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Hide or Seek? Physiological Responses Reflect Both the Decision and the Attempt to Conceal Information

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Abstract

The process of information concealment is more relevant than ever in this day and age. Using a modified concealed-information test (CIT), we aimed to unmask this process by investigating both the decision and the attempt to conceal information in 38 students. The attempt to conceal (vs. reveal) information induced a differential physiological response pattern within subjects—whereas skin conductance increased in both conditions, respiration and heart rate were suppressed only in the conceal condition—confirming the idea that these measures reflect different underlying mechanisms. The decision to conceal (vs. reveal) information induced enhanced anticipatory skin conductance responses. To our knowledge, this is the first study that observed such anticipatory responses in an information-concealment paradigm. Together, these findings imply that our physiological responses reflect, to some degree, both the decision and the attempt to conceal information. In addition to strengthening CIT theory, this knowledge sheds novel light on anticipatory responding in decision making.

Keywords

concealed-information test, orienting response, arousal inhibition, autonomic responses, anticipatory responding, open data, open materials, preregistered

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Throughout our lives, we are often confronted with the decision of whether to keep certain information to ourselves or to share it with others. Although the decision to hide information may be innocent in everyday life contexts, it may hold serious consequences (both to the individual and to society) in the forensic context. Possible scenarios include the wrongful exoneration of a guilty individual hiding knowledge of a burglary and a terrorist hiding knowledge of a planned terror attack. For these reasons, researchers have developed a simple yet refined memory-detection method: the concealed-information test (CIT; Lykken, 1959; Verschuere, Ben-Shakhar, & Meijer, 2011). This test relies on a multiple-choice questioning format in which each of the selected questions is followed by a serial presentation of one critical (concealed) and several control items (e.g., Where is the bomb located? In a building? In a car? In a dumpster? In a park? In a truck?). Only knowledgeable (guilty) suspects will recognize the critical alternatives and show a pattern of differential responses to these items (i.e., the CIT effect): a larger skin conductance response (SCR), a shorter respiration-line length (RLL), and a slower heart rate (HR; e.g., Gamer, 2011). Surprisingly, although extensive research has proven the validity of the CIT (see Meijer, klein Selle, Elber, & Ben-Shakhar, 2014), the test has been extensively used by field practitioners only in Japan.

The predominant and most influential theory of the CIT, *orienting-response theory*, was already proposed decades ago (e.g., Lieblich, Kugelmass, & Ben-Shakhar, 1970; Lykken, 1974). This theory is based on the concept of the orienting response, which is a complex of behavioral and physiological reactions to external novel stimuli. Crucially, the orienting response is enhanced when the stimuli are significant. Knowledgeable (guilty) examinees will therefore show enhanced orienting responses

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in a CIT when recognizing the critical (significant) stimuli, which could account for the CIT effect. A second more recently proposed theory, *arousal-inhibition theory*, holds that attempts at inhibition of physiological arousal underlie the CIT effect (Verschuere, Crombez, Koster, Van Bockstaele, & De Clercq, 2007). Imagine, for instance, the previous example of a terrorist planning an attack. It is conceivable that the terrorist not only recognizes (and orients to) the correct item (e.g., a car) but also, in order to look innocent, attempts to inhibit his experienced physiological arousal. Such attempts to inhibit arousal are, however, typically associated with increased, rather than decreased, physiological responses (Pennebaker & Chew, 1985). Hence, just as with orienting responses, arousal inhibition may explain the CIT effect.

Although few studies have tried to differentiate these two accounts, they did not succeed in entirely disentangling the orienting and inhibition factors (e.g., Elaad, 2013; Matsuda, Nittono, & Ogawa, 2013; Zvi, Nachson, & Elaad, 2012). Two recent studies by klein Selle, Verschuere, Kindt, Meijer, and Ben-Shakhar (2016, 2017) aimed to deal with this shortcoming by contrasting the motivation to conceal with the motivation to reveal. In both conditions, participants were offered a bonus for the successful completion of their task (conceal or reveal information). Consequently, the critical items carried the same significance in the two conditions, and all participants were expected to show enhanced orienting responses to these items. Importantly, however, only participants in the conceal condition were expected to try to inhibit their physiological arousal. Interestingly, the results of both studies revealed a fractionation between the different physiological measures: Whereas the SCR increased in both conditions, the RLL and HR suppressed solely in the conceal condition. These results led to the formulation of a response-fractionation model, suggesting that the SCR is a pure measure of the orienting response, whereas the RLL and HR reflect attempts at arousal inhibition (for two recent event-related-potential studies employing a similar manipulation, see Matsuda & Nittono, 2018; Rosenfeld, Ozsan, & Ward, 2017).

The present study was designed to achieve two major goals. The first goal was to constructively replicate the findings of klein Selle et al. (2016, 2017) by changing the experimental stimuli (cards instead of mock-crime or personal items) and the experimental design (within subjects instead of between subjects). Extending these previous findings was expected to not only strengthen the theoretical framework of the CIT but also encourage a wider use of the CIT as an applied investigative tool instead of other controversial detection methods (e.g., Iacono, 2011). Moreover, with a modified CIT paradigm (see the Method section and Fig. 1), participants decided themselves, on each trial, whether to conceal or reveal the critical item. This free

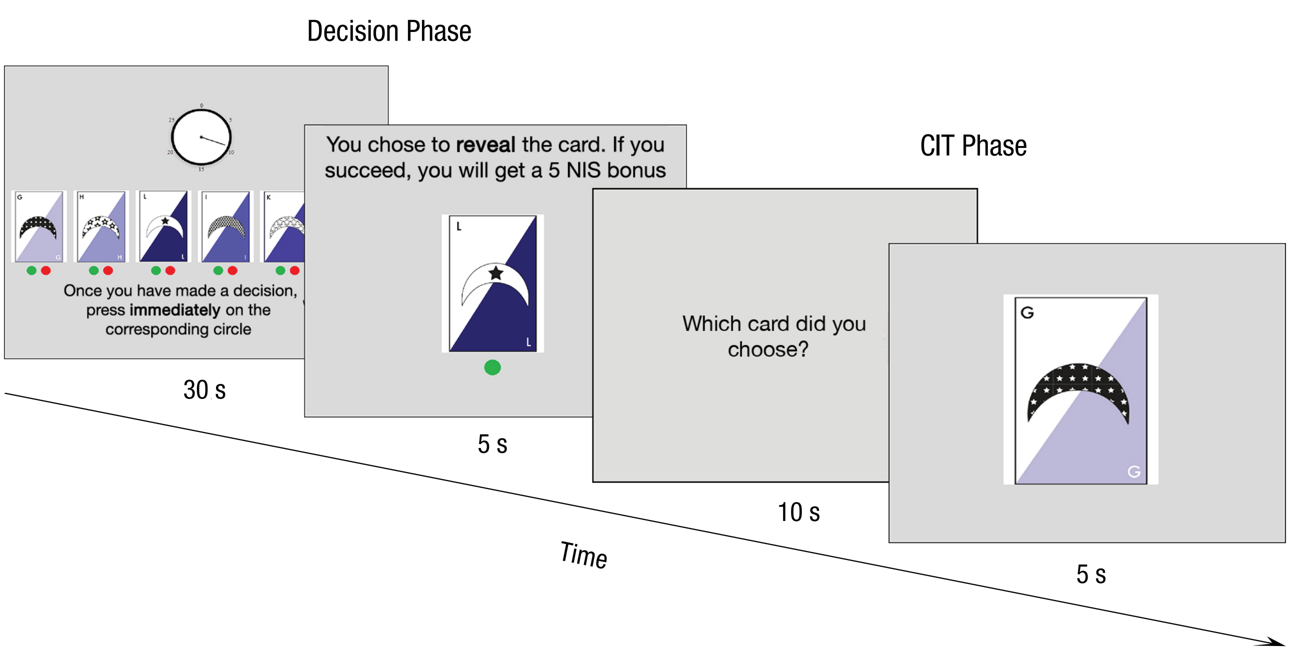

Fig. 1. Sequence of events during one trial of the card game. At the start of the decision phase, participants were instructed to decide within 30 s which of the presented cards they wanted to conceal or reveal during the upcoming concealed-information-test (CIT) phase. Once participants decided, they selected one of the two circles below the chosen card: the red circle (if they wanted to conceal the card) or the green circle (if they wanted to reveal the card; a reveal decision is shown here). In the CIT phase, the question "Which card did you choose?" was followed by the presentation of seven items, the first of which (the buffer item, which was never the chosen item) is shown here.

choice led us to the second goal of the present study, which was an examination of the physiological responses preceding the decision to conceal or reveal information. Free decisions have been shown to be preceded by unconscious neural activity, supporting the notion that the brain may already start shaping such decisions seconds before they enter into conscious awareness (Fried, Mukamel, & Kreiman, 2011; Helfinstein et al., 2014; Soon, Brass, Heinze, & Haynes, 2008; Soon, He, Bode, & Haynes, 2013). In a parallel line of research, phasic SCRs have been observed seconds before immoral decisions or decisions associated with a high risk of monetary loss or cognitive demand (e.g., Bechara, Damasio, Damasio, & Lee, 1999; Bechara, Damasio, Tranel, & Damasio, 1997; Bechara, Tranel, Damasio, & Damasio, 1996; Botvinick & Rosen, 2009; Moretto, Làdavas, Mattioli, & di Pellegrino, 2009). For example, using the famous Iowa gambling task of Bechara and colleagues, participants began to generate anticipatory SCRs whenever they pondered a disadvantageous (risky) choice, before they explicitly knew it was disadvantageous. A few studies that investigated other types of anticipatory responses, such as HR, revealed inconsistent results (e.g., Crone, Somsen, van Beek, & van der Molen, 2004; Crone & van der Molen, 2007; Elvemo, Nilsen, Landrø, Borchgrevink, & Håberg, 2014; Osumi & Ohira, 2009; Studer & Clark, 2011). Moreover, to our knowledge, no previous study has examined whether anticipatory autonomic responses also occur before the decision to conceal information.

Taken together, in the present study, we aimed to examine (a) whether the decision to conceal information induces enhanced anticipatory autonomic responses and (b) whether the actual attempt to conceal or reveal information induces differential autonomic response patterns within individuals (as observed between individuals). The obtained results may contribute to a better understanding of the theoretical basis of the CIT as well as to our understanding of predictive autonomic signaling in different types of decision making.

Method

Participants

Thirty-eight undergraduate students of the Hebrew University of Jerusalem participated in the experiment (23 women; age: M = 24.2 years, SD = 1.9, range = 19–27). All participants were native speakers of Hebrew and received either course credit or an average payment of 65 new Israeli shekels (NIS; ~US$18) for their participation. Each participant provided written informed consent indicating that participation was voluntary.

All data of 1 participant (No. 3) were excluded from analysis because of insufficient memory in the final recognition test (37.5%). Furthermore, the decision data of 1 participant (No. 25) were excluded because of excessive movement, the CIT SCR data of 3 participants (Nos. 11, 25, and 33) were excluded because of nonresponsivity, and the HR data of 1 participant (No. 23) were excluded because of repeated artifacts. Thus, all analyses of the three physiological measures were based on the data of at least 34 participants (SCR: n = 34, RLL: n = 37, HR: n = 36). A power analysis revealed that to obtain a statistical power of at least .80 for detecting a medium effect size (i.e., Cohen's d = 0.50), the sample should include approximately 34 participants. Because we performed a relatively large number of statistical tests, we were unable to use the effect size obtained in previous studies. Our power analysis was therefore based on a medium effect size (an effect that one does not wish to miss if it exists). Finally, 6 participants did not complete the self-report regarding attempts at arousal inhibition (n = 31). The experiment was approved by the ethical committee of the Faculty of Social Sciences of the Hebrew University of Jerusalem.

Procedure

After informed consent was obtained, the experimenter attached the SCR and HR electrodes as well as the RLL band. Then, after 2 min of rest (i.e., baseline period), the experimenter provided instructions about an upcoming card game. Using Adobe Illustrator CC, we created eight card categories of seven cards each; every card featured a unique filled shape and a unique colored background (Card Nos. 1–56; all cards can be found at https://osf.io/mgbck/). The card game consisted of eight randomly presented trials (one for each category), and each trial was split into a decision phase and a CIT phase (see Fig. 1). A short break was inserted after every 2 trials to help maintain participants' attention. Before starting the card game, all participants completed a short practice phase to familiarize them with the procedure (a ninth card category, with Card Nos. 57–63, was created for the practice phase).

Decision phase. On each of the eight trials, participants were presented with six cards of one category (the seventh card of each category served as a catch item in the CIT phase) and a clock with a second hand showing the passage of time (see Fig. 1). A pair of circles (one green, one red) appeared side by side below each card. On each trial, the location of the green circle (left vs. right) was the same in all pairs, but its location varied randomly from trial to trial. Participants were instructed to decide within 30 s (i.e., the decision window) which of the presented cards they wanted to conceal or reveal during the upcoming CIT phase. They were also instructed to think for at least 10 s before making a decision. To enhance thinking time and encourage a well-pondered decision, we instructed participants to play strategically and consider, for each trial separately, which of the six cards they thought they could successfully conceal or reveal. There was, however, one restriction: Participants had to conceal at least three cards and reveal at least three cards throughout the card game. Once participants decided, they were requested to select, using the computer mouse, one of the two circles below the chosen card: either the red circle (if they wanted to conceal the card) or the green circle (if they wanted to reveal the card). After the selection was made, the chosen card and the corresponding circle (either red or green) were highlighted with a yellow frame, and all other cards turned gray. Importantly, participants were instructed to select the circle as soon as they reached their decision and were also told that they could not change their initial decision (the time it took to reach a decision will hereafter be referred to as *decision time*). After 30 s, participants were presented for 5 s with the chosen card and either a red or a green circle, indicating their choice (see Fig. 1). Then, they continued to the CIT phase of the trial.

CIT phase. On each of the eight trials, the question "Which card did you choose?" (for 10 s) was followed by the presentation of 7 items (each for 5 s): 1 buffer item, 1 critical (chosen) item, 4 control items, and 1 catch item. The card chosen during the decision phase served as critical item, whereas the five other cards of the same category served as buffer and control items (see Fig. 1). The catch items were inserted as an extra means to maintain participants' attention and were cards from the same category with a large number presented in the middle. Participants were instructed to say the number out loud as soon as they saw it. When presented with a buffer, control, or critical item, participants were requested to remain silent. Importantly, the questions and items were presented in random order, except for the buffer, which always appeared as the first item after each question. The interstimulus interval between 2 items varied from 14 s to 18 s. Altogether, participants were presented with eight question trials with 7 items each (56 items in total).

Following the procedures in klein Selle et al. (2016, 2017), we told participants that their physiological responses in the CIT phase would change automatically when they recognized the earlier chosen (critical) cards. Moreover, they were motivated to either allow (when the choice was to reveal the card) or not allow (when the choice was to conceal the card) these automatic changes and detection of the critical cards. To enhance motivation, we promised participants a 5 NIS (~US$1.37) bonus for each of the eight cards that they successfully concealed or revealed. Thus, the bonus could reach 40 NIS (~US$11) if all eight cards were successfully concealed or revealed.

After completing the card game, participants were given a recognition-memory test, which included the same eight card categories used in the card game. This time, however, all possible cards belonging to a category were presented simultaneously, and participants were requested to select the correct (earlier chosen) card using the computer mouse. Then, participants were asked to rate, on a scale from 1 (*not at all*) to 9 (*extremely*), the significance, arousal, and valence of the eight critical (chosen) cards and eight randomly selected control cards (one from each card category). For the valence and arousal ratings, participants were asked to rate how pleasant and aroused they felt when presented with the cards in the CIT phase. 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 cards were to them in the CIT phase, irrespective of valence. Finally, participants received a paper-and-pencil questionnaire on which they were asked to rate, on a scale from 1 (*not at all*) to 6 (*very much*), their motivation as well as their efforts to conceal or reveal the critical cards, their efforts to inhibit physiological arousal (during the presentation of the critical cards), and their speed in selecting the red or green circles during the decision phase. In the end, all participants were debriefed and compensated for their participation in the experiment.

Data acquisition and reduction

The experiment was conducted in an air-conditioned laboratory. The apparatus included a 0.5-V constant-voltage system (Atlas Engineering, Hod Hasharon, Israel) to record three physiological signals (i.e., electrodermal activity, respiration, and HR) and a Dell OptiPlex 790 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, Hamilton City, CA) and an A/D (NB-MIO-12) converter (Atlas Engineering) with a sampling rate of 50 Hz. Electrodes were placed on the distal phalanges of the left index and left ring fingers. For the decision phase, we analyzed both the amplitude of the SCR (i.e., the maximal increase in conductance during the decision time) and the mean baseline-corrected tonic skin conductance level (SCL; i.e., the mean SCL during the decision time – the mean SCL during the 2-min baseline period). For the CIT phase, we solely analyzed SCR amplitude (i.e., the maximal increase in conductance during the 1-s to 5-s period after stimulus onset).

Respiration was recorded using a respiratory band positioned around the thoracic area and sampled at 50 Hz. For the CIT phase only, we analyzed the RLL, which is a composite measure of respiratory amplitude (depth of breathing) and respiratory cycle (rate of breathing), during the 0.1-s to 14.0-s interval after 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, 10 windows were created, each 13-s long and beginning 0.1 s later than the previous window, and the RLL was defined as the mean of these 10 length measures.[1]

The electrocardiogram 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 electrocardiogram signal was sampled at 500 Hz, digitized at 12-bit resolution, and band-pass filtered from 1 to 35 Hz. MATLAB (The MathWorks, Natick, MA) was used to detect the *R* peaks, calculate the distance between them, and apply a semi-automatic artifact detection and rejection procedure (following klein Selle et al., 2016, 2017). Prior to analysis, the interbeat intervals were converted to HR in beats per minute per real-time epoch (1 s). The second-by-second HR values following the start of the decision window (for the decision phase) and stimulus onset (for the CIT phase) were baseline corrected by subtracting the average HR value in the 3 s preceding the start of the decision window or stimulus onset, which resulted in poststimulus difference scores (ΔHR). For both the decision and CIT phases, we analyzed the average ΔHR score. Furthermore, for the decision phase only, we analyzed the mean baseline-corrected HR (i.e., the mean HR during the decision time – the mean HR during the 2-min baseline period).

All raw physiological responses during the decision phase (8 responses) and the CIT phase (56 responses) were standardized within subjects (buffer and catch items were excluded from the standardization). The resulting z scores were used to eliminate single responses—both outliers (z score > 5 or < −5) and excessive movements (SCR: movement + z score > 0; RLL/HR: movement + z score > 2 or < −2). A total of 1.4% of SCR, 0.5% of RLL, and 0.4% of HR responses were eliminated from the CIT phase (excluding responses to buffer and catch items), and a total of 5.1% of SCR, 2.7% of SCL, 0.7% of ΔHR, and 0% of mean HR responses were eliminated from the decision phase.

Importantly, for the CIT phase only, within-subjects standardization was performed within question trials, minimizing habituation effects (see Ben-Shakhar & Elaad, 2002), and skin conductance nonresponsivity was determined after the elimination of single items (similar to the procedure of klein Selle et al., 2016, 2017). Specifically, participants whose standard deviation was below 0.01 μS in both the first four and the last four trials of the CIT phase were considered to be nonresponders, and their SCR data were eliminated from all analyses. In cases of nonresponsivity in either the first four or the last four trials, only the data from the respective trials were removed.

Finally, for the decision-phase analyses, two dependent measures were created for each participant and each physiological measure (one for the conceal condition and one for the reveal condition) by averaging the raw scores across categories. In addition, for the CIT-phase analyses, two detection scores were created for each participant and each physiological measure (one for the conceal condition and one for the reveal condition) by averaging the respective z scores of the critical items. Importantly, because concealed information is associated with cardiac and respiratory suppression, the RLL and HR z scores were multiplied by −1 prior to analysis.

Results

All analyses (as well as the experimental design and hypotheses) were preregistered at https://aspredicted.org/8vf8s.pdf. Results were analyzed using MATLAB and JASP software, and the original data and analysis files can be accessed at https://osf.io/mgbck/. Importantly, in addition to classical statistical inference, we relied on Bayesian analyses and supplemented each t test with a Jeffreys-Zellner-Siow (JZS) Bayes factor (BF). The JZS BF is a numerical value quantifying the odds ratio of the null hypothesis (i.e., no difference between conditions) versus the alternative hypothesis (i.e., difference between conditions), given the data (Rouder, Speckman, Sun, Morey, & Iverson, 2009). A default JZS prior with a scaling factor (r) of .707 was used for the alternative hypothesis. The BFs are reported as favoring either the null hypothesis (BF_{01}) or the alternative hypothesis (BF_{10}), and a BF of 3 or more is taken as moderate evidence[2] for the respective hypothesis (Lee & Wagenmakers, 2013).

Memory and subjective ratings

The memory data were analyzed using a paired-samples t test, which revealed significantly better memory of the critical cards in the reveal condition (M = 90.72%, 95% confidence interval, or CI = [86.06, 95.38]) compared with the conceal condition (M = 72.97%, 95% CI = [64.83, 81.11]), $t(36) = -4.44$, $p < .001$, $d = 0.73$, 95% CI = [0.36, 1.09], $BF_{10} = 293.48$.

Table 1. Comparison Between Raw Anticipatory Physiological Responses During the Decision Phase in the Conceal and Reveal Conditions

Measure	Conceal condition (*M*)	Reveal condition (*M*)	*p*	Cohen's *d*	Bayes factor (BF)
Skin conductance response	0.24	0.15	.013	0.44 [0.09, 0.78]	3.35 (BF_{10})
Skin conductance level	0.31	0.16	.181	0.23 [–0.11, 0.56]	2.38 (BF_{01})
ΔHeart rate	0.44	–0.20	.485	0.12 [–0.21, 0.45]	4.38 (BF_{01})
Heart rate	3.17	2.67	.378	0.15 [–0.18, 0.48]	3.81 (BF_{01})

Note: Values in brackets are 95% confidence intervals.

The significance, arousal, and valence ratings were separately analyzed using two-way repeated measures analyses of variance (ANOVAs), with motivation (conceal vs. reveal) and item type (critical vs. control) as within-subjects factors. Each ANOVA showed a significant main effect of item type (all *p*s < .001) and motivation (all *p*s < .05). In addition, the ANOVAs on the significance and arousal ratings revealed a significant Motivation × Item Type interaction (all *p*s < .001). Follow-up paired-samples *t* tests revealed that the critical–control difference was larger in the reveal condition than in the conceal condition—significance: $t(36) = 4.63$, $p < .001$, $d = 0.76$, 95% CI = [0.39, 1.12], $BF_{10} = 496.58$; arousal: $t(36) = 3.70$, $p < .001$, $d = 0.61$, 95% CI = [0.25, 0.96], $BF_{10} = 42.21$. These results are in line with the memory data and reflect the fact that the critical cards were rated as more significant and arousing in the reveal condition than in the conceal condition.[3]

The paper-and-pencil questionnaire data were analyzed using paired-samples *t* tests. These tests revealed no significant difference between the self-reported motivation to conceal ($M = 5.57$, 95% CI = [5.32, 5.81]) and reveal ($M = 5.51$, 95% CI = [5.25, 5.78]) the critical items, $t(36) = 0.50$, $p = .624$, $d = 0.08$, 95% CI = [–0.24, 0.40], $BF_{01} = 5.04$. Similar results were obtained for self-reported efforts to conceal ($M = 5.24$, 95% CI = [4.94, 5.55]) and reveal ($M = 5.00$, 95% CI = [4.66, 5.34]) the critical items, $t(36) = 1.07$, $p = .292$, $d = 0.18$, 95% CI = [–0.15, 0.50], $BF_{01} = 3.33$. Attempts at arousal inhibition were, as expected, significantly higher in the conceal condition ($M = 4.81$, 95% CI = [4.31, 5.30]) compared with the reveal condition ($M = 1.90$, 95% CI = [1.44, 2.37]), $t(30) = 8.06$, $p < .001$, $d = 1.45$, 95% CI = [0.94, 1.95], $BF_{10} = 2.32 \times 10^6$. Finally, with regard to the decision phase, participants reported their speed in selecting the red or green circles to be high ($M = 4.70$, 95% CI = [4.30, 5.11]).

Decision phase

Before analyzing the physiological responses from the decision phase, we examined the average decision time (in seconds) in the conceal condition ($M = 14.52$ s, 95% CI = [13.34, 15.69]) and reveal condition ($M = 13.62$ s, 95% CI = [12.55, 14.69]). A paired-samples *t* test comparing the two conditions showed no significant difference, $t(35) = 1.44$, $p = .160$, $d = 0.24$, 95% CI = [–0.09, 0.57]. However, the BF analysis did not provide sufficient support for the null hypothesis ($BF_{01} = 2.18$).

To examine the raw anticipatory physiological responses, we performed for each measure a paired-samples *t* test comparing the conceal and reveal conditions. These tests revealed no significant difference between conditions when the dependent measure was either the mean SCL, $t(35) = 1.37$, $p = .181$, $d = 0.23$, 95% CI = [–0.11, 0.56], $BF_{01} = 2.38$; ΔHR, $t(34) = 0.71$, $p = .485$, $d = 0.12$, 95% CI = [–0.21, 0.45], $BF_{01} = 4.38$; or mean HR, $t(34) = 0.89$, $p = .378$, $d = 0.15$, 95% CI = [–0.18, 0.48], $BF_{01} = 3.81$ (see Table 1). It should be noted, however, that the SCL result could not be confirmed by the BF (2.38).

On the other hand, when the SCR was examined, significantly larger responses were found in the conceal condition compared with the reveal condition, which was confirmed by the BF, $t(35) = 2.61$, $p = .013$, $d = 0.44$, 95% CI = [0.09, 0.78], $BF_{10} = 3.35$. Importantly, because previous studies have shown that the SCR is highly responsive to item significance (e.g., Barry, 1981; klein Selle et al., 2017) and because our participants chose more significant items in the reveal condition, we ran a covariance analysis, using the item-significance difference score (i.e., the difference between the self-reported significance of chosen revealed cards and chosen concealed cards) as a covariate. This time, the BF provided much stronger evidence for the alternative hypothesis, $BF_{10} = 9.67$. In other words, the present experiment showed (for the first time) that the decision to conceal items induces higher anticipatory SCRs than the decision to reveal items (see Table 1).

CIT phase

To examine the standardized physiological responses from the CIT phase, we performed for each measure a paired-samples *t* test comparing the conceal and reveal

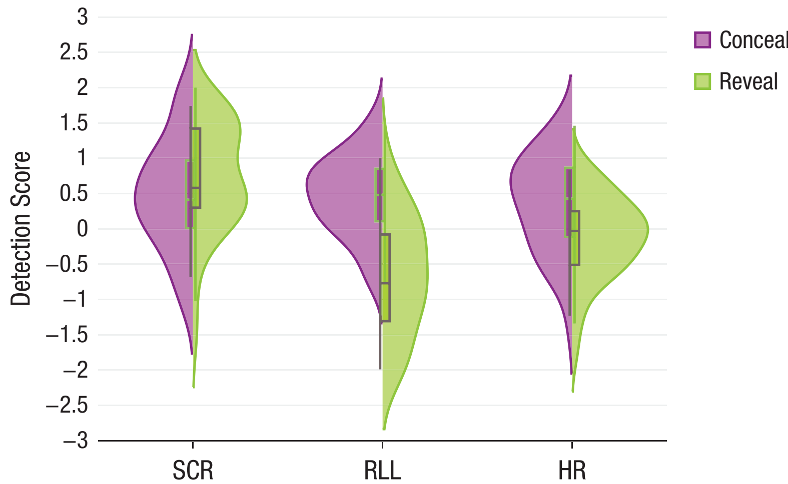

Fig. 2. Violin plots showing the detection-score distributions for skin conductance response (SCR), respiration-line length (RLL), and heart rate (HR) from the conceal and reveal conditions in the concealed-information-test (CIT) phase. Rectangular boxes represent the interquartile range of the distribution; the horizontal line in the middle represents the median. The width of each plot shows the density of the data. The bottom and top of each whisker represents the lowest and highest data point, respectively. An interactive version of the plot is available at https://plot.ly/~naamaag/6/#plot.

conditions. For the SCR, there was no statistically significant difference between conditions, but this result could not be confirmed by the BF, $t(33) = 1.43$, $p = .162$, $d = 0.25$, 95% CI = [−0.10, 0.59], $BF_{01} = 2.15$. As for the decision-phase data, we ran a covariance analysis, using the item-significance difference score (i.e., the difference between the self-reported significance of chosen revealed cards and chosen concealed cards) as a covariate. This time, the BF did provide moderate evidence for the null hypothesis, $BF_{01} = 3.85$, indicating similar SCRs when attempting to conceal versus attempting to reveal the critical cards, when the rated significance value was equated. For both the RLL and the ΔHR, significantly larger detection scores were found in the conceal condition than in the reveal condition, which were also confirmed by the BF—RLL: $t(36) = 6.32$, $p < .001$, $d = 1.04$, 95% CI = [0.63, 1.44], $BF_{10} = 60{,}522.45$; ΔHR: $t(35) = 3.24$, $p = .003$, $d = 0.54$, 95% CI = [0.19, 0.89], $BF_{10} = 13.60$.

Furthermore, to examine whether our CIT effects were significantly larger than 0, we ran for each condition and each physiological measure a one-sample *t* test. These tests revealed significant CIT effects with each measure in the conceal condition—SCR: $t(33) = 3.62$, $p < .001$, $d = 0.62$, 95% CI = [0.25, 0.99], $BF_{10} = 33.05$; RLL: $t(36) = 4.89$, $p < .001$, $d = 0.81$, 95% CI = [0.43, 1.17], $BF_{10} = 1{,}040.53$; ΔHR: $t(35) = 3.20$, $p = .003$, $d = 0.53$, 95% CI = [0.18, 0.88], $BF_{10} = 12.16$. In the reveal condition, on the other hand, a significant CIT effect was observed only with the SCR—SCR: $t(33) = 5.76$, $p < .001$, $d = 0.99$, 95% CI = [0.57, 1.39], $BF_{10} = 9{,}297.41$; ΔHR: $t(35) = −1.19$, $p = .242$, $d = −0.20$, 95% CI = [−0.53, 0.13], $BF_{01} = 2.92$ (note, however, that the ΔHR result is not sufficiently supported by the BF, which is slightly smaller than 3). For the RLL, we observed an opposite effect, reflecting lengthening rather than shortening of the RLL, $t(36) = −4.86$, $p < .001$, $d = −0.80$, 95% CI = [−1.17, −0.42], $BF_{10} = 936.02$. Notably, similar results for this measure were reported by klein Selle et al. (2016, 2017). Taken together, these results reflect the observation that the SCR increased in both conditions, whereas the RLL was suppressed and the HR decreased when attempting to conceal, but not when attempting to reveal, the critical cards (see Fig. 2).

Discussion

In the current study, we took an initial step in examining physiological markers related to both the decision and the attempt to conceal information. When we analyzed the CIT phase, the SCR increased in both motivational conditions, whereas the RLL and HR were suppressed solely when motivated to conceal information. This is the first time that this particular fractionation of responses has been observed in the CIT within single participants. The current results are, however, in line with previous between-subjects findings and support the response-fractionation model proposed by klein

Selle et al. (2017), suggesting that in the CIT, the SCR reflects an enhanced orienting response (which occurs in both conditions), whereas the RLL and HR reflect attempts at arousal inhibition (which occur only in the conceal condition). In addition to the use of a more powerful within-subjects design, the main advantage of the present study is the usage of relatively nonsignificant card stimuli, which differ from the more significant mock-crime and personally related stimuli used in previous studies. The use of such trivial stimuli likely affected the SCR CIT effect in both conditions (larger SCR CIT effects are typically observed; see the meta-analysis by Meijer et al., 2014). Still, despite these changes, very similar results were obtained across studies, and the observed fractionation seems to be a stable phenomenon, strengthening the generalizability of our results and conclusions. Notably, the present constructive replication follows an important trend in psychological science to estimate the reproducibility of both classical and contemporary effects (e.g., Aarts et al., 2015).

The observed fractionation in the CIT phase may hold several applied implications. For example, it may explain why the RLL and HR measures are more resistant to countermeasures (i.e., deliberate actions used by guilty suspects to avoid detection) than the SCR (e.g., Ben-Shakhar & Dolev, 1996; Peth, Suchotzki, & Gamer, 2016). Because countermeasures are typically aimed at enhancing responses to the control items, they are unlikely to affect attempts at arousal inhibition when presented with the critical items (as reflected by the RLL and HR CIT effects). However, this raises the question of whether suspects could be trained to avoid such attempts at inhibition, which may pose a serious threat to CIT validity.

A new direction to the investigation of information concealment was provided by the decision phase. When we analyzed this phase, we observed enhanced SCRs prior to the decision to conceal (vs. reveal) information. To the best of our knowledge, this is the first demonstration of anticipatory SCRs when the decision concerned information concealment. This result does, however, strengthen previous findings using other types of decisions that concerned monetary loss (Bechara et al., 1999; Bechara et al., 1997; Bechara et al., 1996) or a moral violation (Moretto et al., 2009). Interestingly, these studies suggest that our physiological markers may reflect decision formation. An important question, however, is how to interpret these markers and their psychological functions. A variety of theories have been proposed, and a returning theme is that the anticipatory responses may carry information about the "value" or the consequences of a particular choice (see Davis, Love, & Maddox, 2009). Stretching this idea to the present study, both the decision to conceal and the decision to reveal consequently meant that participants had to recognize (and orient to) the chosen card. The decision to conceal, however, additionally meant that participants had to attempt and inhibit their experienced physiological arousal. Hence, the act of concealing may be considered to be more cognitively demanding than the act of revealing, which could possibly explain the enhanced anticipatory SCRs. The fact that we did not find such anticipatory responses with the other measures (i.e., mean SCL, ΔHR, mean HR) follows earlier inconsistent findings (e.g., Crone & van der Molen, 2007; Elvemo et al., 2014; Osumi & Ohira, 2009) and should be more deeply examined in future studies.

As briefly noted in the introduction, predictive signaling has also been examined using neural measures. These studies revealed unconscious neural activity that preceded and potentially influenced subsequent free decisions—both simple decisions regarding movements and more high-level abstract decisions (Fried et al., 2011; Helfinstein et al., 2014; Soon et al., 2008, 2013). Importantly, it has been suggested that this neural activity reflects the operation of a higher level control network that begins to prepare an upcoming decision long before it enters awareness (Soon et al., 2008). However, it remains to be determined whether these early choice-predictive neural signals are related to the anticipatory SCRs observed in the present and other studies.

A few limitations of the present study should be mentioned. First, participants might not always have followed the instruction to indicate their choice as soon as it was made (by selecting the green or red circles). This could have potentially created a delay between the actual (conscious) decision and decision response, making it impossible to determine whether the observed SCR preceded or followed the actual decision. Importantly, however, because participants reported a high synchronization between their decisions and decision responses, the above-described scenario likely played only a minimal role. Second, participants selected more significant cards when they chose to reveal them. However, this difference was controlled for by the covariance analyses.

Taken together, the present study provides preliminary evidence for the idea that our physiological responses can reflect both the decision and the attempt to conceal information. Whereas the decision to conceal (vs. reveal) information induced enhanced anticipatory SCRs, the attempt to conceal (vs. reveal) information induced differential RLL and HR responses. Beyond providing a backbone to the theoretical basis of the CIT, these findings shed a novel light on anticipatory autonomic responding in decision making.

Action Editor

Erika E. Forbes served as action editor for this article.

Author Contributions

All the authors developed the study concept and contributed to the study design. N. klein Selle also helped to acquire the data, performed the statistical analyses, and wrote the manuscript. N. Agari and G. Ben-Shakhar provided critical feedback on the analyses as well as the manuscript. All the authors approved the final manuscript for submission.

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Supplemental Material

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Open Practices

All data and materials have been made publicly available via the Open Science Framework and can be accessed at osf.io/mgbck. The design and analysis plans were preregistered at https://aspredicted.org/8vf8s.pdf. The complete Open Practices Disclosure for this article can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797619864598. This article has received the badges for Open Data, Open Materials, and Preregistration. More information about the Open Practices badges can be found at http://www.psychologicalscience.org/publications/badges.

Notes

1. We used the traditional moving-average method, instead of the newly developed algorithm of Matsuda and Ogawa (2011), because a previous attempt to adopt this algorithm revealed no improvement in RLL detection efficiency.
2. The original label for a BF greater than 3 was "substantial evidence." Lee and Wagenmakers (2013) recommended changing it to "moderate."
3. A small ratings experiment using a different set of participants (n = 25) revealed that there were inherent significance differences between the chosen concealed and revealed cards, which were independent of the choice to conceal or reveal them. For a full description of the results, see the Supplemental Material available online.

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