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Unraveling the roles of orienting and inhibition in the Concealed Information Test

NATHALIE KLEIN SELLE,[a,b] BRUNO VERSCHUERE,[b] MEREL KINDT,[b] EWOUT MEIJER,[c] AND GERSHON BEN-SHAKHAR[a]

[a]Department of Psychology, Hebrew University of Jerusalem, Jerusalem, Israel
[b]Department of Clinical Psychology, University of Amsterdam, Amsterdam, The Netherlands
[c]Faculty of Psychology and Neuroscience, Maastricht University, Maastricht, The Netherlands

Abstract

The Concealed Information Test (CIT) is a well-validated tool for physiological and behavioral detection of concealed knowledge. Two distinct theoretical frameworks have been proposed to explain the differential responses to the concealed critical items: orienting response theory versus arousal inhibition theory. klein Selle, Verschuere, Kindt, Meijer, and Ben-Shakhar (2016), however, argued for a response fractionation model and showed that, while the skin conductance reflects pure orienting, both the respiratory and heart rate measures reflect arousal inhibition. The present study intends to (1) provide a constructive replication of klein Selle et al. (2016) using the autobiographical CIT, and (2) extend their work by testing an additional prediction derived from orienting theory, using an item-salience manipulation. One hundred and nine participants were tested on four high salient and four low salient identity items. Half of the participants were motivated to hide their identity (orienting + arousal inhibition), while the other half were motivated to reveal their identity (orienting only). Confirming earlier findings, the results revealed a fractionation between the different measures: while the skin conductance response (SCR) increased to a similar extent in the two motivational conditions, the respiration line length (RLL) shortened and the heart rate (HR) decelerated solely in the conceal condition. Moreover, while the SCR was larger for high than for low salient critical items, the RLL and HR responses were similar for these two item types. These data led us to conclude that, in the CIT, the skin conductance measure reflects orienting and the respiratory and heart rate measures reflect arousal inhibition.

Descriptors: Concealed Information Test (CIT), Orienting response, Arousal inhibition, Skin conductance response, Respiration line length, Heart rate

The Concealed Information Test (CIT; Lykken, 1959; Verschuere, Ben-Shakhar, & Meijer, 2011) is a well-validated tool for physiological and behavioral detection of concealed knowledge. In a typical forensic application, examinees are presented with several multiple choice-like questions. For each question, one critical (e.g., crime-related) item is presented among a series of control items (e.g., What was the murder weapon? . . . rope? . . . gun? . . . scissors? . . . knife? . . . ice-pick? . . .). Innocent (i.e., unknowledgeable) examinees are unable to discriminate between the critical and control items and are therefore expected to show similar responses to all items. Guilty (i.e., knowledgeable) examinees, on the other hand, are able to make this distinction and are therefore expected to show differential responses to the critical items, namely, phasic increases in skin conductance (i.e., skin conductance responses, SCRs), a suppression of the respiration (captured by the measure called respiration line length or RLL), and a larger decrease in heart rate (HR; Gamer, 2011). These stronger responses to the critical items compared to the control items have been labeled as the CIT effect.

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Address correspondence to: Nathalie klein Selle, Department of Psychology, Hebrew University of Jerusalem, Mt. Scopus, Jerusalem 91905, Israel. E-mail: nathalie.kleinselle1@mail.huji.ac.il

The CIT Effect: Orienting Versus Inhibition

The differential responses to critical items in the CIT have been predominantly explained by orienting response theory (e.g., Ben-Shakhar, 1977; Lieblich, Kugelmass, & Ben-Shakhar, 1970; Lykken, 1974; Verschuere & Ben-Shakhar, 2011). The orienting response is manifested by both physiological and behavioral responses in reaction to external novel stimuli. According to the classical view, the different response measures covary following manipulations of novelty, intensity, and stimulus significance. Importantly, when significance is high (i.e., when a stimulus holds a special importance to an individual), it will elicit an enhanced orienting response (Sokolov, 1963). In the CIT, the critical stimulus is significant for the knowledgeable examinee and, consequently, is expected to elicit a stronger orienting response in this examinee. A series of studies relying on a single physiological measure (i.e., SCR) generally supported the orienting response theory (e.g., Ben-Shakhar, 1977; Ben-Shakhar & Gati, 1987; Gati & Ben-Shakhar, 1990).

In addition to orienting response theory, researchers have explained the differential responses in the CIT by inhibition theory (Verschuere, Crombez, Koster, Van Bocksteale, & De Clercq, 2007). Inhibition has been defined as the executive function that allows one to deliberately and intentionally inhibit a dominant automatic or prepotent response (Miyake et al., 2000). Accordingly, in the CIT, inhibition can reflect either response inhibition or arousal inhibition. Response inhibition refers to the behavioral component of the response (i.e., the overt truth response), while arousal inhibition refers to the physiological component of the response, (i.e., the experienced physiological arousal). Attempting to inhibit the physiological arousal associated with the critical items characterizes individuals motivated to avoid detection (see klein Selle, Verschuere, Kindt, Meijer, & Ben-Shakhar, 2016). Ironically, however, these attempts at arousal inhibition come with a physiological cost (Pennebaker & Chew, 1985). Specifically, arousal inhibition has been shown to induce a physiological response pattern resembling the CIT effect (e.g., Dan-Glauser & Gross, 2011; for studies on experiential and expressive suppression, see Demaree et al., 2006; Gross & Levenson, 1993, 1997).

Differentiating Between Orienting and Inhibition

Several CIT studies aimed to differentiate the role of orienting from inhibition. Although most of these studies targeted the response inhibition factor (e.g., Ambach, Stark, Peper, & Vaitl, 2008; Elaad & Ben-Shakhar, 1989; Furedy & Ben-Shakhar, 1991; Horneman & O'Gorman, 1985; Kugelmass, Lieblich, & Bergman, 1967; Suchotzki, Verschuere, Peth, Crombez, & Gamer, 2015), some studies aimed to manipulate the arousal inhibition factor (e.g., Elaad, 2013; Gustafson & Orne, 1965; Matsuda, Nittono, & Ogawa, 2013; Zvi, Nachson, & Elaad, 2012). Importantly, these studies faced one or both of the following drawbacks: (1) It is unclear whether all attempts at arousal inhibition were eliminated in the noninhibition conditions. Specifically, although participants in the noninhibition conditions might have been less motivated than participants in the other conditions, they were nevertheless motivated to conceal the critical items and, consequently, they might have attempted to inhibit the arousal associated with these items; (2) The reduced motivation in the noninhibition conditions may have reduced the significance level of the critical items and thus affected the size of the orienting response. Hence, it is difficult to say which mechanism caused the differential findings.

In an attempt to overcome these weaknesses, klein Selle et al. (2016) aimed to manipulate the arousal inhibition factor by contrasting the motivation to conceal with the motivation to reveal. Specifically, participants were assigned either the role of a suspect and motivated to avoid detection by concealing the crime-related information (as in typical CIT studies) or the role of a witness and motivated to be detected by revealing the crime-related information. As the significance of the critical items was similar for both groups, no difference in the orienting response was expected. Importantly, however, the enhanced arousal elicited by the critical items was expected to be threatening in the conceal, but welcomed in the reveal condition. Consequently, while all participants oriented to the significant critical items, only concealers should try to inhibit the enhanced arousal associated with these items. In an attempt to separate arousal from response inhibition, all participants were requested to remain silent. Still, even when silent, it cannot be completely ruled out that participants in the conceal condition may have inhibited the overt truth. As predicted by the authors, while the SCR increased to the same extent in both groups, the RLL shortened and the HR decelerated solely in the conceal condition. It was accordingly concluded that the SCR measure reflects orienting processes, while both the RLL and HR reflect inhibition processes.

The Present Study

The present study is intended to build on the mock crime study of klein Selle et al. (2016) by using the autobiographical version of the CIT. In order to accomplish this goal, participants were either motivated to conceal or to reveal their own identity. We also extend our prior study by manipulating item significance, that is, by including both high salient and low salient identity items. While there is ample evidence that the orienting response is influenced by item salience (e.g., Sokolov, 1963), there is no research (that we are aware of) showing that the arousal inhibition factor is influenced by item salience. Hence, the salience manipulation was predicted to primarily affect the orienting response measures.

In the current study, we test four competing models aimed at explaining the CIT effect. Each of these models relies either solely on orienting or inhibition theory or on a combination of these two theories. Importantly, they include predictions concerning the primary motivational manipulation (conceal vs. reveal) as well as the salience manipulation (see Table 1):

- The orienting model holds that the CIT effect, with all three measures, is driven solely by the orienting response. This model predicts that (1) there will be no differences in the CIT effects between the conceal and reveal conditions, and (2) there will be a larger CIT effect for high than for low salient items.
- The inhibition model holds that the CIT effect, with all three measures, is driven solely by arousal inhibition. This model predicts that (1) the CIT effect will be present in the conceal, but not in the reveal condition, and (2) there will be no difference in the CIT effect for high and low salient items.
- The orienting-inhibition model holds that the CIT effect, with all three measures, is driven by both the initial (automatic) orienting response and the subsequent (deliberate) arousal inhibition. This model predicts that (1) there will be a significant CIT effect even in the reveal condition due to orienting, (2) there will be a larger CIT effect in the conceal compared to the reveal condition, due to arousal inhibition, and (3) there will be a larger CIT effect for high than for low salient items, due to increased orienting.
- The response fractionation model, based upon the response fractionation observed in klein Selle et al. (2016), holds that the SCR is a measure of orienting and that the RLL and HR are measures of inhibition. This model predicts that (1) there will be no difference in the SCR CIT effect between the conceal and reveal conditions, and (2) the SCR CIT effect will be larger for high than for low salient critical items. The model further predicts that (3) there will be a significant RLL and HR CIT effect in the conceal, but not in the reveal condition, and (4) there will be no difference in the RLL and HR CIT effects for high versus low salient critical items.

Table 1. *Summary and Performance of the Four Prediction Models*

Models	Predictions	Confirmed?
Orienting model	1. No difference in the CIT effect (with all three measures) between the conceal and reveal conditions.	No
	2. Larger CIT effect (with all three measures) for high than for low salient items.	No
Inhibition model	1. Significant CIT effect (with all three measures) only in the conceal condition.	No
	2. No difference in the CIT effect (with all three measures) for high and low salient items.	No
Orienting-inhibition model	1. Significant CIT effect (with all three measures) in the reveal condition.	No
	2. Larger CIT effect (with all three measures) in the conceal than in the reveal condition.	No
	3. Larger CIT effect (with all three measures) for high than for low salient items.	No
Response fractionation model	1. No difference in the SCR CIT effect between the conceal and reveal conditions.	Yes
	2. Larger SCR CIT effect for high than for low salient items.	Yes
	3. Significant RLL and HR CIT effects only in the conceal condition.	Yes
	4. No difference in the RLL and HR CIT effects for high vs. low salient items.	Yes

Method

Participants

One hundred and nine undergraduate students (70 women) of the Hebrew University of Jerusalem (HUJI) with an age range of 18–39 ($M = 23.7$ $SD = 2.7$ years) participated in this study. Fifty-five participants were assigned to the conceal condition, while 54 participants were assigned to the reveal condition. All participants were native speakers of Hebrew and received either course credits or an average payment of 45 NIS (equivalent to approximately 12 USD) for their participation. Each participant read and signed a consent form indicating that participation was voluntary and that they could withdraw from the experiment at any time without penalty. The experiment was approved by the ethical committee of the Faculty of Social Sciences of the HUJI.

Data Acquisition and Reduction

The experiment was conducted in an air-conditioned laboratory. The apparatus included a constant voltage system (0.5V ASR Atlas Researches, Hod Hasharon, Israel) to record the physiological signals and a HP Compaq DC 5800 Microtower computer to store these physiological signals and control stimulus presentation.

Electrodermal activity was recorded using two Ag/AgCl electrodes (0.8 cm diameter) filled with a 0.05 M NaCL electrode paste (TD-246, Discount Disposables) and an A/D (NB-MIO-12) converter with a sampling rate of 50 Hz. Electrodes were placed on the distal phalanges of the left index and left ring finger. SCRs were defined as the maximal increase in conductance obtained from 1 s to 5 s after stimulus onset.

The electrocardiogram (ECG) was recorded by placing three Ag/AgCl electrodes, filled with electrode paste, in a standard Einthoven Lead I configuration: one electrode attached to the distal phalange of the left index finger (i.e., one of the SCR electrodes), one electrode attached to the right wrist, and the ground electrode attached to the left wrist. The ECG signal was sampled at 500 Hz, digitized at 12-bit resolution, and filtered using a band-pass of 1–35 Hz. MATLAB was used to detect the R peaks, calculate the distance between them, and apply a semiautomatic artifact detection and rejection procedure (similar to, e.g., De Clercq, Verschuere, De Vlieger, & Crombez, 2006). Prior to analysis, the interbeat intervals were converted to HR in beats per minute (bpm) per real-time epoch (1 s). These second-by-second poststimulus HR values were baseline-corrected by subtracting the average HR value in the 3-s preceding stimulus onset (i.e., the prestimulus baseline value), resulting in 15 poststimulus difference scores (ΔHR). The average of all ΔHR scores has been found to outperform the minimum of all ΔHR scores as a detection measure (Gamer, Verschuere, Crombez, & Vossel, 2008) and was therefore the preferred statistic when analyzing the data (for the second-by-second changes in HR, see Figure 1a–d).

Respiration was recorded using a respiratory band positioned around the thoracic area. Respiration responses were defined on the basis of the total RLL, which is a composite measure of respiratory amplitude (depth of breathing) and respiratory cycle (rate of breathing), during the 0.5-s to 13.5-s interval following stimulus onset. Following Elaad, Ginton, and Jungman (1992), we defined each response as the mean of 10 length measures (0.1 s after stimulus onset through 13.1 s after stimulus onset, 0.2 s through 13.2 s after stimulus onset, etc.). In other words, ten 13-s windows were created, each beginning 0.1 s later than the previous window, and the RLL was defined as the mean of the 10 length measures computed for the 10 windows.

For all three measures, individual responses were removed if excessive movements were made during the measurement window or if the response was an outlier (Z score larger than 5 or smaller than -5). Further, similar to klein Selle et al. (2016), skin conductance nonresponsivity was determined using the within-participant standard deviation of the raw SCR scores. Participants whose standard deviation was below 0.01 μS in both blocks of the CIT were considered to be nonresponders, and their SCR data was eliminated from all analyses. In case of nonresponsivity in one of the blocks, only the data from the respective block were removed.

In order to eliminate individual differences in physiological responsivity and baseline activation, within-subject standard scores were calculated for each physiological channel separately (Ben-Shakhar, 1985). Further, to minimize habituation effects, the standard scores were computed within a block of four questions. Specifically, the standard scores were computed by subtracting the mean response computed across all critical and control items within each block of questions (buffer and catch items were excluded from the standardization) from each response to an individual item and dividing this difference by the respective standard deviation (see Ben-Shakhar & Elaad, 2002; Elaad & Ben-Shakhar, 1997). For each participant and for each physiological measure, a detection score was created by averaging the respective Z scores of all critical items.

Material

Item stimuli. Eight identity-related items were chosen to be the focus of the CIT questions. Four of these items were high salient (i.e., first name, last name, mother's name, country of birth) and the other four items were low salient (i.e., age, identity number—

nine-digit number that is issued to all Israeli citizens at birth—academic major, current city). Item salience was based on previous studies (Kleinberg & Verschuere, 2015; Lieblich, Ben-Shakhar, & Kugelmass, 1976; Verschuere, Kleinberg, & Theocharidou, 2015), which have shown that the selected high salient items elicit higher salience ratings and a stronger CIT effect than the low salient items.

Subjective rating scales. The Differential Emotions Scale (DES; Izard, Dougherty, Bloxom, & Kotsch, 1974) was used to assess participants' emotional state. The DES consists of 10 subscales, with three items per scale, which measure the basic emotions of interest, enjoyment, surprise, sadness, anger, disgust, contempt, fear, shame/shyness, and guilt. Participants indicated to what extent they currently experienced each emotion on a scale of 1 (= *not at all*) to 5 (= *a lot*). Although internal consistency of the individual subscales varies and ranges from 0.56 to 0.88, the scales are stable over time and are significantly correlated with personality variables and outcomes (Boyle, 1984; Izard, Libero, Putnam, & Haynes, 1993).

Significance, arousal, and valence ratings were obtained to examine whether the critical items carried the same importance and affective meaning for participants motivated to conceal their identity as for participants motivated to reveal their identity. The ratings were obtained, using a 9-point Likert scale (1 = *not at all*, 9 = *very*), for all eight critical and eight randomly chosen control items (one from each question). For the valence and arousal ratings, participants were asked to rate how pleasant and aroused they felt when presented with the items. For the significance ratings, the procedure of Dindo and Fowles (2008) was followed, and participants were asked to rate how important, significant, or relevant the items are to them, irrespective of valence.

Procedure

All participants were welcomed by Experimenter 1 when entering the laboratory, and allocated to either the conceal or the reveal condition. After signing an informed consent form, participants began the experiment.

Part 1: Identity collection. Part 1 of the experiment was identical for the two motivational conditions. Experimenter 1 asked participants to complete the DES, which provided a baseline measurement of their emotional state. Following the DES, participants answered eight identity-related questions (e.g., provide first name, last name). The answers to these questions later served as critical items in the CIT. Finally, participants were presented with eight sets of 12 intended control items. All items in a set matched the category of a single critical item (e.g., first name, age, identity number). Participants were asked to mark, per set, a maximum of six items that hold a particular relevance to them. After excluding all marked items and items that were too similar to the critical item (e.g., Tamar vs. Tamara), five items, per set, were randomly selected from the remaining items to serve as buffer and controls in the CIT.

Part 2: Identity detection. Part 2 consisted of the actual CIT. Experimenter 2, who was unaware of the critical items, attached the SCR and HR electrodes as well as the RLL band and conducted the CIT examination. After 2 min of rest, the experimenter provided the instructions for the CIT. Importantly, participants were told that their physiological responses would automatically change when recognizing the details related to their identity (i.e., the critical items). Participants in the conceal condition were, however, motivated to hide their identity, while participants in the reveal condition were motivated to reveal their identity. Specifically, participants in the conceal condition were promised a bonus of 10 NIS (about 3 USD) as an incentive to avoid detection of the critical (identity) items, while participants in the reveal condition were promised a bonus of 10 NIS (3 USD) as an incentive to allow detection of the critical (identity) items (see Appendix A for verbatim instructions). The bonus was paid when the average SCR Z score, computed across all critical items in the two blocks (i.e., SCR detection score), was below 0.1 in the conceal condition or above 0.1 in the reveal condition. Consequently, 6 out of 55 participants in the conceal condition and 43 out of 54 participants in the reveal condition received the bonus.

The CIT consisted of two blocks of four questions, with a break between blocks to maintain participants' attention. Each question targeted one of the identity items collected in Part 1 of the experiment. Importantly, the order of these questions was randomly determined, except that high and low salient questions alternated. Each question (e.g., What is your name?) was presented on the computer monitor for 10 s and at the same time the prerecorded question was played through the computer's loudspeakers. After question presentation, the different items (e.g., Sivan, Hila, Hadas) appeared for 5 s each on the computer monitor, with an interstimulus interval of 14–18 s. The first item was always a neutral buffer item designed to absorb the initial orienting response (and excluded from further analyses). Next, one critical item, four control items, and one catch item were presented in a random order. Catch items were included as an extra means of assuring that participants' attention remained focused on the items presented (see also Verschuere, Crombez, Degrootte, & Rosseel, 2010) and contained the command "say" and a random number between one and nine (written in letters). When presented with a catch item, participants said the number out loud. When presented with either a buffer, control, or critical item, participants were requested to remain silent. In sum, participants were presented with 8 questions $\times$ 7 items (1 buffer, 1 critical, 4 control, and 1 catch item), totaling 56 items.

Immediately following the CIT, participants were asked to complete, for a second time, the DES. A comparison between the first and second DES would reveal whether and how the experimental manipulation changed participants' emotional state. At completion of the DES, the electrodes and RLL band were removed, and participants were notified of their test result. Then, participants were requested to provide the significance, valence, and arousal ratings. Following these ratings, participants received a paper-and-pencil questionnaire in which they were asked to rate their motivation to conceal/reveal the critical items (depending on motivational condition), their efforts to conceal the critical items, their efforts to reveal the critical items, and their efforts to inhibit and increase physiological arousal. Further, although not instructed to, participants were asked to indicate whether and what kind of countermeasures they applied. Finally, all participants were debriefed and compensated for their participation in the experiment.

Data Analysis

As concealed information is associated with cardiac and respiratory suppression, the RLL and HR Z scores were multiplied by -1. These measures were used in all statistical analyses (except for the figures). For the main analysis, a three-way mixed analysis of variance (ANOVA), with motivational condition (conceal vs. reveal)

Table 2. *Means (Standard Deviations) of the Significance, Arousal, and Valence Ratings of the High and Low Salient Critical-Control Items in Each Motivational Condition (Conceal vs. Reveal)*

Measure	Motivational condition	*N*	Mean (*SD*) critical items		Mean (*SD*) control items	
			High salient	Low salient	High salient	Low salient
Significance	Conceal	55	8.45 (0.68)	7.39 (1.10)	1.91 (1.04)	1.83 (0.84)
	Reveal	54	8.43 (0.99)	7.71 (1.12)	1.94 (1.09)	1.74 (0.83)
Arousal	Conceal	55	7.56 (1.37)	6.68 (1.55)	3.01 (1.86)	3.05 (1.77)
	Reveal	54	7.81 (1.40)	7.19 (1.29)	2.75 (1.54)	2.50 (1.31)
Valence	Conceal	55	7.50 (1.27)	5.85 (1.36)	3.66 (1.49)	3.52 (1.70)
	Reveal	54	7.72 (1.15)	6.60 (1.24)	3.73 (1.48)	3.47 (1.36)

as a between-subjects factor and item salience (high vs. low) and physiological measure (SCR, RLL, and HR) as within-subject factors, was performed on the detection scores (the mean *Z* scores of all critical items). The expected Physiological Measure × Motivational Condition and Physiological Measure × Item Salience interaction effects were further examined using two orthogonal planned contrasts. For both (interaction) contrasts, we computed a difference score: the SCR detection score minus the mean of the RLL and HR detection scores. The first contrast compared this difference score between the conceal and reveal conditions and is based on klein Selle et al.'s (2016) finding that, while the SCR increased in both the conceal and reveal conditions, the RLL shortened and the HR decelerated only in the conceal condition. The second contrast compared the difference score between high and low salient items and is based on the prediction that only the SCR will be affected by item salience. A rejection region of $p < .05$ was used for all statistical tests, and Cohen's f values were computed as effect size estimates (Cohen, 1988). According to Cohen (1988), the values of $f = 0.1$, $f = 0.25$, and $f = 0.40$ correspond to small, medium, and large effects, respectively. One-tailed tests were used to test directional, a priori formulated hypotheses.

Results

Subjective Ratings

Manipulation checks. Participants' efforts to conceal the critical items (on a scale of 1–6) were significantly larger in the conceal ($M = 4.98$) than in the reveal condition ($M = 1.54$), $t(107) = 17.24$, $p < .001$, $d = 3.30$. On the other hand, participant's efforts to reveal the critical items were significantly larger in the reveal ($M = 4.44$) than in the conceal ($M = 1.64$) condition, $t(107) = -12.14$, $p < .001$, $d = -2.33$. In terms of motivation to conceal/reveal, the two conditions did not differ, $t(107) = .09$, $p = .931$, $d = .02$.

Further, participants' self-reported attempts at arousal inhibition (on a scale of 1–6) were significantly larger in the conceal ($M = 4.78$) than in the reveal ($M = 2.80$) condition, $t(107) = 6.60$, $p < .001$, $d = 1.26$. In contrast, participants' self-reported attempts at increasing physiological arousal (on a scale of 1–6) did not differ between conditions ($M_{conceal} = 3.20$, $M_{reveal} = 3.43$; $t(107) = -.70$, $p = .483$, $d = -.13$).

The significance, arousal, and valence ratings of both critical (high and low salient) and control (high and low salient) items in each motivational condition are shown in Table 2. In order to verify (a) the critical-control difference, and (b) our salience manipulation, three separate three-way mixed ANOVAs (Motivational Condition × Item Type × Item Salience) were performed on the item ratings. A detailed description of the results of these ANOVAs is presented in Appendix B. Most importantly, in both the conceal and reveal conditions, these analyses showed higher ratings of significance, arousal, and valence for critical than control items and for high salient as compared to low salient items.

The DES. In order to check whether the experimental manipulation had an influence on participants' emotional state, we computed difference scores (DES2 − DES1) for each of the 10 emotions and compared these scores across motivational conditions. None of the independent samples *t* tests, with a Bonferroni-adjusted alpha level of .005 per test (.05/10), reached statistical significance. Thus, in other words, the experimentally induced changes in emotion did not differ significantly between the conceal and reveal conditions.

Physiology

The skin conductance and heart rate data of one participant (0.9%) and the respiratory data of one additional participant (0.9%) were lost due to technical issues (i.e., electrode failure, incorrect positioning of respiratory band). Further, all skin conductance data of seven participants (6.4%) and the heart rate data of one participant (0.9%) were removed due to either nonresponsivity, excessive movements, outliers, or a combination of these factors. For the remaining participants, the skin conductance data within the first block of two participants (2%) as well as the skin conductance data within the second block of nine participants (8.9%) were removed due to nonresponsivity. Thus, while sample size varies between 100–109 for the different analyses ($n_{SCR} = 101$, $n_{RLL} = 108$, $n_{HR} = 107$), all analyses of the three physiological measures were based on data of at least 100 participants. For these participants, 3.93% of all SCRs, 0.93% of all RLL, and 3.66% of all HR responses to the individual stimuli were removed due to excessive movements and outliers.

Main analysis. A three-way mixed ANOVA (Motivational Condition × Item Salience × Physiological Measure) on the standardized physiological data revealed a significant main effect of motivational condition, $F(1,98) = 84.34$, $f = .93$, $p < .001$, indicating larger standardized responses in the conceal than in the reveal condition, and a significant main effect of item salience, $F(1,98) = 4.81$, $f = .22$, $p = .031$, indicating larger standardized responses for high than for low salient items. Further, the main effect of physiological measure, $F(2,196) = 77.46$, $f = .89$, $p < .001$, the Physiological Measure × Motivational Condition interaction, $F(2,196) = 17.10$, $f = .42$, $p < .001$, as well as the Physiological Measure × Item Salience interaction, $F(2,196) = 5.96$, $f = .25$, $p = .003$, were statistically significant. All other effects failed to reach significance. The meaning of these interaction effects was further explored using two planned contrasts; for both (interaction) contrasts we computed a

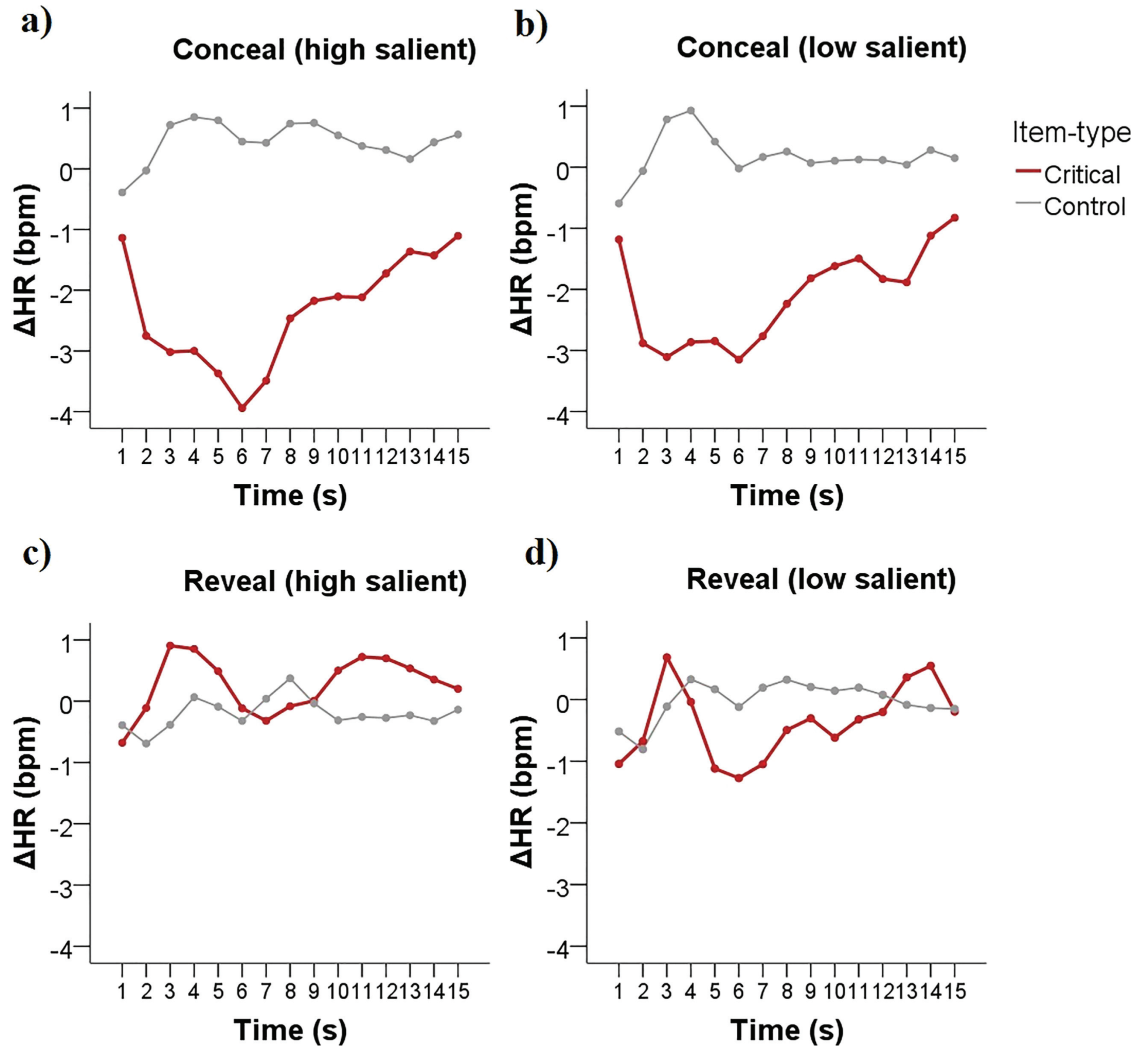

Figure 1. HR change to critical (high and low salient) and control (high and low salient) items in the (a, b) conceal and (c, d) reveal conditions.

difference score: the SCR detection score minus the mean of the RLL and HR detection scores.

The first contrast (examining the Physiological Measure × Motivational Condition interaction) revealed that the SCR versus RLL and HR difference score was larger in the reveal than in the conceal condition, $t(98) = -4.98$, $f = .40$, $p < .001$. This result indicates that, while the SCR increased in both the reveal and conceal conditions, the RLL shortened and the HR decelerated only in the conceal condition (see Figure 1a–d and Figure 2a–c). Notably, just as klein Selle et al. (2016), we observed a significant lengthening of the RLL in the reveal condition (see Table 3)[1].

The second contrast (examining the Physiological Measure × Item Salience interaction) revealed that the SCR versus RLL and HR difference score was significantly larger for high than for low salient critical items, $t(98) = 3.29$, $f = .18$, $p = .001$. This result indicates that the SCR, unlike the RLL and HR, was sensitive to item saliency, with stronger responding to high salient than to low salient items (see Figure 1a–d and Figure 2a–c).

In order to further examine the different models, we relied on Bayesian hypothesis testing and computed for each physiological measure two JZS Bayes factors: (1) for the between-subjects factor of motivational condition, and (2) for the within-subject factor of item salience. The JZS Bayes factor (BF) is a numerical value quantifying the odds ratio between the null (i.e., no detection score differences between the two motivational conditions/item types) and alternative hypothesis (i.e., detection score differences between the two motivational conditions/item types) given the data (Jeffreys, 1961; Rouder, Speckman, Sun, Morey, & Iverson, 2009). A default JZS prior with scaling factor $r = .707$ was used for the alternative hypothesis. Importantly, the BFs are reported as either favoring the null or the alternative hypothesis, and a BF of 3 or more is taken as substantial evidence for the respective hypothesis (Jeffreys, 1961).

When comparing the conceal and reveal conditions, a BF of 3.12 (in favor of the null) was found for the SCR, while a BF of 4.74×10^{12} (in favor of the alternative) was found for the RLL and a BF of 1.55×10^{6} (in favor of the alternative) was found for the

1. The RLL lengthening in the reveal condition was further examined by separating participants in this condition into two groups based on their indicated usage of respiratory countermeasures during the CIT. Importantly, although the RLL lengthening was larger for participants who reported using such countermeasures ($M = -.88$) than for participants who did not report using such countermeasures ($M = -.34$), $t(51) = 3.03$, $p = .004$, $d = 1.03$, the lengthening was significant in both groups; countermeasures: $t(10) = -6.29$, $p < .001$, $d = -1.90$; no countermeasures: $t(41) = -4.08$, $p < .001$, $d = -.63$.

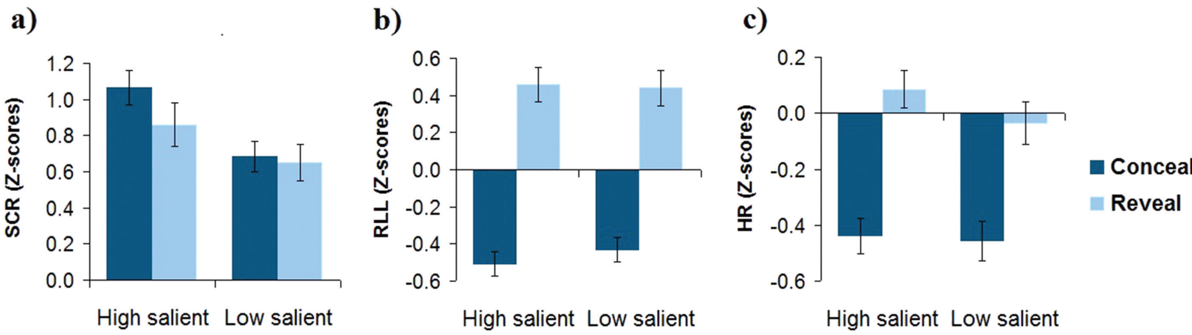

Figure 2. Standardized (a) skin conductance response, (b) respiration line length, and (c) heart rate to high versus low salient critical items in the conceal versus reveal conditions.

HR. Thus, while there is substantial evidence for the alternative hypothesis with the RLL and HR measures, there is substantial evidence for the null hypothesis with the SCR measure. These JZS BFs confirm that, while the SCR increased to a similar extent in the conceal and reveal conditions, the RLL shortened and the HR decelerated only in the conceal condition. Second, when comparing the high and low salient items, a BF of 29.95 (in favor of the alternative) was found for the SCR, while a BF of 6.64 (in favor of the null) was found for the RLL, and a BF of 5.65 (in favor of the null) was found for the HR measure. Thus, while there is substantial evidence for the alternative hypothesis with the SCR measure, there is substantial evidence for the null hypothesis with the RLL and HR measures. These JZS BFs confirm that only the SCR was affected by item salience. Taken together, while the SCR increased in both experimental conditions, the HR decelerated and the RLL shortened solely in the conceal condition. Further, while the SCR was larger for high than for low salient critical items, no such differences in the RLL and HR responses were observed. These results are in line with the response fractionation model (see Table 1).

In addition to comparing the means of the detection scores, we evaluated CIT detection efficiency using the area under the receiver operating characteristic (ROC) curve; e.g., Green & Swets, 1966; Swets, Tanner, & Birdsall, 1961). A detailed description of the ROC analyses and results can be found in Appendix C. Most importantly, while SCR detection efficiency was significant in both the conceal and reveal conditions, RLL and HR detection efficiency was significant only in the conceal condition (see also Table 3).

Discussion

The present study was designed to unravel the roles of orienting and arousal inhibition in the physiological detection of concealed information. To this end, we manipulated participants' need for inhibition when presented with items related to their own identity. Specifically, half of the participants were motivated to conceal their identity, which was expected to result in an orienting response and arousal inhibition, while the other half of the participants were motivated to reveal their identity, resulting in an orienting response only. In addition, we manipulated item salience, and thereby tested the prediction derived from orienting response theory that larger orienting responses are elicited by high than by low salient identity items.

A Double Fractionation

The typical CIT effect was observed in the conceal but not in the reveal condition. Specifically, while the SCR increased to a similar extent in both motivational conditions, the RLL shortened and the HR decelerated only in the conceal condition. This was evident in both the inferential statistics as well as in the Bayesian analysis. While the Bayesian analysis provided substantial evidence for the null hypothesis (i.e., no detection score differences between the conceal and reveal conditions) with the SCR measure, it provided substantial evidence for the alternative hypothesis (i.e., detection score differences between the conceal and reveal conditions) with the other two measures. The finding that the SCR is unaffected by arousal inhibition corresponds with earlier findings that this measure is unaffected by response inhibition (e.g., Ambach et al., 2008; Meijer, klein Selle, Elber, & Ben-Shakhar, 2014; Suchotzki et al., 2015). Further, the present findings partially correspond to those of a recent study that aimed to manipulate the arousal inhibition factor (i.e., Matsuda et al., 2013). In this study, participants witnessed how one of their two stolen (i.e., critical) items was revealed to the experimenter. It was hypothesized that the disclosure of the critical item removed the need to inhibit responses to this item. However, as all critical items (disclosed and nondisclosed) were previously stolen in a mock crime, not all attempts at inhibition may have been successfully eliminated. In the subsequent CIT, only the RLL was affected by the reveal manipulation, while in the present study both the RLL and HR were influenced. Finally, the current findings

Table 3. *Effect Size (d) with 95% CI and Area Under the ROC Curve (a) with 95% CI*

Measure	Motivational condition	*N*	Effect size (Cohen's *d*) with 95% CI: All	High salient	Low salient	Area under the ROC curve (*a*) with 95% CI: All	High salient	Low salient
SCR	Conceal	52	2.05 (1.57, 2.53)	1.98 (1.50, 2.45)	1.37 (0.94, 1.80)	0.92 (0.86, 0.97)	0.91 (0.85, 0.97)	0.82 (0.74, 0.90)
	Reveal	49	1.54 (1.08, 2.00)	1.38 (0.93, 1.83)	1.17 (0.73, 1.60)	0.84 (0.75, 0.92)	0.81 (0.72, 0.89)	0.77 (0.68, 0.87)
RLL	Conceal	55	1.33 (0.91, 1.75)	1.20 (0.79, 1.61)	1.03 (0.63, 1.43)	0.83 (0.75, 0.91)	0.80 (0.72, 0.89)	0.77 (0.68, 0.86)
	Reveal	53	−0.96 (−1.36, −0.55)	−0.86 (−1.26, −0.46)	−0.80 (−1.20, −0.40)	0.26 (0.17, 0.36)	0.28 (0.18, 0.38)	0.31 (0.21, 0.41)
HR	Conceal	54	1.35 (0.93, 1.77)	1.05 (0.65, 1.46)	1.04 (0.63, 1.44)	0.83 (0.75, 0.91)	0.79 (0.71, 0.88)	0.78 (0.69, 0.87)
	Reveal	53	−0.05 (−0.43, 0.34)	−0.20 (−0.58, 0.19)	0.08 (−0.31, 0.46)	0.49 (0.38, 0.60)	0.42 (0.31, 0.53)	0.53 (0.42, 0.65)

are almost identical to those of our previous mock crime study (klein Selle et al., 2016) in which we relied on a similar manipulation of arousal inhibition.

The salience manipulation was predicted to primarily affect the SCR. Indeed, while the SCR was larger for high than for low salient critical items, no differences in the RLL and HR responses between these items were observed. These results were verified by a Bayesian analysis, which provided strong support for the null hypothesis (i.e., no detection score differences between high and low salient items) with both the RLL and HR measures, but provided strong support for the alternative hypothesis (i.e., detection score differences between the high and low salient items) with the SCR measure.

The current findings provide further support for explaining the CIT effect in terms of a response fractionation model. Both its predictions concerning the primary motivational manipulation (conceal vs. reveal) as well as the salience manipulation were confirmed. Consequently, in line with klein Selle et al. (2016), this leads us to conclude that, while the SCR measure is associated with orienting processes, both the RLL and HR measures are associated with arousal inhibition processes. The inhibition account of the RLL and the HR stands in contrast to the classical orienting literature describing a unitary orienting response (e.g., Lacey & Lacey, 1970; Sokolov, 1963). Hence, one may speculate that the present findings are specific to the CIT paradigm. However, as more evidence has been accumulated over time, only the SCR consistently showed the expected effects of novelty, intensity, and significance (e.g., Barry, 1996, 2006, 2009; Dindo & Fowles, 2008). Specifically, while some studies found the HR to decelerate in response to novel stimuli (e.g., Bradley, 2009; Siddle & Turpin, 1987), others found the HR to be insensitive to stimulus novelty (Barry, 1977; Barry & James, 1981; Barry & Maltzman, 1985). Further, as compared to neutral novel stimuli, a greater HR deceleration has been observed for unpleasant novel, but not for pleasant novel stimuli (Bradley, 2009). When considering the significance factor, some studies observed a greater HR deceleration in response to significant stimuli (e.g., Feld, Specht, & Gamer, 2010; Stormark, 2004), while others found that stimulus significance is neither reflected by HR deceleration nor by respiratory suppression (e.g., Baker, 2008; Barry, 1981; Coles & Duncan-Johnson, 1975; Greene, Dengerink, & Staples, 1974; Vico, Guerraa, Robles, Vila, & Anllo-Ventoa, 2010). These latter findings are more relevant in the context of our experiment as the critical CIT items were personally significant. Thus, it seems that the RLL and HR may not be that sensitive to stimulus significance. As such, it may not be surprising that no shortening of the RLL and no deceleration of the HR were observed in the reveal condition. Taken together, our findings are inconsistent with the classical unitary view of the orienting response and support a response fractionation model.

The present findings are only partially consistent with the preliminary process theory (PPT) proposed by Barry and his colleagues (i.e., Barry, 1996, 2006, 2009). Although the PPT provides a principal framework for explaining the phenomenon of physiological response fractionation, it cannot explain the fractionation of responses observed in the present study. According to the PPT, the SCR is a pure measure of the orienting response, while the other autonomic measures reflect earlier processing stages (i.e., HR reflects stimulus registration and RLL reflects novelty registration). As both stimulus registration and stimulus novelty were unlikely to be affected by the motivation to conceal or reveal, the PPT would predict a similar CIT effect in the two motivational conditions. Moreover, as the PPT relates HR to the mere process of stimulus registration, it cannot explain the enhanced HR deceleration to critical stimuli in the conceal condition (see Ben-Shakhar, Gamer, Iacono, Meijer, & Verschuere, 2015).

The Witness Versus Identity Manipulation

The primary difference between this study and the study reported by klein Selle et al. (2016) is the type of critical stimuli used. Specifically, while klein Selle et al. (2016) relied on mock crime-related items, the present study relied on identity-related items. These identity items were either of high or low salience, as confirmed by the significance ratings. Importantly, however, both studies revealed a similar fractionation of the responses.

Unlike klein Selle et al. (2016), the present study included a well-validated measure of participants' emotional state: the DES. This scale includes a number of negative emotions that were most likely to be affected by our manipulation (i.e., anger, shame, fear, guilt). Although the results revealed some small changes in emotion (DES2 − DES1), these changes did not differ systematically for participants in the conceal and the reveal conditions. Hence, it seems that our physiological findings cannot be explained by a difference in emotional state. Similarly, we observed some small differences in the arousal ratings (see Appendix B and Table 2). However, in contrast to what might have been expected, the critical items received higher arousal ratings in the reveal than in the conceal condition. Hence, it seems that our physiological findings cannot be explained by a difference in experienced arousal, either.

Applied Implications

The response fractionation model can account for a number of previously unexplained findings. For instance, as the model suggests that only the SCR reflects an orienting response (which is known to habituate), it can explain why this measure is more sensitive to habituation than the RLL and HR (e.g., Ben-Shakhar & Elaad, 2002; Elaad & Ben-Shakhar, 1997; Gamer, Godert, Keth, Rill, & Vossel, 2008). Further, it may explain why the RLL and HR measures are more resistant to countermeasures than the SCR (Ben-Shakhar & Dolev, 1996; Honts, Devitt, Winbush & Kircher, 1996; Peth, Suchotzki, & Gamer, 2016). Specifically, no matter what countermeasures are used (e.g., mental, physical), examinees motivated to conceal are likely to attempt to inhibit physiological arousal (as reflected by the RLL and HR). In contrast, as such countermeasures may enhance the saliency of the control items, they may also increase the size of the orienting response to these items (as reflected by the SCR). Consequently, SCR differentiation (critical vs. control) may decrease when examinees perform countermeasures.

Besides explaining previous results, the current findings allow for the formulation of a number of suggestions that could potentially benefit forensic practitioners. Clearly, each of these suggestions is made cautiously and requires additional research. First, as the SCR is more sensitive to habituation, it is proposed that less weight be given to this measure when the test takes a long time. In addition, as the SCR is affected by item salience, CIT detection efficiency using this measure may be diminished when the test relies on low salient items. Hence, it is suggested that more weight be given to the RLL and HR measures when the high salient information has been compromised (e.g., by leakage to the media). Furthermore, as the RLL and HR are driven by arousal inhibition, these measures may also be sensitive to manipulations of response inhibition and consequently to a deceptive response. Hence, it is suggested to instruct examinees to answer deceptively (i.e., "no"). Finally, CIT detection efficiency using the RLL and HR measures may be enhanced for individuals with poor inhibitory skills. If such individuals can be identified using a preliminary screening test, it is suggested that more weight be given to the RLL and HR measures (see Matsuda, Ogawa, Tsuneoka, & Verschuere, 2015; Noordraven & Verschuere, 2013).

Limitations

As it was crucial to equalize the orienting response in the two motivational conditions, participants in the reveal condition received a similar motivational incentive as participants in the conceal condition. The motivation to reveal might, however, have prohibited a passive viewing of the items and induced the need to increase, rather than inhibit, physiological arousal. To prevent such deliberate increases in arousal, it was explicitly explained to participants that the detection of the critical identity items depends on automatic changes in their physiological responses. Thus, in order to enable detection, participants in the reveal condition simply had to recognize the identity items. Indeed, participants' self-reported efforts to increase physiological arousal were similar in the two motivational conditions.

Similar to klein Selle et al. (2016), we observed a lengthening of the RLL in the condition attempting to eliminate inhibition (i.e., witness and reveal conditions). Although this lengthening was significant for both participants who reported using respiratory countermeasures and for participants who did not report using such countermeasures, it was significantly larger in the former group. Considering the augmenting effect of these countermeasures on the RLL, one may wonder whether the smaller lengthening in the no-countermeasure group may also be explained by (nonreported) countermeasures. Furthermore, the lengthening of the RLL in the reveal condition might have partly masked a decelerative HR response.

Due to the lack of evidence that the inhibition factor is affected by item salience, we predicted that especially the SCR (orienting measure) would be influenced by the salience manipulation. Still, one might argue that both arousal and the need to inhibit this arousal (as reflected by the RLL and HR) may be stronger for high than for low salient items. Our results, however, showed no influence of item salience on the RLL and HR.

Finally, participants were notified of their test result (i.e., succeeded/not succeeded to conceal/reveal) before they completed the item ratings and motivation/effort questionnaire. Although they were asked to rate the stimuli and their motivation/effort as experienced during the CIT, awareness of the test result might have affected their answers.

Future Directions

The present study included three autonomic nervous system measures commonly used for the detection of concealed information. Recent CIT studies, however, have also relied on central nervous system measures, such as fMRI and ERPs, and behavioral measures, such as reaction times (RTs; e.g., Farwell & Donchin, 1991; Rosenfeld et al., 1988; Seymour, Seifert, Mosmann, & Shafto, 2000; Suchotzki et al., 2015). While fMRI measures have been suggested to reflect both orienting and response inhibition (Gamer, 2014; but see Suchotzki et al., 2015), it has been debated which of these processes drives the P300 component of the ERP (e.g., Donchin et al., 1984). Likewise, enhanced RTs have been primarily associated with the inhibition factor (Seymour & Schumacher, 2009; Verschuere & De Houwer, 2011); however, it hasn't been well investigated whether RTs are affected by orienting (for an exception, see Suchotzki et al., 2015). Importantly, the present manipulation may be of use to disentangle the roles of orienting and inhibition in the CIT based on central nervous system and behavioral measures. We would also like to encourage other researchers to think of alternative manipulations that may be more successful in separating arousal from response inhibition.

Conclusions

The present study confirmed earlier findings by klein Selle et al. (2016) and revealed a fractionation between the different physiological measures. Specifically, while the SCR increased in both motivational conditions, the RLL shortened and the HR decelerated solely when participants were motivated to inhibit their physiological arousal (i.e., conceal condition). Moreover, only the SCR was affected by item salience. These results further strengthen our conclusion that, while the increase in SCR is driven by orienting, the shortening of the RLL and deceleration of the HR are driven by arousal inhibition.

Appendix A

Verbatim Instructions for the Conceal Condition

"You are about to take a memory test in which you are asked to *conceal* your identity, and in the meanwhile we will measure your physiological responses.

In the test, you will be presented with several items, including your identity items. The test is based on the theory that our physiological responses will automatically change when we are exposed to the items related to our identity.

Therefore, your goal is to *prevent* the computer from detecting your identity details. If you will succeed in your task, you will receive a 10 NIS bonus. The possible test results are 'succeeded in your task' or 'not succeeded in your task.'"

Verbatim Instructions for the Reveal Condition

"You are about to take a memory test in which you are asked to *reveal* your identity, and in the meanwhile we will measure your physiological responses.

In the test, you will be presented with several items, including your identity items. The test is based on the theory that our physiological responses will automatically change when we are exposed to the items related to our identity.

Therefore, your goal is to *allow* the computer to detect your identity details. If you will succeed in your task, you will receive a 10 NIS bonus. The possible test results are 'succeeded in your task' or 'not succeeded in your task.'"

Appendix B

Three separate three-way mixed ANOVAs (Condition × Item Type × Item Salience) were performed on the item ratings. Each of the ANOVAs revealed a significant main effect of item type (significance: $F(1,107) = 3163.34$, $f = 5.44$, $p < .001$; arousal: $F(1,107) = 653.19$, $f = 2.47$, $p < .001$; valence: $F(1,107) = 410.20$, $f = 1.96$, $p < .001$), indicating higher ratings for critical compared to control items, and a significant main effect of item salience (significance: $F(1,107) = 57.05$, $f = .73$, $p < .001$; arousal: $F(1,107) = 34.13$, $f = .57$, $p < .001$; valence: $F(1,107) = 102.71$, $f = .98$, $p < .001$), indicating higher ratings for high salient compared to low salient items. Further, each of the ANOVAs revealed a significant Item Type × Item Salience interaction effect (significance: $F(1,107) = 37.73$, $f = .59$, $p < .001$; arousal: $F(1,107) = 21.11$, $f = .44$, $p < .001$; valence: $F(1,107) = 92.89$, $f = .93$, $p < .001$). Follow-up paired sample *t* tests revealed that the critical-control difference was larger for high salient than for low salient items (significance: $t(108) = 6.09$, $p < .001$, $d = .58$; arousal: $t(108) = 4.56$, $p < .001$, $d = .44$; valence: $t(108) = 9.40$, $p < .001$, $d = .90$). Further, the Condition × Item Type interaction was significant only in the ANOVA on the arousal ratings, $F(1,107) = 4.94$, $f = .22$, $p = .028$. A follow-up independent samples *t* test revealed that the critical-control difference in arousal was significantly larger in the reveal than in the conceal condition, $t(107) = -2.22$, $p = .028$, $d = -.43$. Finally, the Condition × Item Ttype × Item Salience interaction was significant only in the ANOVA on the valence ratings, $F(1,107) = 7.01$, $f = .26$, $p = .009$. This interaction was further examined by performing within each experimental condition a two-way repeated measures ANOVA (Item Type × Item Salience). The Item Type × Item Salience interaction was significant in both ANOVAs (conceal: $F(1,107) = 58.38$, $f = 1.04$, $p < .001$; reveal: $F(1,107) = 35.10$, $f = .81$, $p < .001$), indicating that the critical-control difference was larger for high salient than for low salient items in both the conceal and reveal conditions.

Appendix C

ROC curves are typically derived by comparing the detection score distribution of knowledgeable individuals (in this case, either individuals in the conceal or reveal conditions) with the detection score distribution of unknowledgeable individuals. The area under the ROC curve describes the detection efficiency of the CIT across all possible cutoff points on the detection score and varies between 0 and 1, with a chance level of 0.5 (for a more detailed description of signal detection analysis as applied to the detection of concealed information, see Lieblich et al., 1970). As the present experiment did not include a sample of unknowledgeable (innocent) participants, we used a simulation procedure to estimate their expected detection score distribution (see Meijer, Smulders, Johnston, & Merckelbach, 2007). The simulation is based on the assumption that the critical items hold no special meaning for unknowledgeable individuals. Consequently, the critical and the control items will induce similar responses and the standardized responses to the critical items will have a mean of zero and a unit standard deviation. The average of these standardized responses (i.e., the detection score) would then have a mean of zero and a standard deviation of 1 divided by the square root of the number of critical items (here 8). As the simulation procedure further assumes that the detection scores are distributed normally, the hypothetical innocents distribution was created by taking random samples *n* (either $n_{conceal}$ or n_{reveal}) from a normal distribution; $N(0, 1/\sqrt{8})$. The simulated distribution was then compared with the empirical detection score distribution (based on either all critical items, only the high salient or only the low salient critical items) obtained for the knowledgeable participants, and the area under the ROC curve was computed. In addition, we computed Cohen's *d*, defined as the standardized difference between the means of these two detection score distributions, where *d* of 0.20, 0.50, and 0.80 are considered as small, moderate, and large effects, respectively (Cohen, 1988). This process was repeated 10,000 times for each physiological measure in each condition and the mean *d* value and area, as well as their 95% confidence intervals across the 10,000 repetitions were computed.

As can be seen in Table 3, detection efficiency with the SCR measure was well above chance in both the conceal and reveal conditions (i.e., the confidence intervals do not include a chance level of 0.5), with ROC values ranging between 0.77 and 0.92. In contrast, detection efficiency with the RLL (with values ranging between 0.26 and 0.83) and HR (with values ranging between 0.42 and 0.83) measures was significant only in the conceal condition. When comparing the areas (based on all critical items) obtained in the conceal and reveal conditions, a statistically significant difference was revealed for the RLL, $Z = 9.05$, $p < .001$, and the HR, $Z = 4.84$, $p < .001$, but not for the SCR ($Z = 1.63$, $p = .102$). A comparison of the areas obtained for the high and low salient critical items was significant solely in the conceal condition with the SCR measure, $Z = 1.74$, $p = .041$ (for a one-tailed test); all ROC comparisons were based on Hanley & McNeil's (1983) method.

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