Preliminary evidence for physiological markers of implicit memory

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

DOI
10.1016/j.biopsycho.2018.02.012

Publication date
2018

Document Version
Final published version

Published in
Biological Psychology

License
Article 25fa Dutch Copyright Act

Biological Psychology 135 (2018) 220–235

Contents lists available at ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

Preliminary evidence for physiological markers of implicit memory

Nathalie klein Selle[a,b,*], Gershon Ben-Shakhar[a], Merel Kindt[b], Bruno Verschuere[b]

[a] Department of Psychology, Hebrew University of Jerusalem, Mount Scopus, Jerusalem 91905, Israel
[b] Department of Clinical Psychology, University of Amsterdam, Postbus 15933, 1001 NK Amsterdam, The Netherlands

ARTICLE INFO

Keywords:
Concealed Information Test (CIT)
Explicit memory
Implicit memory
Skin conductance response (SCR)
Respiration line length (RLL)
Heart rate (HR)

ABSTRACT

The Concealed Information Test (CIT) aims to detect concealed knowledge and is known to be sensitive to explicit memory. In two experiments, we examined whether the CIT is also sensitive to implicit memory using skin conductance, respiration and heart rate measures. For each participant, previously studied items were either categorized as explicitly remembered, implicitly remembered or forgotten. The two experiments differed in the strength of memory encoding, the type of implicit memory test, the delay between study and test and the number of critical CIT items. The results of Experiment 1 revealed that CIT detection efficiency was weak and significant only in the explicit memory condition. In Experiment 2, however, CIT detection efficiency was stronger and significant in both the explicit and implicit memory conditions as indexed by skin conductance and respiration. Altogether, our results provide initial evidence that the CIT may be sensitive to implicit memory. Theoretical and practical implications are discussed.

1. Memory detection

Memory detection using the Concealed Information Test (CIT; Lykken, 1959; Verschuere, Ben-Shakhar, & Meijer, 2011) is a valid method to detect concealed memories through the measurement of physiological and/or behavioral indices. In a typical CIT, examinees are presented with several multiple-choice questions. For each question, one critical item (e.g., a distinctive crime-detail) is presented among a series of control items (e.g., "Where was the victim found?"… "in the garage?"… "under the bridge?"… "in the barn?"… "in the river?"… "in the car?"…). Individuals involved in the criminal event are expected to have encoded and stored the critical items in memory. Consequently, they will recognize these items and show differential responses to them in the CIT (e.g., an increased skin conductance response, SCR; a shorter respiration line length, RLL; and a deceleration of the heart rate, HR – Gamer, 2011). This pattern of differential responses elicited by the critical items has been labeled as the CIT effect (Ben-Shakhar, 2012). Extensive research has demonstrated large CIT effect sizes with different physiological measures and different concealed memory paradigms (e.g., card-test, personal items, mock-crime; see Ben-Shakhar & Elaad, 2003; Meijer, klein Selle, Elber, & Ben-Shakhar, 2014).

As the CIT is essentially a "memory test", it is important to explore its sensitivity to different types of memory (i.e., explicit vs. implicit). While explicit memory typically refers to the conscious retrieval of past events, implicit memory typically refers to an unintentional, non-conscious form of retrieval (see Schacter, 1992). This is especially important from an applied perspective as explicit memory cannot be ensured in real-life forensic cases. Specifically, the crime-related information may have been encoded too shallow to be explicitly remembered. Moreover, even when the information had been strongly encoded, this type of memory may decay due to the passage of time. This concern is particularly relevant to real-life cases where long time delays between crimes and interrogations are common (see e.g., Elaad, 1990; Elaad, Ginton, & Jungman, 1992). Hence, it is crucial to examine whether the differential responses to the critical items can reflect implicit memory. A positive answer to this question may enhance the applicability of the CIT and a negative answer may limit it. In any case, it would shed light on an important question in this research area.

2. Explicit versus implicit memory

Memories of past events are not always verbally accessible, but may be preserved in an implicit form. According to the classical threshold account, implicit memory was thought to represent a memory trace that was too weak to enter consciousness (Korsakoff, 1889; Leibniz, 1916; Prince, 1914). Hence, explicit and implicit memories were assumed to be qualitatively the same and variables that affect one type of memory should also affect the other type. During the last three decades, however, a number of studies have shown a dissociation between explicit and implicit memory using a combination of retention tasks (Graf & Schacter, 1985). The most compelling evidence for this dissociation comes from amnesic patients who often perform at chance in explicit

* Corresponding author at: Department of Psychology, Hebrew University of Jerusalem, Mt. Scopus, Jerusalem 91905, Israel.
E-mail address: nathalie.kleinselle1@mail.huji.ac.il (N. klein Selle).

https://doi.org/10.1016/j.biopsycho.2018.02.012
Received 7 September 2017; Received in revised form 18 February 2018; Accepted 19 February 2018
Available online 08 May 2018

memory tests, but perform normally in implicit memory tests, speaking against the idea that implicit memory is merely a weaker form of explicit memory, but rather suggesting the existence of two types of memory (e.g., Girelli, Semenza, & Delazer, 2004; Graf & Schacter, 1985; Graf, Squire, & Mandler, 1984). Graf et al. (1984), for instance, assessed the memory performance of three kinds of amnesic patients (patients with Korsakoff syndrome, patients receiving bilateral electroconvulsive therapy, and patients with anoxic encephalopathy) and found these patients to be impaired on different measures of explicit memory (i.e., free recall, recognition, and cued recall), but to perform normally on a measure of implicit memory (i.e., word completion).

A comparable dissociation between explicit and implicit memory performance has been observed in healthy individuals when cognitive load was high (e.g., Jenkins, Burton, & Ellis, 2002), when a shallow encoding task was used (Roediger & McDermott, 1993), or when tested after a long delay from encoding (e.g., Kolers, 1976; Mitchell & Brown, 1988; but see also Moscovitch & Bentin, 1993). In the studies manipulating time-delay, individuals were tested at different intervals (from a week to a year), for both explicit and implicit memory of previously encoded stimulus material (e.g., pictures, inverted text). Mitchell and Brown (1988) for example used a picture-naming paradigm; participants were presented with a large array of pictures and were requested to name each picture as quickly as possible. Implicit (naming latencies) and explicit (recognition) memory performance were tested 1 week, 4 weeks and 6-weeks later. Consistent with other studies, faster picture naming latencies were observed over the 6-weeks period. Episodic recognition, on the other hand, showed a decline across this time interval. Thus, in contrast to explicit memory performance, implicit memory performance remains relatively stable over time. Taken together, these data are inconsistent with the threshold account and support a multiple memory systems account, which holds that neurologically distinct systems underlie the different types of memory (Schacter, 1992; Squire, 1992; Tulving & Schacter, 1990). Consequently, explicit and implicit memories are also assumed to be qualitatively different.

3. Explicit memory in the CIT

Nearly all CIT research up to date has focused on explicit memory. These studies revealed a clear positive association between explicit recollection and CIT detection efficiency (e.g., Carmel, Dayan, Naveh, Raveh, & Ben-Shakhar, 2003; Iacono, Boisvenu, & Fleming, 1984). Carmel et al. (2003), for instance, compared a standard mock crime procedure, where all the relevant details are specified in advance to a more realistic procedure and found that both recall and SCR detection efficiency were attenuated in the realistic procedure. Using a code word paradigm, Waid, Orne, Cook, and Orne (1978) found CIT detection efficiency to be positively correlated with the number of words recalled after the test. Moreover, recalled items were more likely to evoke a SCR than non-recalled items (see also Waid, Orne, & Orne, 1981). A similar positive correlation between recall and skin conductance was also observed in orienting response studies (e.g., Corteen, 1969; Maltzman, Kantor, & Langdon, 1966; McLean, 1969). Importantly however, it is unclear how many of the non-recalled items in these studies were purely forgotten and how many were implicitly remembered. Hence, although these findings imply that CIT detection efficiency for explicit memory is likely to be higher than that for implicit memory, it leaves the question of whether the CIT is sensitive to implicit memory unanswered.

4. Is the CIT sensitive to implicit memory? Clinical evidence

A number of clinical observations demonstrated that the CIT may be sensitive to implicit memory. Bauer (1984) indexed spared recognition in a patient with prosopagnosia (i.e., a profound inability to recognize faces). The prosopagnosic patient was shown two sets of faces, one including famous personalities and one including family members. During the presentation of each face, five names, only one of which matched the face, were presented auditorily. As expected, the patient was unable to spontaneously identify any of the faces and performed at chance level when asked to select the correct name from the five alternatives. Electrodermal discrimination of the name that matched the correct identity was however well above chance and comparable to control subjects. Two follow-up studies with patients suffering from prosopagnosia found similar results and suggest that SCR differentiation can represent covert recognition (Bauer & Verfaellie, 1988; Tranel & Damasio, 1985). Importantly however, the results of these case studies should be interpreted with caution as they are based on either one or two patients.

Using a CIT-paradigm, case-studies of patients suffering from the "amnesic syndrome" also revealed enhanced SCRs ($n = 1$; Verfaellie, Bauer, & Bowers, 1991) and event-related potentials (ERPs; $n = 1$; Lalouschek et al., 1997) to items that could not be explicitly recalled or recognized. Likewise, Allen and Movius (2000) used a CIT paradigm to examine amnesia associated with Dissociative Identity Disorder (DID) in a sample of four patients. DID is characterized by the presence of at least two identities that alternately control the individual's behavior. These identities are allegedly accompanied by amnesia of personal information, which goes beyond that of ordinary forgetfulness, usually referred to as inter-identity amnesia. The authors administered a learning protocol to one personality and tested a second personality for recognition in the CIT. While the second identity denied knowledge of the learned material, enhanced ERPs and response latencies were observed, which could be interpreted as evidence for implicit familiarity of the material (see also Huntjens, Verschuere, & McNally, 2012). The status of amnesia in DID patients is however strongly debated, and the case can also be made that the CIT actually assessed explicit memory (e.g., Huntjens et al., 2012; Kong, Allen, & Glisky, 2008; Merckelbach, Devilly, & Rassin, 2002).

5. Is the CIT sensitive to implicit memory? Experimental evidence

Although memory is typically high in laboratory CIT studies, it is known to decrease with time especially when tested on memory for peripheral CIT items (Carmel et al., 2003; Gamer, Kosiol, & Vossel, 2010; Gronau, Elber, Satran, Breska, & Ben-Shakhar, 2015; Nahari & Ben-Shakhar, 2011; Peth, Vossel, & Gamer, 2012). Considering that memory loss is not an all-or-none phenomenon and may be confined to the explicit system, an examination of the differential responses to the explicitly forgotten items (as indicated by a recognition or recall test), may provide some insight into the sensitivity of the CIT to implicit memory. Gamer et al. (2010) examined this question and found a small CIT effect for the forgotten critical items (Cohen's $f = 0.19$). This finding indicates that the sensitivity of the measures used in the CIT may expand beyond conscious recognition (for CIT studies on false recognition: see Allen & Mertens, 2009; Baioui, Ambach, Walter, & Vaitl, 2012; Volz, Leonhart, Stark, Vaitl, & Ambach, 2017).

The potential sensitivity of the CIT to implicit memory is further supported by a CIT study using a subliminal perception paradigm (Maoz, Breska, & Ben-Shakhar, 2012). There is an apparent parallel between implicit memory and subliminal perception. In implicit memory there is evidence of memory despite the subjects' claim that they can't remember, and in subliminal perception there is evidence of perception despite the subjects' claim that they can't perceive. Maoz et al. (2012) showed that subliminally presented personally significant items can elicit a SCR CIT effect. It bears mentioning however that in spite of the usage of highly significant personal items (i.e., first name, family name), the effects were rather small and solely observed in the first block of the CIT.

Further evidence for the implicit sensitivity of the CIT comes from a number of other research areas: Maybe the most convincing evidence comes from two different child studies examining covert face recognition of former classmates (i.e., Newcombe & Fox, 1994; Stormark, 2004). Even though verbal responses did not differentiate between former classmates and unfamiliar children, increased SCRs and more pronounced HR deceleration to former classmates, compared to unfamiliar children, were observed. Still, one may question the reliability of assessing explicit recognition through self-report in very young children (see also Discussion). Additional indirect support comes from studies using different subliminal presentation methods. For instance, phobic participants have been shown to react with stronger SCRs when presented with masked phobic-related pictures or words as compared to masked neutral pictures or words (Öhman & Soares, 1994; van den Hout, de Jong, & Kindt, 2000). These findings were extended to normal subjects showing stronger SCRs to subliminally presented aversive words, compared to subliminally presented neutral words (Silvert, Delplanque, Bouwalerh, Verpoort, & Sequeira, 2004). Finally, several other studies examining conditioning (Wiens, Katkin, & Öhman, 2003), learning (Bechara, Damasio, Tranel, & Damasio, 1997) and perception (Soares & Öhman, 1993), suggest that increased SCRs can occur in the absence of phenomenal awareness. Taken together, there is preliminary clinical and experimental evidence to suggest that physiological measures may be able to tap into implicit memory.

6. The present study

There is wealth of evidence that the CIT can detect explicit memory. However, in spite of the experimental and clinical findings presented above, it remains elusive whether implicit memory can actually be detected by the CIT in healthy adults. We therefore designed two experiments aiming to create explicit as well as implicit memory within participants (Experiment 2 was planned and designed only after analyzing the full data of Experiment 1). This allowed for a direct comparison between the CIT effect produced by explicit and implicit items. Importantly, to ensure that the selected implicit items were truly implicitly remembered, we relied on two different methods that are known to reduce explicit, but not implicit recognition (see above). Specifically, while Experiment 1 relied on a shallow encoding task (prompting weak encoding), Experiment 2 relied on an extended interval between encoding and test (prompting the forgetting of strongly encoded information). Based on previous findings from a variety of research domains (e.g., Bauer, 1984; Maoz et al., 2012; Stormark, 2004), we expected implicitly remembered critical items to be successfully detected in the CIT. Further, based upon research showing a clear link between explicit memory and physiological responding in the CIT (Carmel et al., 2003; Iacono et al., 1984), CIT detection efficiency was expected to be higher for explicitly compared to implicitly remembered items. Finally, as a manipulation check, fully forgotten critical items were expected to be undetectable.

7. Experiment 1

Experiment 1 was divided into two parts: memory formation (part 1) and memory detection (part 2, see Fig. 1 and procedure). Part 1 relied on a 4-phased experimental design aimed at creating explicit, implicit and no memory within participants. This resulted in three within-subject experimental conditions: (1) Explicit memory; (2) Implicit memory; (3) No memory. Specifically, part 1 started with a study (i.e., encoding) phase in which participants were presented twice with 30 critical items. Next, in the implicit memory phase, participants performed a Word Stem Completion (WSC) task and in the final explicit memory phase, which followed a distracter phase, participants performed a recognition memory test. Based on the results of the implicit and explicit memory phases, the number of explicitly remembered, implicitly remembered and forgotten items were determined. Participants with at least one item in each category continued to part 2 of the experiment in which the CIT was administered (see Fig. 1). Notably, the usage of a WSC task (i.e., behavioral measure) to determine implicit memory has an important advantage over self-reports that were used in previous CIT experiments (e.g., Bauer, 1984; Gamer et al., 2010).

7.1. Method

7.1.1. Participants

One hundred and thirty-five young Dutch adults (91 women) with an age range of 18–32 (M = 22.5, SD = 2.9 years) participated in part 1 of the experiment, aimed at creating explicit memory, implicit memory and no memory within each individual (see procedure). Forty-five (28 women; aged 18–31, M = 22.6, SD = 3.0 years) of them proceeded to part 2 of the study (i.e., the CIT); ninety participants had no available critical item for at least one of the memory conditions. All participants were native speakers of Dutch and received either course credits or a monetary compensation of 10 Euro per hour. Each participant read and signed a consent form indicating that participation was voluntary and that they could withdraw from the experiment at any time without penalty. The ethical committee of the Faculty of Social and Behavioral Sciences of the University of Amsterdam (EC No. 2015-CP-4113) approved the experiment.

7.1.2. Data acquisition and reduction

The experiment was conducted in an air-conditioned laboratory. The apparatus included a Dell Optiplex 9020 computer for stimulus presentation on a Samsung S24D590 monitor and a second Dell Optiplex 9020 computer with Vsrrp98 software for recording of the physiological data.

Electrodermal activity was measured using an amplifier with a sine-shaped excitation voltage (1 V peak-peak) of 50 Hz and two curved Ag/AgCl electrodes (20 × 16 mm). Dry electrodes were placed on the distal phalanges of the left index and left ring finger. SCRs were defined as the maximal increase in conductance obtained from 1 to 5 s after stimulus onset (Boucsein et al., 2012).

The electrocardiogram (ECG) was recorded by placing three Ag/AgCl electrodes in a modified Einthoven lead II configuration. The ECG signal was sampled at 1000 Hz. To detect the R peaks, the signal was lead through a peak filter at 17 Hz and analyzed by using the first derivative of the resulting trace. An adaptive algorithm was used to remove incorrect R peak detections caused by movement or noise artifacts from the trace. The main criteria for rejecting false positives are Q-S distance, R peak amplitude and R-R distance. Remaining artifacts were manually removed. The interbeat intervals (IBIs) were converted to HR in beats per minute (bpm) per real-time epoch (1 s). These second-by-second post-stimulus HR values were baseline-corrected by subtracting the average HR value in the second preceding stimulus onset (i.e., the pre-stimulus baseline value), resulting in 10 post-stimulus difference scores (ΔHR).[1] The average of all ΔHR scores has been found to outperform the minimum of all ΔHR scores as a detection measure (Gamer, Verschuere, Crombez, & Vossel, 2008) and was therefore the preferred measure when analyzing the data.

For both measures, individual responses were removed if excessive movements were made during the measurement window or if the response was an outlier (Z score larger than 5 or smaller than −5). Further, similar to klein Selle, Verschuere, Kindt, Meijer, and Ben-Shakhar (2016, 2017) non-responsivity was based on the within-participant standard deviation of the raw SCR scores. Participants whose standard deviation was below 0.01 μS in either two or three blocks of the CIT were considered to be skin conductance non-responders and their SCR data were eliminated from all analyses. In case of non-responsivity in one of the blocks, only the data from the respective block were removed.

[1] Due to the relatively short inter-stimulus interval (5–9 s), a 1 s pre-stimulus baseline was used and 10 ΔHR scores were computed. In Experiment 2, the inter-stimulus interval was increased (14–18 s) and, hence, a 3 s pre-stimulus baseline was used and 15 ΔHR scores were computed.

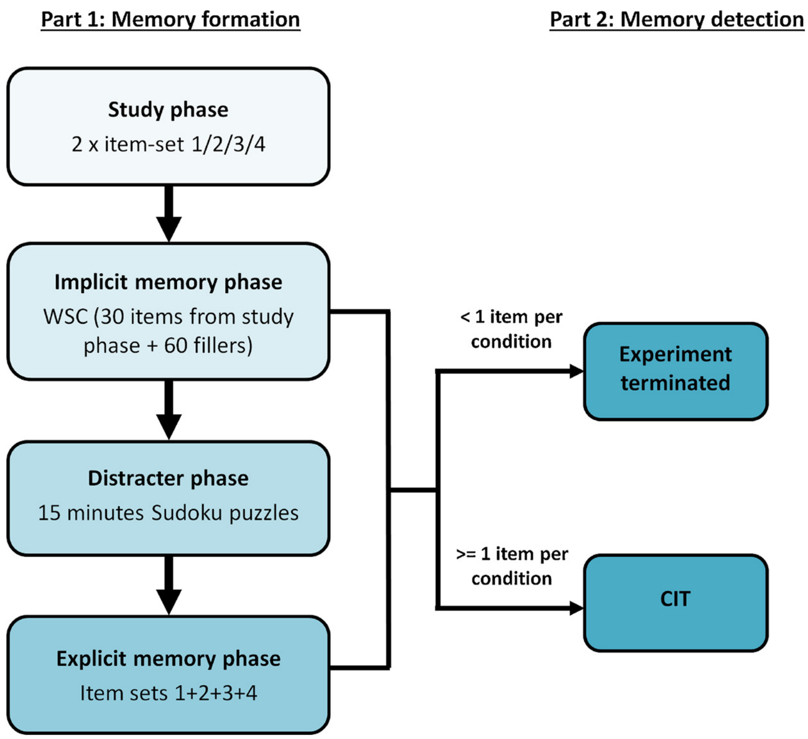

Fig. 1. Experimental design of Experiment 1: Part 1 (memory formation) and part 2 (memory detection).

7.1.3. *Items*

Four sets of 30 items (i.e., Dutch words), totaling 120 items, were created for the present experiment (see Appendix A). All items in set 1 were taken from Moors et al. (2013) and were rated as "average" (on a scale of 1–7) on valence, arousal and dominance: $M_{\text{valence}} = 4.55, M_{\text{arousal}} = 4.02, M_{\text{dominance}} = 3.99$. These items were chosen such that each item belonged to a different item-category (e.g., fruit, animals). The additional three item-sets were created by choosing for each item in set 1 three alternative items from the same category. Importantly, all items were selected on basis of the following criteria: six to nine letters, no two items had the same word-stem of three letters, and each word-stem could be completed with at least five unique solutions. At the outset of the experiment, one of the four item-sets was assigned to participants, such that each set served as the critical set for 25% of the participants. An additional set of buffer items (six to nine letters), did not necessarily satisfy the other two constraints (as buffer items were solely used in the memory detection phase; see procedure below). Finally, a set of sixty filler items, selected from different item-categories, was used in the implicit memory phase (see procedure below) and satisfied the same three constraints.

7.1.4. *Procedure*

7.1.4.1. Part 1: memory formation. In order to create both implicit and explicit memory within participants, the first part of the experiment was divided into four different phases: the study phase, the implicit memory phase, the distracter phase and the explicit memory phase (see Fig. 1). The duration and content of the different phases were carefully constructed based on an extensive pilot study in which the presentation-time of items in the study phase, the number of distracter items in the study phase, the number of filler items in the implicit memory phase and the formulation of the answer-options in the explicit memory phase were varied. The final design optimized our chances of finding at least one explicitly remembered, one implicitly remembered and one forgotten item per participant.

Experimenter 1 provided all participants with general instructions about the four different phases and explained that all tasks in this part of the experiment would be performed independently on the computer. Each of the four phases started with written instructions on the computer monitor, reminding participants about the to-be-followed task.

Study phase – At the beginning of the study phase, a fixation cross appeared for 500 ms at the center of the computer monitor. Then, 30 critical items were presented twice in a consecutive order; each item was shown for 1 s, with no interruption between successive trials. The order of item-presentation was randomly determined, with one restriction, namely that the same item could not appear twice in a row. In order to ensure 100% identification accuracy of the items, participants were instructed to read the items out loud. Importantly, the task was introduced as an attention test, in order to prevent participants from using explicit memorization strategies.

Implicit memory phase – The implicit memory phase consisted of a WSC task, which is a widely used implicit memory test (Rajaram & Roediger, 1993). In line with previous research, the WSC task was ostensibly unrelated to the prior study phase (Graf & Schacter, 1985) and was introduced as a letter game. Specifically, participants were presented with 90 word-stems, which were composed of the first three letters of either a critical or a filler item (e.g., aar___). Thus, the word stems either did (for 30 critical stems) or did not (for 60 filler stems) correspond to the items presented in the study phase. The task was preceded by three practice trials, which included the same stems for all participants, and allowed participants to get familiar with the procedure. Taken together, participants were presented with a total of 93 stems (3 practice + 30 critical + 60 filler item-stems). With the exception of the first three practice-trials, all word-stems were presented in a random order. Each trial started with a 500 ms fixation point, followed by the presentation of a stem for 4000 ms. During these four seconds participants were requested to complete the stem with the first word that came to mind. Stem-presentation was rather short to prevent the use of explicit memory strategies. Moreover, emphasis was placed on the importance of revealing the first "impulse" and a creative completion of the stems was discouraged. By disabling the backspace key, participants were unable to change their initial answer. Whenever the stem was completed in less than four seconds, participants could continue to the next stem by pressing the spacebar. Whenever the stem was not completed within four seconds, participants were automatically forwarded to the next trial.

Distracter phase – In the distracter phase participants were requested to solve Sudoku puzzles for a time period of fifteen minutes. After reading the instructions, a first puzzle automatically appeared on the computer monitor. Although the puzzles were of high difficulty, a second puzzle automatically appeared when the first one was completed. When reaching the fifteen-minutes time limit, all participants were redirected to the explicit memory phase of the experiment, regardless of their progress on the puzzle.

Explicit memory phase – In the explicit memory phase, participants were presented with a total of 120 items: 30 items from the critical set (which were also presented in the study and the implicit memory phase) and 90 additional items from the three other sets. When presented with the items, one by one, participants were requested to indicate whether they remembered the item and whether they remembered having read (in the study phase) or typed (in the implicit memory phase) the item. Specifically, participants were requested to select one of five possible answer-options: (1) yes, read; (2) yes, typed; (3) yes, read and typed; (4) yes, not sure, and; (5) no.

7.1.4.2. CIT item selection. After completion of part 1 of the experiment, the number of critical item-options for each of the three CIT conditions was computed based on the results of the implicit and explicit memory phases of the experiment; when this number equaled zero in one of the conditions, the experiment was terminated (see Fig. 1). This typically happened because of a lack of implicit items ($M_{\text{numberofimplicititems}} = 0.87, M_{\text{numberofexplicititems}} = 3.70, M_{\text{numberofnoitems}} = 4.29$). Items that were correctly completed in the WSC task and rated as “yes, read” or “yes, both” in the explicit recognition test fulfilled our criteria for inclusion in the explicit memory condition. Items that were correctly completed in the WSC task and rated as “no” in the explicit recognition test fulfilled our criteria for inclusion in the implicit memory condition. Items that were incorrectly completed in the WSC task (excluding those that were not completed at all within four seconds) and rated as “no” in the explicit recognition test fulfilled our criteria for inclusion in the no memory condition. For each memory condition, one of the available options was randomly chosen to serve as critical item in the CIT (i.e., one explicitly remembered item, one implicitly remembered item, one forgotten item). When there was only one available option, it was automatically selected. Before the random selection, however, we checked manually how the stems of the item-options in the no memory condition were completed in the WSC task. Specifically, we checked whether the completed stems resembled the intended studied items and might have been misclassified due to either spelling (e.g., vulaan versus vulkaan) or other language mistakes (e.g., knor versus knorren). When resemblance was low the item was removed as an option from the no memory condition and when resemblance was high it was removed from the no memory condition and added to the implicit memory condition.

7.1.4.3. Part 2: memory detection. Forty-five, out of one hundred and thirty-five, participants continued to the second part of the experiment. Experimenter 2, who was unaware of the critical items, attached the SCR and HR electrodes and conducted the CIT examination. Before the CIT, participants were told that they would undergo a “polygraph”-examination in which they had to hide their knowledge of the items seen during the study phase. Participants were also promised a bonus of 5 Euro as an incentive for a successful concealment (i.e., passing the test). The bonus was paid when the average SCR standard-score, computed across all critical items (i.e., SCR detection score), was below 0.

The CIT consisted of three blocks, with a break between blocks to maintain participants' attention. Each block was composed of the same three questions and each question targeted one of the critical items. Taken together, participants were presented with a total of 3 blocks × 3 questions = 9 questions. Each question was presented on the computer monitor for 10 s and at the same time the prerecorded question was played through the computer's loudspeakers. The order of question presentation was random in all blocks, except that the last question within a block could not appear as the first question in the succeeding block. Following question presentation, the different items appeared for 5 s each, with an inter-stimulus interval of 5–9 s (Breska, Maoz, & Ben-Shakhar, 2011). The first item was always a neutral, buffer item designed to absorb the initial orienting response. Next, 1 critical item, 3 control items and 1 catch item were presented in a random order. Catch items were included as an extra means of assuring that participants' attention remained focused on the items presented (see also Verschuere, Crombez, Degrootte, & Rosseel, 2010) and were random numbers between zero and ten (written in letters, in Dutch). When presented with a catch item, participants were requested to say the number out loud. In response to all other items, participants were requested to say “no” in Dutch. In sum, participants were presented with 9 questions × 6 items (1 buffer, 1 critical, 3 control and 1 catch item), totaling 54 items.

Following the CIT, participants received a paper-and-pencil questionnaire (with 6-point scales) in which they were asked to rate their level of motivation during the experiment, their efforts to conceal the critical items, their subjective memory of the critical items, and, although not instructed to, whether and what kind of countermeasures they applied. Further, participants were asked whether they noticed that part of the word-stems in the implicit memory phase matched the items seen in the study phase and if so, whether this awareness influenced their answers in the implicit memory phase (i.e., WSC). Finally, all participants were debriefed and compensated for their participation in the experiment.

7.1.5. Data analysis

For the main analysis a 3 × 2 repeated measures ANOVA, with memory condition (explicit memory vs. implicit memory vs. no memory) and item type (critical vs. control) as within-subject factors was performed on the raw physiological data. The predicted Memory Condition × Item Type interaction was followed by post-hoc comparisons with a Bonferroni correction. Further, in order to check whether the CIT effect was significant in the different conditions, we performed, per condition, a paired sample t test comparing the critical and control items. As we were primarily interested in the implicit sensitivity of the CIT, we used the more powerful one-tailed t test for all analyses with a clear directional prediction. A rejection region of $p < 0.05$ was used for all statistical tests and both Cohen's f and Cohen’s d values were computed as effect size estimates (Cohen, 1988). According to Cohen (1988), the values of $f = 0.1$, $f = 0.25$, and $f = 0.40$ as well as the values of $d = 0.2$, $d = 0.5$, and $d = 0.8$ correspond to small, medium, and large effects, respectively.

The t tests were supplemented by JZS Bayes factors (BFs). The JZS BF is a numerical value quantifying the odds ratio of the null (i.e., no response differences between the two item types) vs. the alternative hypothesis (i.e., larger responses to the critical than to the control items) given the data (Rouder, Speckman, Sun, Morey, & Iverson, 2009). A default JZS prior with scaling factor $r = 0.707$ was used for the alternative hypothesis. Importantly, the BFs are reported as either favoring the null or the alternative hypothesis and a BF of 3 or more is taken as substantial evidence for the respective hypothesis (Jeffreys, 1961).

7.2. Results

The original data and analysis files are publically available on the Open Science Framework and accessible through the following link: https://osf.io/6v6hv/.

7.2.1. Subjective ratings

Participants reported high motivation ($M = 5.27$), high efforts to conceal knowledge of the critical items ($M = 5.36$) and moderate subjective memory of the critical items ($M = 3.80$). Further, we examined the possibility of explicit contamination in the implicit memory phase (i.e., WSC). In other words, whether or not participants used explicit memory strategies to complete the word-stems presented in the WSC task. Only two participants were unaware that these word-stems matched the items seen in the study phase. From the 43 aware participants, 41 indicated to have completed the stems with the first word that came to mind.

7.2.2. Main analyses

All skin conductance data of 4 participants (8.8%) was removed due to non-responsivity. For the remaining participants, the skin conductance data within the first block of 1 participant (2.4%), the skin conductance data within the second block of 2 participants (4.9%) as well as the skin conductance data within the third block of 3 participants (7.3%) were removed due to non-responsivity. Thus, while the HR analysis is based on data of 45 participants, the SCR analysis is based on data of 41 participants. For these participants, 3.6% of all SCRs and 1.2% of all HR responses to the individual stimuli were removed due to excessive movements and outliers. Means and standard deviations of the raw responses to critical and control items were computed for each memory condition and each physiological measure and are displayed in Table 1. As the HR typically decelerates in response to critical items, the average HR response to all critical items is expected to be negative. The average responses to both critical and control items were however positive in all three memory conditions (see Table 1). As can be seen in Fig. 2, these positive values are the result of an initial large cardiac acceleration.

7.2.2.1. SCR. A 3 × 2 ANOVA on the raw SCR data revealed a significant main effect of item type, $F(1,40) = 5.64$, $f = 0.38$, $p = 0.022$, and a significant main effect of memory condition, $F(2,80) = 4.01$, $f = 0.32$, $p = 0.041$ (after correcting for sphericity, $\varepsilon = 0.64$), that were qualified by the Item Type × Memory Condition interaction, $F(2,80) = 3.22$, $f = 0.28$, $p = 0.045$. This interaction was followed by post-hoc comparisons with a Bonferroni correction, which revealed a significant difference in the responses to critical-control items between the explicit memory condition and the no memory condition, $t(40) = 2.28$, $p = 0.042$, $d = 0.36$. No significant difference in the responses to critical-control items between the implicit memory condition and the no memory condition was revealed ($t(40) = 0.74$, $p = 0.500$, $d = 0.11$). Similarly, no significant difference in the responses to critical-control items between the explicit memory condition and the implicit memory condition was revealed ($t(40) = 1.70$, $p = 0.145$, $d = 0.27$). Importantly, however, the critical-control difference was significant only in the explicit memory condition, $t(40) = 2.68$, $p = 0.005$, $d = 0.42$, see Table 1 (implicit memory condition: $t(40) = 0.65$, $p = 0.259$, $d = 0.10$; no memory condition: $t(40) = -0.40$, $p = 0.692$, $d = -0.06$).

In order to assess the strength of evidence in favor of the alternative hypothesis in the explicit memory condition and in favor of the null hypothesis in the implicit and no memory conditions, we computed BFs. A BF of 7.61 (favoring the alternative) was found in the explicit memory condition, a BF of 3.31 (favoring the null) was found in the implicit memory condition and a BF of 5.49 (favoring the null) was found in the no memory condition. Thus, while there is substantial evidence for the null hypothesis in both the implicit and no memory conditions, there is substantial evidence for the alternative hypothesis in the explicit memory condition.

7.2.2.2. HR. A 3 × 2 ANOVA on the raw HR data revealed no significant effects (item type: $F(1,44) = 1.65$, $f = 0.19$, $p = 0.206$; memory condition: $F(2,88) = 0.76$, $f = 0.13$, $p = 0.473$; Item Type × Memory Condition: $F(1,80) = 1.09$, $f = 0.16$, $p = 0.332$, after correcting for sphericity, $\varepsilon = 0.85$). Although the interaction-effect was not significant, it was crucial to check if the CIT effect (i.e., critical-control difference) was at least significant in the explicit memory condition. Therefore, for each memory condition, a paired sample t test, comparing the critical and control items, was performed. These t tests revealed a significant difference only in the explicit memory condition, $t(44) = 1.93$, $p = 0.030$, $d = 0.29$ (implicit memory condition: $t(44) = 0.20$, $p = 0.578$, $d = 0.03$; no memory condition: $t(44) = -0.74$, $p = 0.461$, $d = -0.11$). It should be noted, however, that while the CIT effect in the explicit condition was statistically significant in a one-tailed test, the 95% confidence interval of the effect size includes 0 (see Table 1).

Just as for the SCR, we computed JZS BFs in each condition. A BF of 1.69 (favoring the alternative) was found in the explicit memory condition, a BF of 7.17 (favoring the null) was found in the implicit memory condition and a BF of 4.77 (favoring the null) was found in the no memory condition. Thus, while there is substantial evidence for the null hypothesis in both the implicit and no memory conditions, there is no clear evidence for either hypothesis in the explicit memory condition.

7.3. Discussion

The present experiment explored the sensitivity of the CIT to implicit memory in healthy adults. The CIT effect (i.e., critical-control difference) was not significant in the implicit memory condition for either the SCR or HR, with effect sizes (i.e., Cohen's d) close to zero. In other words, the implicitly remembered critical items were undetectable using the electrodermal and heart rate measures. In contrast, there was a significant CIT effect in the explicit memory condition for both the SCR and HR. The sizes of these effects were however small ($d_{SCR} = 0.42$, $d_{HR} = 0.29$).

The atypical design of Experiment 1 likely affected CIT detection efficiency; the effect sizes in the explicit memory condition were far below the typically observed values (see the meta-analysis conducted by Meijer et al., 2014: $d_{SCR} = 1.55$; $d_{HR} = 0.89$). As the detection efficiency of implicit memory is expected to be lower than that of explicit memory, the absence of an implicit memory effect may also be due to

Table 1
Raw means (SDs) of the Physiological Responses to Critical and Control Items in the Three Within-Subject Conditions of Experiment 1; p-value; Cohen's d with 95% CI; BF.

Measure	Condition	Mean raw scores (*SD*)		*p*-value	Cohen's *d* with 95% CI	BF
		Critical	Control			
SCR (μS)	Explicit memory	0.27 (0.46)	0.19 (0.34)	0.005	0.42 (0.27, 0.57)	7.61 (favors alternative)
	Implicit memory	0.16 (0.25)	0.15 (0.19)	0.259	0.10 (−0.09, 0.29)	3.31 (favors null)
	No memory	0.15 (0.24)	0.16 (0.23)	0.692	−0.06 (−0.22, 0.09)	5.49 (favors null)
HR (*bpm*)	Explicit memory	0.47 (2.39)	1.28 (1.67)	0.030	−0.29 (−0.62, 0.05)	1.69 (favors alternative)
	Implicit memory	1.23 (3.16)	1.14 (1.81)	0.422	0.03 (−0.34, 0.40)	7.17 (favors null)
	No memory	0.66 (2.77)	0.99 (1.48)	0.461	−0.11 (−0.52, 0.30)	4.77 (favors null)

Note. As concealed information is associated with cardiac suppression, negative Cohen's d values are expected for the HR.

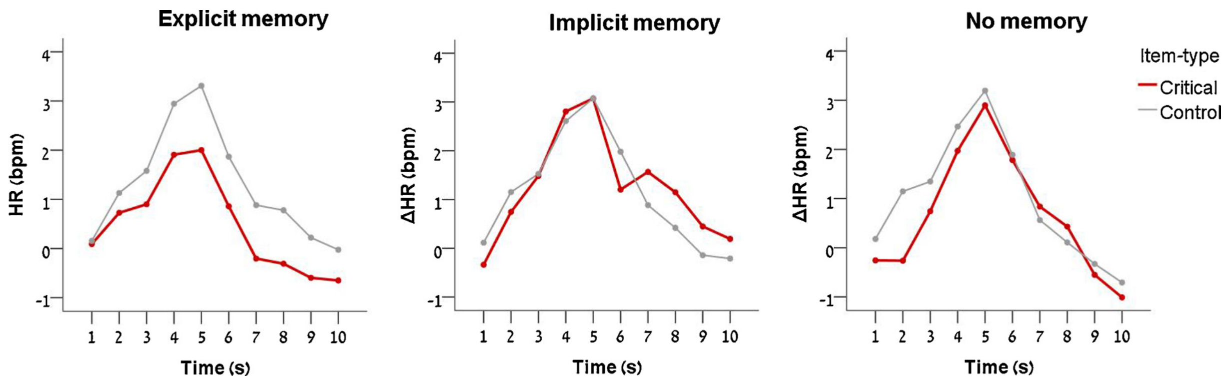

Fig. 2. HR change to critical and control items in the explicit memory, implicit memory and no memory conditions of Experiment 1.

the atypical design and may actually reflect a floor effect. In particular, there are two design-related factors that are probably responsible for the reduced detection efficiency: the small number of critical items and the weak memory encoding. Specifically, the present study relied on just a single critical item that was shallowly encoded in each condition. In contrast, the few studies supporting the sensitivity of the CIT to implicit memory relied on a number of distinct critical items that were more deeply encoded (Bauer, 1984; Carmel et al., 2003; Newcombe & Fox, 1994; Stormark, 2004).

Taking into account these considerations, we tried to enhance CIT detection efficiency in Experiment 2 by using two, rather than one, critical item per memory condition. Further, encoding was strengthened by asking participants to study the critical items for several minutes.

8. Experiment 2

Using more deeply encoded information, Experiment 2 re-investigated the sensitivity of the CIT to implicit memory. Because of the deeper encoding, the study and the implicit/explicit memory phases of the experiment were separated by a week delay. This delay was expected to decrease explicit, but not implicit memory performance (see Kolers, 1976; Mitchell & Brown, 1988). Further, to simplify the experiment, we focused on the two conditions of main interest (i.e., the implicit and the explicit memory conditions) and hence the no memory condition was dropped from the design. Thus, each participant was tested in the CIT on two explicitly remembered and two implicitly remembered critical items. Moreover, as some of the word stems in the WSC task may have been correctly completed because of explicit memory (explicit contamination; e.g., Mitchell & Bruss, 2003) or because it was simply the most obvious answer, an alternative implicit memory test was used (i.e., dot clearing task, see procedure below). Importantly however, as in Experiment 1, the implicit memory test relied on a behavioral measure (i.e., reaction time), while previous CIT studies relied solely on self-reports (e.g., Bauer, 1984; Gamer et al., 2010). The design, hypotheses, and main analyses of Experiment 2 were preregistered on aspredicted.org: https://aspredicted.org/ai6kw.pdf.

8.1. Method

8.1.1. Participants

Two hundred and five undergraduate students (120 women) of the Hebrew University of Jerusalem (HUJI) with an age range of 18–34 (M = 24.1, SD = 2.4 years) participated in part 1 of the experiment, aimed at creating explicit and implicit memory within each individual (see procedure). Thirty-nine (18 women; aged 19–32, M = 24.3, SD = 2.6 years) of them proceeded to part 2 of the study (i.e., the CIT); 6 participants did not pass the study phase (see procedure below) and one hundred and sixty participants had fewer than two available critical items for at least one of the memory conditions. All participants were native speakers of Hebrew, with no prior knowledge of Dutch or German, and received either course credits or an average payment of 55 NIS (equivalent to approximately 14.3 USD) for their participation. Each participant read and signed a consent form indicating that participation was voluntary and that they could withdraw from the experiment at any time without penalty. The ethical committee of the Faculty of Social Sciences of the HUJI approved the study.

8.1.2. Data acquisition and reduction

The experiment was conducted in an air-conditioned laboratory. The apparatus included a HP Compaq DC 5800 Microtower computer that was used to control stimulus presentation and compute skin conductance, respiration and heart rate.

Electrodermal activity was recorded using a constant voltage system (0.5 V ASR Atlas Researches, Hod Hasharon, Israel), two Ag/AgCl electrodes (0.8 cm diameter) filled with a 0.05 M NaCL electrolyte (TD-246, Discount Disposables) and an A/D (NB-MIO-12) converter with a sampling rate of 50 Hz. Electrodes were placed on the distal phalanges of the left index and left ring finger. SCRs were defined as the maximal increase in conductance obtained from 1 to 5 s after stimulus onset (Boucsein et al., 2012).

The ECG was recorded by placing three Ag/AgCl electrodes filled with an electrode paste in a standard Einthoven lead I configuration: one electrode attached to the distal phalange of the left index finger (i.e., one of the SCR electrodes), one electrode attached to the right wrist and the ground electrode attached to the left wrist. The ECG signal was sampled at 500 Hz, digitized at 12-bit resolution and filtered using a band pass of 1–35 Hz. Matlab was used to detect the R peaks, calculate the distance between them and apply a semi-automatic artefact detection and rejection procedure (similar to e.g., De Clercq, Verschuere, De Vlieger, & Crombez, 2006). Prior to analysis, the IBIs were converted to HR in bpm per real-time epoch (1 s). These second-by-second post-stimulus HR values were baseline-corrected by subtracting the average HR value in the 3 s preceding stimulus onset (i.e., the pre-stimulus baseline value), resulting in 15 post-stimulus difference scores (ΔHR).

Respiration was also recorded in Experiment 2 by using a respiratory band positioned around the thoracic area. Respiration responses were defined on the basis of the total RLL, which is a composite measure of respiratory amplitude (depth of breathing) and respiratory cycle (rate of breathing), during the 0.5-s to 13.5-s interval following stimulus onset. Following Elaad et al. (1992), we defined each response as the mean of ten length measures (0.1 s after stimulus onset through 13.1 s after stimulus onset, 0.2 s through 13.2 s after stimulus onset, etc.). In other words, ten 13-s windows were created, each beginning 0.1 s later than the previous window, and the RLL was defined as the mean of the ten length measures computed for the ten windows.

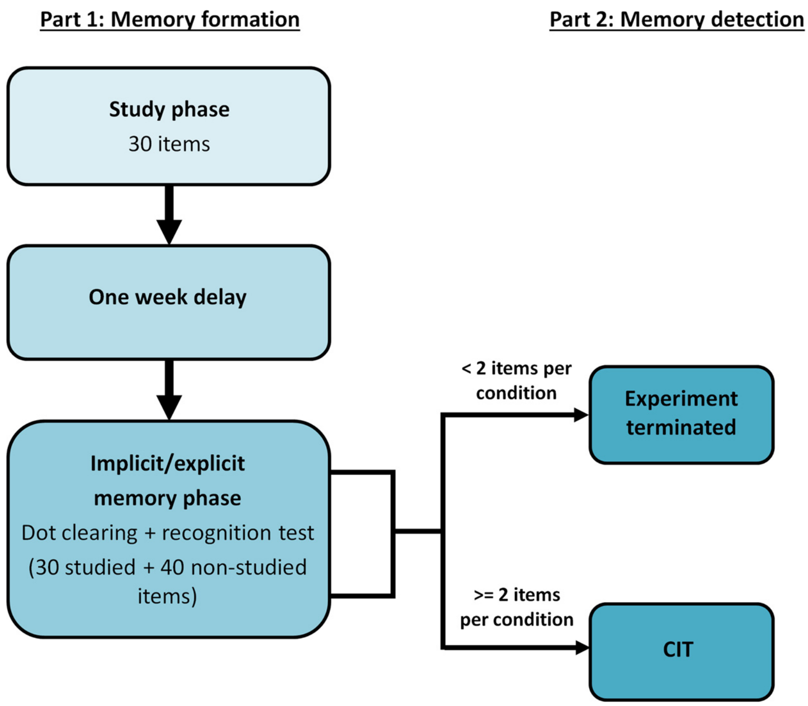

Fig. 3. Experimental design of Experiment 2: Part 1 (memory formation) and part 2 (memory detection).

8.1.3. Items

Two sets of items (Dutch words), a studied and a non-studied set, were created for the present experiment (see Appendix B). All items were taken from Moors et al. (2013) and rated as "average" (on a scale of 1–7) on valence, arousal and dominance: $M_{\text{valence}} = 4.12, M_{\text{arousal}} = 4.13, M_{\text{dominance}} = 4.06$. Importantly, all items were between four to nine letters long and had low resemblance to words in languages that participants were likely to be familiar with (English, French or Hebrew). The studied item-set contained 30 different Dutch words and was used in the study phase, the implicit/explicit memory phase and the memory detection phase of the experiment. The non-studied item-set, on the other hand, contained 40 different Dutch words and was used in the implicit/explicit memory phase and the memory detection phase of the experiment (see procedure below).

8.1.4. Procedure

Similar to Experiment 1, Experiment 2 consisted of a memory formation (part 1) and a memory detection (part 2) part. Part 1 was composed of two (rather than 4) different phases that were separated by a week delay: the study phase and the implicit/explicit memory phase (see Fig. 3). Thus, in contrast to Experiment 1, there was no distracter phase and the implicit and explicit memory phases were combined into a single memory test. The duration and content of the different phases was carefully constructed based on an extensive piloting phase in which the number of studied items, the number of study rounds, the study time and the formulation of the answer-options in the implicit/explicit memory phase were varied.

8.1.4.1. Part 1: memory formation. Study phase – Experimenter 1 instructed participants to learn the meaning of 30 Dutch words. All items plus their Hebrew translation were presented simultaneously, in a randomized order, on the computer monitor and participants were given 7 min to study them. After 7 min, participants were tested on their knowledge of the Dutch items using a recall test. In this recall test, participants viewed the Dutch items one by one and were requested to type the correct Hebrew translation. When answering incorrectly or making a spelling mistake, an error message (i.e., 'INCORRECT') was presented at the bottom of the screen for 500 ms. Importantly, when memory was at least 70%, the study phase was terminated. When memory was below 70%, participants were requested to study the items again for 5 min followed by a second recall test. Participants were given a maximum of three study/test rounds to reach the 70% limit; six participants did not succeed within three rounds and, hence, did not continue the experiment.

Implicit/explicit memory phase – all participants returned to the laboratory after one week delay to complete the implicit/explicit memory phase of the experiment. In this phase, Experimenter 2 instructed participants that they had to perform a combined implicit and explicit memory test on the previously learned Dutch words. Implicit memory was tested by means of a dot clearing test (adapted from Johnston, Dark, & Jacoby, 1985) and explicit memory was tested by means of a recognition test. Specifically, the items were initially masked by a cloud of dots and then slowly came into view as the dots gradually disappeared. Participants were instructed to press the spacebar as soon as they were able to read the word. Implicit memory would be indicated when the identification speed of a studied item was significantly faster than the average identification speed of all non-studied items (see CIT item selection below). After pressing, the item was fully presented and participants were asked to indicate whether it appeared in the word-list that they studied the week before: (1) No, the item did not appear in the word-list, (2) The item may have appeared in the word-list, and (3) Yes, the item appeared in the word-list. In addition to the 30 studied items, 40 non-studied Dutch items were also used in this phase of the experiment.[2] These items further served as controls and buffers in the CIT. Each of the studied and non-studied items were shown 3 times, which provided a more stable implicit/explicit measurement; item-presentation was random, with one restriction, that the same item could not

[2] A first pilot study (n = 5) showed that when participants did not learn the items from the studied set, the identification speed (in the dot clearing test) of these items was similar to the identification speed of items in the non-studied set: $M_{\text{RT-diff}} = -6.07$, Cohen's $d = -0.15$. A second pilot study (n = 26) showed that when participants did learn the items from the studied set, the identification speed (in the dot clearing test) of these items was significantly faster than the identification speed of items in the non-studied set: $M_{\text{RT-diff}} = 79.75$, Cohen's $d = 0.78$.

appear twice in a row. Thus, taken together, participants were presented with 70 items (30 studied + 40 non-studied) × 3 repetitions = 210 trials. These test trials were preceded by 4 practice trials that allowed participants to get familiar with the task. Finally, once all items had been presented, participants were asked to write the Hebrew meaning of the items that they explicitly remembered (i.e., marked at least twice with 3).

8.1.4.2. CIT item selection. After completion of part 1 of the experiment, the number of critical item-options for each of the two CIT conditions (explicit memory and implicit memory) was computed based on the results of the implicit/explicit memory phase; when this number was smaller than two in either condition, the experiment was terminated. As in Experiment 1, this typically happened due to lack of implicit items ($M_{\text{numberofimplicititems}} = 0.81$, $M_{\text{numberofexplicititems}} = 6.44$). When more than two options were available per condition, the two options with the fastest RT were selected as critical CIT items. Specifically, items included in the explicit memory condition had to fulfill the following criteria: (a) It should have been recognized (on average) at least 100 ms faster than the average RT computed across all non-studied items of the participant in the dot clearing test; (b) It had to be rated at least twice with '3' (i.e., "The item appeared in the word-list"); (c) its meaning in Hebrew should have been correctly written. Items included in the implicit memory condition had to fulfill the following criteria: (a) It should have been recognized (on average) at least 100 ms faster than the average RT computed across all non-studied items of the participant in the dot clearing test; (b) It had to be rated either three times with '1' (i.e., "No, the item did not appear in the word-list") or twice with '1' and once with '2' (i.e., "The item may have appeared in the word-list").[3] The 100 ms cutoff was based on our pilot findings, which showed a RT difference of 79.75 ms between the studied and non-studied item-set.

8.1.4.3. Part 2: memory detection. Thirty-nine (out of two hundred and five) participants continued to the second part of the experiment in which the actual CIT was conducted. Experimenter 2, who was unaware of the critical items, attached the SCR and HR electrodes as well as the RLL band and conducted the CIT examination. Before the CIT, participants were told that they would undergo a "polygraph"-examination in which they had to hide their knowledge of the Dutch items they had studied the week before. Participants were also promised a bonus of 10 NIS as an incentive for a successful concealment (i.e., passing the test). The bonus was paid when the average SCR standard-score, computed across all critical items (i.e., SCR detection score), was below 0.

The CIT consisted of two blocks, with a break between blocks to maintain participants' attention. Each block was composed of the same four questions and each question targeted one of the critical items. Taken together, participants were presented with a total of 2 blocks × 4 questions = 8 questions. Each question was presented on the computer monitor for 10 s and at the same time the prerecorded question was played through the computer's loudspeakers. The order of question presentation was random in each block, except that the last question in the first block could not appear as the first question in the second block. Following question presentation, the different items appeared for 5 s each, with an inter-stimulus interval of 14–18 s (Breska et al., 2011). The first item was always a neutral, buffer item designed to absorb the initial orienting response. Next, 1 critical item, 4 control items and 1 catch item were presented in a random order. Catch items were included as an extra means of assuring that participants' attention remained focused on the items presented and were similar to those described in Experiment 1 (except that the numbers were presented in English). When presented with a catch item, participants were requested to say the number out loud in English. In response to all other items, participants were requested to say "no" in Hebrew. In sum, participants were presented with 8 questions × 7 items (1 buffer, 1 critical, 4 control and 1 catch items), totaling 56 items. Following the CIT, participants completed the same paper-and-pencil questionnaire as in Experiment 1, after which they were debriefed and compensated for their participation in the experiment.

8.1.5. Data analysis

For the main analyses a 2 × 2 repeated measures ANOVA, with memory condition (explicit memory vs. implicit memory) and item type (critical vs. control) as within-subject factors was performed on each of the three physiological measures. The predicted Memory Condition × Item Type interaction was followed up by paired sample *t* tests comparing the critical and control items, separately for the explicit and for the implicit memory conditions. As in Experiment 1, we used the more powerful one-tailed *t* test for all analyses with a clear directional prediction. A rejection region of $p < 0.05$ was used for all statistical tests and both Cohen's *f* and Cohen's *d* values were computed as effect size estimates (Cohen, 1988). According to Cohen (1988), the values of $f = 0.1$, $f = 0.25$, and $f = 0.40$ as well as the values of $d = 0.2$, $d = 0.5$, and $d = 0.8$ correspond to small, medium, and large effects, respectively. Further, JZS BFs were computed for the critical-control comparison in each memory condition.

8.2. Results

The original data and analysis files are publically available on the Open Science Framework and accessible through the following link: https://osf.io/6v6hv/.

8.2.1. Subjective ratings

Participants reported high motivation ($M = 4.85$), high efforts to conceal knowledge of the critical items ($M = 4.77$) and moderate subjective memory of the critical items ($M = 3.69$).

8.2.2. Reaction times in the dot clearing test

The mean reaction time (RT) of the items in the studied set was 2970.62 ms and the mean RT of the items in the non-studied set was 3076.55. A paired sample *t*-test comparing these RTs revealed a significant difference, $t(198) = 14.77$, $p < 0.001$, $d = 1.05$. Thus, the dot clearing test provided a valid measure to differentiate between studied and non-studied items, regardless of explicit recognition.

8.2.3. Main analyses

All skin conductance data of 4 participants (10.3%) were removed due to non-responsivity. For the remaining participants, the skin conductance data within the first block of 1 participant (2.6%) and the skin conductance data within the second block of 3 participants (7.7%) were removed due to non-responsivity. Further, the heart rate data of 1 participant (2.6%) was lost due to too many undetected R peaks. Thus, while the RLL analysis is based on data of 39 participants, the HR analysis is based on data of 38 participants and the SCR analysis is based on data of 35 participants. For these participants, 2.7% of all SCRs, 2.8% of all RLL and 4.7% of all HR responses to the individual stimuli were removed due to excessive movements and outliers. Means and standard deviations of the raw responses to critical and control items were computed for each memory condition and each physiological measure and are displayed in Table 2.

8.2.3.1. SCR. A 2 × 2 repeated measures ANOVA revealed a significant main effect of item type, $F(1,34) = 17.35$, $f = 0.71$, $p < 0.001$ and a significant main effect of memory condition, *F*

[3] For seven participants we added an item to the implicit memory condition that was either marked twice with 2 and once with 1 or that had an RT difference of less than 100 ms with items in the non-studied set. As the removal of these items did not change the significance of our results, we decided to report only the full results.

Table 2
Raw means (SDs) of the Physiological Responses to Critical and Control Items in the Two Within-Subject Conditions of Experiment 2; *p*-value; Cohen's *d* with 95% CI; BF.

Measure	Condition	Mean raw scores (*SD*)		*p*-value	Cohen's *d* with 95% CI	BF
		Critical	Control			
SCR (*μ*S)	Explicit memory	0.35 (0.45)	0.14 (0.18)	0.000	0.70 (0.46, 0.93)	236.16 (favors alternative)
	Implicit memory	0.15 (0.26)	0.12 (0.22)	0.010	0.41 (0.28, 0.54)	4.36 (favors alternative)
RLL (*arb. units*)	Explicit memory	2213.24 (530.73)	2405.09 (582.31)	0.000	−0.60 (−0.83, −0.38)	105.08 (favors alternative)
	Implicit memory	2262.31 (518.63)	2369.52 (526.69)	0.004	−0.45 (−0.62, −0.29)	10.66 (favors alternative)
HR (*bpm*)	Explicit memory	−0.95 (2.29)	0.58 (1.58)	0.002	−0.49 (−1.01, 0.03)	16.05 (favors alternative)
	Implicit memory	−0.09 (2.84)	0.43 (1.47)	0.146	−0.17 (−0.59, 0.24)	2.00 (favors null)

Note. As concealed information is associated with respiratory and cardiac suppression, negative Cohen's *d* values are expected for the RLL and HR.

$(1,34) = 10.51$, $f = 0.56$, $p = 0.003$. Moreover, the predicted Memory Condition × Item Type interaction-effect was significant, $F(1,13) = 14.62$, $f = 0.66$, $p < 0.001$, reflecting a larger CIT effect in the explicit than the implicit condition. Follow-up paired sample *t* tests revealed a significant critical-control difference in both the explicit memory condition, $t(34) = 4.13$, $p < 0.001$, $d = 0.70$, and the implicit memory condition, $t(34) = 2.43$, $p = 0.010$, $d = 0.41$. These results were strengthened by the BFs: a value of 236.16 (favoring the alternative) was found for the explicit memory condition and a value of 4.36 (favoring the alternative) was found for the implicit memory condition. Thus, there is substantial evidence for the alternative hypothesis (i.e., larger responses to the critical than to the control items) in both the explicit and the implicit memory condition.

8.2.3.2. RLL. A 2 × 2 repeated measures ANOVA revealed a significant main effect of item type, $F(1,38) = 24.41$, $f = 0.80$, $p < 0.001$. Both the main effect of memory condition ($F(1,38) = 0.04$, $f = 0.03$, $p = 0.837$) and the Memory Condition × Item Type interaction ($F(1,38) = 1.64$, $f = 0.21$, $p = 0.104$) were not statistically significant. However, as we were primarily interested in the sensitivity of the CIT to implicit memory, we followed the ANOVA with paired sample *t* tests contrasting critical versus control items in each of the two memory conditions. The *t* tests revealed a significant critical-control difference in both the explicit memory condition, $t(38) = 3.77$, $p < 0.001$, $d = 0.60$, and the implicit memory condition, $t(38) = 2.83$, $p = 0.004$, $d = 0.45$. These results were strengthened by the BFs: a value of 105.08 (favoring the alternative) was found for the explicit memory condition and a value of 10.66 (favoring the alternative) was found for the implicit memory condition. Thus, there is substantial evidence for the alternative hypothesis in both the explicit and implicit memory condition.

8.2.3.3. HR. A 2 × 2 repeated measures ANOVA revealed a significant main effect of item type, $F(1,37) = 7.59$, $f = 0.45$, $p = 0.005$. Just as for the RLL, both the main effect of memory condition ($F(1,37) = 1.43$, $f = 0.20$, $p = 0.240$) and the Memory Condition × Item Type interaction ($F(1,37) = 2.32$, $f = 0.25$, $p = 0.068$) failed to reach significance. However, as we were primarily interested in the sensitivity of the CIT to implicit memory, we followed the ANOVA with paired sample *t* tests contrasting critical versus control items in each of the two memory conditions. The *t* tests revealed a significant critical-control difference in the explicit memory condition, $t(37) = 3.01$, $p = 0.002$, $d = 0.49$, but not in the implicit memory condition ($t(37) = 1.07$, $p = 0.146$, $d = 0.17$). These results were strengthened by the BFs: a value of 16.05 (favoring the alternative) was found for the explicit memory condition and a value of 2.00 (favoring the null) was found for the implicit memory condition. Thus, while there is substantial evidence for the alternative hypothesis in the explicit memory condition, there is no strong support for either hypothesis in the implicit memory condition.

8.3. Discussion

Experiment 2 re-examined whether implicitly recognized concealed information can be detected in the CIT. Two important changes were implemented: memory encoding was strengthened and two, rather than one, critical items were used per memory condition in the CIT. Because of the stronger encoding we also introduced a time-delay of a week between study and test. Thus, while Experiment 1 relied on weak encoding, Experiment 2 relied on the forgetting of strongly encoded information. When analyzing the results, CIT detection efficiency of the explicitly remembered items was found to be significant and stronger than in Experiment 1 (Cohen's *d* effect sizes in Experiment 1 were around 0.28-0.42 vs. 0.49-0.70 in Experiment 2). Detection efficiency of the implicitly remembered items was less strong, but it was statistically significant when relying on either the SCR or the RLL. Taken together, these results provide initial evidence that the CIT may be sensitive to implicit memory.

9. General discussion

In two separate experiments we examined whether the CIT is sensitive to implicit memory. This was accomplished by creating within participants both explicit and implicit memory. Experiment 1 relied on weak encoding (by presenting each item twice for one second in the study phase) and assessed implicit memory using a word-stem completion task and explicit memory using a recognition test. The results of Experiment 1 revealed that while the CIT effects with the SCR and HR measures were significant in the explicit memory condition, it was non-significant in the implicit memory condition. The sizes of the CIT effects for explicit memory were however far below the typically observed values. Experiment 2 therefore aimed to enhance overall detection efficiency by increasing the number of critical CIT items and by using more deeply encoded information. Thus, in Experiment 2 we relied on the decay of deeply encoded information (by asking participants to study the items for several minutes and testing them after a week delay) and assessed implicit memory using a dot clearing test and explicit memory using both recognition and recall measures. As expected, the CIT effect, with all three physiological measures (SCR, RLL and HR), was significant in the explicit memory condition and stronger than in Experiment 1. Further, although the CIT effect remained relatively weak in the implicit memory condition, it was statistically significant with the SCR and RLL measures. Moreover, Bayesian analyses in the implicit memory condition provided substantial evidence for the alternative hypothesis (i.e., larger responses to the critical than to the control items) with the SCR and RLL measures and no clear evidence for either hypothesis with the HR measure. Taken together, the results of Experiments 1 and 2 confirm the CITs sensitivity to explicit memory and the results of Experiment 2 provide initial evidence for its sensitivity to implicit memory.

9.1. CIT sensitivity to implicit memory

The first prediction of the present study stated that implicitly remembered information would be successfully detected with the CIT. The results of Experiment 2 provided initial support for this idea when using either the SCR or RLL, but not when using the HR measure. The non-significant detection of the HR is, however, not entirely surprising, as this is typically the least sensitive measure (see Gamer et al., 2008, and Meijer et al., 2014). There is also some evidence for this sensitivity difference in our explicit memory condition, with the SCR and RLL CIT effects being larger than the HR CIT effect.

The significant detection in the implicit memory condition using the SCR and RLL measures is in line with previous studies (e.g., Allen & Movius, 2000; Bauer, 1984; Newcombe & Fox, 1994). It should be noted, however, that some of these previous studies may have suffered from a certain degree of explicit contamination. For example, in the case studies of DID patients, both a meta-memory problem, i.e., the patients hold incorrect beliefs about their own memory functioning, and explicit memory transfer between identities that is denied by the patient may underlie the observed findings (see Huntjens et al., 2006, 2012). Indeed, two out of the four patients tested by Allen and Movius (2000) reported some degree of explicit recognition (i.e., "co-consciousness") and one of these patients also malingered his amnesia in a forced-choice task. Moreover, the P300 difference (between learned and unlearned items) was reliable only for the two patients reporting co-consciousness. Furthermore, while the child study of Newcombe and Fox (1994) relied on 9–10 year olds, the children tested by Stormark (2004) were only between 2 and 4 years of age and their verbal answers, indicating explicit or no explicit recognition, may have been unreliable. Indeed, Stormark (2004) indicated that 5 out of 12 children also reported recognizing unfamiliar children. Taken together, the earlier clinical and child studies suffered from several drawbacks and may actually have tapped into explicit memory. Hence, we believe that the novel design of our second experiment, which allowed the formation of both explicit and implicit memory within healthy adults, provides new and stronger evidence for the idea that different physiological measures can reveal implicit memories.

9.2. CIT sensitivity to explicit memory

A number of previous studies – both orienting response and CIT studies – have found a positive association between explicit recognition and detection efficiency (e.g., Carmel et al., 2003; Corteen, 1969; Gamer et al., 2010; Iacono et al., 1984; Waid et al., 1978, 1981). These studies revealed a decrease in both explicit recognition and SCR detection efficiency when more realistic types of mock-crimes were used. For example, when the critical items were not explicitly pointed out, when the CIT relied on peripheral instead of central crime-related items and when the time-delay between crime and test was increased. These findings suggest a link between the CIT and explicit memory. The second prediction of the present study therefore stated that the detection efficiency of explicit memory would be stronger than the detection efficiency of implicit memory. This prediction was confirmed in both experiments. Thus, the present study corroborates previous findings suggesting that CIT validity is closely tied to explicit recognition.

9.3. Practical implications

Are there applied implications for our finding that implicit memories may be detected in the CIT? Obviously, it raises the intriguing possibility that the CIT may be used in cases where implicit memory is preserved in the absence of explicit memory. For example, when there is a long time delay between crime and test, as is typical in real-life forensic cases, explicit memory may reduce, while implicit memory may survive (e.g., Kolers, 1976; Mitchell & Brown, 1988; Moscovitch & Bentin, 1993). It is worth considering, however, that the observed effects in the implicit memory condition were relatively weak. Moreover, it should also be noted that the possibility of detecting implicit memories may not always be advantageous. For example, an innocent suspect who obtained knowledge of the crime through leakage (either through the media or the police interrogation) may not always be explicitly aware of this knowledge or how it was obtained, and implicit memory would entail the risk of a false positive outcome.

At any case, as both this and other studies have shown a link between explicit recognition and CIT validity, critical items that are more likely to be remembered explicitly should be preferred whenever possible. Although such explicit memory cannot be ensured, several relevant considerations could be taken into account. First, items that were more likely to have been deeply encoded due for instance to prolonged or repeated exposure (e.g., the murder weapon, victim) should be preferred. Second, items that are less likely to have been forgotten due for instance to a higher intrinsic arousal level should be preferred.

Another less obvious, but equally important, implication of the present findings is the possibility of using the CIT as an implicit memory assessment tool in both children and certain patient groups. A major advantage of the CIT in comparison to other implicit memory tests (e.g., word stem completion or fragmentation tasks) is the ease of the task. Participants simply need to watch or listen to the different items which require minimal effort. In contrast, other common implicit tasks require a more active involvement, which may be difficult for certain patient groups and small children. Moreover, it should also be noted that some of the most well-known implicit memory tests (i.e., word stem completion task) have been criticized on methodological grounds, because they may suffer from explicit contamination (e.g., Mitchell & Bruss, 2003). Hence, there is a need for other types of implicit memory assessment tools.

9.4. Limitations and future directions

In spite of the discussed implications, the present study also suffers from several limitations. First and foremost, the effect sizes observed in the implicit memory condition of Experiment 2 were only small to medium. Hence, it is unclear whether they are strong enough to have a significant applied value as suggested above. Moreover, the effects in the implicit memory condition of Experiment 1 were even smaller and non-significant. This difference between experiments may in part be related to several design-related factors. Consequently, a number of suggestions for future research can be formulated. First, it is suggested to rely on several different critical items, thereby enhancing the overall detection efficiency of the CIT. Further, it is suggested to rely on more deeply encoded and more significant information. For example, by asking participants to perform a number of different activities with the critical items in the lab (i.e., an enactment procedure). Alternatively, encoding (i.e., the study phase) can be skipped and items which are known to have been previously encoded may be used in the CIT. For instance, similar to the child studies of Newcombe and Fox (1994) and Stormark (2004), faces or names of previous classmates or colleagues may be selected. This idea may however prove challenging as one will need to obtain such names/pictures from either the participant himself (e.g., by bringing a yearbook) or from the relevant institution (e.g., school, work-place). Similarly, future studies may test participants' knowledge of a language or skill learned in childhood, which has been explicitly forgotten. In sum, there are a number of interesting possibilities to further explore the sensitivity of the CIT to implicit memory.

A second limitation pertains to the question of whether we really created implicit memory. Although the combination of implicit and explicit measures in the present study heightened the likelihood that our selected implicit items were indeed purely implicit, this may not always have been the case. In Experiment 1, implicit items were correctly completed in a WSC task. Although this method has been used in many previous studies, it is possible that some of the stems were correctly completed because it was simply the most obvious answer. Consequently, the selected implicit items might actually have been forgotten, which may explain the non-significant detection. In a similar vein, the significant detection in the implicit memory condition of Experiment 2 may possibly have resulted from miss-classifying explicit as implicit items. Note however that we used more strict inclusion criteria in the second experiment. Specifically, to enhance the reliability of our explicit-implicit categorization, each item was shown three times. The average RT of these three presentations should have been at least 100 ms faster than the average RT of all non-studied items and explicit recognition should have remained absent during all three presentations. There is a slight possibility that explicit recognition returned only during the CIT (the fourth time the item was presented). However, as these cases seem to be the exception rather than the rule, it is unlikely that they can explain our findings. Future studies may examine other implicit tests and thresholds or attempt to use a between-subjects design. The between-subjects option (one group of participants will be tested only on explicit items and another group of participants will be tested only on implicit items) is preferable if it increases the chance of finding multiple explicit/implicit items per participant.

A third limitation refers to the fact that only few participants were selected for the second part of the experiment in which the CIT was conducted (33% in Experiment 1 and 19% in Experiment 2). This may have possibly caused some kind of bias to the results. A low number of implicit items was usually the reason for early termination of the experiment. In Experiment 2, for example, explicit recognition returned in many cases on the second or third presentation of the item in the implicit/explicit memory phase. This finding brings us back to the question about the nature of explicit and implicit memory. Is implicit memory simply a weak explicit memory (as suggested by the threshold theory) or are they qualitatively different (as suggested by the multiple memory systems theory)? Moreover, it may be questioned whether we found physiological evidence of weakened explicit memory or true implicit memory. This question seems pivotal for our understanding of the CIT and should definitely be further examined in future studies.

10. Conclusions

This study provides initial evidence that the CIT may be sensitive to implicit memory. Although the observed effects in the implicit memory condition tended to be smaller than the effects in the explicit memory condition (this direction was observed in both Experiments, but it was statistically significant only for the SCR measure in Experiment 2), the results of Experiment 2 are promising as they demonstrate that even implicitly remembered items can be detected to some extent. We therefore hope that this initial study will encourage future research examining the boundary conditions of the CIT effect. Such a line of research will more definitely determine the physiological markers of implicit memory.

Author notes

This research was funded by a grant, No. 238/15, from the Israel Science Foundation to Gershon Ben-Shakhar and by the University of Amsterdam. We wish to thank Marceline Veen, Saskia van den Born, Mirte van Hal, Noa Feldman, Shani Vaknine, Eli Rosner, Naama Agari, Neomi Cohen, Guy Amir, Karin Avraham, Danna Waxman and Gal Samuel for their assistance in data collection.

Appendix A

Category	Item-sets				
	1	2	3	4	buffer
fruit	aardbei [strawberry]	mandarijn [tangerine]	banaan [banana]	perzik [peach]	ananas [pineapple]
animals	antilope [antelope]	kameel [camel]	pinguin [penguin]	tijger [tiger]	gorilla [gorilla]
time indicators	minuut [minute]	decennium [decade]	seconde [second]	kwartier [quarter hour]	semester [semester]
sport	tennis [tennis]	ballet [ballet]	roeien [rowing]	klimmen [climbing]	zeilen [sailing]
herbs	gember [ginger]	bieslook [chive]	basilicum [basil]	kerrie [curry]	koflook [garlic]
head of state	koning [king]	keizer [emperor]	hertog [duke]	president [president]	sultan [sultan]
accessories	broche [brooch]	paraplu [umbrella]	bretels [suspenders]	ketting [necklace]	piercing [piercing]
artists	zanger [singer]	regisseur [director]	acteur [actor]	tekenaar [draftsman]	schilder [painter]

precious stones	diamant [diamond]	kristal [cristal]	smaragd [emerald]	briljant [brilliant]	robijn [ruby]
house types	kasteel [castle]	paleis [palace]	caravan [caravan]	burcht [castle]	boerderij [farm]
profession	kapper [hairdresser]	advocaat [lawyer]	bewaker [guard]	monteur [mechanic]	docent [teacher]
rooms in house	keuken [kitchen]	terras [terrace]	berging [storage]	kantoor [office]	badkamer [bathroom]
relations	kennis [acquaintance]	vriend [friend]	collega [colleague]	geliefde [lover]	verloofde [fiancee]
fabric	fluweel [velvet]	flannel [flannel]	katoen [cotton]	satijn [satin]	polyester [polyester]
home appliances	fornuis [stove]	droger [dryer]	magnetron [microwave]	radiator [radiator]	televisie [television]
natural phenomena	geiser [geyser]	krater [crater]	vulkaan [volcano]	lagune [lagoon]	gletsjer [glacier]
musical instruments	trompet [trumpet]	drumstel [drumkit]	klarinet [clarinet]	accordion [accordion]	gitaar [guitar]
animal noises	piepen [to squeak]	zoemen [to zoom]	blaffen [to bark]	knorren [to grunt]	brullen [to roar]
toys	hoepel [hula hoop]	domino [domino]	barbie [barbie]	knikker [marble]	knuffel [stuffed animal]
life stages	kleuter [preschooler]	zuigeling [infant]	dreumes [infant]	senior [senior]	peuter [toddler]
materials	papier [paper]	porselein [porcelain]	graniet [granite]	metaal [metal]	rubber [rubber]
office supplies	schaar [scissors]	kalender [calendar]	potlood [pencil]	liniaal [ruler]	agenda [diary]
astronomy	planeet [planet]	komeet [comet]	ruimte [space]	heelal [universe]	asteroïde [asteroid]
flowers	margriet [daisy]	krokus [crocus]	geranium [geranium]	chrysant [chrysanthemum]	narcis [narcissus]
body parts	vinger [finger]	bekken [pelvis]	gezicht [face]	boezem [breast]	taille [waist]
organs	darmen [intestines]	longen [lungs]	nieren [kidneys]	prostaat [prostate]	spieren [muscles]
vegetables	wortel [carrot]	courgette [zucchini]	champignon [mushroom]	spruitjes [sprouts]	andijvie [endive]
sweets	chocolade [chocolate]	praline [praline]	caramel [caramel]	vanille [vanilla]	meringue [meringue]
seafood	garnaal [shrimp]	kreeft [lobster]	tonijn [tuna]	makreel [mackerel]	kabeljauw [codfish]
cooking methods	grillen [to grill]	stomen [to steam]	frituren [to fry]	braden [to roast]	bakken [to bake]

Note. For each participant, one set of items (1, 2, 3 or 4) served as the critical item-set.

Appendix B

Studied set (Dutch)	Studied set (English)	Studied set (Hebrew)	Unstudied set (Dutch)	Unstudied set (English)	Unstudied set (Hebrew)
afstand	distance	מרחק	arbeid	labor	עבודה
akte	document	מסמך	bijster	very	די
bezem	broom	מטאטא	blaffen	to bark	לנבוח
degen	sword	חרב	bliksem	lightning	ברק
ezel	donkey	חמור	diefstal	theft	גנבה
geschenk	gift	מתנה	doelwit	target	מטרה
gezicht	face	פרצוף	emmer	bucket	דלי
kantoor	office	משרד	erwt	pea	אפונה
karwei	job	עבודה	fakkel	torch	לפיד
koning	king	מלך	garnaal	shrimp	שרימפ
meeuw	seagull	שחף	geel	yellow	צהוב
onkruid	weed	עשב	geheim	secret	סוד
perzik	peach	אפרסק	gember	ginger	ג'ינג'ר
plein	square	כיכר	haasten	to hurry	למהר
rijkdom	wealth	עושר	kapper	hairdresser	ספר
rimboe	jungle	ג'ונגל	katoen	cotton	כותנה
schaar	scissors	מספריים	kleed	carpet	מרבר
sluis	lock	מנעול	krachtig	forceful	חזק
spiegel	mirror	מראה	luiden	to sound	להישמע
stuiver	penny	אגורה	machtig	powerful	עוצמתי
tapijt	carpet	שטיח	meisje	girl	ילדה
toekomst	future	עתיד	niezen	to sneeze	להתעטש
twijfel	doubt	ספק	nijver	industrious	שקוד
verlegen	shy	ביישן	onecht	spurious	בדוי
vleugel	wing	כנף	peinzen	to ponder	להרהר
vlinder	butterfly	פרפר	pijnlijk	painful	כואב
vrucht	fruit	פרי	ridder	knight	אביר
werf	yard	חצר	roebel	ruble	זבל
wortel	root	גזר	rumoerig	noisy	רועש
zanger	singer	זמר	schillen	to peel	לקלף
			schuldig	guilty	אשם
			spannend	exciting	מלהיב
			telg	scion	נצר
			termijn	term	המועד האחרון
			veilig	safe	בטוח
			vlecht	braid	צמה
			wimper	eyelash	ריס
			wrijven	to rub	לשפשף
			zoet	sweet	מתוק
			zorgen	to care	לדאוג

References

Allen, J. J. B., & Mertens, R. (2009). Limitations to the detection of deception: True and false recollections are poorly distinguished using and event-related potential procedure. *Social Neuroscience, 4*, 473–490. http://dx.doi.org/10.1080/17470910802109939.

Allen, J. J. B., & Movius, H. L. (2000). The objective assessment of amnesia in dissociative identity disorder using event-related potentials. *International Journal of Psychophysiology, 38*, 21–41. http://dx.doi.org/10.1016/S0167-8760(00)00128-8.

Baioui, A., Ambach, W., Walter, B., & Vaitl, D. (2012). Psychophysiology of false memories in a Deese-Roediger-McDermott paradigm with visual scenes. *PUBLIC LIBRARY OF SCIENCE, 7*, e30416. http://dx.doi.org/10.1371/journal.pone.0030416.

Bauer, R. M., & Verfaellie, M. (1988). Electrodermal discrimination of familiar but not unfamiliar faces in prosopagnosia. *Brain and Cognition, 8*, 240–252. http://dx.doi.org/10.1016/0278-2626(88)90052-8.

Bauer, R. M. (1984). Autonomic recognition of names and faces in prosopagnosia: a neuropsychological application of the Guilty Knowledge Test. *Neuropsychologia, 22*, 457–469. http://dx.doi.org/10.1016/0028-3932(84)90040-X.

Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science, 275*, 1293–1295. http://dx.doi.org/10.1126/science.275.5304.1293.

Ben-Shakhar, G., & Elaad, E. (2003). The validity of psychophysiological detection of information with the Guilty Knowledge Test: A meta-analytic review. *Journal of Applied Psychology, 88*, 131–151. http://dx.doi.org/10.1037/0021-9010.88.1.131.

Ben-Shakhar, G. (2012). Current research and potential applications of the concealed information test: An overview. *Frontiers in Psychology, 3*, 342. http://dx.doi.org/10.3389/fpsyg.2012.00342.

Boucsein, W., Fowles, D. C., Grimnes, S., Ben-Shakhar, G., Roth, W. T., Dawson, M. E., & Filion, D. L. (2012). Publication recommendations for electrodermal measurements. *Psychophysiology, 49*, 1017–1034. http://dx.doi.org/10.1111/j.1469-8986.2012.01384.x.

Breska, A., Maoz, K., & Ben-Shakhar, G. (2011). Inter-stimulus intervals for skin conductance response measurement. *Psychophysiology, 48*, 437–440. http://dx.doi.org/10.1111/j.1469-8986.2010.01084.x.

Carmel, D., Dayan, E., Naveh, A., Raveh, O., & Ben-Shakhar, G. (2003). Estimating the validity of the guilty knowledge test from simulated experiments: The external validity of mock crime studies. *Journal of Experimental Psychology: Applied, 9*, 261–269. http://dx.doi.org/10.1037/1076-898X.9.4.261.

Cohen, J. E. (1988). *Statistical power analysis for the behavioral sciences.* Hillsdale, NJ: Lawrence Erlbaum.

Corteen, R. S. (1969). Skin conductance changes and word recall. *British Journal of Psychology, 60*, 81–84. http://dx.doi.org/10.1111/j.2044-8295.1969.tb01179.x.

De Clercq, A., Verschuere, B., De Vlieger, P., & Crombez, G. (2006). Psychophysiological Analysis (PSPHA): A modular script-based program for analyzing psychophysiological data. *Behavior Research Methods, 38*, 504–510. http://dx.doi.org/10.3758/BF03192805.

Elaad, E., Ginton, A., & Jungman, N. (1992). Detection measures in real-life criminal guilty knowledge tests. *Journal of Applied Psychology, 77*, 757–767. http://dx.doi.org/10.1037//0021-9010.77.5.757.

Elaad, E. (1990). Detection of guilty knowledge in real-life criminal investigations. *Journal of Applied Psychology, 75*, 521–529. http://dx.doi.org/10.1037/0021-9010.75.5.521.

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

Gamer, M., Kosiol, D., & Vossel, G. (2010). Strength of memory encoding affects physiological responses in the Guilty Actions Test. *Biological Psychology, 83*, 101–107. http://dx.doi.org/10.1016/j.biopsycho.2009.11.005.

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. http://dx.doi.org/10.1017/CBO9780511975196.003.

Girelli, L., Semenza, C., & Delazer, M. (2004). Inductive reasoning and implicit memory: Evidence from intact and impaired memory systems. *Neuropsychologia, 42*, 926–938. http://dx.doi.org/10.1016/j.neuropsychologia.2003.11.016.

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11*, 501–518. http://dx.doi.org/10.1037//0278-7393.11.3.501.

Graf, P., Squire, L. R., & Mandler, G. (1984). The information that amnesic patients do not forget. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10*, 164–178. http://dx.doi.org/10.1037/0278-7393.10.1.164.

Gronau, N., Elber, L., Satran, S., Breska, A., & Ben-Shakhar, G. (2015). Retroactive memory interference: A potential countermeasure technique against psychophysiological knowledge detection methods. *Biological Psychology, 106*, 68–78. http://dx.doi.org/10.1016/j.biopsycho.2015.02.002.

van den Hout, M. A., de Jong, P., & Kindt, M. (2000). Masked fear words produce increased SCRs: An anomaly for Öhman's theory of pre-attentive processing in anxiety. *Psychophysiology, 37*, 283–288. http://dx.doi.org/10.1111/1469-8986.3730283.

Huntjens, R. J. C., Peters, M. L., Woertman, L., Bovenschen, L. M., Martin, R. C., & Postma, A. (2006). Inter-identity amnesia in dissociative identity disorder: A simulated memory impairment? *Psychological Medicine, 36*, 857–863. http://dx.doi.org/10.1371/journal.pone.0040580.

Huntjens, R. J. C., Verschuere, B., & McNally, R. J. (2012). Inter-identity autobiographical amnesia in patients with Dissociative Identity Disorder. *PUBLIC LIBRARY OF SCIENCE, 7*, e40580. http://dx.doi.org/10.1371/journal.pone.0040580.

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

Jeffreys, H. (1961). *Theory of probability* (3rd ed.). New York: Oxford University Press.

Jenkins, R., Burton, A. M., & Ellis, A. W. (2002). Long-term effects of covert face recognition. *Cognition, 86*, B43–B52. http://dx.doi.org/10.1016/S0010-0277(02)00172-5.

Johnston, W. A., Dark, V. J., & Jacoby, L. L. (1985). Perceptual fluency and recognition judgments. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 11*, 3–11. http://dx.doi.org/10.1037/0278-7393.11.1.3.

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. http://dx.doi.org/10.1111/psyp.12583.

klein Selle, N., Verschuere, B., Kindt, M., Meijer, E. H., & Ben-Shakhar, G. (2017). Unraveling the roles of orienting and inhibition in the Concealed Information Test. *Psychophysiology, 54*, 628–639. http://dx.doi.org/10.1111/psyp.12825.

Kolers, P. A. (1976). Reading a year later. *Journal of Experimental Psychology: Human Learning and Memory, 2*, 554–565. http://dx.doi.org/10.1037/0278-7393.2.5.554.

Kong, L. L., Allen, J. J. B., & Glisky, E. L. (2008). Inter-identity memory transfer in dissociative identity disorder. *Journal of Abnormal Psychology, 3*, 686–692. http://dx.doi.org/10.1037/0021-843X.117.3.686.

Korsakoff, S. S. (1889). Etude medico-psychologique sur une forme des maladies do la memoire. *Revue Philosophique, 28*, 501–530.

Lalouschek, W., Goldenberg, G., Marterer, A., Beisteiner, R., Lindinger, G., & Lang, W. (1997). Brain/behaviour dissociation on old/new distinction in a patient with amnesic syndrome. *Electroencephalography and Clinical Neurophysiology, 104*, 222–227. http://dx.doi.org/10.1016/S0168-5597(96)96552-1.

Leibniz, G. W. (1916). *New essays concerning human understanding.* Chicago: Open Court.

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

Maltzman, I., Kantor, W., & Langdon, B. (1966). Immediate and delayed retention, arousal, and the orienting and defensive reflexes. *Psychonomic Science, 6*, 445–446. http://dx.doi.org/10.3758/BF03328083.

Maoz, K., Breska, A., & Ben-Shakhar, G. (2012). Orienting response elicitation by personally significant information under subliminal stimulus presentation: A demonstration using the concealed information test. *Psychophysiology, 49*, 1610–1617. http://dx.doi.org/10.1111/j.1469-8986.2012.01470.x.

McLean, P. D. (1969). Induced arousal and time of recall as determinants of paired associate recall. *British Journal of Psychology, 60*, 57–62. http://dx.doi.org/10.1111/j.2044-8295.1969. tb01176.x.

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. http://dx.doi.org/10.1111/psyp.12239.

Merckelbach, H., Devilly, G. J., & Rassin, E. (2002). Alters in dissociative identity disorder: Metaphors or genuine entities? *Clinical Psychology Review, 22*, 481–497. http://dx.doi.org/10.1016/S0272-7358(01)00115-5.

Mitchell, D. B., & Brown, A. S. (1988). Persistent repetition priming in picture naming and its dissociation from recognition memory. *Journal of Experimental Psychology: Learning, Memory and Cognition, 14*, 213–223. http://dx.doi.org/10.1037//0278-7393.14.2.213.

Mitchell, D. B., & Bruss, P. J. (2003). Age differences in implicit memory: Conceptual, perceptual, or methodological? *Psychology and Aging, 18*, 807–822. http://dx.doi.org/10.1037/0882-7974.18.4.807.

Moors, A., de Houwer, J., Hermans, D., Wanmaker, S., van Schie, K., van Harmelen, A. L., et al. (2013). Norms of valence, arousal, dominance, and age of acquisition for 4,300 Dutch words. *Behavior Research Methods, 45*, 169–177. http://dx.doi.org/10.3758/s13428-012-0243-8.

Moscovitch, M., & Bentin, S. (1993). The fate of repetition effects when recognition approaches chance. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 148–158. http://dx.doi.org/10.1037/0278-7393.19.1.148.

Nahari, G., & Ben-Shakhar, G. (2011). Psychophysiological and behavioral measures for detecting concealed information: The role of memory for crime details. *Psychophysiology, 48*, 733–744. http://dx.doi.org/10.1111/j.1469-8986.2010.01148.x.

Newcombe, N. S., & Fox, N. (1994). Infantile amnesia: Through a glass darkly. *Child Development, 65*, 31–40. http://dx.doi.org/10.2307/1131363.

Öhman, A., & Soares, J. J. (1994). Unconscious anxiety: Phobic responses to masked stimuli. *Journal of Abnormal Psychology, 103*, 231–240. http://dx.doi.org/10.1037//0021-843X.103.2.231.

Peth, J., Vossel, G., & Gamer, M. (2012). Emotional arousal modulates the encoding of crime related details and corresponding physiological responses in the Concealed Information Test. *Psychophysiology, 49*, 381–390. http://dx.doi.org/10.1111/j.1469-8986.2011.01313.x.

Prince, M. (1914). *The unconscious.* New York: Macmillen.

Rajaram, S., & Roediger, H. L. (1993). Direct comparison of four implicit memory tests. *Journal of Experimental Psychology, 19*, 765–776. http://dx.doi.org/10.1037/0278-7393.19.4.765.

Roediger, H. L., & McDermott, K. B. (1993). Implicit memory in normal human subjects. In F. Boller, & J. Grafman (Vol. Eds.), *Handbook of neuropsychology: Vol 8*, (pp. 63–131). Amsterdam: Elsevier.

Rouder, J. N., Speckman, P. L., Sun, D., Morey, R. D., & Iverson, G. (2009). Bayesian *t*-tests for accepting and rejecting the null hypothesis. *Psychonomic Bulletin & Review, 16*, 225–237. http://dx.doi.org/10.3758/PBR.16.2.225.

Schacter, D. L. (1992). Understanding implicit memory: A cognitive neuroscience

approach. *American Psychologist, 47*, 559–569. http://dx.doi.org/10.1037/0003-066X.47.4.559.
Silvert, L., Delplanque, S., Bouwalerh, H., Verpoort, C., & Sequeira, H. (2004). Autonomic responding to aversive words without conscious valence discrimination. *International Journal of Psychophysiology, 53*, 135–145. http://dx.doi.org/10.1016/j.ijpsycho.2004.03.005.
Soares, J. J., & Öhman, A. (1993). Backward masking and skin conductance responses after conditioning to nonfeared but fear-relevant stimuli in fearful subjects. *Psychophysiology, 30*, 460–466. http://dx.doi.org/10.1111/j.1469-8986.1993.tb02069.x.
Squire, L. R. (1992). Memory and the hippocampus: A synthesis from findings with rats, monkeys and humans. *Psychological Review, 99*, 195–231.
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. http://dx.doi.org/10.1002/icd.368.
Tranel, D., & Damasio, A. R. (1985). Knowledge without awareness: An autonomic index of facial recognition by prosopagnosics. *Science, 228*, 1453–1454. http://dx.doi.org/10.1126/science.4012303.
Tulving, E., & Schacter, D. L. (1990). Priming and human memory systems. *Science, 247*, 301–306.
Verfaellie, M., Bauer, R. M., & Bowers, D. (1991). Autonomic and behavioral evidence of implicit memory in amnesia. *Brain and Cognition, 15*, 10–25. http://dx.doi.org/10.1016/0278-2626(91)90012-W.
Verschuere, B., Crombez, G., Degrootte, T., & Rosseel, Y. (2010). Detecting concealed information with reaction times: Validity and comparison with the polygraph. *Applied Cognitive Psychology, 24*, 991–1002. http://dx.doi.org/10.1002/acp.1601.
Verschuere, B., Ben-Shakhar, G., & Meijer, E. H. (Eds.). (2011). *Memory detection: Theory and application of the Concealed Information Test*. Cambridge, UK: Cambridge University Press.
Volz, K., Leonhart, R., Stark, R., Vaitl, D., & Ambach, W. (2017). Psychophysiological correlates of the misinformation effect. *International Journal of Psychophysiology, 117*, 1–9. http://dx.doi.org/10.1016/j.ijpsycho.2017.04.004.
Waid, W. M., Orne, E. C., Cook, M. R., & Orne, M. T. (1978). Effects of attention, as indexed by subsequent memory, on electrodermal detection of information. *Journal of Applied Psychology, 63*, 728–733. http://dx.doi.org/10.1037/0021-9010.63.6.728.
Waid, W. M., Orne, E. C., & Orne, M. T. (1981). Selective memory for social information, alertness, and physiological arousal in the detection of deception. *Journal of Applied Psychology, 66*, 224–232. http://dx.doi.org/10.1037/0021-9010.66.2.224.
Wiens, S., Katkin, E. S., & Öhman, A. (2003). Effects of trial order and differential conditioning on acquisition of differential shock expectancy and skin conductance conditioning to masked stimuli. *Psychophysiology, 40*, 989–997. http://dx.doi.org/10.1111/1469-8986.00117.