Concealed Information Test: Theoretical Background

klein Selle, N.; Verschuere, B.; Ben-Shakhar, G.

DOI
10.1016/B978-0-12-812729-2.00002-1

Publication date
2018

Document Version
Submitted manuscript

Published in
Detecting Concealed Information and Deception

Chapter 7

Concealed Information Test: Theoretical background.

Nathalie klein Selle[12], Bruno Verschuere[2], & Gershon Ben-Shakhar[1]

[1]Department of Psychology, Hebrew University of Jerusalem

[2]Department of Clinical Psychology, University of Amsterdam

klein Selle, N., Verschuere, B. J., & Ben-Shakhar, G. (2018). Concealed Information Test: Theoretical background. In: P. Rosenfeld (Ed), *Detecting Concealed Information and Deception: Verbal, Behavioral, and Biological Methods.* San Diego, CA: Elsevier/Academic Press.

Abstract

After 6 decades of research it has now been well established that physiological measures can validly detect concealed memories. However, the exact theoretical underpinnings of concealed information testing (CIT) remain to be elucidated. In the present chapter we review the various theoretical accounts of the CIT effect and discuss their development over time. We start with several unitary theories that each focused on a single emotional-motivational factor. As it appeared that such factors have little impact on the CIT, cognitive factors became the focus of examination early on. The orienting response theory in particular, has dominated the field for years. Recent evidence, however, suggests that orienting theory may well apply to the skin conductance measure, but may not fully explain physiological reactivity in the CIT for other response measures such as respiration and heart rate. Hence, a response fractionation model which suggests that the skin conductance measure reflects orienting and the respiration and heart rate measures reflect attempts at arousal inhibition was proposed. Future work is needed to validate this model and test whether it holds under real-life circumstances. Furthermore, more research is needed to examine the underlying mechanisms of other physiological and behavioral measures.

Key Words: Concealed Information Test; Theory; Orienting; Inhibition; Response Fractionation

Introduction

"He who loves practice without theory is like the sailor who boards ship without a rudder and compass and never knows where he may be cast."

– Leonardo da Vinci (1452-1519)

The idea that physiological measures can be used to detect hidden (crime-related) memories has intrigued researchers around the globe since the last century. Memory detection, using the Concealed Information Test (CIT), relies on a simple multiple choice questioning format. Specifically, each of the selected questions is followed by the serial presentation of one critical (concealed) and several control items. When the critical items consistently induce a pattern of differential responses, relative to the control items (i.e., the CIT effect), knowledge about the event (e.g., crime) is inferred. The initial studies inspiring this field of research examined the validity of the CIT using just a single physiological measure, namely, the skin conductance response (SCR; e.g., Ellson, Burke, Davis, & Saltzman, 1952; Geldreich, 1941, 1942; Lykken, 1959, 1960). Subsequent studies examined the validity of additional physiological measures, such as respiration and heart rate (e.g., Cutrow, Parks, Lucas, & Thomas, 1972; Thackray & Orne, 1968), and factors that affect their validity (e.g., the type of verbal responses: Ambach, Stark, Peper, & Vaitl, 2008; Horneman & O'Gorman, 1985; Kugelmass, Lieblich, & Bergman, 1967; drugs: Waid, Orne, Cook, & Orne, 1981; Iacono, Boisvenu, & Fleming, 1984). Moreover, attempts were made to shed light on the theoretical underpinnings of the CIT effect. This line of research carries a special importance as a theoretical foundation is an essential requirement of any scientifically based technique (Messick, 1995). A well grounded theory allows one to determine the optimal conditions under which the technique will be most effective, as well as its limitations. Moreover, it provides knowledge about different factors that affect the outcomes of the test, which is especially important for the CIT as we generalize from experimental to real-life forensic settings. Finally, in the case of the CIT, a theory could also be informative regarding the most efficient physiological and behavioral measures.

In this chapter we shall review the various theoretical accounts of the CIT effect, with a focus upon the oldest and most often applied autonomic nervous system (ANS) based CIT. Importantly, we will make a distinction between (1) several unitary approaches (that rely on a single underlying mechanism; e.g., the orienting response), and (2) a recently proposed response fractionation approach (that relies on multiple underlying mechanisms). We will also evaluate the quality and utility of current CIT theory using a number of explicit criteria: parsimony, precision, testability and empirical validity. Finally, towards the end of this chapter we will touch upon the theoretical underpinnings of the more recently used central nervous system (CNS) and behavioral based CIT.

I. Unitary Approaches

Over the last few decades, CIT theory has been characterized by a predominantly unitary focus. Specifically, each theory was built around a single underlying mechanism assumed to elicit enhanced responses to the critical CIT items in all the ANS measures applied in the CIT. The earliest theories focused primarily on emotional-motivational factors, such as punishment and emotional conflict, while the later theories focused on cognitive factors such as orientation and inhibition (see Ben-Shakhar & Furedy, 1990; Verschuere & Ben-Shakhar, 2011).

Emotional Theories

Three of the earliest unitary theories emphasized emotional factors and were formulated by Davis (1961): the conditioned response theory, the punishment theory and the emotional conflict theory. The conditioned response theory holds that the critical items serve as conditioned stimuli which induce fear and arousal, similar to the emotions typically experienced during crimes. The punishment theory, on the other hand, holds that the fear of punishment (i.e., consequences of failing the test) underlies the CIT effect and the emotional conflict theory states that the CIT effect reflects an emotional conflict between the pre-potent truth response and the need to lie[1]. These theories are, however, not specific to the CIT and have never been fully elaborated. Moreover, the limited

[1] Emotional conflict theory is related to arousal inhibition theory which will be discussed below.

available research suggests that such emotional factors as stress, arousal, fear of punishment, have little to no effect on detection efficiency with the CIT (e.g., Bradley & Janisse, 1981; Elaad & Ben-Shakhar, 1989; Horneman & O'Gorman, 1985; klein Selle, Verschuere, Kindt, Meijer, Nahari, & Ben-Shakhar, 2017b; Kugelmass & Lieblich, 1966; Kugelmass et al., 1967; Verschuere, Crombez, Smolders, & De Clercq, 2009). Hence, other processes are likely to lie at the core of this test.

Motivation-Impairment Theory

The motivation-impairment theory relates the CIT effect to the motivation to avoid detection. Specifically, the more motivated the examinees, the more likely they are to be detected. The role of motivation has been examined in numerous studies, using either a financial incentive or motivational instructions. In the first two of these studies (Gustafson & Orne, 1963, 1965) half of the participants were told that only people of superior intelligence could beat the polygraph test, thereby motivating them to avoid detection. The other half of the participants were told that only people with psychopathic tendencies could beat the test, thereby motivating them to be detected. While these and later studies have revealed mixed effects, Meijer, klein Selle, Elber, and Ben-Shakhar (2014) showed in their meta-analysis that the motivation to conceal increases SCR detection efficiency. Still, detection was also high under low motivational conditions (d = 1.33 as compared to d = 1.66 for the high motivation condition), implying that motivation is not a necessary condition for obtaining a CIT effect. Furthermore, the effect of motivation to avoid detection can be accounted for by other theories (see below).

Orienting Response Theory

You're at a crowded party where the music is loud, glasses are clinking and different conversations fill up the room. Yet, amid this abundance of distracting stimuli, you can zero in on the one conversation you want to hear. Then, when someone mentions your name from across the room, you quickly turn your head and redirect your attention to that (more interesting) conversation. This phenomenon has been labelled as the "cocktail party effect" and illustrates the concept of the orienting response (OR). Sokolov (1963, 1966) described the OR as a complex of behavioural and physiological reactions in response to any novel stimulus or a change in stimulation. Importantly, when a stimulus carries a special significance (e.g., one's own name) an enhanced orienting response occurs. It was quickly realized this quality of the orienting response could be used to identify "guilty examinees" (e.g., Lieblich, Kugelmass, & Ben-Shakhar, 1970; Lykken, 1974). In particular, Lykken (1974) argued that: "... for the guilty subject only, the 'correct' alternative will have a special significance, an added 'signal value', which will tend to produce a stronger orienting reflex than that subject will show to other alternatives (p. 728)". For the innocent examinees, the correct items do not possess such significance or signal value and thus all items are equivalent and evoke similar ORs.

OR theory has, up till now, been the most influential account of the CIT effect. The strongest (indirect) evidence for this theory relates to the observation that the critical CIT items elicit a pattern of enhanced responding that characterizes OR to significant stimuli: a larger skin conductance response (SCR), a shorter respiration line length (RLL)[2], slower heart rate (HR) and increased pupil dilation (Gamer, 2011). More direct evidence for this theory, however, was only found with the SCR. In this line of research, different features of the orienting response were examined. The most examined feature, habituation, refers to a gradual decline in responding with repeated stimulus presentation. In various CIT studies, response habituation has been shown for the SCR, but not for the RLL and HR (e.g., Ben-Shakhar & Elaad, 2002; Elaad & Ben-Shakhar, 1997; Gamer, Godert, Keth, Rill, & Vossel, 2008). Two less examined features are generalization (e.g., responding to stimuli presented in one modality generalizes to other modalities) and dishabituation (i.e., the recovery of a response that habituated). Generalization has been shown in one previous study, but again only for the SCR (Ben-Shakhar, Frost, Gati, & Kresh, 1996). Dishabituation, on the other hand, has not been observed in the CIT (Ben-Shakhar, Gati, Ben-Bassat, & Sniper, 2000). Ben-Shakhar and colleagues argued, however, that dishabituation has not been always demonstrated in OR research either (see Siddle & Lipp, 1997).

Another well-known feature of the OR is its sensitivity to stimulus significance. A stimulus is considered to be significant when it carries a special importance, relevance, or

[2] The RLL is a composite measure of both the depth and speed of respiration. Hence, a shorter RLL reflects a relatively slow and shallow respiration pattern.

interest, whether positive or negative (see Bernstein, 1979; Dindo & Fowles, 2008). Although classical OR theory does not explicitly state whether it views significance as a dichotomy (see dichotomization theory below) or as a continuum (see feature-matching theory below), a continuous view, in which stimuli differ in the degree of significance, is generally accepted. This implies that the higher the significance level of the critical CIT stimuli, the larger the OR, and consequently the larger the CIT effect. Indeed, a number of studies revealed larger responses for high significant compared to low significant stimuli, however the majority of these studies observed such enhanced responses only with the SCR, but not with the RLL and HR measures (Baker, 2008; Barry, 1981; Ben-Shakhar & Gati, 1987; Coles & Duncan-Johnson, 1975; Feld, Specht, & Gamer, 2010; Greene, Dengerink, & Staples, 1974; Jokinen, Santtila, Ravaja, & Puttonen, 2006; klein Selle, Verschuere, Kindt, Meijer, & Ben-Shakhar, 2017a; Stormark, 2004; Vico, Guerra, Robles, Vila, & Anllo-Vento, 2010). Similarly, klein Selle et al. (2017b; Experiment 2) found preliminary evidence that the use of emotional stimuli in the CIT (both critical and control) can increase detection efficiency, at least for the SCR (no effect was found for RLL or HR). The higher significance of the emotional stimuli might explain the larger CIT effect observed with the SCR. Indeed, the degree of significance or importance of a stimulus is not only determined by cognitive factors, but also by motivational and emotional factors. For example, the effects of motivation to avoid detection discussed above can be accounted for by OR theory because the critical CIT items are more significant for highly motivated than for indifferent examinees. Still, the concept of significance is rather broad and vague. It is therefore not always clear whether (1) a stimulus is highly or only slightly significant, and (2) whether the significance level of a stimulus is sufficient to induce an enhanced OR. For example, although it may be predicted that the murder weapon is sufficiently significant to induce an enhanced OR, what about the victim's clothes? Even with perfect memory, it cannot be ascertained that such information will have sufficient significance.

Taken together, while the SCR seems to posses several important OR characteristics such as habituation, generalization and sensitivity to stimulus significance, other response measures (RLL, HR) do not seem to follow the predicted OR characteristics.

The Dichotomization Theory

The dichotomization theory, which is closely linked to OR theory, originated from the work of Lieblich et al. (1970) and was later extended by Ben-Shakhar (1977, 1980). According to this approach, knowledgeable examinees dichotomize the stimulus set into two distinct categories – critical versus control – and ignore the differences between stimuli within each category. In terms of Sokolov's (1963) theoretical formulation, it is postulated that a single neuronal model is formed for each stimulus category. Ben-Shakhar and colleagues tested several predictions derived from the dichotomization approach using the SCR measure. First, as it was assumed that the differences within categories are ignored, similar SCR detection scores were predicted when a single control item is repeated and when several different control items are used. This prediction was tested and confirmed by Ben-Shakhar (1977). Second, as it was assumed that habituation generalizes within each category, with little to no carry over across categories, it was predicted that the more frequently presented category (typically the control category) will habituate faster. It was accordingly demonstrated that the responses to frequently presented critical stimuli habituate faster than the responses to rare control stimuli, demonstrating a "negative detection" (detection of the rare control stimuli) (Ben-Shakhar, 1977; Ben-Shakhar, Lieblich, & Kugelmass, 1975; Lieblich et al., 1970). Rare critical stimuli, however, induced larger responses than rare control stimuli. Hence, the theory was updated to include the effect of significance. Indeed, a subsequent study showed that relative significance may be a more potent factor in eliciting orienting than relative novelty (Ben-Shakhar, 1994). Third, the dichotomization theory predicts that differential responding depends on the serial position of the stimulus within its own, but not within the alternative category. Hence, when the CIT is based on a single critical item (and thus its serial position within its own category is always 1), similar responses should be observed throughout the test. Ben-Shakhar and Lieblich (1982), however, found larger SCRs with earlier presentations of the critical stimulus, which led to a revision of the dichotomization theory and the formulation of a feature-matching theory (see below).

The Feature-Matching Theory

The feature-matching theory was intended to supplement OR theory by specifying the nature of the comparator (match/mismatch) mechanism proposed by Sokolov (1963). Specifically, it is posited that each incoming stimulus is compared with the representation of the critical stimulus and with the representations of recently presented stimuli by two feature-matching processes (Tversky, 1977). The degree of match/mismatch between the input and the critical stimulus determines the significance value of the input and the degree of match/mismatch of the input with previously presented stimuli determines the novelty value of the input. The levels of novelty and significance are then integrated to determine the magnitude of the OR. One major advantage of this approach, compared to the dichotomization approach, is that stimulus significance and novelty are viewed as a continuum rather than a dichotomy. The feature matching approach was also tested, and largely corroborated, in a series of studies conducted by Ben-Shakhar and Gati (e.g., Ben-Shakhar & Gati, 1987; Ben-Shakhar et al., 2000; Gati & Ben-Shakhar, 1990). All these studies, however, relied again only on the SCR measure. Furthermore, contrary to prediction, Ben-Shakhar and Gati (2003) found that the frequency of components common to the critical and control stimuli had no effect on OR magnitude to the critical stimulus. OR magnitude was affected only by the serial position of these components and consequently Ben-Shakhar and Gati (2003) suggested a revision of the feature matching theory.

Arousal Inhibition Theory

Arousal inhibition theory holds that attempts at inhibition of physiological arousal underlie the CIT effect. Thinking of the situation of the knowledgeable examinee in a CIT, it is conceivable that the examinee not only recognizes (and orients to) the critical items, but in order to look innocent also attempts to inhibit the experienced physiological arousal. Attempts to inhibit arousal are however typically associated with increased, rather than decreased physiological responses (Pennebaker & Chew, 1985). It is further noteworthy that attempts at arousal inhibition are likely to be accompanied by a conflicting emotional state (i.e., emotional conflict theory). This experienced conflict may however be reduced when participants remain silent and do not answer deceptively.

Attempts at arousal inhibition, on the other hand, are expected to be high in both a deceptive and a silent condition.

The inhibition theory is immediately appealing as arousal inhibition characterizes individuals motivated to avoid detection. The theory is also indirectly supported by the emotional regulation literature, which has shown that attempts at arousal inhibition come with a physiological cost. Specifically, several studies revealed that inhibition of physiological arousal results in a response pattern that resembles the CIT effect (e.g., Dan-Glauser & Gross, 2011; for studies on experiential and expressive suppression see Demaree et al., 2006; Gross & Levenson, 1993, 1997). A direct test of the inhibition theory was provided by Verschuere, Crombez, Koster, Van Bockstaele, and De Clercq (2007). These authors used a startle eye blink paradigm in which startle probes were presented both during critical and control items. While OR theory predicted greater startle modulation (measured by eye blink magnitude) to the critical pictures, inhibition theory predicted reduced startle modulation. The data supported an inhibition account and hence the authors ran two additional experiments in which participants either were or were not instructed to inhibit physiological responding. Only when instructed to inhibit, reduced startle modulation was observed.

Evaluation of the Unitary Approaches

Over the last few decades, a number of unitary theories have aimed to explain the differential responses to concealed information – each of these theories emphasized a single underlying mechanism. Some of the earlier unitary theories focused on emotional and motivational mechanisms, which were found to contribute to, but are not necessary for the CIT effect to occur. Hence, other approaches emphasizing cognitive mechanisms, such as orienting and inhibition, were proposed and considered to be more likely candidates. The unitary nature of these theories, however, means that a single mechanism was proposed to explain the differential responding (to the critical stimuli) of all physiological measures (e.g., SCR, RLL, HR). This is rather surprising as most of the evidence for these theories (especially for OR and its related theories) was based entirely on the SCR measure.

II. Response Fractionation Approach

The automatic generalization of findings with the SCR to other physiological measures seems to have been premature; a number of research findings revealed a divergence or even a fractionation between the different measures. First, while the SCR has been shown to habituate over the course of the CIT, both the RLL and HR are relatively resistant to habituation (e.g., Ben-Shakhar & Elaad, 2002; Elaad & Ben-Shakhar, 1997; Gamer, Godert et al., 2008). Second, the different measures were found neither to correlate across participants (Gamer, Verschuere, Crombez, & Vossel, 2008) nor within participants across CIT questions (Gamer, Godert et al., 2008). Third, a number of experimental manipulations were found to divergently affect the SCR and cardiorespiratory (RLL and HR) measures (e.g., overt deception: Ambach et al., 2008; interfering task: Ambach, Stark, & Vaitl, 2011; question repetition: Ben-Shakhar & Elaad, 2002). Ambach et al. (2011), for example, introduced a parallel n-back task during the CIT which was assumed to engage additional mental activity. While the parallel task enhanced the SCR CIT effect, it reduced the RLL and HR CIT effects. A similar fractionation was observed by Ben-Shakhar and Elaad (2002) who examined the effects of question repetition and variation. The authors found a monotonic relationship between the number of different questions used and the CIT effect with the SCR, but not with the RLL or HR. Importantly, the observed fractionation in these studies may be caused by either one or two of the following: (1) the RLL and HR measures may simply be more noisy and less sensitive measures than the SCR, or (2) the SCR and cardiorespiratory (RLL and HR) measures may be driven by different mechanisms.

The idea of physiological response fractionation is not new and a series of studies conducted by Barry and his colleagues, which refuted Sokolov's classical unitary OR, were largely ignored by the majority of the CIT community (for an exception see Ambach et al., 2011). To accommodate the results of various studies demonstrating response fractionation, Barry developed the preliminary process theory (PPT; i.e., Barry, 1996, 2006, 2009). This theory describes different processing stages that innervate the physiological measures separately, rather than in a unitary fashion. The initial processing stage, stimulus registration, is triggered by the presentation of a stimulus and functions on an all-or-none basis. It is the beginning of the sequential stimulus processing and is reflected by a deceleration of the heart rate (the first evoked cardiac response to the event). The output of this stage then triggers the parallel processing of stimulus novelty and intensity and while novelty processing is reflected by a respiratory pause, intensity processing is reflected in peripheral vasoconstriction (the peripheral pulse amplitude response). The interaction of stimulus novelty and intensity then generates the occurrence of a phasic OR which is reflected by the SCR. All in all, this theory aims to provide a comprehensive framework for explaining the phenomenon of physiological response fractionation. When applying the PPT to the CIT, it may explain the differential respiration (the critical items are rare and in that sense also novel) and skin conductance (the critical items are significant) responses to the critical, concealed items. It however fails to explain the differential HR responses to concealed information items. Specifically, as the PPT relates HR to the mere process of stimulus registration, all stimuli would be expected to induce a similar deceleration (Ben-Shakhar, Gamer, Iacono, Meijer, & Verschuere, 2015). Consequently, there was a need for another response fractionation model that would better account for the CIT effect.

Response Fractionation Theory

As there is much evidence for the orienting account of the CIT effect based on SCR, but not on the other measures, the question remains which of the previously discussed mechanisms may underlie the RLL and HR measures. One likely candidate is arousal inhibition. Indeed, both the respiratory suppression and deceleration of the HR typically observed in the CIT, have also been observed in several emotional response inhibition studies (e.g., Dan-Glauser & Gross, 2011; Demaree et al., 2006; Gross & Levenson, 1993, 1997). Moreover, the prolonged deceleration of the HR (up to 15 seconds) induced by concealed information items, seems to fit with intentional attempts to inhibit responding, attempt that persist until another item is presented.

Several studies aimed to examine the roles of orienting and inhibition in the CIT. Most of these studies, however, targeted the response inhibition factor (i.e., inhibition of the behavioral component), not the arousal inhibition factor (i.e., inhibition of the physiological component, e.g., Ambach et al., 2008; Elaad & Ben-Shakhar, 1989; Furedy & Ben-Shakhar, 1991; Horneman & O'Gorman, 1985; Kugelmass et al., 1967; Suchotzki, Verschuere, Peth, Crombez, & Gamer, 2015). Ambach et al. (2008), for example, examined the effects of response inhibition by requiring their participants to answer either deceptively or truthfully four seconds after item presentation (see also Verschuere et al., 2009). The deceptive and truthful responses were given both by pressing one of two response-keys and by means of a vocal *yes* or *no* response. This overt response manipulation had a rather drastic effect on the outcomes of the CIT: while the SCR CIT effect was similar in the deceptive and truthful conditions, the RLL and HR CIT effects disappeared in the truthful condition. Similarly, Suchotzki et al. (2015) tried to disentangle orienting and response inhibition by instructing participants to deny knowledge of one crime and admit knowledge of a second crime. Although overt deception was not necessary for the SCR, it was crucial for finding a CIT effect with both RT and fMRI measures. Suchotzki et al. (2015) subsequently reasoned that overt deception was needed for these measures as it increases the need for inhibition. Importantly, however, as Ambach et al. (2008) indicated, the differential response (yes vs. no) in the two conditions may have acted as a confound and influenced the physiological responses (a critique that also holds for Suchotzki et al., 2015). Consequently, it cannot be stated with certainty which mechanism caused the differential findings (e.g., inhibition, overt deception, answer-related processes).

Several other studies aimed to manipulate arousal inhibition rather than response inhibition. An initial attempt was made by Gustafson and Orne (1965), who compared the commonly used "deceive" condition, in which participants were motivated to avoid detection, with an additional "detected" condition in which participants were motivated to be detected. Participants were also given feedback about their performance in the first CIT trial (succeeded vs. not succeeded) before continuing on to the second trial. The results revealed no main effect of motivational state, but an interaction between motivational state and feedback. Specifically, when feedback was compatible with participants' motivational state (e.g., detected by the machine when motivated to be detected), participants were detected significantly less with the electrodermal measure on the second trial, as compared to when feedback was incompatible with their motivational state. It is however unclear whether this feedback effect was moderated by inhibition. Two later studies (Horvath, 1978, 1979), which relied on a card-test paradigm, used similar motivational instructions and also found little support for the role of inhibition. Specifically, Horvath (1979) motivated half of its participants to have their card detected and the other half to avoid detection of their card. Although SCR detection efficiency was higher for examinees trying to be detected, it was highly similar to that of a non-motivated group in Horvath (1978) which suggests that SCR detection efficiency is not contingent on the need for inhibition. Several decades later, Matsuda, Nittono, and Ogawa (2013) manipulated the arousal inhibition factor by using a disclosure manipulation. Specifically, participants witnessed how one of their stolen (i.e., critical) items was disclosed to the experimenter. Importantly, this disclosure was reasoned to remove the need to inhibit experienced arousal during the CIT. Still, as all participants were tested on "stolen" mock-crime items, it may be argued that not all attempts at arousal inhibition were successfully eliminated. While the results revealed no effect on the SCR and HR measures, the RLL CIT effect disappeared when tested on previously disclosed items. Two more recent studies (Elaad, 2013; Zvi, Nachson, & Elaad, 2012) manipulated guilty and informed innocent participants' state of mind (coping or cooperative). The coping instructions were reasoned to increase a defensive motivation and attempts at arousal inhibition. Importantly, however, as all participants were motivated to prove their innocence, also participants in the cooperative condition might have attempted to inhibit their responses. While the state of mind had no influence on the RLL, larger SCRs were observed when participants tried to cope with the CIT. Taken together, the results of the above discussed studies were inconsistent. Importantly, it is unclear whether all attempts at arousal inhibition were eliminated and whether the size of the orienting response was unaffected. Consequently, it cannot be concluded with certainty which of the mechanisms caused the differential findings.

In an attempt to overcome these potential weaknesses, klein Selle, Verschuere, Kindt, Meijer, and Ben-Shakhar (2016) manipulated the arousal inhibition factor by contrasting the motivation to conceal with the motivation to reveal. These contrasting motivational states were induced using a suspect versus a witness role-playing scenario. Specifically, participants were either assigned the role of a suspect and motivated to *avoid detection* by *concealing* the crime-related information (as in typical CIT studies), or assigned the role of a witness and motivated to *be detected* by *revealing* the crime-related information. Importantly, as the enhanced arousal elicited by the concealed critical items was expected to be threatening to suspects, but not to witnesses, only suspects should inhibit responses. On the other hand, as the significance of the critical items was expected to be equal in the two conditions, suspects and witnesses should show a similar OR to these items. The results confirmed the authors' prediction by showing a similar increase in the SCR (elicited by the critical stimuli) in the two conditions. The RLL and HR, on the other hand, suppressed only in the suspect condition suggesting that these measures are driven by arousal inhibition.

In a follow-up study, klein Selle et al. (2017a) extended their earlier work to the autobiographical version of the CIT. Thus, instead of relying on mock-crime related items, they relied on personally related items. The motivational manipulation however remained the same: while half of the participants were motivated to *conceal* their personal items, the other half was motivated to *reveal* their personal items. Further, in order to allow for a more definite conclusion regarding the roles of orienting and inhibition, item significance was manipulated by including both high and low salient personal items. Corroborating the earlier findings, the SCR increased similarly in both motivational conditions, while the RLL and HR suppressed only when motivated to conceal. Moreover, while the SCR was sensitive to item-salience (as predicted from OR theory), the RLL and HR were not. The results of these two studies led the authors to formulate a response fractionation model which holds that, in the CIT, the SCR is driven by orienting, while the RLL and HR are driven by arousal inhibition.

Evaluation of the Response Fractionation Theory

The above presented response fractionation model can explain why several previous studies found divergent effects of their manipulations on the SCR and cardiorespiratory (RLL and HR) measures (e.g., Ambach et al., 2011; Ben-Shakhar & Elaad, 2002). It can further explain why the correlations between the different response-measures are low (Gamer, Godert et al., 2008; Gamer, Verschuere et al., 2008). The response fractionation model can also account for a number of more specific findings. First, as the model suggests that only the SCR reflects an orienting response (which is known to habituate) it can explain why this measure is more sensitive to habituation than the RLL and HR (e.g., Ben-Shakhar & Elaad, 2002; Elaad & Ben-Shakhar, 1997; Gamer, Godert et al., 2008). Second, as the model suggests that the HR reflects inhibition, it can explain why the typically observed deceleration may last for 15 seconds, rather than only 5 seconds as predicted by orienting theory (Richards & Casey, 1992). Finally, it may explain why the RLL and HR measures are more resistant to countermeasures than the SCR (Ben-Shakhar & Dolev, 1996; Honts, Devitt, Winbush, & Kircher, 1996; Peth, Suchotzki, & Gamer, 2016). Countermeasures are deliberate attempts to distort the physiological responses and are most effective when examinees aim to enhance responses to the neutral control items. This can be accomplished either by physical means (e.g., biting the tongue, wiggling the toes) or by mental means (e.g., recalling sad events, exercising mental arithmetic). Importantly, these methods may increase the saliency of the control items and also increase the size of the orienting response to these items (as reflected by the SCR). Consequently, SCR differentiation may decrease. Attempts at arousal inhibition (when viewing the critical items), on the other hand, are unlikely to be affected (as reflected by the RLL and HR). Taken together, the response fractionation model can explain a number of old findings, even those that previously seemed contradictory. This ability is a key feature of a good theory and is a testimony to its generalizability.

When digging into the CIT literature, one finds that there are also a number of previous findings that cannot be readily explained by our model. For example, Zaitsu (2016) found the CIT effect with the RLL, but not with the SCR and HR, to be stronger in the field than in the laboratory. Similarly, the inhibition manipulation applied by Matsuda et al. (2013) affected the RLL, but not the SCR and HR. This particular fractionation of responses points to the possibility that the RLL and HR are driven by different processes, while our model assumes that they are driven by the same mechanism. Alternatively, the RLL-HR dissociation may also reflect measurement error. Moreover, it bears mentioning that the artificial nature of the laboratory studies may not have revealed the mechanisms underlying physiological responding in real-life CIT examinations. Suzuki, Nakayama, and Furedy (2004), for example, noted that respiratory apnea occurs rarely in the lab, but frequently in the field and may reflect an emotional factor. Hence, there may be other yet-to-be-identified factors that play a role in forensic applications of the CIT.

At the beginning of this chapter we mentioned several explicit criteria that can be used to evaluate the quality and utility of current CIT theory: parsimony, precision, testability and empirical validity. First: parsimony. The criterion of parsimony is one of simplicity and stems from the work of the English philosopher and theologian William of Occam (1284-1347). In short, it states that a simpler or more parsimonious theory is preferred over a complex one. Theories gain power when they can explain much data with a few constructs. Second, a good theory should be precise, especially in psychology. Specifically, its constructs should be explicitly and clearly defined, making the theory understandable and free from ambiguities. If different researchers can't agree about its predictions, the theory is useless because it cannot be evaluated. Third, a good theory should be testable. If a theory cannot be tested, it can't be confirmed nor refuted. Finally, a good theory should fit the empirical data it aims to explain. When applying these criteria to the response fractionation theory of the CIT, it seems that while it is less parsimonious than the unitary theories, the criterion of parsimony is nevertheless largely satisfied. Indeed, the theory describes only two underlying mechanisms and includes no unnecessary constructs which are not a vital part of the theory. The theory may however become more complex when future research will also try to uncover the mechanisms underlying other types of physiological or behavioral measures and/or some of the currently unexplained research findings (Matsuda et al., 2013; Zaitsu, 2016). Similarly, also the criterion of testability seems to be satisfied. Indeed, the two studies by klein Selle et al. (2016, 2017a) successfully tested two differing predictions. Moreover, several other predictions that can be generated from the theory could be easily tested in future studies (see Future directions). The criterion of precision, on the other hand, seems only partly satisfied. Specifically, although the orienting and arousal inhibition factors are clearly defined, the concept of significance remains somewhat ambiguous (see above), context-dependent and requires a more precise definition. Finally, the criterion of empirical validity seems to be only partly satisfied. As discussed above, although the response fractional model can explain a wide variety of previous findings, several findings are inconsistent with the theory. Taken together, the CIT fractionation theory is strong in the sense of being parsimonious, and testable. At the same time, more empirical validation is needed and some of its concepts can be formulated with more precision.

Future directions

More studies are needed to verify the response fractionation theory. This future line of research could take several directions. First, the results found in the klein Selle et al. (2016, 2017a) studies should be replicated in other laboratories. Second, different manipulations of arousal inhibition, or orienting should be tested. Third, other predictions derived from the theory should be experimentally investigated. For example, if the RLL and HR measures reflect attempts at arousal inhibition, they could possibly also be sensitive to manipulations of response inhibition (e.g., a deceptive verbal response, see Verschuere et al., 2009). Similarly, detection efficiency using these measures would be expected to be enhanced for individuals with poor inhibitory skills – poor skills will lead to greater efforts to inhibit and enhanced responses. Future studies could test this by identifying such individuals using a preliminary screening test (see also Matsuda, Ogawa, Tsuneoka, & Verschuere, 2015; Noordraven & Verschuere, 2013).

Furthermore, as research progresses, the response fractionation model is expected to expand and include other measures and their mechanisms. This development is crucial as recent CIT studies have not relied only on ANS measures, but also on central nervous system and behavioral measures (see introduction). An increasingly popular measure is the P300 component of the ERP. Although the P300, like the orienting response, is affected by stimulus novelty and significance (Donchin, 1981; Kubo & Nittono, 2009), its amplitude has also been shown to be sensitive to inhibition (Polich, 2007). These findings are supported by Rosenfeld, Ozsan, & Ward, (2017) who replicated klein Selle et al. (2016) with ERP measures. Their results indicated that both orienting and inhibition contribute to the P300 CIT effect. Specifically, while orienting only (in the witness condition) was sufficient to induce enlarged P300s to the critical compared to the control items, the critical-control difference was larger when both orienting and inhibition played a role (in the suspect condition). In contrast to klein Selle et al. (2016), however, Rosenfeld et al. (2017) had participants watch a video of the crime in addition to reading a fake newspaper article. Hence, the authors argue that their results may also be explained by differences in item processing caused by the video. Another recently used measure that is both cheap and easy to implement is reaction time (RT). No sensors or electrodes need to be attached – all that is needed is a computer with software that can record RT. The underlying mechanisms of the RT-CIT, however, remain to be explored; while research suggests a pivotal role of response inhibition (Seymour & Schumacher, 2009; Verschuere & De Houwer, 2011), the orienting factor hasn't been properly investigated (but see Suchotzki et al., 2015). Although RTs are easily obtained, examinees are aware that their responses are being recorded and this awareness may induce attempts at countermeasures. Hence, there seems to be a need for measures that can be obtained covertly. Covert respiration measures were already successfully applied by Elaad and Ben-Shakhar (2009). These authors used hidden respiratory transducers in the seat and the back support of the examination chair. Likewise, eye-tracking technology may be used to covertly detect concealed knowledge. Peth, Kim, and Gamer (2013) already suggested that while eye fixations may be more related to an initial orienting response, eye-blinks might reflect processes related to inhibition. Support for the latter claim was provided by a second study of Peth et al. (2016). These authors found that mental countermeasures, that require cognitive effort and inhibition, lead to a similar degree of blinking suppression as the presentation of critical, crime-related details. It should be noted however that the available CIT studies examining eye movements are scarce and the validity estimates are only weak to moderate (see also Schwedes & Wentura, 2012, 2016). More promising validity estimates were obtained using a novel CIT paradigm that combines both simultaneous and serial presentation of the stimuli (see Lancry, Nahari, Ben-Shakhar, & Pertzov, 2017). Interestingly, these authors found an initial attraction of eye gaze (which may reflect orienting) to the critical items followed by a strong repulsion of eye gaze (which may reflect inhibition). Taken together, the research on the underlying mechanisms of several central nervous and behavioral measures is scarce. Hence, future studies are needed to clarify which mechanisms increase the P300, delay the RT and direct our eyes to the concealed items.

Summary and conclusions

A scientific test is much stronger with a solid theory at its base. In the present chapter we therefore reviewed the different accounts of the CIT and covered the theoretical development over time. Although many studies supported the orienting-based theories, most of them were based solely on the SCR measure. Moreover, several research findings revealed a divergence between the various response measures. This led to the idea of physiological response fractionation. Based on the results of two studies, klein Selle et al. (2016, 2017a) accordingly presented a response fractionation model in which the SCR is assumed to reflect an OR and the RLL and HR measures are assumed to reflect attempts at arousal inhibition.

Still, future research is needed to verify and expand current CIT theory – to test differing predictions, to determine the mechanisms underlying other physiological and behavioral measures and to examine whether the theory holds under real-life circumstances. A strong theory will not only benefit CIT researchers and practitioners, but (hopefully) may also encourage a wider use of the test.

References

Ambach, W., Stark, R., Peper, M., & Vaitl, D. (2008). Separating deceptive and orienting components in a Concealed Information Test. *International Journal of Psychophysiology*, *70,* 95–104. doi: 10.1016/j.ijpsycho.2008.07.002

Ambach, W., Stark, R., & Vaitl, D. (2011). An interfering n-back task facilitates the detection of concealed information with EDA but impedes it with cardiopulmonary physiology. *International Journal of Psychophysiology, 80*, 217–226. doi: 10.1016/j.ijpsycho.2011.03.010.

Baker, C. A. (2008). Differentiating attention *and* motor system-based mechanisms underlying concealed knowledge detection (Doctoral dissertation). Retrieved from http://search.proquest.com/docview/304661115

Barry, R. J. (1981). Signal value and preliminary processes in OR elicitation. *Pavlovian Journal of Biological Science, 16,* 116–150. doi: 10.1007/BF03003219

Barry, R. J. (1996). Preliminary process theory: towards an integrated account of the psychophysiology of cognitive processes. *Acta Neurobioliae Experimentalis, 56*, 469–484.

Barry, R. J. (2006). Promise versus reality in relation to the unitary orienting reflex: A case study examining the role of theory in psychophysiology. *International Journal of Psychophysiology, 62*, 353–366. doi: 10.1016/j.ijpsycho.2006.01.004

Barry, R. J. (2009). Habituation of the orienting reflex and the development of preliminary process theory. *Neurobiology of Learning and Mem*ory, *92*, 235–242. doi: 10.1016/j.nlm.2008.07.007

Ben-Shakhar, G. (1977). A further study of dichotomization theory in detection of information, *Psychophysiology, 14*, 408–413. doi: 10.1111/j.1469-8986.1977.tb02974.x

Ben-Shakhar, G. (1980). Habituation of the orienting response to complex sequences of stimuli. *Psychophysiology, 17,* 524–534. doi: 10.1111/j.1469-8986.1980.tb02292.x

Ben-Shakhar, G. (1994). The roles of stimulus novelty and significance in determining the electrodermal orienting response: Interactive vs. additive approaches. *Psychophysiology*, *31*, 402–411. doi: 10.1111/j.1469-8986.1994.tb02448.x

Ben-Shakhar, G., & Dolev, K. (1996). Psychophysiological detection through the guilty knowledge technique: effects of mental countermeasures. *Journal of Applied Psychology, 81*, 273–281. doi: 10.1037/0021-9010.81.3.273

Ben-Shakhar, G., & Elaad, E. (2002). Effects of questions' repetition and variation on the efficiency of the guilty knowledge test: A reexamination. *Journal of Applied Psychology, 87*, 972–977. doi: 10.1037/0021-9010.87.5.972.

Ben-Shakhar, G., Frost, R., Gati, I., & Kresh, Y. (1996). Is an apple a fruit? Semantic relatedness as reflected by psychophysiological responsivity. *Psychophysiology, 33*, 671–679. doi: 10.1111/j.1469-8986.1996.tb02363.x

Ben-Shakhar, G., & Furedy, J. J. (1990). Theories and applications in the detection of deception: A psychophysiological and international perspective. New York, US: Springer Verlag Publishing. doi: 10.1007/978-1-4612-3282-7

Ben-Shakhar, G., Gamer, M., Iacono, W., Meijer, E., & Verschuere, B. (2015). Preliminary process theory does not validate the comparison question test: a comment on Palmatier and Rovner. *International Journal of Psychophysiology, 95,* 16–19. doi: 10.1016/j.ijpsycho.2014.08.582

Ben-Shakhar, G., & Gati, I. (1987). Common and distinctive features of verbal and pictorial stimuli as determinants of psychophysiological responsivity. *Journal of Experimental Psychology: General, 116*, 91–105. doi: 10.1037/0096-3445.116.2.91

Ben-Shakhar, G., & Gati, I. (2003). The effects of serial position and frequency of presentation of common stimulus features on orienting response reinstatement. *Psychophysiology, 40,* 139–145. doi: 10.1111/1469-8986.00014

Ben-Shakhar, G., Gati, I., Ben-Bassat, N., & Sniper, G. (2000). Orienting response reinstatement and dishabituation: The effects of substituting, adding and deleting components of nonsignificant stimuli. *Psychophysiology, 37,* 102–110. doi: 10.1111/1469-8986.3710102

Ben-Shakhar, G., & Lieblich, I. (1982). The dichotomization theory for differential autonomic responsivity reconsidered. *Psychophysiology, 19,* 277–281. doi: 10.1111/j.1469-8986.1982.tb02562.x

Ben-Shakhar, G., Lieblich., I., & Kugelmass, S. (1975). Detection of information and GSR habituation: An attempt to derive detection efficiency from two habituation curves. *Psychophysiology*, *12*, 283–288. doi: 10.1111/j.1469-8986.1975.tb01291.x

Bernstein, A. S. (1979). The orienting response as novelty and significance detector: Reply to O'Gorman. *Psychophysiology*, *16*, 263–273. doi: 10.1111/j.1469-8986.1979.tb02989.x

Bradley, M. T., & Janisse, M. P. (1981). Accuracy demonstrations, threat, and the detection of deception: cardiovascular, electrodermal, and papillary measures. *Psychophysiology*, *18*, 307–315. doi: 10.1111/j.1469-8986.1981.tb03040.x

Coles, M. G. H., & Duncan-Johnson, C. C. (1975). Cardiac activity and information processing: The effects of stimulus significance and detection and response requirements. *Journal of Experimental Psychology: Human Perception and Performance, 1,* 418–428. doi: 10.1037/0096-1523.1.4.418

Cutrow, R. J., Parks, A., Lucas, N., & Thomas, K. (1972). The objective use of multiple physiological indices in the detection of deception. *Psychophysiology, 9,* 578–587. doi: 10.1111/j.1469-8986.1972.tb00767.x

Dan-Glauser, E. S., & Gross, J. J. (2011). The temporal dynamics of two response focused forms of emotion regulation: experiential, expressive, and autonomic consequences. *Psychophysiology, 48*, 1309–1322. doi: 10.1111/j.1469-8986.2011.01191.x

Davis, R. C. (1961). Physiological responses as a means of evaluating information. In: A. D. Biderman & H. Zimmer (Eds.), *The manipulation of human behavior* (pp. 142–168). New York: John Wiley and Sons.

Demaree, H. A., Schmeichel, B. J., Robinson, J. L., Pu, J., Everhart, D. E., & Berntson, G. G. (2006). Up- and down-regulating facial disgust: affective, vagal, sympathetic, and respiratory consequences. *Biological Psychology, 71*, 90–99. doi: 10.1016/j.biopsycho.2005.02.006

Dindo, L., & Fowles, D. C. (2008). The skin conductance orienting response to semantic stimuli: significance can be independent of arousal. *Psychophysiology*, *45*, 111–8. doi: 10.1111/j.1469-8986.2007.00604.x

Donchin, E. (1981). Surprise! . . . surprise? *Psychophysiology, 18,* 493–513. doi: 10.1111/j.1469-8986.1981.tb01815.x

Elaad, E. (2013). Effects of goal-and task-oriented motivation in the guilty action test. *International Journal of Psychophysiology, 88,* 82–90. doi: 10.1016/j.ijpsycho.2013.02.004

Elaad, E., & Ben-Shakhar, G. (1989). Effects of motivation and verbal response type on psychophysiological detection of information. *Psychophysiology*, *26*, 442–451. doi: 10.1111/j.1469-8986.1989.tb01950.x

Elaad, E., & Ben-Shakhar, G. (2009). Countering countermeasures in the Concealed Information Test using covert respiration measures. *Applied Psychophysiology and Biofeedback*, *34,* 197–209. doi: 10.1007/s10484-009-9090-5

Elaad, E., & Ben-Shakhar, G. (1997). Effects of item repetitions and variations on the efficiency of the guilty knowledge test. *Psychophysiology, 34,* 587–596. doi: 10.1111/j.1469 8986.1997.tb01745.x

Ellson, D. C., Burke, C. G., Davis, R. C., & Saltzman, I. J. (1952). A report of research on detection of deception. Contract NG onr-18011, Office of Naval Research.

Feld, G. B., Specht, M., & Gamer, M. (2010). Differential electrodermal and phasic heart rate responses to personally relevant information: Comparing sleep and wakefulness. *Sleep and Biological Rhythms, 8,* 72–78. doi: 10.1111/j.1479-8425.2010.00434.x

Furedy, J. J., & Ben-Shakhar, G. (1991). The roles of deception, intention to deceive, and motivation to avoid detection in the psychophysiological detection of guilty knowledge. *Psychophysiology, 28,* 163–171. doi: 10.1111/j.1469-8986.1991.tb00407.x

Gamer, M. (2011). Detecting concealed information using autonomic measures. In: B. Verschuere, G. Ben-Shakhar, & E. Meijer (Eds.), *Memory detection: theory and application of the Concealed Information Test* (pp. 27–45). Cambridge, UK: Cambridge University Press. doi: 10.1017/CBO9780511975196.003

Gamer, M., Godert, H. W., Keth, A., Rill, H-G., & Vossel, G. (2008). Electrodermal and phasic heart rate responses in the guilty actions test: comparing guilty examinees to informed and uninformed innocents. *International Journal of Psychophysiology*, *69*, 61–68. doi: 10.1016/j.ijpsycho.2008.03.001

Gamer, M., Verschuere, B., Crombez, G., & Vossel, G. (2008). Combining physiological measures in the detection of concealed information. *Physiology and Behavior, 95*, 333–340. doi: 10.1016/j.physbeh.2008.06.011

Gati, I., & Ben-Shakhar, G. (1990). Novelty and significance in orientation and habituation: A feature-matching approach. *Journal of Experimental Psychology: General, 119*, 251–263. doi: 10.1037/0096-3445.119.3.251

Geldreich, E. W. (1941). Studies of the use of the galvanic skin response as a deception indicator. *Transactions of the Kansas Academy of Science, 44*, 346–351. doi: 10.2307/3624902

Geldreich, E. W. (1942). Further studies of the use of the galvanic skin response as a deception indicator. *Transactions of the Kansas Academy of Science, 45,* 279–284. doi: 10.2307/3625011

Greene, R., Dengerink, H., & Staples, S. (1974). To what does the terminal orienting response respond? *Psychophysiology, 11*, 639–646. doi: 10.1111/j.1469-8986.1974.tb01131.x

Gross, J. J., & Levenson, R. W. (1993). Emotional suppression: physiology, self-report, and expressive behavior. *Journal of Personality and Social Psychology, 64*, 970–986. doi: 10.1037//0022-3514.64.6.970

Gross, J. J., & Levenson, R. W. (1997). Hiding feelings: the acute effects of inhibiting negative and positive emotion. *Journal of Abnormal Psychology, 106*, 95–103. doi: 10.1037/0021-843X.106.1.95

Gustafson, L. A., & Orne, M. T. (1963). Effects of heightened motivation on the detection of deception. *Journal of Applied Psychology, 47,* 408–411. doi: 10.1037/h0041899

Gustafson, L. A., & Orne, M. T. (1965).The effects of perceived role and role success on the detection of deception. *Journal of Applied Psychology*, *49*, 412–417. doi: 10.1037/h0022798

Honts, C. R., Devitt, M. K., Winbush, M., & Kircher, J. C. (1996). Mental and physical countermeasures reduce the accuracy of the concealed knowledge test. *Psychophysiology, 33*, 84–92. doi: 10.1111/j.1469-8986.1996.tb02111.x

Horneman, C. J., & O'Gorman, J. G. (1985). Detectability in the card test as a function of the subject's verbal response. *Psychophysiology, 22,* 330–333. doi: 10.1111/j.1469-8986.1985.tb01609.x

Horvath, F. (1978). An experimental comparison of the psychological stress evaluator and the galvanic skin response in detection of deception. *Journal of Applied Psychology, 63,* 338–344. doi: 10.1037/0021-9010.63.3.338

Horvath, F. (1979). Effect of different motivational instructions on detection of deception with the psychological stress evaluator and the galvanic skin response. *Journal of Applied Psychology, 64,* 323–330. doi: 10.1037/0021-9010.64.3.323

Iacono, W. G., Boisvenu, G. A., Fleming, J. A. (1984). Effects of diazepam and methylphenidate on the electrodermal detection of guilty knowledge. *Journal of Applied Psychology, 69,* 289–299. doi: 10.1037/0021-9010.69.2.289

Jokinen, A., Santtila, P., Ravaja, N., & Puttonen, S. (2006). Salience of guilty knowledge test items affects accuracy in realistic mock crimes. *International Journal of Psychophysiology*, *62*, 175–184. doi: 10.1016/j.ijpsycho.2006.04.004

klein Selle, N., Verschuere, B., Kindt, M., Meijer, E. H., & Ben-Shakhar, G. (2016). Orienting versus inhibition in the Concealed Information Test: Different cognitive processes drive different physiological measures. *Psychophysiology, 53*, 579–590. doi: 10.1111/psyp.12583

klein Selle, N., Verschuere, B. J., Kindt, M., Meijer, E. H., & Ben-Shakhar, G. (2017a). Unraveling the roles of orienting and inhibition in the Concealed Information Test. *Psychophysiology.* Advance online publication. doi: 10.1111/psyp.12825

klein Selle, N., Verschuere, B. J., Kindt, M., Meijer, E. H., Nahari, T., & Ben-Shakhar, G. (2017b). *Memory detection: The effects of emotional stimuli.* Manuscript submitted for publication.

Kubo, K., & Nittono, H. (2009). The role of intention to conceal in the P300 based concealed information test. *Applied Psychophysiology and Biofeedback*, *34*, 227–235. doi: 10.1007/s10484-009-9089-y

Kugelmass, S. S., & Lieblich, I. (1966). Effects of realistic stress and procedural interference in experimental lie detection. *Journal of Applied Psychology, 50*, 211–216. doi: 10.1037/h0023324.

Lancry, O. C., Nahari, T., Ben-Shakhar, G., & Pertzov, Y. (2017). *Detecting concealed memory of personally familiar faces via eye movements*. Manuscript in preparation.

Lieblich, I., Kugelmass, S., & Ben-Shakhar, G. (1970). Efficiency of GSR detection of information as a function of stimulus set size. *Psychophysiology*, *6*, 601–608. doi: 10.1111/j.1469-8986.1970.tb02249.x

Kugelmass, S., Lieblich, I., & Bergman, Z. (1967). The role of "lying" in psychophysiological detection. *Psychophysiology, 3,* 312–315. doi: 10.1111/j.1469-8986.1967.tb02711.x

Lykken, D. T. (1959). The GSR in the detection of guilt. *Journal of Applied Psychology*, *43*, 385–388. doi: 10.1037/h0046060

Lykken, D. T. (1960). The validity of the guilty knowledge technique: The effects of faking. *Journal of Applied Psychology*, *44*, 258–262. doi: 10.1037/h0044413

Lykken, D. T. (1974). Psychology and the lie detector industry. *American Psychologist*, *29*, 725–739. doi: 10.1037/h0037441

Matsuda, I., Nittono, H., & Ogawa, T. (2013). Identifying concealment-related responses in the concealed information test. *Psychophysiology*, *50*, 617–626. doi: 10.1111/psyp.12046

Matsuda, I., Ogawa, T., Tsuneoka, M., & Verschuere, B. (2015). Using pretest data to screen low-reactivity individuals in the autonomic-based concealed information test. *Psychophysiology, 52,* 436–439. doi: 10.1111/psyp.12328

Meijer, E. H., klein Selle, N., Elber, L., & Ben-Shakhar, G. (2014). Memory detection with the Concealed Information Test: A Meta Analysis of Skin Conductance, Respiration, Heart Rate, and P300 data. *Psychophysiology, 51*, 879–904. doi: 10.1111/psyp.12239

Messick, S. (1995). Validity of psychological assessment: Validation of inferences from persons' responses and performances as scientific inquiry into score meaning. *American Psychologist, 50,* 741–749. doi: 10.1037/0003-066X.50.9.741

Noordraven, E., & Verschuere, B. (2013). Predicting the sensitivity of the Reaction Time-based Concealed Information Test. *Applied Cognitive Psychology, 27*, 328–335. doi: 10.1002/acp.2910

Pennebaker, J. W., & Chew, C. H. (1985). Behavioral-inhibition and electrodermal activity during deception. *Journal of Personality and Social Psychology 49*, 1427–1433. doi: 10.1037/0022-3514.49.5.1427

Peth, J., Kim, J. S. C., & Gamer, M. (2013). Fixations and eye-blinks allow for detecting concealed crime related memories. *International Journal of Psychophysiology, 88*, 96-103. doi.org/10.1037/1076-898X.9.4.261

Peth, J., Suchotzki, K., & Gamer, M. (2016). Influence of countermeasures on the validity of the Concealed Information Test. *Psychophysiology. Advance online publication.* doi: 10.1111/psyp.12690

Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology, 118,* 2128–2148. doi: 10.1016/j.clinph.2007.04.019

Richards, J. E., & Casey, B. J. (1992). Development of sustained visual attention in the human infant. In: B. A. Campbell, H. Hayne, and R. Richardson. *Attention and information processing in infants and adults: Perspectives from human and animal research* (pp. 30–60). Hillsdale, NJ: Lawrence Erlbaum Associates.

Rosenfeld, J. P., Ozsan, I., Ward, A. C. (2017). P300 amplitude at Pz and N200/N300 latency at F3 differ between participants simulating suspect versus witness roles in a mock crime. *Psychophysiology*. Advance online publication. doi: 10.1111/psyp.12823

Schwedes, C., & Wentura, D. (2012). The revealing glance: Eye gaze behavior to concealed information. *Memory & Cognition, 40*, 642–651. doi: 10.3758/s13421-011-0173-1

Schwedes, C., & Wentura, D. (2016). Through the eyes to memory: Fixation durations as an early indirect index of concealed knowledge. *Memory & Cognition, 44*, 1244–1258. doi: 10.3758/s13421-016-0630-y

Seymour, T. L., & Schumacher, E. H. (2009). Electromyographic evidence for response conflict in the exclude recognition task. *Cognitive, Affective, & Behavioral Neuroscience, 9*, 71–82. doi: 10.3758/CABN.9.1.71

Siddle, D. A. T., & Lipp, O. V. (1997). Orienting, habituation, and information processing: The effects of omission, the role of expectancy, and the problem of dishabituation. In: P. J. Lang, R. F. Simons, & M. T. Balaban (Eds.). *Attention and orienting: Sensory and motivational processes* (pp. 23-40). Mahwah, NJ: Lawrence, Erlbaum Associates, Publishers.

Sokolov, E. N. (1963). *Perception and the conditioned reflex.* New York: Macmillan.

Sokolov, E. N. (1966). Orienting reflex as information regulator. In A. Leontyev, A. Luria, & A. Smirnov (Eds.), *Psychological research in U.S.S.R.* (pp 334–360). Moscow: Progress Publishers.

Stormark., K. M. (2004). Skin conductance and heart-rate responses as indices of covert face recognition in preschool children. *Infant and Child Development, 13*, 423–433. doi: 10.1002/icd.368

Suchotzki, K., Verschuere, B., Peth, J., Crombez, G., & Gamer, M. (2015). Manipulating item proportion and deception reveals crucial dissociation between behavioral, autonomic and neural indices of concealed information. *Human Brain Mapping, 36,* 427–39. doi: 10.1002/hbm.22637

Suzuki, R., Nakayama, M., & Furedy, J. J. (2004). Specific and reactive sensitivities of skin resistance response and respiratory apnea in a Japanese concealed information test (CIT) of criminal guilt. *Canadian Journal of Behavioral Science, 36*, 202–209.

Thackray, R. I., & Orne, M. T. (1968). A comparison of physiological indices in detection of deception. *Psychophysiology, 4,* 329–339. doi: 10.1111/j.1469-8986.1968.tb02775.x

Tversky, A. (1977). Features of similarity. *Psychological Review, 84*, 327–352. doi: 10.1037/0033-295X.84.4.327

Verschuere, B., & Ben-Shakhar, G. (2011). Theory of the concealed information test. In: B. Verschuere, G. Ben-Shakhar, & E. Meijer (Eds.), *Memory detection: theory and application of the Concealed Information Test* (pp. 128–148). Cambridge, UK: Cambridge University Press. doi: 10.1017/CBO9780511975196.008

Verschuere, B., Crombez, G., Koster, E. H., Van Bockstaele, B., & De Clercq, A. (2007). Startling secrets: startle eye blink modulation by concealed crime information. *Biological Psychology, 76,* 52–60. doi: 10.1016/j.biopsycho.2007.06.001

Verschuere, B., Crombez, G., Smolders, L., & De Clercq, A. (2009). Differentiating defensive and orienting responses to concealed information: The role of verbalization. *Applied Psychophysiology & Biofeedback*, *34*, 237–244. doi: 10.1007/s10484-009-9093-2

Verschuere, B., & De Houwer, J. (2011). Detecting concealed information in less than a second: response latency-based measures. In: B. Verschuere, G. Ben-Shakhar, & E. Meijer (Eds.), *Memory detection: theory and application of the Concealed Information Test* (pp. 128–148). Cambridge, UK: Cambridge University Press. doi: 10.1017/CBO9780511975196.004

Vico, C., Guerra, P., Robles, H., Vila, J., & Anllo-Vento, L. (2010). Affective processing of loved faces: contributions from peripheral and central electrophysiology. *Neuropsychologia, 48,* 2894–2902. doi: 10.1016/j.neuropsychologia.2010.05.031

Waid, W. M., Orne, E. C., Cook, M. R., & Orne, M. T. (1981). Meprobamate reduces accuracy of physiological detection of deception. *Science, 212,* 71–73. doi: 10.1126/science.7209522

Zaitsu, W. (2016). External validity of Concealed Information Test experiment: Comparison of respiration, skin conductance, and heart rate between experimental and field card tests. *Psychophysiology, 53,* 1100–1107. doi: 10.1111/psyp.12650

Zvi, L., Nachson, I., & Elaad, E. (2012). Effects of coping and cooperative instructions on guilty and informed innocents' physiological responses to concealed information. *International Journal of Psychophysiology, 84,* 140–148. doi: 10.1016/j.ijpsycho.2012.01.022