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An interfering n-back task facilitates the detection of concealed information with EDA but impedes it with cardiopulmonary physiology

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Abstract

One approach to investigate psychophysiological processes occurring in the Concealed Information Test (CIT) is to use a parallel task, which engages specific mental activity in addition to the CIT. In the present study, the influence of an interfering n-back task on the physiological responses in a Concealed Information Test (CIT) was investigated. Forty participants underwent a mock-crime experiment with a modified CIT. In a within-subject design, the CIT was applied in blocks with and without an additional n-back task. Electrodermal activity (EDA), respiration line length (RLL), heart rate (HR), and finger pulse waveform length (FPWL) were registered. Reaction times in the n-back task and the CIT were recorded. The parallel task enhanced the differential EDA response to *probe* vs. *irrelevant* items, while it diminished the response differences for RLL and phasic HR. Results shed light upon working-memory-related processes in the CIT. The diverging effects of the interfering mental activity on electrodermal and cardiopulmonary measures, if replicable, might contribute to a better understanding of the psychophysiological responsiveness underlying the CIT.

Key Words

Concealed Information Test; Deception; Working Memory; Interference Task

Introduction

The Concealed Information Test

The Concealed Information Test (CIT) originally called Guilty Knowledge Test by Lykken (1959) is a systematic and standardized test procedure employed to detect hidden knowledge by means of physiological recordings. The relevance and validity of the different physiological measures for the detection of concealed knowledge are still a matter of ongoing research (see Elaad et al., 1992; Elaad and Ben-Shakhar, 2006; Hirota et al., 2003, Vandenbosch et al., 2009). A typical investigation procedure combines a standardized interrogation with the continuous collection of electrodermal activity (EDA), electrocardiogram (ECG), breathing activity, and finger plethysmogram.

In the CIT, the physiological responses of a subject towards a number of crime-relevant questions, each combined with several answer alternatives, called 'items', are compared (for a review, see Ben-Shakhar and Elaad, 2002; Elaad, 1998). Each crime-relevant question is combined with one '*probe*' item and a number of '*irrelevant*' items of the same category (e.g. keys, tools) resulting in a set of trials with the same question. The *probe* item is never presented first; the first item of each block is discarded from evaluation. Only a person with specific knowledge is expected to distinguish between *probe* and *irrelevant* items. This is reflected in the physiological measures even when the subject is trying to conceal his or her crucial knowledge. Subjects possessing the critical knowledge will tend to show the largest response to the *probe* item within a set. In contrast, for a person without specific knowledge, a random pattern of response measures is expected, without preference for either *probe* or *irrelevant* items. If a CIT comprises six or seven questions, each having several answer alternatives, the presence or absence of concealed knowledge can be assessed with considerable accuracy (for meta-analyses on the accuracy of the CIT, see Ben-Shakhar and Elaad, 2003, and MacLaren, 2001).

Sub-processes of deception and information concealment

Theoretically, the CIT is based predominantly on the orienting reflex; this is empirically supported (Ben-Shakhar and Elaad, 2002; Gati and Ben-Shakhar, 1990; Lykken, 1974; Verschuere et al., 2004; Verschuere et al., 2005). Besides the orienting reflex, various other mental functions are discussed as possible sub-

processes involved in information concealment and its detection. The typical CIT involves attention, episodic memory, emotions, response selection, and motor responses (Vendemia et al., 2005a; Vendemia et al., 2005b) as well as working memory processes (e.g. Gamer et al., 2009; Langleben et al., 2002; Walczyk et al., 2003). Several approaches focused on disentangling the sub-processes of deception (e.g. Furedy et al., 1988; Furedy and Ben-Shakhar, 1991) and information concealment (e.g. Ambach et al., 2008b; Gamer and Berti, 2010; Verschuere et al., 2005; Verschuere et al., 2007b; Verschuere et al., 2009). Prolonged reaction times were predominantly (although not consistently) found when information was concealed (e.g. Farwell and Donchin, 1991; Gronau et al., 2005; Seymour et al., 2000); this is regarded as a possible sign of inhibition and response conflict (Vendemia et al., 2005a); the finding that deceptive answering can improve CIT accuracy has been interpreted in the same way (Ben-Shakhar and Elaad, 2002; Ben-Shakhar and Elaad, 2003; Bradley et al., 1996; Elaad and Ben-Shakhar, 1991; Furedy and Ben-Shakhar, 1991). The involvement of executive processes, including inhibition and working memory, in the CIT is supported by neuroimaging studies (e.g. Gamer et al., 2007; Hughes et al., 2005; Langleben et al., 2005). Working memory has been suggested to be involved in the comparison of CIT stimuli with memorized items, the inhibition of the prepotent truthful answer, and the preparation of a deceptive answer (Gombos, 2006; Nuñez et al., 2005; Spence et al., 2001; Spence et al., 2004).

Interfering mental activity

One approach to investigate the processes involved in a CIT is to study the effects of an additional mental load demanded in parallel to the CIT. The observed effects of such specific interfering procedures on the physiological responding in a CIT can possibly be used to elucidate the sub-processes ongoing in a CIT.

The influence of additional mental load on the detection of concealed information has been studied extensively in the context of mental countermeasures (e.g. thinking exciting thoughts, imagery, or arithmetics). The selective application of mental countermeasures during the presentation of *irrelevant* items has been shown to distort the test by increasing autonomic arousal to these items (e.g. Ben-Shakhar and Dolev, 1996; Elaad and Ben-Shakhar, 2009; Honts et al., 1996; Lykken, 1998). The attempt to distract attention selectively from *probe* items tended to increase

psychophysiological detection with EDA, whereas additional tasks continuously demanding attention throughout the entire test - "continuous countermeasures" - tended to decrease CIT accuracy (Elaad and Ben-Shakhar, 1991). Considering "continuous countermeasures", results suggest that 'detection is mediated by attentional mechanisms' and that 'the subject's ability to ignore the relevant items is a crucial factor that determines detection efficiency' (Elaad and Ben-Shakhar, 1991). Only a few studies have used parallel tasks in order to interfere with CIT sub-processes. Referring to deception detection in general, Vrij et al. (2006) suggested manipulating cognitive load; they supposed that 'liars, whose cognitive resources will already be partially depleted by the act of lying, should find this additional, concurrent task particularly debilitating'. With increased cognitive load, more cues to deception were found (Vrij et al., 2008), while tonic arousal was decreased (Leal et al., 2008). Referring to the CIT, Verschuere et al. (2007b) suggested to study the role of inhibitory processes in a CIT by experimentally manipulating these processes. Consistently, a previous study investigated whether an interfering Go/no-go task, which was performed parallel to the CIT, affects the accuracy of the CIT (Ambach et al., 2008a). There, no interaction of the parallel task with the CIT was found for any of the physiological measures. The results were discussed as inconclusive with respect to the intended identification of sub-processes of the CIT via interference; particularly, no evidence for a specific interaction of inhibitory processes initiated by the Go/No-go task, with response inhibition as a supposed sub-process of the CIT, was found. Specific limitations of this study, e.g. the assignment of conditions (with and without parallel task) to large blocks, i.e. to either the first or the second half of the CIT, might also have contributed to the negative outcome. Thus, for the present follow-up study, we used a within-subject manipulation with a randomized series of blocks, which allowed for repeated switches between two conditions (with and without parallel task). Consequently, possible sequence effects arising from the series of conditions were minimized. A pseudo-randomized selection of the *probe* item within each category further improved the experimental design overcoming possible single-item effects, which might e.g. be due to differences in salience.

The main intention of the follow-up study, presented here, was to focus on another specific sub-process supposedly engaged in the CIT. We assumed working memory activity, particularly the supervisory attentional system (SAS; Norman and Shallice, 1986), a part of the central executive, to be essential in information concealment.

Working memory has frequently been investigated using dual task paradigms (e.g. Baddeley and Della Sala, 1996), which utilized its limited capacity (see Just and Carpenter, 1992). For our purpose, the interfering task had to engage the central executive (Baddeley, 1986; Baddeley, 1996; Baddeley, 2003; Jonides et al., 2003; Mayr, 2003); particularly, the SAS needed to be demanded continuously. Thus, an n-back task run in parallel to the CIT was chosen (see Watter et al., 2001). In an n-back task, a series of stimuli (e.g. letters) is presented; with each new stimulus, the participant is asked to determine whether the new stimulus is identical to the n-th stimulus presented previously. N-back tasks are commonly used to investigate working memory processes by continuously demanding cognitive load, with the amount of cognitive load adjustable to the particular requirements (Owen et al., 2005; Watter et al., 2001).

Proceeding from a recent conceptualization of working memory by Baddeley (2003), we assumed that in our study the SAS would be essentially involved in the CIT, in the n-back parallel task, and in switching between both tasks. Regarding the CIT, proposed sub-tasks ascribed to the SAS comprised: retrieving mock-crime information from long-term memory into the episodic buffer, shifting visual information of the viewed CIT item from the visual sketchpad to the episodic buffer, matching the visual information in the episodic buffer, shifting textual information of the CIT question from the phonological loop into the episodic buffer, inhibiting the prepotent, truthful answer (generated by the automatic habitual control system), and manipulating the prepotent truthful answer towards an 'appropriate' answer.

Regarding the n-back parallel task, sub-tasks ascribed to the SAS were shifting, replacing, and matching the single (letter) items as well as preparing the answer (see Chen et al., 2008). Demands from the CIT and the n-back task were assumed to be temporally overlapping to a considerable degree. The simultaneous demand of the same, limited resources was expected to result in an interference of the n-back task with the CIT. This should be reflected in the physiological measures.

Aim of the present study

The present study aimed at investigating the influence of interfering working-memory activity on the physiological responses in a CIT. In a within-subject design, the experimental condition included an n-back task, which had to be performed simultaneously with the CIT. The additional mental load demanded by the n-back

parallel task was expected to interfere with working-memory processes engaged in the CIT.

As a general expectation, any parallel task will most likely distract attention from the CIT and thereby decrease differential physiological responding to *probe* items in contrast to *irrelevant* items, as seen for continuous countermeasures (e.g. Elaad and Ben-Shakhar, 1991). Any cognitive task run in parallel to the CIT might principally have this effect. Yet, specific parallel tasks might utilize specific mental resources, which might simultaneously be involved in concealing information. If the required specific resources, such as supposedly the SAS (Baddeley, 2003), are limited, then this limitation should be particularly crucial to probe items. Hence, an influence of the parallel task on differential responding to *probe* and *irrelevant* items is conceivable even beyond the expected distractor effect. While the direction of such an additional influence is hard to foresee, the effect would in any case be superimposed on differential CIT responding. The research question, whether the effects of an n-back parallel task resemble those of a continuously distracting countermeasure, and to what extent they differ from effects previously observed in the literature, motivated the present study.

A secondary research question addressed the issue of whether the performance measures (reaction times and error rates) in the n-back task, when occurring during the presentation of *probe* and *irrelevant* CIT items, provide additional information that could improve CIT accuracy. Compared to truthful responding to *irrelevant* items, concealing knowledge about *probe* items might shift attention from the parallel task towards the CIT and thereby, worsen accuracy and speed in the additional task during the presentation of *probe* items.

Materials and Methods

Subjects

Forty healthy undergraduate students (13 m, 27 f; mean age 24.5 ± 6.6 years, 33 right-handed) voluntarily participated in the study for course credit and an additional incentive of 3 Euros. Informed consent was obtained from all subjects.

'Mock crime' scenario

Subjects underwent a mock-crime-like procedure in a shielded room. The written instructions did not suggest an association with criminal actions; participants, however, were informed that they had to conceal knowledge about all their actions later. A task list instructed them to handle ten specific objects, each chosen from one of 10 specific object categories, that were placed in the '*deed room*'. Subjects took one object after the other into their hands, looked at it in detail, and deposited it on top of a storage rack. After completion, they packed all ten objects, one after the other, attentively into a suitcase located in the same room. For each participant, one particular object, serving as *probe* object for this participant, had been drawn randomly from each of the ten object categories. Object categories, each comprising four objects, were household items, key pendants, boxes, office material, cosmetics, wooden toy fruits, drink packages, sweets, pieces of clothing, and artificial flowers. Finally, subjects came across a small box containing three Euros. They handed the money together with the filled suitcase to the experimenter who kept it until the end of the experiment. Participants were told that they would receive the money at the end of the experiment given that their knowledge about the objects and their experiences in the deed room would not be detected in the polygraph examination.

Concealed Information Test

In the CIT, questions and item pictures were presented on a 19" monitor at a distance of 90 cm; picture size was 8.4° by 11.2° of visual angle. Onset asynchrony was 13.5-18.0 seconds; each picture was presented for 10 seconds, followed by a blank screen for 3.5-8.0 seconds.

The CIT consisted of 10 questions, each with four alternatives ('items'), one of which was the *probe* and one of which, the first *irrelevant* alternative in the series, was

discarded as a buffer. Each question (e.g. 'Did you see this wooden fruit in the deed room?') was presented four times in sequence, together with a different item picture displayed below it. The *probe* and *irrelevant* items of a question belonged to the same item category (e.g. key pendants, cosmetics) and had some categorical similarity. However, only the *probe* item was known to the subjects.

Preceding each of the 10 CIT questions, one *neutral* question was presented as a distractor; all transitions from one CIT question to the next and across conditions (e.g., going from the CIT with the parallel task to the CIT without the parallel task) occurred during the presentation of these neutral questions. The *neutral* questions referred to everyday objects that had to be identified (e.g. 'Is this a soft-toy?'); these questions had to be correctly answered, half with 'yes' and half with 'no'. This was done to ensure and monitor the subjects' attention; the *neutral* questions were not further evaluated.

The ten questions were presented in succession. Together with the neutral questions, each of which had one "item", this resulted in a total of 50 item presentations per run. The entire experiment consisted of two runs with a five-minute break. Sequence of questions and order of items for each question were counterbalanced.

Subjects were instructed to deny any knowledge of the *probe* items they had seen and touched in the deed room, but to correctly answer the other presented questions and items. Thus, they had to say 'no' to all - *probe* and *irrelevant* - item presentations as well as to the incorrect *neutral* questions; they had to answer with 'yes' to the correct *neutral* questions. Two indication fields containing question marks appeared simultaneously with the questions and prompted the subjects to answer. Answers had to be given as quickly as possible by pressing one of two response keys (left or right arrow key) as well as by vocally responding with 'yes' or 'no'. Key assignment to 'yes' and 'no' was balanced across subjects. Following the answer, their answer of 'yes' or 'no' replaced the question marks and remained visible on the screen as long as the item question was presented. If no answer was given within 3.5 seconds, the indication fields disappeared and no further feedback was provided for this trial.

Interference task

Two CIT task conditions with and without parallel task were introduced as a within-subject manipulation. Repeated switches between conditions were implemented: for

each subject, half of the 10 questions were presented together with a literal 2-back task, which had to be carried out simultaneously. Assignment of conditions to CIT question categories in the first half of the experiment was randomized and balanced over subjects. CIT question categories combined with the additional task in the first half were presented without the additional task in the second half, and vice versa. The 2-back task was presented in the upper part of the same monitor (see figure 1). The size of the 2-back task display was a 4.2° visual angle in both dimensions. In the inner part of a black square figure, upper-case letters, with a 2.1° visual angle appeared for 1.0 seconds every 4.5 seconds. Letter onsets were randomly positioned relative to CIT question onsets; an equally distributed random jitter of 0-4.5 seconds between CIT trials ensured that - independent of the exact scoring method and time window used - the physiological responses to the parallel task (including motor activity) did not systematically bias the CIT-related responses. By pressing one of two marked keys, subjects had to indicate as quickly as possible, whether or not the currently presented letter was identical to the one presented two trials previously; 50% were in fact identical.

As described above, the items and questions of the CIT had to be addressed at the same time. Immediate responses to both tasks were demanded in the instruction; no preference for either task was suggested. In the control condition 'without parallel task', the additional figure remained on the screen but was grey; subjects were instructed to ignore this part of the screen.

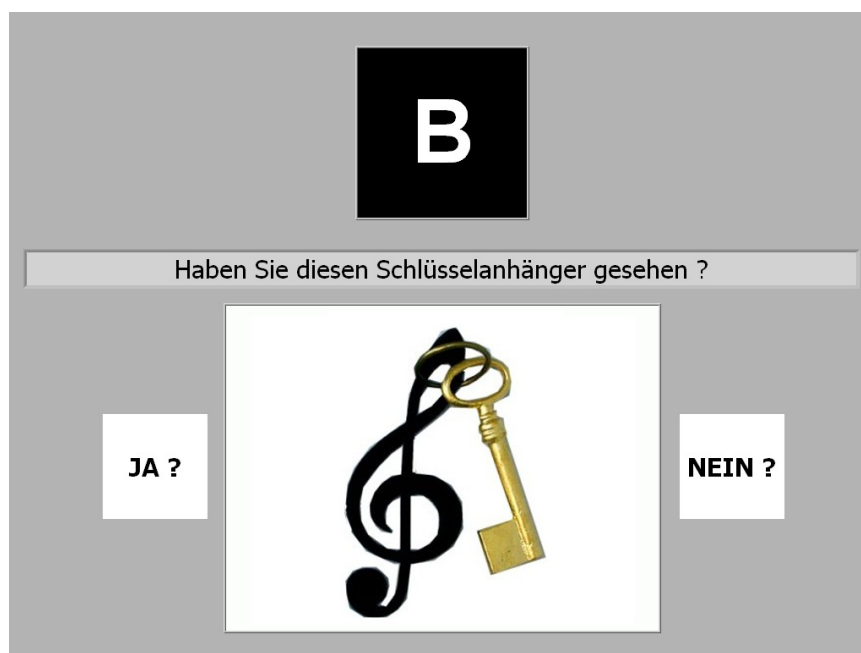


Figure 1. Presentation of Concealed Information Test and the Parallel n-Back Task. In the upper part of the screen, the literal 2-back task is presented in a square black field. Below it, the Concealed Information Test is performed and a question and item picture is shown. Two fields with 'yes ?' and 'no?' besides the depicted item prompted the subject to answer; after the answer was given, only the field with the answer remained, and the text was then displayed without the question mark. (Translation of the German question text: 'Did you see this key pendant?')

Procedure

Two experimenters guided the two parts of the experiment in order to keep the procedures for the mock crime and the CIT distinct and separate. After the subjects had given their informed consent, they were led to the experimental room; there, the second experimenter informed them about the subsequent mock crime scenario. After the mock crime procedure, subjects were led back to the first experimenter who performed the 'psychophysiological investigation'. Participants were connected to the measurement leads and asked to answer the CIT questions. The two main runs of CIT started after two different training runs were successfully completed. In the first training run, subjects became familiar with the 2-back task, which they had to carry out for 90 seconds without any additional questions being presented. In the second training run lasting for 180 seconds, they had to perform both tasks simultaneously; the training questions were all of the *neutral* type. The training runs were repeated until subjects reached a performance of 75% correct responses in the 2-back task. After completing both main runs of the CIT and being disconnected from the psychophysiological recording leads, subjects performed a memory test. In this test, all four pictures of each category were presented simultaneously on the screen, one item category after the other. Subjects were asked to identify the *probe* item within each of the ten categories.

Physiological measurement

The physiological recordings took place in a dimly lit, electromagnetically and acoustically shielded experimental chamber (*Industrial Acoustics GmbH*, Niederkrüchten, Germany). Subjects sat in an upright position so that they could comfortably watch the monitor and reach the keyboard. Temperature in the chamber was set to 21 °C at the beginning of the first run, with an increase of no more than 2 °C throughout the course of the experiment. Skin conductance response

electrodermal activity (EDA), respiratory activity, electrocardiogram (ECG), and finger plethysmogram were registered. Physiological measures were A/D-converted and logged by the *Physiological Data System I 410-BCS* manufactured by *J&J engineering (Poulsbo, Washington)*. The A/D-converting resolution was 14 bit, allowing skin conductance to be measured with a resolution of 0.01 μ S. All data were sampled with 510 Hz. Triggers indicating question onsets and letter onsets of the 2-back task were registered with the same sampling frequency. For EDA recordings, standard Ag/AgCl electrodes (*Hellige*; diameter 0.8 cm), isotonic electrode cream (*signa creme, Parker Laboratories Inc.*), and a constant voltage of 0.5 volts were used. The electrodes were fixed at thenar and hypothenar sites of the non-dominant hand. For registration of thoracic and abdominal respiratory activity, two PS-2 biofeedback respiration sensor belts (*KarmaMatters, Berkeley, California*), with a built-in length-dependent electrical resistance, were used. They were fixed at the upper thorax and the abdomen. ECG was measured with *Hellige* electrodes (diameter 1.3 cm) according to Einthoven II. Finger pulse signal was transmitted by an infrared system in a cuff around the middle finger of the non-dominant hand.

Behavioral measures

Subjects responded by key presses as well as verbal answers (the latter were not analysed). Key presses indicating 'yes' or 'no' as answers to the CIT questions and the key presses carried out in response to the 2-back task were registered. The behavioral data were time-logged and stored on the stimulus-presenting computer for later evaluation of reaction times and error rates. Behavioral data were synchronized with physiological measures with an accuracy of ± 2 ms.

Data processing

Data from two subjects were treated as invalid because they did not comply with the CIT instructions; one answered with "yes" to the *irrelevant* items, the other with "yes" to one irrelevant item in each category.

Data from one subject had to be discarded from skin conductance analysis because of abnormal conductance due to dermatosis; two further subjects were excluded because of electrodermal hypo- or non-responding (more than 80% non-responses). Skin conductance response was defined as any increase in conductance initiated within a time window from 1.0 to 5.0 seconds after trial onset. The amplitude of the

response was automatically evaluated as the difference between response onset and the subsequent maximum value in the set time window (Furedy et al., 1991). As a measure of tonic arousal, skin conductance level (SCL) was determined at trial onsets and analyzed in the same way.

Respiratory data were low-pass filtered; the total respiration line length (RLL) was automatically computed over a time interval of 10 seconds after trial onset. The RLL measure integrates information about frequency and depth of respiration. The method was derived from Timm (1982) and modified according to Kircher and Raskin (2003).

ECG data from four subjects had to be excluded from analysis because of frequent extrasystoles. After notch filtering at 50 Hz, R-wave peaks were automatically detected and visually controlled. The R-R intervals were transformed into heart rate (HR) and real-time scaled (Velden and Wölk, 1987). The HR during the last second before trial onset served as pre-stimulus baseline. The phasic heart rate (pHR) was calculated by subtracting this baseline value from each second-per-second post-stimulus value. For extracting the trial-wise information of the phasic HR, the mean change in HR within 15 seconds after trial onset compared with the pre-stimulus baseline was calculated (Verschuere et al., 2007a; derived from Bradley and Janisse, 1981). As a measure of tonic arousal, tonic HR was determined at trial onsets and analyzed in the same way.

From the finger pulse waveform, the finger pulse waveform length (FPWL) within the first 15 seconds after trial onset was calculated and subjected to further analyses (Elaad and Ben-Shakhar, 2006). The FPWL comprises information about HR and pulse amplitude and is often interpreted as an indirect measure of arterial blood pressure.

The delay between trial onset and the pressing of the key was calculated as reaction time. In the 2-back parallel task, additional reaction times were recorded after each letter appeared on the screen. The number of errors (missing or false reactions) within the 2-back task was calculated per trial.

Lykken and Venables (1971) proposed a within-subject standardization of measured values. In our study, the physiological and behavioral measures were z-transformed for each subject and each data channel according to Ben-Shakhar (1985), Gamer et al. (2006), and Gronau et al. (2005). The psychophysiological data associated with all *probe* and *irrelevant* items including both runs of the experiment (not including the

first item of each question and the *neutral* questions) were used for the calculation of individual means and standard deviations (Ambach et al., 2008a). The z-transformed values were used in subsequent statistical analyses.

Statistical analysis

Statistical analyses were performed with *SPSS*, Version 12.0 (*SPSS Inc.*, Chicago). For each physiological and behavioral measure, a repeated measures 2 x 2 (Probe x Task) ANOVA was calculated, using the epsilon correction as appropriate. The first factor, Probe, differentiated *probe* vs. *irrelevant* trials and the second factor, Task, differentiated between the experimental conditions with and without the parallel n-back task. The significance level for the assessment of main and interaction effects was set to 0.05. Follow-up t-tests for matched samples (two-tailed, significance level 0.05) were carried out when interactions were found. Cohen's *d* was calculated as the effect size estimate.

Besides investigating the effects of the parallel task on the single physiological measures, the impact on the capability of detecting concealed information was of interest. For this purpose, the validity of each data channel and the validity of an equal-weight combination of the measures EDA, pHR, and RLL were analyzed using receiver-operating characteristic (ROC) curves. The ROC curve reflects the subject-differentiation capability of the single data channels and their combination for all possible cutoff-points; the area under the ROC curve varying between 0 and 1 with a chance level of 0.5 serves as an overall index of detection accuracy (Bamber, 1975; Ben-Shakhar and Elaad, 2003; Gronau et al., 2005). Because only 'guilty' participants were included in the study, responses of a hypothetical group of 'innocents' were simulated according to Meijer et al. (2007); simulated values were randomly drawn from a standard normal distribution. Each ROC analysis aimed at identifying the capability of differentiating 'guilty' vs. (hypothetical) 'innocent' subjects.

Results

1.8% of the *probe* and 2.4% of the *irrelevant* items were followed by incorrect answers; these trials were discarded from further analyses.

In the concluding memory test, 99.25% of *probe* items were identified correctly.

Table 1 summarizes means and standard errors of means of raw scores for each data channel separately for both conditions.

	without parallel task				with parallel task				over conditions			
	<i>probe</i> items		<i>irrelevant</i> items		<i>probe</i> items		<i>irrelevant</i> items		<i>probe</i> items		<i>irrelevant</i> items	
	Mean	(SEM)	Mean	(SEM)	Mean	(SEM)	Mean	(SEM)	Mean	(SEM)	Mean	(SEM)
EDA [μ S]	0.576	(0.068)	0.357	(0.050)	0.601	(0.063)	0.340	(0.043)	0.588	(0.064)	0.349	(0.045)
RLL [arb. units]	1634	(167)	1982	(163)	1723	(172)	1898	(177)	1679	(169)	1940	(168)
pHR [1/min]	-2.33	(0.43)	1.11	(0.22)	-1.40	(0.37)	0.69	(0.17)	-1.86	(0.36)	0.90	(0.16)
FPWL [arb. units]	153	(17)	164	(19)	165	(18)	179	(21)	159	(18)	172	(20)
RT [ms]	1397	(47)	1567	(58)	1524	(57)	1621	(58)	1460	(50)	1594	(56)
NBE [1/trial]					0.632	(0.047)	0.596	(0.046)	0.632	(0.047)	0.596	(0.046)
NBRT [ms]					1240	(50)	1200	(47)	1240	(50)	1200	(47)

Table 1.

Means and standard errors of means (SEM, in brackets) of raw scores for each data channel. Responses to *probe* vs. *irrelevant* items are listed for the conditions without and with parallel task as well as over conditions. Electrodermal activity (EDA, phasic response amplitude), respiration line length (RLL), phasic heart rate (pHR), finger pulse waveform length (FPWL), CIT reaction time (RT), n-back errors per trial (NBE), and reaction times from the n-back task (NBRT) are listed.

Based on z-standardized data, figure 2 illustrates effect sizes for each measure separately for both conditions.

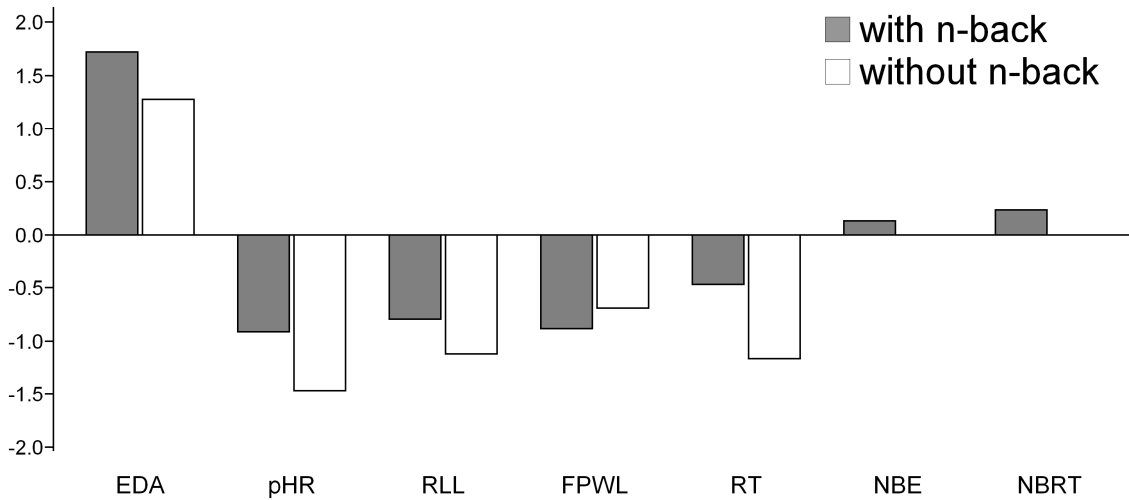


Figure 2. Effect sizes based on z-standardized data for the differential responses to *probe* vs. *irrelevant* items with and without parallel task. Cohen's *d* is depicted for electrodermal activity (EDA, phasic response amplitude), phasic heart rate (pHR), respiration line length (RLL), finger pulse waveform length (FPWL), CIT reaction times (RT), errors in the n-back task (NBE), and reaction times in the n-back task (NBRT).

Skin conductance:

Figure 3 illustrates the averaged skin-conductance response for *probe* and *irrelevant* items in both experimental conditions. Mean response amplitudes were larger in *probe* than in *irrelevant* trials. Interestingly, the response difference between item types was increased in the parallel task condition.

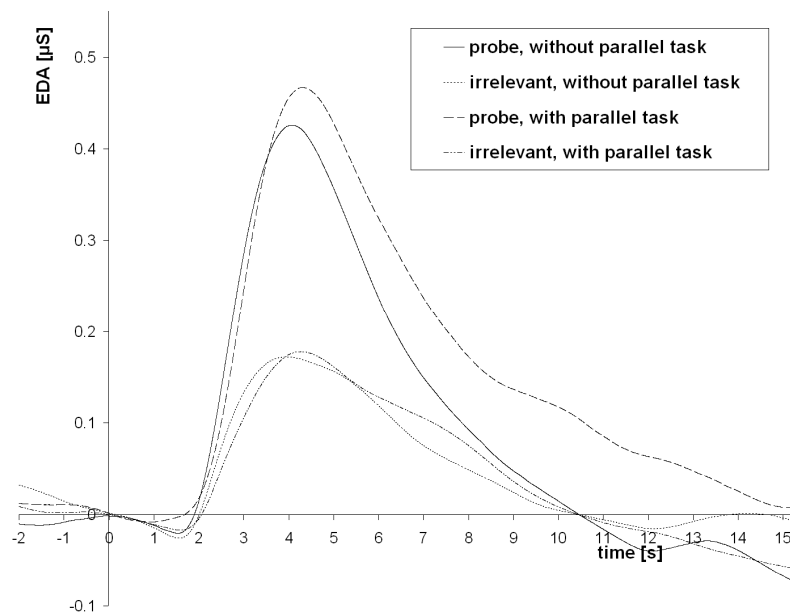


Figure 3. Grand means of skin conductance reactions. Conductance time courses are shown for *probe* and *irrelevant* items.

ANOVA for skin conductance responses showed greater overall response amplitudes to *probe* items than to *irrelevant* items ($F_{1,34} = 110.97$; $p < 0.001$; $\epsilon = 1.19$). No main effect for Task was found ($F_{1,34} = 0.42$). A significant Probe by Task interaction ($F_{1,34} = 4.86$; $p < 0.05$; $\epsilon = 0.13$) corresponds to the greater Probe effect in the condition with the parallel task in contrast to the condition without it ($t_{34} = 10.23$; $p < 0.001$; $d = 2.59$ and $t_{34} = 7.71$; $p < 0.001$; $d = 1.58$, respectively).

The additional analysis of SCL measured at item onsets did not reveal a difference between conditions ($F_{1,34} = 0.27$), a main effect for Probe ($F_{1,34} = 0.03$), or a Probe by Task interaction ($F_{1,34} = 3.15$).

Respiration:

ANOVA for RLL data showed lower respiratory activity in *probe* than in *irrelevant* trials ($F_{1,37} = 46.37$; $p < 0.001$; $\epsilon = 0.67$), but no main effect for Task ($F_{1,37} = 0.03$). The Probe by Task interaction ($F_{1,37} = 18.38$; $p < 0.001$; $\epsilon = 0.35$) indicated greater differential responding without parallel task ($t_{37} = -6.78$; $p < 0.001$; $d = -1.82$) than with ($t_{37} = -4.84$; $p < 0.001$; $d = -1.14$).

Heart rate:

Second-per-second values of HR after trial onsets of *probe* and *irrelevant* items are depicted for both experimental conditions in figure 4.

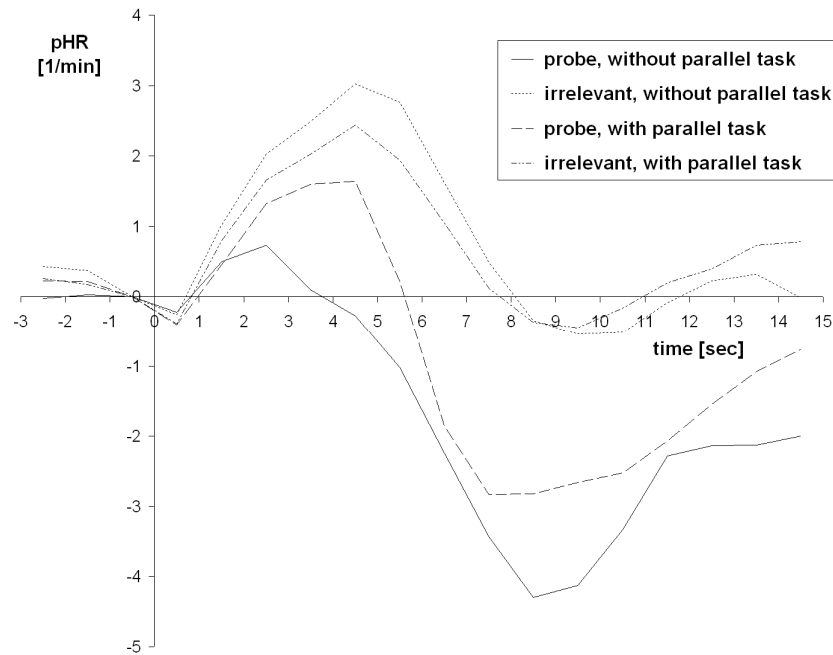


Figure 4. Second-per-second values of heart rate following CIT item onsets.

A typical biphasic HR course consists of an increase within the first three seconds after trial onset, followed by a decrease lasting about ten seconds. Phasic HR averaged over fifteen seconds after trial onset differed strongly between trial types. The deceleration was more pronounced for *probe* than for *irrelevant* trials. The parallel task visibly weakened this differentiation, which was mainly due to an increased pHR in *probe* trials.

The ANOVA for pHR data showed enhanced HR decelerations after *probe* items in comparison to *irrelevant* items ($F_{1,33} = 72.61$; $p < 0.001$; $\epsilon = 0.95$) but did not reveal a main effect for Task ($F_{1,33} = 0.90$). A Probe by Task interaction ($F_{1,33} = 9.89$; $p < 0.01$; $\epsilon = 0.24$) reflected a greater Probe effect without the parallel task ($t_{33} = -8.99$; $p < 0.001$; $d = -2.62$) than with it ($t_{33} = -5.34$; $p < 0.001$; $d = -1.56$).

An additional analysis of tonic HR measured at item onsets revealed higher beat rates in the parallel task condition than without the parallel task (80.4 and 77.6 bpm, respectively; $F_{1,33} = 37.49$; $p < 0.001$; $\epsilon = 0.63$). Neither a main effect for Probe ($F_{1,33} = 0.36$) nor a Probe by Task interaction ($F_{1,33} = 0.84$) was found.

Finger pulse:

The ANOVA indicated lower FPWL values for *probe* items in comparison to *irrelevant* items ($F_{1,37} = 28.28$; $p < 0.001$; $\epsilon = 0.48$). Values were lower in the condition without

than with the parallel task ($F_{1,37} = 32.25$; $p < 0.001$; $\epsilon = 0.53$), but no Probe by Task interaction was found ($F_{1,37} = 2.35$).

Reaction times:

The mean reaction time to the CIT questions was 1550 ms with a standard deviation of 317 ms. ANOVA for reaction times yielded effects for Probe ($F_{1,37} = 31.39$; $p < 0.001$; $\epsilon = 0.52$) and Task ($F_{1,37} = 9.61$; $p < 0.01$; $\epsilon = 0.21$) as well as a Probe by Task interaction ($F_{1,37} = 6.33$; $p < 0.05$; $\epsilon = 0.15$). Mean reaction times to the CIT questions were shorter to *probe* than to *irrelevant* items in both conditions with a diminished effect with the parallel task ($t_{37} = -7.27$; $p < 0.001$; $d = -1.51$ and $t_{37} = -3.04$; $p < 0.01$; $d = -0.71$ for conditions without and with parallel task, respectively).

2-back reaction times:

The reaction times of the 2-back task had a mean of 1214 ms and a standard deviation of 278 ms. They did not significantly differ between *probe* and *irrelevant* trials ($t_{37} = 1.54$; $p > 0.05$).

2-back errors:

Each trial of the CIT with parallel task contained either three or four letter presentations in the 2-back task; the number of errors (false misses, false alarms, and missing reactions) during the time an item was presented varied around a mean of 0.61 (mean error rate: 17.4 % of all letter presentations) with a standard deviation of 0.25. A t-test did not reveal a significant difference between *probe* and *irrelevant* items ($t_{37} = 0.87$; $p > 0.05$).

Analyzing false misses and false alarms separately did not reveal a significant *probe* vs. *irrelevant* difference for either error type ($t_{37} = 1.20$; $p > 0.05$ and $t_{37} = 0.80$; $p > 0.05$ for false misses and false alarms, respectively).

Receiver-operating characteristic (ROC)

The following results refer to a classification of 'guilty' vs. hypothetical 'innocent' subjects with an a-priori probability of 0.5. ROC analyses were performed for the equal-weight combination of EDA, pHR, and RLL, as well as for each singular measure: 'electrodermal activity' (EDA), 'phasic heart rate' (pHR), 'respiration line length' (RLL), 'finger pulse waveform length' (FPWL), and 'reaction time' (RT). For

the condition with parallel task, ROC area values for the behavioral measures from the parallel task, i.e. 'n-back task reaction time' (NBRT) and 'n-back task errors' (NBE), were added. The different rates of false-positive (classification of an innocent subject as guilty) and false-negative outcomes (classification of a guilty subject as innocent) obtained under variation of the cut-off point for decision were calculated separately for both experimental conditions (with and without parallel task) and across both conditions. Table 2 shows the areas under the ROC curves and their confidence intervals for the equal-weight combination of EDA, pHR, and RLL, and for each of the single measures.

included parameters	area under the ROC curve and 95% confidence intervals					
	without parallel task		with parallel task		overall	
	area	confidence interval	area	confidence interval	area	confidence interval
single measures:						
EDA	0.841	0.741 - 0.925	0.909	0.831 - 0.971	0.934	0.859 - 0.988
pHR	0.845	0.740 - 0.935	0.716	0.585 - 0.834	0.828	0.713 - 0.926
RLL	0.837	0.734 - 0.926	0.681	0.557 - 0.797	0.826	0.717 - 0.918
FPWL	0.612	0.475 - 0.744	0.777	0.665 - 0.879	0.733	0.612 - 0.843
RT	0.855	0.764 - 0.931	0.649	0.521 - 0.772	0.792	0.684 - 0.888
NBRT			0.545	0.411 - 0.676		
NBE			0.559	0.425 - 0.691		
equal-weight combination:						
EDA + pHR + RLL	0.941	0.877 - 0.991	0.895	0.795 - 0.970	0.938	0.863 - 0.990

Table 2.

Area under the receiver operating characteristic (ROC) curves and 95% confidence intervals for a differentiation of guilty vs. hypothetical innocent subjects.

Values are listed for inclusion of each single measure and for an equal-weight combination of EDA, pHR, and RLL. Conditions without and with parallel task and results across conditions ('overall') are presented in separate columns.

With the equal-weight combination of EDA, pHR, and RLL, the differentiation between guilty and hypothetical innocent subjects, as reflected in ROC areas, was neither facilitated nor significantly impeded in the parallel task condition compared

with the control condition. With a fixed criterion (combined z value > 0.5 for classification as 'guilty'), the rates of correct subject classification with the equal-weight combination were 90.3% without parallel task, 87.1% with parallel task, and 90.3% over conditions. In the evaluation which included each of the single measures singularly, ROC area values appeared larger for EDA and FPWL, but diminished for pHR, RLL, and RT in the parallel task condition; yet, the differences between conditions were not significant. FPWL and RT differentiated significantly in both conditions, but apparently weaker than the other measures. The behavioral measures (NBRT and NBE) of the parallel task did not contribute to differentiation.

Discussion

The goal of the present study was to examine the influence of additional working memory activity on behavioral and physiological responding in a CIT. In a laboratory mock-crime experiment, each participant underwent a CIT with repeated switches between two conditions, with and without an n-back parallel task.

Effects of information concealment on behavioral and physiological measures (without interfering task)

In the control condition without the n-back parallel task, large effects of concealing information on electrodermal activity, respiration line length, and phasic heart rate were found. The observation of large effects is in general accordance with the literature (e.g. Ben-Shakhar and Elaad, 2003; Bradley and Janisse, 1981; Gamer et al., 2006). Untypically, phasic heart rate appeared equivalent to EDA and RLL with respect to effect sizes. Finger pulse waveform length yielded a significant effect; yet, the effect size remained far below the recent findings by Elaad and Ben-Shakhar (2006) and Vandenbosch et al. (2009). Slightly atypical for CIT studies, each CIT question was combined with one *probe* and three *irrelevant* items in the present study; a more usual ratio is one *probe* to five *irrelevants*. Physiological response differences between item types depend on the ratio of *probe* to *irrelevant* items presented (e.g. Liebllich et al., 1970). Therefore, all effect sizes and ROC areas reported here may have been attenuated relative to most other studies.

The reaction times in the CIT without parallel task differed between truthful and deceptive denial of knowledge (i.e. between *irrelevant* and *probe* items, respectively); yet, the direction of the difference was atypical. Recent studies found either no RT differences or significantly longer reaction times to *probe* than to *irrelevant* items and attributed this to the higher cognitive load necessary for deception (Gronau et al., 2005; Seymour et al., 2000; Vendemia et al., 2005b; Walczyk et al., 2003). In contrast, the present study showed shorter reaction times in *probe* trials. This has also been reported in a previous study (Ambach et al., 2008a); the shorter reaction times found in *probe* trials was discussed in terms of possible strategic manipulations (Farwell and Donchin, 1991; Ratcliff and McKoon, 1981; Seymour et al., 2000). The possibility of strategic manipulations is underpinned by the observation that absolute RTs in the study by Ambach et al. (2008a) and the present study are equivalent and

exceed the typical RT range known from CIT studies. With mean RTs clearly exceeding one second, it seems likely that the faster RTs are due to intentionally faster reactions in probe trials ("in order to keep a low profile"). The longer overall RTs could however also be due to subjects being presented a question as well as a picture with each trial onset and both had to be evaluated before responding. Furthermore, subjects might not have reacted with their maximum possible speed, although they had been asked to answer 'immediately after item and question presentation'. Subjects possibly preferred to answer "correctly", instead of fast. All in all, differences in RTs between conditions have to be interpreted cautiously in this study.

Behavioral effects of the interfering n-back task

In the experimental condition, the present study used a demanding n-back parallel task engaging working memory – specifically, the supervisory attentional system (Baddeley, 2003) - to resume investigating the influence of interfering mental activity on differential physiological responding in a CIT.

As a manipulation check, two psychophysiological indicators of arousal were analyzed. Notably, the electrodermal and the cardiovascular system were affected differently by the task manipulation: While the tonic SCL did not show an increase in arousal by the additional demands, tonic HR was markedly higher in the dual task condition. The higher tonic HR might reflect the additional workload steadily demanded by the interfering task; additionally, motor activity may have contributed to this (e.g. Obrist, 1976). The n-back task obviously accomplished a steady increase in arousal, which was not found for the Go/No-go task investigated previously (Ambach et al., 2008a), despite the fact that the Go/No-go task demanded a greater amount of motor activity than the n-back task used in the present investigation. Besides the increased heart rate, subjects' accuracy and speed in the parallel task document that a sufficient task difficulty was achieved¹.

¹ In order to reach 75% correct answers in this task in the training runs, most subjects needed several repetitions; during the main run of the experiment, the proportion of correct responses increased only moderately and remained below those of other studies (82.6% here, whereas e.g. Watter et al., 2001, reported 87.6% correct responses in their 2-back task). Correspondingly, the n-back reaction times clearly exceeded those of other studies (1214 ms here, whereas e.g. Watter et al., 2001, reported 554 ms).

RTs were longer in the parallel task condition as compared with the control condition, which held for *probe* and *irrelevant* items; this is thought to be due to the additional cognitive load required by the n-back task. The prolongation of RTs with parallel task was more pronounced to *probe* items, which diminished the difference between trial types. One might speculate that this finding reflects a successful task interference, which might possibly become even clearer if subjects were forced to respond faster, e.g. within one second.

The additional behavioral measures (reaction times, error rates) of the parallel task were not sensitive to information concealment. One might regard this as contradictory to an accomplished task interference; alternatively, it could be explained by the different timing of demands: While the n-back task demands working memory resources steadily, answering the CIT questions is thought to engage mental resources only phasically. Correct or false answers in the n-back task are determined by the previous nine seconds, while answering the CIT questions is completed within a short time window after stimulus presentation. This could mean that the interfering task might have had more impact on the CIT than vice versa.

Psychophysiological effects of the interfering n-back task

Most important is the finding that in the parallel task condition the mean response difference between truthful and deceptive denial of knowledge was increased for EDA, but diminished for pHR and RLL. The results for pHR and RLL confirm the primary hypothesis of the study: The continuous additional activity was expected to divert attention from the CIT and thereby weaken differential physiological responding. The observed opposite effect found with EDA can however not be explained with a mere distractor effect of the parallel task. More generally, it appears difficult to align the finding with a unitary enhancement or diminishment of differential physiological responding in the CIT. The increase in differential electrodermal responding with the parallel task was an unexpected finding, which requires replication before drawing any definite conclusions. As a possible post-hoc account, it might be assumed that EDA and the cardiopulmonary measures reflect different CIT sub-processes, which were differently influenced by the experimental manipulation.

Relation to countermeasure studies

The contrast of the present results with those of earlier countermeasure studies is obvious. Continuous countermeasures tend to weaken the accuracy of the test with EDA, but not with respiratory measures (Ben-Shakhar and Dolev, 1996; Elaad and Ben-Shakhar, 1991); in previous studies, the countermeasure was discussed as distractor task: 'the subject's ability to ignore the relevant item is a crucial factor that determines detection efficiency' (Elaad and Ben-Shakhar, 1991). In the parallel task condition of our study, differential responding was diminished with pHR and RLL, but enhanced with EDA. While the decreased effects with pHR and RLL can be explained with the shifting of attention away from the *probe* item, previous insights from countermeasure studies do not provide an explanation for the enhanced effect found with EDA. Because the electrodermal finding contrasts the existing countermeasure literature, a replication is desirable.

Comparison with Go/No-go parallel task

The finding of an increased differential EDA response with the interfering n-back task exceeds the previous findings obtained with an interfering Go/No-go task (Ambach et al., 2008a). This could be due to various reasons: First, the n-back task compared to the Go/No-go task engages different mental resources; this possibly led to a more specific competition for resources between the CIT and the parallel task in the present study. Second, the Go/No-go task and the n-back task have different temporal characteristics; the n-back task implements the additional mental load in a more continuous manner than the Go/No-go task. Therefore, sequentially processing CIT questions and the parallel task, which might have been possible previously, was impeded in the present study. Third, an improved experimental design with repeated within-subject changes between both conditions might have contributed to the significant findings; sequence effects were largely avoided; this improved the statistical power. Fourth, the use of a new item set consisting of ten categories and the balanced randomization of the *probe* items within each category also improved test power.

Theoretical implications

The question then arises how the opposed effects of the interfering task on the individual measures can be connected to existing models of information concealment and detection. Although differential responding in a CIT is mostly discussed as

modulation of the orienting reflex (Sokolov, 1963), cognitive processes, e.g. attentional mechanisms, are known to influence its amplitude (e.g. Ambach et al., 2008b; Elaad and Ben-Shakhar, 1991; Furedy and Ben-Shakhar, 1991; Verschuere et al., 2007b). Whatever mechanisms one assumes important in the present study, including the interference with the supervisory attentional system, a model explaining the present results will have to adopt the idea that the individual measures are mediated by different mechanisms, which were differently affected by the additional task.

If the present results, particularly those for EDA, will be replicated, it will be impossible to explain these results exclusively on the basis of a unitary concept of the orienting reflex; obviously, the parallel task cannot be understood as uniformly enhancing or diminishing the strength of the orienting reflex and its psychophysiological correlates. An approach extending Sokolov's orienting theory is the preliminary process theory (Barry, 1996), which assumes that EDA and ECG responses to a stimulus are mediated by different mechanisms. In terms of the preliminary process theory, changes in the 'cortical set', which integrates voluntary attentional control into the involuntary orienting reflex, can lead to a fractionation of psychophysiological responses. While the preliminary process theory yields a principal framework for explaining the phenomenon of physiological response fractionation, it does not provide a direct clue to the fractionation of responses revealed by the current interfering task. Considering the present results, one might speculate whether the specific type of the additional mental load or rather the specific distribution of attention in the dual-task paradigm has led to the dissociation of two mechanisms of responding, one affecting EDA, the second affecting cardiac and respiratory activity².

²A response fractionation was also observed in a previous CIT study (Ambach et al., 2008b). There, respiratory and cardiovascular measures appeared to be determined by deception-related processes rather than by orienting, whereas EDA depended on both deception and orienting. Although the former results and explanations cannot be directly transferred to the present study, it seems noteworthy that - there also - the cardiopulmonary responses seem to have been mediated by different CIT sub-processes than the EDA responses.

For the observed decrease of differential pHR, an additional explanation based on the findings and theory of Lacey, J.I. and Lacey, B.C. (1970) is conceivable. The additional demand of the n-back task is expected to increase heart rate; this increase overlaps the phasic decelerations following *probe* items in the CIT. The present

finding that the decelerations following *probe* items diminished in the parallel task condition might point towards a selective enhancement of cognitive processes in *probe* trials. Very tentatively, this could be seen as reflecting a successfully accomplished task interference, which affected pHR with a different mechanism and in opposite direction to EDA. One more alternative explanation for the heart rate results seems possible. The key presses in the n-back task demanded additional motor action; possibly, heart rate decelerations due to deceptive responding were masked by an increase in heart rate due to motor actions.

Implications from an applied perspective

Areas under the ROC curve and their confidence intervals were used to assess the capability of the CIT to differentiate between the actual ('guilty') participants and a group of hypothetical innocent subjects. The equal-weight combination of measures did not show a tendency towards an enhanced validity with the parallel task. Overall, item-type differentiation appeared even less accurate in the parallel task condition. This suggests that the seemingly improved validity found for EDA was at least balanced, possibly even outbalanced by the decreased validity of pHR and RLL. Further research is needed to evaluate the implications of the parallel task condition for actual practice. A replication of the present EDA results is recommended before drawing any further conclusions. Behavioral measures of the n-back task were not found to be valid additional indicators of information concealment; mean differences were far from statistical significance.

Conclusions

Following the idea that working memory plays a central role in concealing information, a demanding n-back task was chosen to interfere with the processes engaged in a CIT. As a main finding, the effect of the interfering task depended on the physiological measure investigated. Physiological response differences between concealed knowledge and absent knowledge increased with EDA, but decreased with heart rate, respiration, and behavioral measures.

Findings underpin that the physiological measures recorded in a CIT reflect different sub-processes, which in turn are affected differently by additional task demands. Tentatively, this could be seen as a successful attempt to interfere with CIT sub-processes associated with working memory. While from an applied

perspective, the manipulation used in this study did not improve overall detection accuracy, the interfering task paradigm seems valuable with respect to theoretical models of information concealment and its detection.

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