Detecting Deception via Eyeblink Frequency Modulation

To assess the efficacy of using eyeblink frequency modulation to detect deception about a third party, 32 participants were sent on a mission to deliver a package to an interviewer. 17 of the participants lied to the interviewer about the details of their mock mission and 15 responded truthfully. During the interview, eyeblink frequency data were collected via electromyography and recorded video. Liars displayed eyeblink frequency suppression while lying, while truth tellers exhibited an increase in eyeblink frequency during the mission relevant questioning period. The compensatory flurry of eyeblinks following deception observed in previous studies was absent in the present study. A discriminant function using eyeblink suppression to predict lying correctly classified 81.3% of cases, with a sensitivity of 88.2% and a specificity of 73.3%. This technique, yielding a reasonable sensitivity, shows promise for future testing as, unlike polygraph, it is compatible with distance technology.

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52 53 54 Introduction 55 56 Modern deception detection methods testing physiological indices of deception use 57 techniques such as galvanic skin response (GSR; e.g., Carmel et al., 2003), fMRI (e.g. Bhatt et 58 al., 2009; Langleben, 2005; Shah et al., 2001), and EEG detected P300 event related potentials 59 (Abootalebi, Moradi, & Khalilzadeh, 2006; Ambach et al., 2010; Meijer et al., 2007). In the 60 academic literature, responses are sometimes elicited (e.g., Langleben, 2008) using some 61 variation of the Guilty Knowledge Test (GKT; Lykken, 1957; 1959). Though these physiological 62 techniques may provide strong sensitivity and specificity in laboratory settings (MacLaren, 63 2001), they require proprietary equipment, proximity to the suspect, and suspect awareness of the analysis. Furthermore, classification accuracy of GKT based tests obtained in laboratory settings 64 65 from mock crime scenarios may not generalize to naturalistic settings (Carmel et al., 2003). 66 The present study explores a known behavioral indicator of deception, cognitive demand modulated blink frequency (BF). BF modulation is an attractive behavioral indicator of deception 67 68 because BF data may be collected using hidden cameras or distance technology (i.e., web cams) 69 and analyzed surreptitiously either in real time or post hoc from recorded video. Furthermore, BF 70 data collection does not require any special equipment or questioning schemes. BF modulation 71 has been experimentally validated using both GKT based questioning methods reliant upon 72 recognition (Leal & Vrij, 2010) and a conversationally natural free recall method (Leal & Vrij, 73 2008). The present study builds upon previous research using a mission based scenario in which

74 the deception pertains to a third party, under conditions that more closely resemble an interaction

- 75 using distance technology. In particular, the present study accounts for variance attributable to
- cognitive demand resulting from participants monitoring the interviewer's body language. As the 76
- literature regarding deception about a third party is somewhat sparse, the study expands prior 77

work on third party deception to include validation using BF based measures of cognitivedemand.

80 Cognitive Demand Modulated BF and Deception Detection

81 The cognitive demand hypothesis follows that deception is more demanding than truth 82 telling because, in addition to recall and speech production required during truth telling, deception requires suppressing deceptive cues in body language (DePaulo, 1988; Ekman, 1989), 83 84 fabricating an alternate story, and carefully monitoring that story to ensure that it does not 85 contradict interviewer knowledge of the event (Leal & Vrij, 2008). Cognitive demand during 86 deception is detectable in experimental settings using measures such as response time (Gronau, 87 Ben-Shakhar, & Cohen, 2005; Seymour, Kerlin, & Kurtz, 2003) and startle response modulation 88 (Cacioppo, 2006; Verschuere et al., 2007). Cognitive demand during deception is also observed in 89 real high stakes police interviews (Mann, Vrij, & Bull, 2002).

BF based deception detection techniques use cognitive demand induced BF suppression to 90 91 indicate deception. Numerous studies demonstrate that increases in cognitive demand cause a 92 reduction in BF (e.g. Drew, 1951; Siegle, Ichikawa, & Steinhauser, 2008). In addition to BF 93 suppression during lying, liars may also display a flurry of compensatory blinks after lying (Leal 94 & Vrij, 2008). Importantly, truth tellers in that experiment exhibited an increase in BF during the 95 relevant questioning period. While BF is correlated with many physiological and emotional 96 states, this effect may be partially explained by the accusatory subject matter of the questions 97 delivered during that period.

98 **Detecting Deception about a Third Party**

99 The majority of deception research has focused on subjective deception, or deception 100 related to a personal transgression (Iacono, 2000). However, recent work has broadened the 101 literature to include lying about characteristics of a third party (Bhatt et al., 2009; Leal et al., 102 2011; Meijer et al., 2007; Shah et al., 2001). Deception regarding a third party may differ 103 characteristically from subjective deception because the stakes may be perceived as lower.

Response times (Haque & Conway, 2001) indicate that recalling autobiographical information is more demanding than semantic recall, however the literature is unclear regarding differences in cognitive demand during deception about these types of information. Establishing these characteristics is important, since detecting deception about person recognition or familiarity may provide a means for establishing group affiliation, which in particular is not reliably detectable via traditional polygraph tests (Sullivan, 2007).

110 While comparative cognitive demands associated with discussing these topics truthfully 111 and deceptively are not well understood, a number of studies explore deception about a third 112 party using other means. In a novel experiment, Leal et al. (2011) asked participants to participate 113 in mock espionage mission similar to the mock crime scenarios used by Lykken (1957; 1959) to 114 validate the GKT. Participants were briefed by one of the experimenters who revealed personal 115 characteristics (i.e., hobbies), and later they were asked to identify and describe this experimenter 116 from amongst a set of photographs. Cognitive demand as rated by observers, as well as 117 differences in gaze direction, allowed discrimination between liars and truth tellers.

118 Hypotheses

First, differences in BF between liars and truth tellers should be similar to those described in cases of subjective deception by Leal and Vrij (2008). Second, liars are expected to exhibit a reduction in BF while lying, followed by a compensatory flurry of blinks. Finally, truth tellers are expected to exhibit an increase in BF while answering the mission relevant questions.

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Method

124 Participants

125 The Saint Joseph's University (Philadelphia, PA) IRB board approved (IRB 2012-12) 34 126 participants (25 female, 9 male, age 18-21) for the experiment from the undergraduate population 127 enrolled in introductory level psychology classes. All participants signed informed consent forms and were informed of the physiological measures, though they were blind with regard to the specific aspects of the electrooculography (EOG) data used in the analysis. One participant was excluded due to a failure to adequately follow the directions of the experiment and another participant exhibited an exceptionally low BF ($D_i = 2.16$). The sample used in the analyses therefore consisted of 23 females and nine males after exclusions.

133 Data Collection and Analysis

134 Eyeblinks were monitored using an Apple iSight camera mounted on a modified Yukon 135 Advanced Optics Inc. night vision head mount kit and positioned roughly 2 inches from the eye. 136 For convenient analysis, blink frequencies were also recorded via EOG using AD Instruments' 137 PowerLab 26T and the LabChart Pro v. 7 software package. Three electrodes, one on the 138 orbicularis oculi muscle, one on the frontalis muscle, and a third on the ear as ground monitored 139 eyeblinks in accordance with the protocol outlined by Conduit (2012) for monitoring blink 140 amplitude. Since the present study is concerned only with quantifying blink frequency, no 141 electrodes were placed to monitor more subtle eye movements. An Apple Macintosh iMAC 142 computer was used for collecting and analyzing data. Blink data was recorded continuously, and 143 quantification began immediately after the interviewer read the question and continued until the 144 participant's response terminated. Blinks were quantified manually from concurrent recorded 145 video of the eye from which EOG data was recorded. During this quantification, the experimenter 146 was blind to the participant's experimental condition. The EOG data were amplified (using the 147 default sampling rate of 1 KHz) and filtered (Range = 2 mV, Low Pass = 10 Hz, High Pass = .5 148 Hz) and normalized in terms of SD. While slightly more liberal than other filters recommended 149 for similar electrode placement (e.g., Wissel & Palaniappan, 2011, in which the authors 150 recommend a filter with cutoff frequencies of 1 and 5 Hz), these parameters provided a smooth 151 baseline with little noise and clearly discernible peaks. Peaks with an amplitude at least 4 SD higher than baseline activity indicated eyeblinks. There was no difference between blink 152

153 occurrences recorded manually from video, or using EOG.

154 BF data was collected for each participant in four experimental periods: two baseline 155 periods (at the beginning and end of the interview, during which the participants answered 156 personal questions), a target period (containing the mission relevant questions), and a target offset 157 period defined as the 6 s period following the target period (as observed by Leal & Vrij, 2008). By participant, for each experimental period, BF was quantified as the number of blinks in that 158 159 period divided by the mean number of blinks exhibited in the two baseline periods. This value 160 provides a measure of percent deviation in BF from baseline. Percent deviation scales the frequencies to account for individual differences in BF (Leal & Vrij, 2008). Results will be 161 162 described in terms of this percent deviation metric.

163 **Procedure**

164 The experimental protocol was an immersive mission based scenario similar to that used 165 by Leal et al. (2011) and Leal and Vrij (2008). The protocol consisted of a briefing and an 166 interview. Participants arrived at a room in an academic building and received a briefing from 167 one of the experimenters posing as a friendly agent, then went on a mock mission to deliver a 168 package to a second room in the same building. There, participants would be interviewed by 169 another experimenter role playing an anonymous agent. Participants were instructed to tell the 170 truth to the interviewer or lie based on the interviewer's response to a challenge question. 171 Correctly answering this challenge question would indicate to the participant that the interviewer 172 is friendly, and that the participant should be entirely truthful. An incorrect response to the 173 challenge question by the interviewer would indicate that the interviewer is an enemy agent to 174 whom the participant should lie about all details of the mission. Participants were randomly 175 assigned to the lying and truth telling conditions, leaving 15 truth tellers and 17 liars after 176 exclusions.

177 During the briefing in the first room, participants were informed that the agent delivering

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178 the briefing was (1) a Saint Joseph's University graduate student, (2) did not receive his/her 179 bachelor's degree from Saint Joseph's University, and (3) enjoys running. After the briefing, 180 participants were sent to deliver the package to the second room. Participants were briefed by a 181 male or female experimenter, and t tests revealed no significant effect of briefer gender, all t(30)< .31, all p > .75, or participant gender, all t(31) < 1.64, all p > .1, on the experimental variables. 182 183 Upon arrival at the second room, participants were prepared for the EOG analysis and 184 interviewed by another experimenter. Participants were interviewed through a one way mirror 185 and the voice of the interviewer was modified using a voice distortion microphone. This protocol

was adopted to eliminate variance attributable to the interviewer's gender and body language.

The interview consisted of two periods of free recall, the target period consisting of mission

The interviewer waited 10 s between questioning periods.

relevant questions, and a 6 s period immediately following the target period (target offset period).

190 During the baseline periods, participants were asked to freely recall information regarding 191 irrelevant subject matter. For one baseline period, participants were told, "Please take one minute 192 to tell me about your favorite actor or actress." Participants were asked to include in their 193 responses shows or movies in which this person has acted, this person's on screen characters, and 194 why they like this actor or actress. During the other baseline period, participants were asked to 195 describe their favorite food, and to specifically address its national origin, whether there are any 196 local restaurants in which to eat it, and whether they like it for its nutritional value or just for the 197 taste. Baseline period content was counterbalanced to eliminate order effects. Despite one 198 baseline period requiring description of a food and one of a person, there were no significant 199 differences in BF between baseline periods, indicating that each baseline recall task was similarly 200 demanding (data not shown). Likewise, both liars (M = .59, SD = .22) and truth tellers (M = .50, 201 SD = .13) exhibited similar BF (per second) during the baseline periods, t(30) = -1.46, p = .15. 202 During the target period, participants answered mission relevant questions about the agent 203 who delivered the briefing. The questions were:

- 1. Who sent you?
- 205 2. What does this person look like?
- 206 3. What does this person do for a living?

4. Did this person earn his or her bachelor's degree at SJU?

208 5. Does this person have a hobby?

209 For the three questioning periods (i.e., the two baseline periods and the target period), the

210 experimenter delivered the questions, without breaks, then allowed the participants to freely

211 recall the information and respond. In cases where participants' responses lasted less than 15 s,

the experimenter prompted the participant to elaborate and continue. Participants were allowed to

213 speak for up to 120 s. After questioning, participants completed a 7-point motivation Likert scale

214 ("How motivated were you to do well in the interview?") and were debriefed.

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Results

216 No between groups differences were found in response length during the "favorite actor,"

217 "favorite food," or target period for liars and truth tellers, all t(30) < .81, all p > .42. Response

218 length data for each group during the experimental periods are available in Table 1. All

219 participants reported a high degree of motivation according to the Likert scale (M = 6.00, SD = .

220 73) and condition assignment did not affect participants' reported motivation to perform well in

221 the interview, t(29) < .001, p > .99.

A 2 (Veracity: lying vs. truth telling) x 2 (Experimental Period: target period deviation vs. target offset deviation) factorial ANOVA, with repeated measures on the second factor, was conducted to assess differences in BF modulation patterns between liars and truth tellers. The analysis revealed a main effect for Experimental Period, F(1, 30) = 16.17, p < .001, $\eta p^2 = .35$, such that participants exhibited a higher BF during the target period (M = .98, SD = .21) than the

target offset period (M = .71, SD = .36). The analysis also found an interaction effect of Veracity

x Experimental Period, F(1, 30) = 6.00, p = .020, $\eta p^2 = .167$. The Veracity x Experimental Period interaction effect indicated that liars displayed a significantly suppressed BF during the target period (M = .85, SD = .13) compared to the increase exhibited by truth tellers (M = 1.12, SD = .19; d = 1.66), and less BF reduction during the target offset period (M = .74, SD = .36) compared to truth tellers (M = .66, SD = .34; d = .23; Figure 1). Followup *t*-tests indicated significant differences in target period deviation for both liars, t(16) = 4.56, p < .001, and truth-tellers, t(14)= -2.27, p = .039.

235 MANOVA identified between groups differences in the predictor variables, the target and 236 target offset deviation scores, based on veracity as the independent variable. The data satisfied the 237 assumption of homoscedasticity using Box's M. Hotelling's Trace revealed a significant multivariate effect of veracity on the dependent variables, F(2, 29) = 9.91, p = .001, $np^2 = .406$. 238 239 Univariate ANOVAs showed a significant effect of veracity on the target deviation score, F(1, 30)= 19.95, p < .001, $\eta p^2 = .40$, but an insignificant effect on target offset deviation, F(1, 30) = .38, p 240 = .54, ηp^2 = .01. Target period deviation from baseline was therefore retained as the sole predictor 241 242 for discriminant analysis.

243 Discriminant analysis tested the capability of target period deviation to discriminate 244 between liars and truth tellers. The discriminant function incorporating the predictor was 245 significant, $\chi^2(2) = 15.04$, p < .001, with 81.3% of cases correctly classified. Using the 246 discriminant function, 88.2% of liars and 73.3% of truth tellers were correctly classified, 247 indicating that the function favored sensitivity over specificity. Because of the small sample size, 248 the data were cross validated to check external validity using a jackknife procedure 249 (Lachenbruch, 1967) which is appropriate for small sample sizes (Stevens, 2009). The original 250 and cross validated classification results are shown in Table 2, and the significance and power of 251 the discriminant function are provided in Table 3. Cross validation resulted in the 252 misclassification of one truth telling participant.

Discussion

One goal of the present study was to replicate the findings of Leal and Vrij (2008) in which, during free recall, liars exhibited suppressed BF during the target period followed by a compensatory flurry of eyeblinks, whereas truth tellers exhibited an increase in BF during the target period. The present study found a similar difference in BF between groups during the target period; however, neither group exhibited a compensatory flurry of eyeblinks during the target offset period (Figure 1).

260 Though truth tellers' BF dynamics matched the findings of Leal and Vrij (2008), there is a 261 possible alternative to the anxiety explanation provided in that study that is congruent with the 262 cognitive demand hypothesis. Since BF reflects state cognitive demand, it is possible that the 263 increase from baseline observed in truth tellers during the target period is attributable to a state of 264 reduced cognitive demand. Recalling the recently acquired semantic information truthfully was 265 perhaps less demanding than retrieving autobiographical information to answer the baseline 266 questions. This is supported by reaction time studies on autobiographical versus semantic recall 267 (Haque & Conway, 2001). Therefore, it is possible that BF changes in truth tellers are the result 268 of cognitive demand changes rather than anxiety or another emotional response.

The differences observed by Leal and Vrij (2008) may also be attributed to the content of the experimental periods used in that study; during the target period, participants were given no specific instruction, while their behaviors during the baseline periods were directed. In addition, participants in the lying and truth telling conditions engaged in different behaviors; liars committed a mock crime whereas truth tellers did not. If truth tellers' actions during the target period were less complex than their directed behaviors during the baseline periods, then recalling the target period information may have been less demanding.

The sharp BF reduction during the target offset period in the present study contradicts the findings of Leal and Vrij (2008), who noted a flurry of compensatory blinks in liars. For this

278 result, three proposed explanations follow. First, capturing that information may be exceptionally 279 difficult due to the short window in which the flurry would occur. Frequency data for the target 280 offset period is calculated over a 6 s period, which is significantly shorter than the other 281 experimental periods. Second, these inconsistent results may be the result of differences in 282 experimental protocol, such that a view of the interviewer, present in the study by Leal and Vrij (2008) but obscured in the present study, is necessary to induce these compensatory blinks. The 283 284 final possibility is that the BF reduction observed in the present study is due to the fact that 285 participants were not speaking or listening during this period. This possibility is supported by 286 other literature on blink BF dynamics (e.g., Karson et al., 1981), which suggest that BF during 287 silence is significantly lower than during speech or listening. These results, taken together, seem 288 to indicate that the post-questioning compensatory flurry of blinks does not always follow 289 deceptive responses, and depends heavily on other factors.

The second goal of the present study was to evaluate the BF modulation during a free 290 291 recall test for application beyond subjective deception, to deception regarding a third party. 292 Validating the method in this way indicates greater robustness required for application, and an 293 advantage over GKT-based techniques. Prior research using BF (Leal & Vrij, 2008) focused on 294 recent subjective events, whereas the present study primarily focused on semantic details about a 295 third party, though the target period did include a question regarding the purpose of the 296 participant's "mission." BF characteristics were similar in the present study to those observed by 297 Leal and Vrij (2008) for subjective deception.

While the results obtained herein indicate that it is possible to discriminate between liars and truth tellers, studies in this area do not speak to the fact that is perhaps more important in application: detecting deception within subjects. Since BF does not indicate deception, but rather cognitive demand, these techniques rely on between group comparisons to make causal inferences regarding the cause of the blink frequency suppression. Future research in this area should seek to explore BF dynamics associated with varying question content. Cognitive task
analysis of common interrogation questions may aid in identifying analogue questions to serve as
baselines (i.e., questions requiring similar cognitive demand to answer).

306 Additionally, certain ecological validity issues remain unresolved. The present study did 307 not incorporate any meaningful interval between encoding of information (briefing) and testing 308 (interview). Carmel et al. (2003) demonstrated that intervals as short as one week can 309 significantly impair accuracy of other tests of deception (specifically the GSR based GKT) 310 employed in experimental conditions. In addition, if liars are allowed to construct and rehearse an 311 alibi, this would likely reduce cognitive demand as the fabrication component of deception would 312 be removed. Therefore, the accuracy obtained in the present study should not be considered 313 externally valid.

314 315

Conclusions

Results of the present study suggest that a technique measuring BF reduction during deception, presumably resulting from increased cognitive demand, is sufficiently robust to detect deception when the suspect does not have a view of the interviewer, and when the suspect is asked about a third party. Because BF data can be collected surreptitiously using webcams and hidden cameras, and analyzed either in real time or post-hoc from recorded video, BF based techniques warrant consideration. However, there exist a number of hurdles to application that appear intrinsic to BF based techniques.

In the absence of between subject comparisons, it is perhaps not possible to definitively attribute BF suppression to deception. To the extent that it is possible to ameliorate this shortcoming, baseline content must be carefully developed and selected so as to be similarly demanding as truth telling in order to detect BF reductions indicative of lying. Manipulating the content of baseline and target questions could improve the sensitivity and specificity of the test. Furthermore, tests such as the GKT benefit from repetition of target questions (Ben-Shakar & Elaad, 2002), so perhaps multiple presentations of target questions, changed slightly as to require the fabrication of new responses, would also increase classification accuracy. While the technique offers several advantages to traditional physiological methods for lie detection, additional research is required to determine if it is suitable for detecting deception within subjects. Acknowledgements This work was completed to satisfy the requirements of a MS thesis. All materials and space used for this work are property of Saint Joseph's University, Philadelphia, PA. The author thanks Victoria Kurzeja for her participation as a confederate during this study. Additionally, the author thanks Ashley L. Adams, Donald S. Leitner, Philip Schatz, and Alex J. Skolnick for their input on this manuscript. References Abootalebi, V., Moradi, M. H., & Khalilzadeh, M. A. (2006). A comparison of

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Table 1(on next page)

Response lengths for liars and truth tellers during experimental periods

| Experimental Group | "Favorite Food" | "Target" | "Favorite Actor" |
|--------------------|-----------------------|-----------------------|-----------------------|
| | | - | |
| Liars | M = 37.76, SD = 20.05 | M = 38.47, SD = 14.45 | M = 31.32, SD = 14.17 |
| | | | |
| Truth Tellers | M = 43.9, SD = 27.80 | M = 33.03, SD = 15.58 | M = 32.70, SD = 19.53 |

Figure 1

Results of 2 (Veracity: Lying vs. Truth-telling) x 2 (Experimental Period: Target vs. Target Offset) ANOVA. BF for each group across experimental periods quantified as percent change from baseline.



Table 2(on next page)

Classification table for percent-change scores between experimental periods

| Actual | Predicted Veracity - Original | | | |
|-----------|-------------------------------|-----------|-------|--|
| | | | | |
| | Lying | Not Lying | Total | |
| Lying (N) | 15 | 2 | 17 | |
| Not Lying | 4 | 11 | 15 | |
| Lying (%) | 88.2 | 11.8 | 100 | |
| Not Lying | 26.7 | 73.3 | 100 | |
| | | | | |
| Actual | | | | |
| | | | | |
| | Lying | Not Lying | Total | |
| Lying (N) | 15 | 2 | 17 | |
| Not Lying | 5 | 10 | 15 | |
| Lying (%) | 88.2 | 11.8 | 100 | |
| Not Lying | 33.3 | 66.7 | 100 | |

Note. 81.3% of original grouped cases correctly classified. 78.1% of cross-validated grouped cases correctly classified.

Table 3(on next page)

Significance of the discriminant function predicting veracity, and discriminating power of the discriminant function

| Wilk's Lambda | X^2 | d.f. | Significance | |
|---------------|------------------------|-----------------------|--------------|--|
| .601 | 15.04 | 1 | <.001 | |
| Eigenvalue | Percentage of variance | Canonical correlation | | |

.632

.665 100