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An interfering dot-probe task facilitates the detection of mock crime memory in a reaction time (RT)-based concealed information test

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The present study aimed to test the hypothesis that an interfering task in the concealed information test will help the detection of concealed memory based on participants' behavioral performance (e.g. reaction time, error rate). Here, after participants enacted a mock crime, they were introduced to a concealed information test either with or without an interfering dot-probe task. Results showed that the RT-based pure-CIT (without interference) can detect concealed memory well above chance (AUC = .88). The detection efficiency was higher (AUC = .94) in the interference-CIT based on participants' performance of the interfering task. The findings suggested that the elevation of cognitive workload could possibly increase the detection efficiency of concealed memory based on behavioral measures.

1. Introduction

Feigning memory loss or intentionally concealing information may serve to maximize one's personal benefits at the cost of another individual or society. Thus, it is critical to establish an objective test to identify a suspect's true memory status. One method that has been used to evaluate the veracity of one's statement is known as the concealed information test (Lykken, 1959, 1960; for an overview, see Verschuere, Ben-Shakhar, & Meijer, 2011). Originally developed by Lykken, the concealed information test (CIT) was designed to uncover specific crime-relevant information via physiological activities such as skin conductance responses (SCRs). Specifically, the item-of-interest (e.g. the weapon used in the murder, the place where the body was hidden, or the amount of money that was stolen) was embedded among a series of crime-irrelevant stimuli (e.g., other possible weapons that could be used). Since only the criminal possesses the crime-relevant information, the item-of-interest should elicit strong orienting responses (ORs) compared to crime-irrelevant stimuli for guilty suspects. In contrast, for an innocent person who was not involved in the crime, the crime-relevant item response should be processed in a similar way as crime-irrelevant stimuli, thus showing no differentiated responses between these two classes of stimuli. The CIT has been shown to be a valid tool for uncovering information that has personally significant meaning to an examinee (Hu, Hegeman, Landry, & Rosenfeld, 2012; Meijer, Smulders, Johnston, & Merckelbach, 2007), even when the examinee lacks a conscious recognition of that stimulus (e.g. prosopagnosia, Bauer, 1984; Tranel & Damasio, 1985), or the examinee deliberately tries to conceal the knowledge of the stimulus by lying (Ben-Shakhar & Elaad, 2003; Gamer, Kosiol, & Vossel, 2010; Rosenfeld, Hu, & Pederson, 2012; for an overview, see Verschuere et al., 2011).

In the majority of CIT studies physiological measures (both autonomic nervous system and central nervous system activities) have been used as indicators of concealed information, however, the CIT could also be used with behavioral measures such as reaction times (RTs). For instance, Farwell and Donchin (1991) found that in addition to brain activities, RTs could also be used to distinguish concealed information from irrelevant information (for using RTs as an indicator in addition to physiological measures, see also Allen, Iacono, & Danielson, 1992; Gamer, Bauermann, Stoeter, & Vessel, 2007; Gamer, 2011a;

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Gronau, Ben-Shakhar, & Cohen, 2005; Rosenfeld, 2011). However, Farwell and Donchin (1991) argued that RTs may be voluntarily controlled thus may not be a valid tool for memory detection. Seymour, Seifert, Shafto, and Mosmann (2000), for the first time, showed that RT alone is a valid and sensitive indicator for identifying concealed information with individual detection accuracy above 90%, and the RT-CIT paradigm can resist deliberate faking (also see Seymour & Kerlin, 2008). Recently, Verschuere, Crombez, Degrootte, and Rosseel (2010) directly compared the detection efficiency of RT-based CIT and polygraph-based CIT in identifying personally meaningful stimulus such as one's first name. Results suggested that RTs can differentiate probe from irrelevant items even better than skin-conductance responses (SCRs, Cohen's *d*: RTs: 1.97 vs. SCRs: 1.46).

There are arguments for including behavioral measures such as RTs in addition to physiological measure when administering the CIT. First, from a theoretical perspective, the physiological activities during the CIT may not capture all aspects of the psychological processes associated with information concealment. For instance, in the polygraph-based CIT, it has been shown that the electrodermal activity, respiratory, and cardiovascular activities are each related to slightly different aspects of orienting responses in the CIT (see Gamer, 2011b). Moreover, in addition to the dominant role of orienting responses played in the CIT, recent studies have shown that there are other mechanisms that underlie the CIT, such as response conflict/monitoring and response intention (Gamer & Berti, 2010; Hu, Wu, & Fu, 2011; Kubo & Nittono, 2009). Thus, as a classic measure of information processing and cognitive operations (Donders, 1969), RT may provide information about the sum of mental processes underlying CIT (including stimulus evaluation, conflict monitoring and resolution, response preparation, and execution) which may not be entirely measured via existing physiological measures.

Second, from an applied perspective, it has been reported that the CIT's sensitivity for detecting guilty suspects was relatively low compared to its protection for innocents (e.g. Carmel, Dayan, Naveh, Raveh, & Ben-Shakhar, 2003; Elaad, 1990, 2011). The relatively lower level of sensitivity for detecting guilty suspects in polygraph-based CITs could be due to large individual differences in physiological responses (i.e. under-arousal or non-responders, see Gamer, 2011b). This leaves room for improving the CIT's sensitivity by recoding different dependent measures that may complement each other (e.g. Ambach, Bursch, Stark, & Vaitl, 2010; Gamer, Verschuere, Crombez, & Vossel, 2008; Hu & Rosenfeld, 2012; Meijer et al., 2007; Nahari & Ben-Shakhar, 2011). Thus, as discussed above, if RTs can serve as an indicator of the sum of a series of information processing stages underlying the CIT, it may further improve the sensitivity of the CIT.

In the present investigation, we employed the RT-based CIT to further investigate its detection efficiency in identifying concealed information, especially information acquired via a mock crime. Previous RT-based CIT studies, despite their remarkable success, focused mostly on either well-rehearsed items or autobiographical information (see Seymour & Kerlin, 2008; Verschuere et al., 2010). Recently, Visu-Petra, Miclea, and Visu-Petra (2012) showed that when using pictorial stimuli from a mock crime in an RT-based CIT, RTs can accurately detect concealed information. Applications of behavioral measures in CITs using mock crime scenario are important because in the field, not every detail is elaborated on or as salient as one's autobiographical information. Thus, here we aim to further establish the validity and classification efficiency of RT-based CIT using mock crime scenarios.

Another objective of the present investigation was to increase the sensitivity of the CIT. As mentioned above, there have been several studies that have reported relatively low sensitivity of physiological activity-based CITs (e.g. Elaad, 2011). Recently, several strategies have been employed in an attempt to solve this issue. One often-adopted strategy is to record multiple physiological activities simultaneously during the CIT (e.g., skin conductance responses, heart rate, respiration line length, event-related brain potentials (ERPs), see Ambach et al., 2010; Gamer et al., 2008; Hu, Pornpattananangkul, & Rosenfeld, 2013). The hypothesis is that each measure may capture non-overlapping aspects of processes underlying the CIT (e.g. attention, memory retrieval, response monitoring, etc.). Another strategy is to use separate tasks such as the symptom validity test or the autobiographical implicit associate test in addition to the CIT (Hu & Rosenfeld, 2012; Meijer et al., 2007; Nahari & Ben-Shakhar, 2011). This strategy is based on the hypothesis that each task may add non-redundant information in identifying concealed information.

However, fewer attempts have been made to modify the CIT task itself to increase its detection efficiency (but see Ambach, Stark, Peper, & Vaitl, 2008; Ambach, Stark, & Vaitl, 2011; Rosenfeld et al., 2012). The present study aimed to increase the sensitivity of the test by embedding an interfering task within each trial of the CIT. It is hypothesized that as concealing information in the CIT has been shown to be an attention demanding task that involves executive control (Christ, Van Essen, Watson, Brubaker, & McDermott, 2009), participants would be left with fewer cognitive resources for the interfering task. In contrast, processing meaningless, irrelevant stimuli is usually not as demanding as processing personally significant stimuli (e.g. crime details for guilty participants). Thus, the interfering task within each trial of the CIT was hypothesized to increase the cognitive load for guilty participants specifically during to-be-concealed information trials, resulting in inferior performance such as increased errors and prolonged RT to the interfering task.

2. Method

2.1. Participants

Sixty-three participants were recruited through flyers and advertisements at a major university in P. R. China at a compensation rate of 10 CNY/h (approximately 1.61 USD/h). Participants were randomly assigned into either a guilty group ($N = 31$, $M_{age} = 21.6$ years, $SD = 2.88$, 20 males) or an innocent group ($N = 32$, $M_{age} = 20.8$ years, $SD = 2.16$, 17 males). Ten additional participants were excluded from analyses due to a failure to follow instructions or computer program errors. All participants had normal or corrected-to-normal vision and provided informed consents prior to the study.

2.2. Materials

Experimental stimuli were presented in words using E-Prime software on a 17″ LCD screen. Stimuli for the Concealed Information Test consisted of six probes (each referring to one aspect of the mock crime), 24 irrelevant stimuli (unrelated to the crime), and six targets that were unrelated to the crime and required a unique button press response. The irrelevant and target stimuli were matched with their probe counterpart for the number of characters and semantic meanings. Each stimulus was randomly repeated for four times, resulting in a total of 144 ($6 \times 6 \times 4$) stimuli.

For the interference task, a dot-probe task was employed. Participants were asked to judge whether a pair of dots was placed either horizontally "‥" or vertically, ":". These two versions of dots were presented randomly after the presentation of the stimuli (either target, probe, or irrelevant item) with an equal proportion of presentations of each orientation. The stimulus onset asynchrony (SOA), the time interval between the presentation of CIT-item and the dot-probe task, randomly varied from 300 to 800 ms (see Fig. 1B). This SOA was chosen because based on previous ERPs-CIT studies, it has been found that the detectable difference between probe and irrelevant occurred during this time window (e.g. Allen et al., 1992; Rosenfeld, 2011). We thus hypothesized that placing an interfering task within this time window would maximize the interference effects for guilty participants.

2.3. Procedure

After signing consent forms, the guilty group completed five phases of the study: mock crime phase, recall test phase, target word study

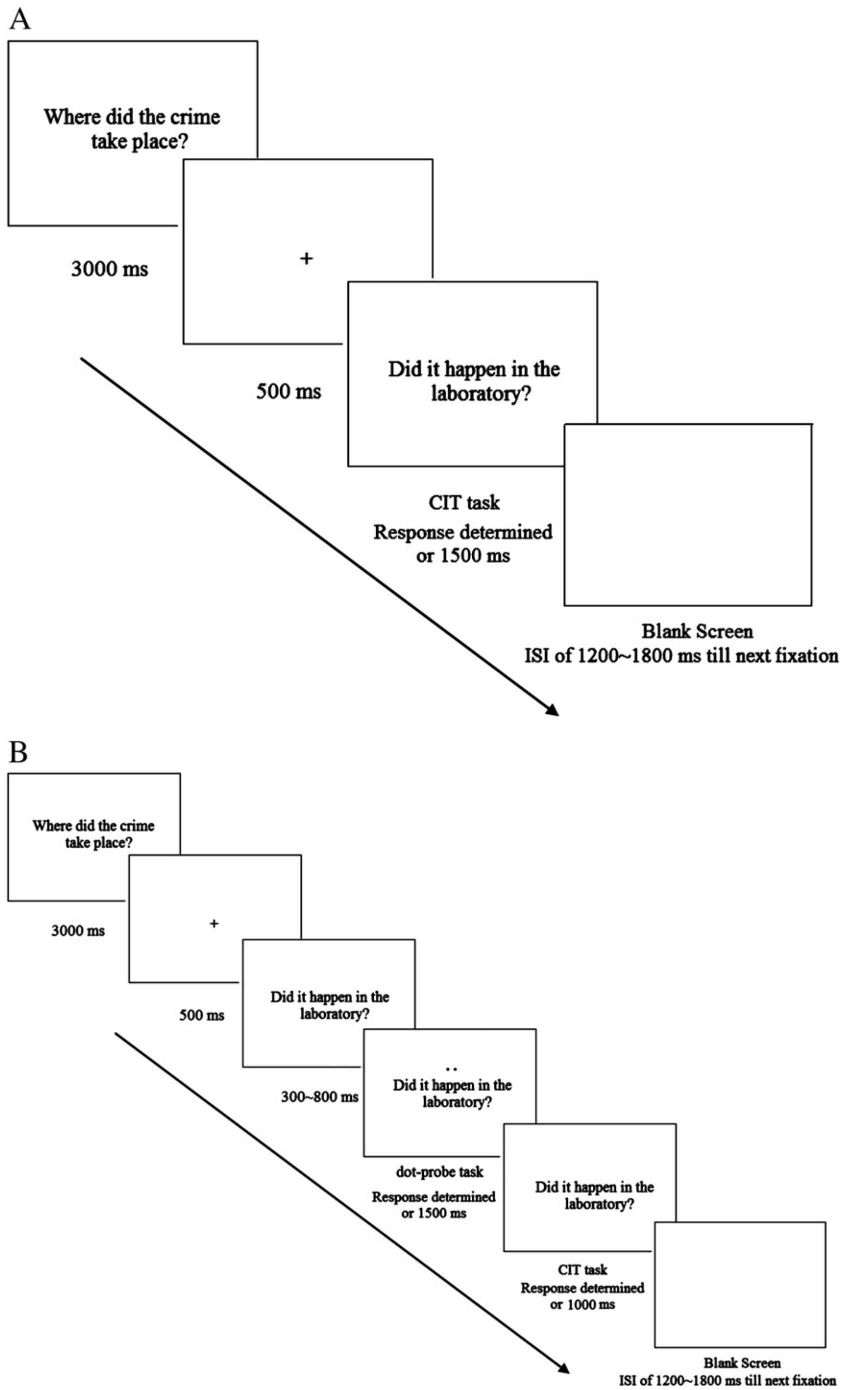

Fig. 1. A: Task structure of the pure RT-based CIT task. B: Task structure of the interference RT-based CIT task.

phase, the CIT-without-interference phase, and the CIT-interference phase. Participants in the innocent group did not experience a mock crime. They just completed the target word study phase, the CIT-without-interference phase, and the CIT-interference phase. The order of the last two CIT tasks was counterbalanced between participants.

2.3.1. Mock crime phase

Participants in the guilty group were instructed to steal a *yellow compact disc* (*CD*) in a *laboratory*. All other crime-relevant information was learned during the mock-crime. During the mock-crime, the door of the laboratory was unlocked but was blocked by a *chair*, which the participants had to move to enter the room. In the laboratory, participants found a key next to a *textbook*. This key was used to unlock the drawer where the CD was located. After opening the drawer, participants unfolded a *music card* (a greeting card that played music) to retrieve the CD. After the participants retrieved the CD, they returned to the waiting room and handed the CD to the experimenter. The probes used in the present experiment were the same (i.e. not randomized) across all guilty participants.

2.3.2. Recall test phase

Next, participants were led to an interrogation room, where the remaining tests were conducted. Participants were asked six questions concerning the six probe details involved in the mock crime and were asked to answer these details truthfully. This was done to ensure that participants encoded the target items during the mock-crime.

2.3.3. Target word study phase

Participants were asked to memorize a set of six words that would serve as the target words in the CIT task. These six words were matched for the number of characters and semantic meaning with the probes and irrelevant from the CIT task. Participants were told that they were to press the key labeled "YES" in response to these words during the CIT. Further, participants were told that the correct responses to this set of words indicate their cooperation with the test. The inclusion of targets forces participants' attention on all words preventing participants from simply disengaging to avoid the guilty words (e.g. Seymour et al., 2000; Verschuere et al., 2010).

2.3.4. Concealed information test without interference

Six series of questions were created, each containing one probe, one target, and four irrelevant stimuli. Each category corresponded to a specific detail from the mock crime (e.g. the "site" question category asked about where the crime took place, see Gronau et al., 2005, p. 149).

Prior to each question category a cue-question appeared for 3000 milliseconds (ms) to orient participants to the class of stimuli that they were going to be questioned on (e.g., "Where did the crime take place?"). Following the cue-question, each trial began with a cross (+) as fixation for 500 ms in the center of the screen, followed by the stimulus-question presentation for 1500 ms. e.g. "Did it happen in the laboratory?". Participants were prompted to respond within this 1500 ms time window. The inter-stimulus-interval was randomly varied between 1200 and 1800 ms (Fig. 1A). Question categories and stimuli within that category were randomly presented to participants.

Participants were instructed to deny any knowledge related to the crime by pressing the "NO" button meaning "I don't know" (based on Verschuere et al., 2010). Thus, innocent participants who had not experienced the mock crime would respond honestly and guilty participants who had completed the mock crime would respond deceptively to the probe items. In addition, participants were to reject the irrelevant stimuli by pressing the same button. Participants were required to press the "YES" button whenever they encountered the targets that they had memorized previously. If participants did not respond prior to the end of the presentation, a feedback message of "too slow" appeared for 1000 ms.

To increase participants' motivation, they were told that only strong-willed and intelligent individuals can beat the lie detector and were promised a monetary reward if they were classified as "innocent" (all participants were given the monetary reward regardless of their performance). Response speed and accuracy were equally emphasized to participants. Three breaks of approximately 3 min were given during the CIT task.

2.3.5. Concealed information test with interference

The stimuli and procedure for this task were the same as those of the CIT except for the addition of the dot-probe task, which was embedded within each trial of the CIT. Specifically, after the presentation of the CIT question, participants waited till a pair of dots was presented (with a SOA of 300–800 ms, see Fig. 1B) either above or below the stimuli-question randomly as either ".." or ":". Participants were required to classify the dots as either ".." by pressing "YES" or ":" by pressing "NO". The pair of dots remained on the screen until a response was registered within a 1500 ms time window. Upon the completion of the dot-probe task, participants were asked to respond to the CIT question, which remained on the screen until a response was registered within 1000 ms. Participants were asked to answer the CIT question in the same manner as in the pure-CIT condition. The importance of both the dot-probe task and the CIT task were equally emphasized (Fig. 2).

3. Results

Trials with errors (in the pure-CIT condition, error means wrong button press to either probe or irrelevant, in the interference-CIT condition, error means incorrect button press to either the dot-probe task or stimuli-questions) were discarded (less than 3%), and RT data that exceeded 3 standard deviation in each stimuli category (probe and irrelevant) within individual were excluded (less than 2%). Furthermore, preliminary analyses revealed no significant effects of task order (all $Fs < 1$, $ps > .05$). Thus all analyses were performed collapsing across this variable.

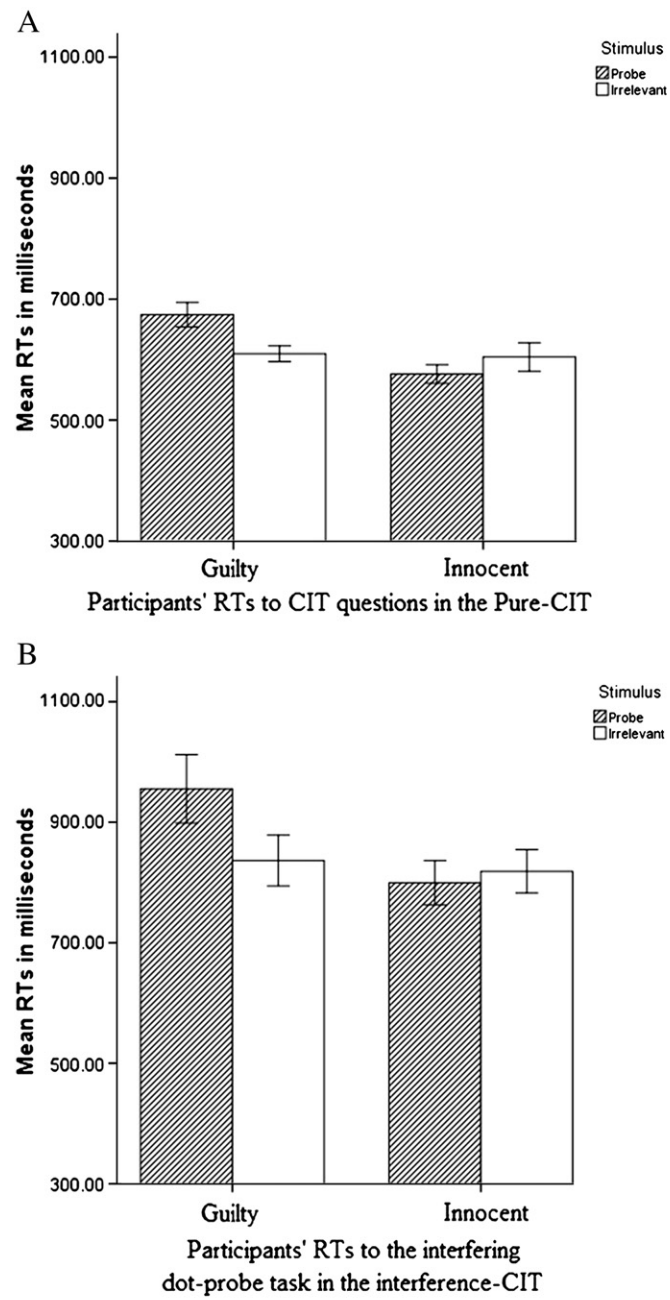

Fig. 2. A: Guilty and innocent participants' mean of reaction times (RTs) for probe and irrelevant questions in the pure-CIT condition. B: Guilty and innocent participants' mean RTs for the dot-probe task as a function of probe and irrelevant question type in the interference-CIT condition. The error bar stands for one standard error.

3.1. Reaction times

To examine any significant differences in RTs, a mix ANOVA with stimulus type (probe vs. irrelevant) as within-subject variables and group (guilty vs. innocent) as a between-subject variable was performed on participant reaction time scores for two CIT conditions: the CIT without interference (pure-CIT) condition and the CIT with interference (interference-CIT) condition.

3.1.1. The pure-CIT condition

In the CIT task, participants' RTs were response latencies to probe and irrelevant questions. A 2 (stimulus type: probe vs. irrelevant as a within-subject variable) by 2 (group: guilty vs. innocent as a between-subject variable) mixed ANOVA revealed a significant main effect of stimulus type: $F(1,61)=21.49$, $p<.001$, $\eta^2=.26$, indicating the probe had longer RTs than irrelevant (*Mean*±*S.E.*: 597.18±9.78 ms vs. 625.14±12.61 ms). The main effect of group was also significant: $F(1,61)=7.99$, $p<.01$, $\eta^2=.12$, suggesting guilty participants generally had longer RTs than innocent participants (*Mean*±*S.E.*: 641.90±15.50 ms vs. 580.42±15.26 ms). Importantly, the stimulus by group interaction was also significant: $F(1,61)=36.73$, $p<.001$, $\eta^2=.38$. Post-hoc tests suggested that this interaction was driven by the probe-irrelevant differences in the guilty group ($t(30)=5.56$, $p<.001$, probe: 674.16±20.13 ms vs. irrelevant: 609.65±13.02 ms). In contrast in the innocent group, the RTs of irrelevant stimuli were unexpectedly larger than the RTs of probe stimuli ($t(31)=2.26$, $p<.05$, probe: 576.12±15.37 ms vs. irrelevant: 584.72±14.55 ms), which may be due to chance as the difference was only 8 ms.

3.1.2. The CIT with interference condition

In the CIT with interference task, participants completed two tasks (the interfering dot-probe task and the CIT task) within one trial. Thus, we ran separate ANOVAs on the RTs associated with these two tasks.

For participants' performance in the dot-probe task, the RTs were participants' response latencies to the dot pair that was associated with either probe or irrelevant stimulus. The 2 (stimulus type: probe vs. irrelevant as a within-subject variable) by 2 (group: guilty vs. innocent as a between-subject variable) mixed ANOVA revealed a significant main effect of stimulus type: $F(1,61)=19.37$, $p<.001$, $\eta^2=.24$, indicating that the probe had longer RTs than irrelevant (*Mean*±*S.E.*: 883.41±33.85 ms vs. 827.33±27.70 ms). Moreover, the stimulus by group interaction was significant: $F(1,61)=24.46$, $p<.001$, $\eta^2=.29$. Post-hoc tests suggested that this interaction was driven by significant probe-irrelevant differences in the guilty group ($t(30)=4.83$, $p<.001$, probe: 955.39±56.87 ms vs. irrelevant: 836.29±42.20 ms). In contrast, there was no significant difference for the innocent group ($t(31)=.91$, $p>.3$, probe: 818.38±36.07 ms vs. irrelevant: 811.44±37.50 ms). No other effect was significant ($p>.1$).

For participants' performance in the CIT task, the RTs were participants' response latencies to either probe or irrelevant stimulus. The same 2 by 2 mixed ANOVA revealed that neither the main effects nor the interaction reached significance ($p>.2$ for all tests). The lack of differences between probe and irrelevant stimuli in this task may be because participants had prepared their responses for the probe/irrelevant stimuli during the interference task, which rendered this CIT task as a simple response execution task.

Since participants used the same YES/NO buttons for responses of both the interference task and the CIT task, it allowed us to conduct further analyses regarding the possible role of response compatibility in the paradigm. Specifically, as the target's required response is "YES", answering "NO" to vertical dot-pairs in the dot-probe task would involve higher level of response conflict than answering "YES" to horizontal dot-pairs. In contrast, as the frequent irrelevant required a predominant response of "NO". In this case, answering "YES" to the horizontal dot-pairs would involve higher response conflict than answering "NO". To test this hypothesis, we conducted a 2 (dot pairs: horizontal vs. vertical dot pairs) by 3 (stimulus type: target vs. probe vs. irrelevant) within-subject ANOVA on the RTs of the dot-probe task for all participants. Results showed a main effect of question type ($F(2,122)=10.18$, $p<.001$, $\eta^2=.14$), post-hoc tests with Bonferroni correction suggested that the target (889.83±26.12 ms) and probe (867.23±23.31 ms) took significantly longer RTs than irrelevant (836.75±22.80 ms, both $ps<.05$). Moreover, there was a significant two-way interaction: $F(2,122)=18.54$, $p<.001$, $\eta^2=.23$. Post-hoc analyses suggested that when embedded within an irrelevant question, the dot-probe task had longer RTs for horizontal dot-pairs (i.e. requiring "yes" responses) than for vertical dot-pairs (i.e. requiring "no" responses, $t(62)=5.86$, $p<.001$). However, when embedded within a target question, the dot-probe task had longer RTs for vertical dot-pairs than for horizontal dot-pairs, $t(62)=-3.97$, $p<.001$. No difference was found for probe questions: $t(62)=1.58$, $p>.1$ (see Table 1, for all descriptive statistics).

3.2. Error rate

We did the same 2 (stimulus type: probe vs. irrelevant) by 2 (group: guilty vs. innocent) mixed ANOVA analyses on error rate in the pure-CIT and the interference-CIT condition separately. Specifically, in the pure-CIT condition, the error rate was associated with participants' responses to CIT questions. In the interference-CIT condition, the error rate was associated with participants' responses to the interfering dot-probe task.

Results showed that in the pure-CIT condition, neither stimulus type nor stimulus by group interaction was significant ($F<2$, $p>.15$). Only the main effect of group was significant: $F(1,61)=10.87$, $p<.01$, $\eta^2=.15$, suggesting that the guilty participants generally made more errors than the innocent participants. In the interference-CIT condition, however, the stimulus by group interaction was significant: $F(1,61)=11.04$, $p<.01$, $\eta^2=.15$. Follow-up t-tests showed that in guilty participants, probe stimuli were associated with more errors than irrelevant stimuli ($t(30)=2.69$, $p<.02$). In contrast, no difference was found for innocent participants, ($p>.1$).

3.3. Individual classification and receiver operating characteristic (ROC) analysis

To identify an individual participant who possesses crime-relevant knowledge, a binary logistic regression analysis was employed based on the following measures: 1) RTs means, 2) RTs variances, and 3) error rates (see also Seymour & Kerlin, 2008). Specifically, longer RTs, larger RT variances, and higher error rates associated with probe relative to irrelevant were indicative of concealed crime-relevant memory. In the pure-CIT, the indicators were the performance differences between probe and irrelevant stimuli. In the interference-CIT, the indicators were the performance differences between the dot-probe tasks embedded within the probe and irrelevant stimuli. When entering all three indicators in this regression model with a cutoff of .5, the classification rate in the pure-CIT was 85.7%, with a hit rate of 83.9% and a correct rejection rate of 87.5%. In the interference-CIT, the same regression

Table 1
The mean of reaction times (in milliseconds) for the dot-probe task (collapsing guilty and innocent group) as a function of dot-probe stimuli type (horizontal dot-pair, vertical dot-pair) and CIT stimuli type (target, probe, irrelevant). Standard deviations are provided in parenthesis.

	Horizontal dot-pair ("yes" response)	Vertical dot-pair ("no" response)
Target ("yes" response)	863.31 (215.88)	914.92 (221.90)
Probe ("no" response)	880.05 (193.47)	854.40 (222.32)
Irrelevants ("no" response)	860.67 (182.16)	812.19 (185.16)

model resulted in a classification rate of 92.1%, with a hit rate of 87.1% and a correct rejection rate of 96.9%.

To determine the overall discriminative ability of the RT-based CIT, we employed the receiver operating characteristic (ROC) analysis based on the signal detection theory (see Bamber, 1975; Ben-Shakhar & Elaad, 2003; National Research Council, 2003). Specifically, the area under the curve (AUC) is a threshold-independent indicator of discrimination efficiency of a test considering both sensitivity (i.e. hits) and specificity (i.e. correct rejections). The AUC represents the degree of separation between the distributions of the dependent measures from guilty and innocent participants. It varies between 0 and 1, with a chance level of 0.5 and with a perfect classification level of 1. The ROC analyses were conducted based on the same measures as in the logistic regression analysis. Moreover, to allow the ROC analysis to be performed based on a combined measure within each condition, each of these three indictors was first transformed into z-scores based on the entire sample's mean and standard deviation. Then these three z-scores were averaged together as a single indicator for each condition (Hu & Rosenfeld, 2012; Nahari & Ben-Shakhar, 2011; Seymour & Kerlin, 2008). The ROC analyses based on this indicator showed that the AUC in the interference-CIT condition was .94; whereas the AUC in the pure-CIT condition was .88 (for the AUCs associated with the single and the averaged indicator, see Table 2). We further compared the AUCs based on this overall indicator in these two conditions using Hanley and McNeil (1982)'s methods. Results showed that although the AUC in the interference-CIT was larger than that in the pure-CIT, this difference was not significant ($z = 1.16$, $p = .12$). In sum, individual classification results from the regression analyses and the ROC analyses consistently showed that the detection efficiency was higher when using the interfering task performance in the interference-CIT condition.

4. Discussion

The present study investigated the validity of reaction times (RTs) in detecting mock crime knowledge using the concealed information test. Our findings revealed that behavioral performance on the pure RT-based CIT showed well-above-chance levels of detection efficiency. Moreover, when using the performance of an embedded interfering dot-probe task within the CIT, an increased sensitivity in detecting concealed information was discovered.

Consistent with previous studies, we demonstrated that reaction times in the CIT alone could effectively detect concealed information (Seymour & Kerlin, 2008; Seymour et al., 2000; Verschuere et al., 2010). The present investigation also extended previous research findings using personal information (e.g. names, Verschuere et al., 2010) or well-rehearsed information (Seymour & Kerlin, 2008; Seymour et al., 2000) to more incidentally encoded, mock-crime information. Consistent with one recent mock crime RT-based CIT study using pictorial stimuli (Visu-Petra et al., 2012), the present study demonstrated the validity and sensitivity of behavioral measures in detecting information that was acquired during a mock crime. This effect can be largely ascribed to the stimulus–response incompatibility involved in the task. Stimulus–response incompatibility, as argued by Verschuere and De Houwer (2011), is a necessary condition in RT-based memory detection procedures to allow for individual detection (see also Hu, Rosenfeld et al., 2012; Sartori, Agosta, Zogmaister, Ferrara, & Castiello, 2008). It is also worth noting that the pure RT-based CIT detection accuracy is somehow lower than previous studies using this method with well-memorized stimuli (e.g. Seymour & Kerlin, 2008; Seymour et al., 2000). This reduced detection accuracy rate may be due to participants in the present experiment acquiring the details from a mock crime. The weak memory strength of the crime details may decrease the sensitivity of the CIT (e.g. Gamer et al., 2010).

Consistent with our hypothesis, using an interfering task embedded within each trial of the CIT task further increased the sensitivity of the CIT, producing individual detection above 90%. As far as we know, this is the first study using an interfering task during a mock-crime RT-based CIT. Given the increased cognitive load produced by the interfering task, this finding extends previous studies indicating that manipulating cognitive load not only assists in spotting liars but also in memory detection (Vrij et al., 2008).

Three possible explanations exist for the increased sensitivity of the interference-CIT task. First, our design aimed to maximize the interference between the dot-probe task and the concealing information task. We hypothesized that an interfering task embedded within each trial of the CIT, rather than an on-going non-selective secondary task, would increase phasic rather than tonic workload (cf. Ambach et al., 2008). In other words, the within-trial interference may selectively increase the workload for probe questions (i.e. crime-relevant knowledge) than for irrelevant question. This difference in workload may result in larger differentiation between probe and irrelevant.

Second, the SOA between the CIT stimuli and the dot-probe task was between 300 and 800 ms. Previous P300-CIT studies showed the difference between probe and irrelevant occurred during the 300–800 ms post-stimulus time window (Hu, Hegeman et al., 2012; Rosenfeld, 2011). Since P300 is thought to reflect the on-line process of stimulus evaluation and classification (e.g. Donchin & Coles, 1988), the 300–800 ms time window may be the critical period within which participants were evaluating/classifying stimuli. Thus, a secondary task appearing in this time window may have resulted in greater interfere with the stimulus evaluation stages, enlarging the differences between probe and irrelevant.

Third, the interfering dot-probe task that was embedded within a CIT trial may also introduce task switching processes, as these two tasks entailed different rules (Kiesel et al., 2010). Specifically, the dot-probe task involved a 50%–50% dot pair differentiation task; the CIT task involved an oddball probe classification task and target/non-target discrimination task. Since concealing information or lying has been found to recruit considerable executive control resources (Christ et al., 2009), and task switching is one of the three components of executive function (Miyake et al., 2000), the task switching nature of our interference paradigm may deplete participants' cognitive resources. This may further contribute to the differentiation between probe and irrelevant. One recent study lends more direct support to this task-switch account: in a RT-based CIT, guilty participants' performances were found to be correlated with their task switching scores (Visu-Petra et al., 2012).

The task-switching account we proposed above may at least partially explain our results. This explanation may also have applied implications for future deception detection or memory detection research. For instance, although we adopted a within-trial task switching paradigm, it is also possible that a between-trial task switching paradigm may cause a similar effect (e.g. ABAB paradigm, see Kiesel et al., 2010). Specifically, participants could be asked to execute a different task (B) right after each CIT question (A). Since guilty participants are expected to exert control resources to the CIT questions, their performance on the following task may get worse. However, it should be noted that the task switching account is not mutually exclusive with the cognitive workload hypothesis, as task switching occupies general-purpose executive functions.

Table 2
The areas under the curve (AUC) were calculated from the receiver operating characteristic (ROC) analysis based on three indicators (z-scores of RTs means, RTs variances, and error rates) and the averaged indicator. In the pure-CIT condition, the analysis was based on participants' performance of the CIT questions; whereas in the interference-CIT condition, the analysis was based on participants' performance of the interference task in the interference-CIT. The 95% confidence intervals of the AUCs are given in the parenthesis.

Conditions	RT means	RT variances	Error Rate	Averaged
Pure-CIT	.91(.83–.98)	.78(.66–.89)	.49(.33–.64)	.88 (.79–.97)
Interference-CIT	.85(.76–.95)	.90(.82–.98)	.69(.56–.82)	.94(.87-1.00)

In the present study we adopted the abovementioned strategies (e.g. within-trial, SOAs, task switch) simultaneously, as we intended to maximize the possible interference effect. Future studies are thus warranted to examine each parameter's unique influence over the interference effect and its detection efficiency.

Analysis of the dot-pair and CIT stimulus in the interference-CIT provided a more detailed picture regarding how participants' performance to dot-pairs was influenced by CIT stimulus type. Specifically, for irrelevant stimuli, the dominant response was “NO”. This would render responses to horizontal dot-probe (requiring “YES”) as the incompatible response, which resulted in longer RTs. For target stimuli, the dominant response was “YES”. This would render responses to vertical dot-probe (requiring “NO”) as the incompatible response. Indeed, this incompatibility effect was confirmed by the two-way interaction of dot-pair and CIT stimulus type. For probe stimuli, however, the dominant response was rather ambiguous. On one hand, it explicitly required the “NO” response, while on the other hand, the recognition of the crime detail among guilty participants would implicitly drive the “YES” response. Due to this response ambiguity, the dot-probe task associated with probe did not differ between the horizontal YES and the vertical NO response.

It is also worth noting that an interference task may be used as a countermeasure by participants during the CIT to distort the results (Ben-Shakhar, 2011). In this case, an interference task would lead to decreased sensitivity, rather than the increased sensitivity observed in the present investigation. It is also possible that since participants' mental capacity is occupied with the CIT and the secondary task designated by the experimenter, it will be a daunting task for participants to execute a third covert task as countermeasures. The interference task approach may also help in detecting “prepared” lies (Hu, Chen, & Fu, 2012; Van Bockstaele et al., 2012). Although liars may well practice their deceptive responses before the interrogation, an interference task during the interrogation may still make the prepared lies more detectable given the increased distractions. Future studies are needed to investigate the effects of these possible faking strategies on interference-CIT paradigms.

In conclusion, the present study demonstrated that behavioral performance alone on the CIT can accurately detect concealed mock-crime relevant memories. Moreover, as hypothesized, performance on an interfering dot-probe task within the CIT was strongly influenced by the crime-relevant questions. Furthermore, the effect of the interfering dot-probe was strong enough to allow for individual detection. Overall, the present study highlighted a novel approach of manipulating one's cognitive workload can aid in the detection of concealed memories.

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