations. Furthermore, they are quick and do not need to probe the subject with any wires or instruments. However, its ultimate success depends on the skill and attentiveness of the administering officer.

Physiological measurement methods constitute the second class of lie detection techniques. Instantaneous changes in skin conductance while lying was demonstrated by Lykken [6] in 1959 which is now one of the primary indicators in polygraph readings. Respiration [7] and heart rate [8] are other common physiological channels monitored in deception analysis. These techniques provide a quantifiable feedback which examiners can use within the context of their interrogation to assess credibility. However these are contact based approaches and are not very practical in on-the-fly screening. Having one probed with its sensors may be reason enough to stress an individual prior to the interrogation.

We present a method that capitalizes on the benefits of behavioral methods of being quick and discreet, with the advantage of physiological measurements which is provides quantifiable and instantaneous feedback. We validate this method with an experimental protocol which presents subjects with some high stakes behind convincing the interrogators of their innocence. Our method does not require attachment of any sensors, nor does it impose any restrictions on the subjects, similar to realistic scenarios. Our initial results show great promise in being able to detect when a person is lying about their intentions to commit a crime with initial successful classification rate of 92%.

II. Experimental Design

A mock stealing experiment was setup at the University of Houston. 30 subjects were recruited from among the students and staff of the university through advertisement fliers. This experiment was designed to consist of two interrogations for the subject to go through. The first interrogation was to detect intention to commit a crime before the subject had the opportunity to commit a high stakes mock crime and the second one was to detect guilt after the subject returned back from committing the mock crime. The simulated crime here was the act of stealing a check of $80 made out to an organization that they opposed. A primary requirement for the experiment to be successful was that subjects needed to be emotionally involved in a cause. An example of some of the supported cause were pro-life vs. pro-choice, supporters of republicans vs. democrats etc. All subjects were initially pre-screened for the requirements over the telephone before an appointment for participation was setup. During the pre-screening information was gathered about the cause that they supported. Based on this, another organization was researched which worked opposite to the subjects supported cause and a check of $80 was made out to the opposed organization.

The experiment was conducted as a blind study in which the ground truth about the subjects intentions and actions was kept hidden from the experimenters by an independent party in the psychology department at the University of Houston. When subjects arrived they were given the consent form which explained to them that there was a check of $80 made out to an organization that they opposed. The subjects

had the opportunity of stealing this check and depriving that organization from getting that sum of money, and in turn re-directing that amount to the organization that they supported. To complete the experiment, they would have to face two interrogations. In the first interrogation they would have to convince an interrogator that they had no intention of stealing the check. Then they would be given the chance to visit the room alone in which the check was stored. Depending on the role they decided to play, they would either take or leave the check. Next they would be escorted to the second interrogation where they would be questioned about their actions in the room. If the interrogator felt that they were telling the truth in both interrogators, the check amount would be redirected, and in addition they would also get an additional sum of $80 for themselves. If the subject decided not to take the check, and the interrogator felt they were telling the truth, they would get $25 for themselves, however the opposed organization would get a monetary benefit of $80 too. Finally, if at any time the interrogator felt that the subject was lying about their intention or action, the experiment would be over for them and they would receive only $10 for their participation and the opposed organization would benefit. After subjects finished with the consent process, they were required to write down their intentions on a piece of paper and seal it in a brown envelop which is the ground truth. Also after the subject visited the room with the check, one of the individuals maintaining the ground truth would replenish the checks so the actions of the subject in the room would be hidden from the experimenters.

Additionally, whenever a subject would arrive for the experiment, there would be two confederate subjects, one arriving before and the other after the subject. All three would undergo the consent process together and the confederates would pretend to ask questions too. Then all three would be taken outside the interrogation room where another confederate dressed up as a security guard would pat-down the three and put their personal belongings like cell phones and wallets in individual storage bins. Next the security guard would pretend to randomly select one of the confederates to go in first for the first interrogation. The interrogators were Drs. Pavlidis and Shastri, whose research areas include lie detection techniques and they are well versed in interrogation methods. The subjects were told that the interrogator represented the opposed organization. Six to seven minutes later, the confederate subject would exit the room, and would be told that the interrogator suspected that they were lying about their intentions, and hence dismissed in front of the subject. Immediately following this, the subject would be taken in for their first interrogation. After the first interrogation was over, all the subjects were allowed to proceed to the next phase of the experiment, irrespective of the interrogators impression. However their decision was recorded and was used by the party holding the ground truth to accordingly compensate the subjects based on the interrogators judgment and the subjects recorded intentions. The subjects then visited the room where they were exposed to the check alone and following that they faced the second interrogation.

After the experiment was over, subjects were informed that they would need to contact the person holding the ground truth to receive their appropriate compensation. Further more it was revealed to them that the other two subjects along with them were just acting and that also the check was fake. They were told that if they succeeded to deceive the interrogator, instead of $80 they would actually receive $160 and that they were free to use the additional $80 as they pleased.

The interrogations were structured and consisted of a fixed number of questions which the interrogators asked the subjects in sequence. For the sake of this paper, we are only discussing details relating to the first interrogation to detect intention. The complete list of questions in the first interrogation is given below.

Interrogation 1

I am the interviewer, and I am going to ask you a few questions. Before we begin, I want to let you know that I am aware that there are a number of items in the room that you will visit next that belong to certain groups, such as computers, checks and so forth. My job is to ask you some questions to determine your intentions concerning these items. OK?

I am going to start by asking you a few background questions before moving on.

(A) Did you find this room easily?
(B) What was the best thing that happened to you this week?
(C) What was the worst thing that happened to you this week?

(1) Do you know why you are sitting here with me right now?
(2) Why do you think the checkpoint screener selected you for this interview?
(3) Please tell me what you were planning to do.
(4) Do you have any plans that might involve you taking something that doesn't belong to you?
(5) Please tell me exactly what you were thinking when you decided whether or not to take a check made out to a group that you oppose?
[Think carefully before you answer the next question...]
(6) Is everything yo've told me the truth?
(7) What would you say if I determined you are lying to me about your intentions?
(8) I happen to have a photo that I's like you to take a look at. Do you recognize it? Have you seen this before, or know what it is?
[Think carefully before you answer the next question...]
(9) Is there anything else you'd like to say at this point?
I will keep my judgment to myself at this point. You are free to visit that room now. Please wait here. The experimenter will be with you shortly.

The interrogation was conducted through the course of one month. The subjects, 12 males and 18 females were mostly undergraduate students at the University of Houston. No contact probes were attached to the subjects. The experimental setup did not pose any restrictions on the subjects' motion or postures very similar to real life interrogation

conditions. Throughout the interview, the subjects' faces were recorded via a thermal imaging system and a visual recording camera. The system consisted of a ThermoVision SC6000 Mid-Wave Infrared (MWIR) camera from FLIR Systems, MWIR 100mm lens, and a HP Pavilion M9040N desktop. The distance between the camera and the subject position was kept about $8ft$. The thermal data was recorded at a rate of 25 frames per second.

The conversation between the subject and the interviewer was recorded via two separate microphones clipped to the collar, one microphone per individual. The audio was recorded in sync with the thermal and video recording to facilitate audio-video mapping. The audio recording was later used to mark the start and end of each question and answer of the interrogation. From every interrogation session, a thermal data clip, a video of the subjects face and an audio recording was collected.

III. Methodology

A. Perspiration Signal Extraction

The perspiration signal is extracted using a combination of tissue tracking and perspiration quantification algorithms explained in [9] and in [10] respectively. The perinasal region on the face is first tracked, and within the tracked region a subsection is selected from which the perspiration measurement is extracted. See Figure 1.

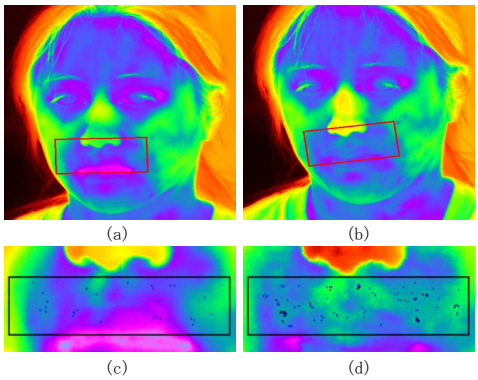

Fig. 1: The red boxes in (a) and (b) show the tracked region of the face in the first frame and the frame corresponding to the 120^{th} second. (c) and (d) correspond to the tracked regions within (a) and (b) respectively. The black boxes within the tracked regions outline the region from which perspiration measurement is made.

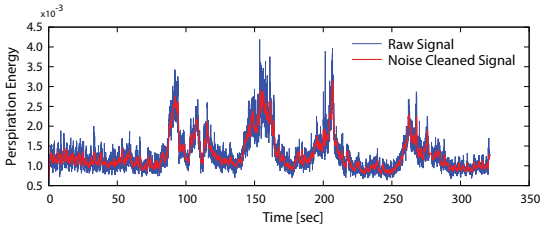

Fig. 2: Raw perspiration signal and noise cleaned signal

Figure 2 shows the raw extracted signal which contain high frequency noise due to imperfections in the tracking algorithm and systemic thermal noise. To suppress such noise, we use the FFT (Fast Fourier Transformation)-based noise cleaning algorithm reported in [11]. The resulting cleaned signal is free from this noise and retains the overall signal characteristics.

B. Feature Extraction

A number of factors such as an individual's metabolic rate and body mass index affect for variances in the amount of perspiration secretion. For these reasons, we normalized each signal intensity in the range of 0 to 1.

The start and end of each question and answer segment was identified using the audio recording and accordingly the perspiration signals were segmented. Hence, each signal from Interrogation 1 was segmented into 13 segments which includes the initial briefing of the interrogation, the three introductory questions (A-C) and the nine questions of the interrogation. We formed a 13 feature vector for each subject, which was the mean of the perspiration intensities for each question-answer segment.

C. Pattern Classification

Before subjects enter the interrogation room for the first interrogation, they have already witnessed one of the confederate subjects attend the interrogation and get dismissed due to the fact that the interrogator thought that he/she was lying about his/her intentions. This makes them realize that if they are not convincing enough, their intentions would be uncovered and that they would fail. Subjects who have no intention of taking the check have nothing to be worried about, however subjects who intend to steal the check would try to prepare in advance for questions that they expect that the interrogator could ask [12]. This already places this cohort of subjects at an elevated stress level. Taking this into consideration, we hypothesize that subjects who do not plan to lie about their intentions will be fairly relaxed towards the start of the interrogation and would have a much lower perspiration intensity, however this may not be true for subjects who have ill-intentions to conceal.

The ground truth of 16 subjects was initially requested to develop a model of the perspiration phenomenon as the interrogation progressed. Out of the 16 subjects, 5 subjects chose to not take the check, while 11 subjects chose to take the check and lie about their intentions. Figure 3 shows the means of the normalized perspiration intensities per question for the truthful and deceptive subjects. The mean normalized question-vise signals, support the above hypothesis that truthful subjects begin the interrogation well relaxed, as compared to deceptive subjects. Further we fit each of these signals with a second order polynomial to diminish the inter-subject variability within the two classes to be trained.

We explore four representative machine learning classifiers. Specifically, we use a Naïve Bayes classifier from the Bayes approaches. From the tree-based approaches, we use

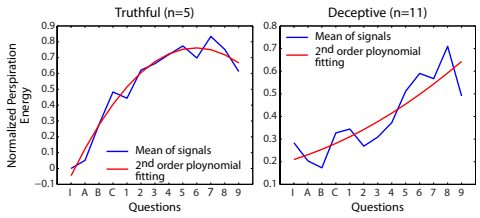

Fig. 3: Mean normalized perspiration intensities per question of the intent detection interrogation.

a decision tree classifier and the decision stump classifier. These classifiers use C4.5 algorithm to generate decision trees. The decision stump is used with AdaBoost boosting method. From the neural network approaches, we use a backpropagation neural network. The classifiers are modeled on the training set and validated via the *leave-one-out cross* validation method. We use the Weka v3.7 tool for modeling and predictions [13]. We use the default parameters that the tool provides for each classifier.

IV. Experimental Results

We performed a leave one out cross validation with the four machine learning algorithms and the results are reported in Table I. The mean success rate of the four classifiers together is above 92%. In particular, they have a good classification performance for both truthful and deceptive subjects.

	Training Set: n = 16			
	Leave one out cross validation			
Decision Tree	T	5/5	100.00%	93.75%
	D	10/11	90.90%	
Multilayered Perceptron	T	5/5	100.00%	87.50%
	D	9/11	81.81%	
AdaBoost - Decision Stump	T	4/5	80.00%	93.75%
	D	11/11	100.00%	
AdaBoost - Naïve Bayes	T	4/5	80.00%	93.75%
	D	11/11	100.00%	

TABLE I: Results of cross validation on training set.

V. Discussions

This research presents a novel method to use perinasal perspiration to detect malicious intent just in the way that one would use measuring EDA on the finger tips. This new perinasal measurement channel has been validated in [10]. It describes a way to conveniently and quickly screen people with quantifiable physiological measurement. Also, the experimental design implemented in this paper, imposes high stakes upon the participating subjects, which simulates a real life stressed interrogation.

An interesting observation is that from the training set, 11 out of 16 subjects decided to take the risk of facing the interrogations in a deceptive role than facing the interrogations truthfully. It is unclear whether the main motivating factor for their choice was to try to walk away with a greater reward or to help support the cause they followed. Nevertheless, it is a clear indicator that subjects were in one way or the other enticed to take on high risk behavior, the perinasal response to which can be detected through the methods described above.

To the best of our knowledge, this is the beginning of research efforts that has been made, to investigate the role of the facial perspiration in high-stakes deceptive behavior. This work opens new avenues for perinasal perspiration feature should be studied in conjunction with the other facial thermal indicators such as the periorbital indicator of instantaneous stress [11]. An effort should be made to make the system portable and fully automated to facilitate field applications such as detecting suspicious activities at border checkpoints.

VI. Future Work

Currently, we have analyzed the perinasal perspiratory signals for the first interrogation, to detect any intent to commit the mock crime. We acquired ground truth for 16 out of the 30 subjects and developed a model to classify deceptive versus true intent. Next we will use the remainder of the data set to test our models, and make predictions of the subjects intentions and cross verify them with the unseen ground truth. At the same time, we still have to analyze the signal from the second interrogation which was to detect guilt during the interrogation. We hypothesize that by the time the subject attends the second interrogation the subjects stress levels have already changed, and some would have also got more accustomed to the interrogation. Hence, a completely different approach to analysis may be needed.

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