Importance-related Fillers Improve the Classification Accuracy of the Response Time
Concealed Information Test in a Crime Scenario

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Abstract

Purpose. The Response Time Concealed Information Test (RT-CIT) can reveal when a person recognizes a relevant item among other irrelevant items, based on comparatively slower responding. Therefore, if a person is concealing knowledge about the relevance of this item (e.g., recognizing it as a murder weapon), this deception can be revealed. A recent study introduced additional “familiarity-related fillers”, and these items substantially enhanced diagnostic efficiency in detecting autobiographical data. However, the generalizability of the efficiency of fillers to other scenarios remains an open question. We empirically investigated whether new importance-related fillers enhanced diagnostic efficiency in an imaginary crime scenario.

Methods. Two hundred and thirty-nine volunteers participated in an independent samples experiment. Participants were asked to imagine either committing a crime (“guilty” group) or to imagine visiting a museum (“innocent” group). Then, all participants underwent RT-CIT testing using either a standard single probe or an enhanced single probe (with importance-related fillers) protocol.

Results. The enhanced RT-CIT (with importance-related fillers) showed high diagnostic efficiency ($AUC = .810$), and significantly outperformed the standard version ($AUC = .562$). Neither dropout rates nor exclusion criteria influenced this enhancement.

Conclusions. Importance-related fillers improve diagnostic efficiency when detecting episodic information using the RT-CIT, and seem to be useful in detecting knowledge in a wide range of scenarios.

Keywords: deception, Concealed Information Test, response time, validation

Introduction

One of the most prominent techniques used in detecting deception is the Concealed Information Test (CIT). At the end of the 1950s, Lykken (1959) proposed a CIT based on skin conductance responses as a scientifically-based alternative to the classic, but much criticized, technique of using polygraph interrogation with a Control Question Test (CQT; for a critical review of the usage of CQTs see, e.g., National Research Council, 2003; Iacono & Ben-Shakhar, 2019). Lykken claimed that, instead of focusing on lie detection, his method focused on the detection of guilty knowledge: information regarding a certain crime detail known only to the perpetrator and the investigators. To illustrate the basic notion of the CIT, let us consider a murder case scenario in which the murder weapon is known only to the offender and the Police. In this case, the CIT could include the actual murder weapon (the *probe*; e.g., “rifle”) and several other weapons (*irrelevants*; e.g., “knife,” and “rope”). These items would be presented sequentially to a suspect in random or sometimes pseudorandom order. Lykken and his successors showed that the CIT could be successfully used in conjunction with recording and analyzing changes in autonomic nervous system measures (see, e.g., Lykken, 1960; Verschuere, Meijer, & De Clercq, 2011; Meijer, Klein Selle, Elber, & Ben-Shakhar, 2014). However, in the years that have elapsed since Lykken’s initial publication, other measures have been introduced and used to detect the concealment of information, for example, P300 amplitude (P300-CIT; for a review, see Rosenfeld, 2020), and response time (RT-CIT; e.g., Seymour, Seifert, Shafto, & Mosmann, 2000; Verschuere, Crombez, Degrootte, & Rosseel, 2010).

In the RT-CIT, each test item is responded to with a keypress. Recognition of the probe (in the present case, “rifle”) by a guilty person (who is aware of the relevance of the item) will typically result in a slower response to the item compared to irrelevant items (for a

theoretical review, see e.g. Verschuere & De Houwer, 2011). Therefore, based on probe-irrelevant RT differences (a RT-CIT-effect), a guilty person can be distinguished from an innocent one (Verschuere, Crombez, Degrootte, & Rosseel, 2010). The standard RT-CIT (henceforth referred to as the S-CIT) includes a single (randomly chosen) *target* irrelevant item that requires the pressing of a response key which is different from the one pressed in response to probe and nontarget irrelevant items. For example, the key “I” has to be pressed whenever the target item appears, while the key “E” has to be pressed whenever any of the other items (probe and nontarget irrelevants) appear. However, some studies have shown that the accuracy of the technique is considerably lowered or even ineffective when only one probe (and corresponding target) per test block is used (“single-probe” protocol), as opposed to when all probes (and targets) are mixed randomly within each block (“multiple-probe” protocol; Verschuere, Kleinberg, & Theocharidou, 2015; Kleinberg & Verschuere, 2015; see Figure 1 (Lukács, Kleinberg, et al., 2017, fig. 1). The single-probe protocol however has several important practical advantages, such as applicability even in case of a limited number of probe items (e.g., Podlesny, 2003), compatibility with common test procedures and scoring algorithms (e.g., Krapohl, 2011), and sequential testing to narrow down possibilities (e.g., Lukács, Kleinberg, et al., 2017).

<<Insert figure 1 about here>>

A recent study introduced a significantly enhanced version of the RT-CIT (henceforth referred to as the E-CIT) by adding filler items to the task (Lukács, Kleinberg, et al., 2017). In a knowledgeable condition of this study, the probes were certain personal details of a

participant (birthdate, favorite animal, etc.)¹, which were therefore “familiar” (self-related, recognizable, etc.) to a given participant, as opposed to the irrelevants (e.g., other dates, random animal names) that were in this context rather “unfamiliar” (other-related, etc.). Two corresponding types of filler words were added to the task: (a) familiarity- and self-related filler words (“FAMILIAR,” “RECOGNIZED,” and “MINE”) that had to be categorized using the key which was also used for the target (and, thus, with the opposite key to that used for the probe and irrelevants), and; (b) unfamiliarity- and other-related filler words (“UNFAMILIAR,” etc.) that had to be categorized using the key which was also used for the probe and irrelevants.

In the E-CIT it is hypothesized² that responses to familiar probes (true personal details for a given participant) should be even slower than for probes in the S-CIT because they have to be categorized *together* with unfamiliarity-related stimuli (and oppositely to familiarity-related stimuli; see, e.g., Greenwald, et al., 2009). In contrast, participants given random details as probes (i.e., not their own personal details) should see no substantial difference between probes and irrelevants (the probes should be no more familiar, self-related, or recognizable than the irrelevants), and therefore the fillers should not slow down responses to probes. The results of the Lukács, Kleinberg, et al. (2017) study confirmed this reasoning. Also, a follow-up study (Lukács & Ansorge, 2021) provided strong evidence that the meaning of the fillers matters: reversing key mapping (unfamiliarity-related fillers categorized together with targets), as well as using neutral (e.g., object name) or pseudoword fillers, both reduced, or even obliterated, the enhancing effect of fillers.

¹ In a naive condition, the probes for participants were just other irrelevant items (random dates, animals, etc.).

² The hypothesis described here is only one of two key possibilities. The other one is less relevant to the present paper, but, in brief, it is related to the fact that the increased complexity also requires more attention throughout the task, which likely facilitates deeper processing of the stimuli (Lukács, Kleinberg, et al., 2017; see also Hu et al., 2013; Visu-Petra et al., 2013).

Since the meaning of fillers is therefore clearly crucial, the question arises as to how well the efficacy of fillers generalizes to other types of probe (in particular, to crime-related items), which are more likely to occur in real police investigations than autobiographical items. In the present study, we introduced importance-related fillers to the RT-CIT, to be used with crime-related items. More precisely, the fillers to be categorized together with the target were “IMPORTANT,” “SIGNIFICANT,” and “RECOGNIZED” – while those to be categorized together with the probe and irrelevants were the antonyms of these (e.g., “UNIMPORTANT”, etc.). It should be noted that these fillers are not specifically crime-related, but are related to the essence of the CIT: the importance, relevance, and recognition of probes (from the perspective of a “guilty” or knowledgeable examinee) – and therefore they are likely to be generalizable to any type of probe item.

<<Insert table 1 about here>>

The necessity of, and suggestions for, examining the generalizability of fillers have been mooted several times (e.g., already by Lukács, Gula, et al., 2017). But, to date, all studies except one have only used autobiographical items when examining the E-CIT. The one exception (Olson et al., 2020) included both autobiographical and crime-related probes, and, presumably due to relatively small sample sizes (ca. 19 per group), no substantial evidence was found for a difference or equivalence between crime-related and autobiographical probes, despite a significant increase in probe-irrelevant reaction time differences for the authors’ P300-CIT protocol with fillers. Furthermore, there were no “innocent” control groups, and therefore it was not possible to assess whether there was an increase in diagnostic efficiency.

Taking into account the above-mentioned issues, the current study's aims were: (1) to introduce importance-related fillers, and; (2) to test whether the E-CIT is more sensitive (in terms of displaying a larger probe-irrelevant mean RT difference and area under the curve) than the S-CIT in the case of episodic data.

Method

Participants

Our sample size of a minimum of 50 observations per group was based on a preregistered power analysis indicating that with a one-tailed test for the critical t-test (comparing probe-irrelevant differences between the E-CIT and S-CIT), for an effect size of 1.54 (observed by Lukács, Kleinberg, et al., 2017), the achieved power is 1.00 (i.e., practically 100%). This relatively large sample size thus also accounted for the possibility of a relatively lower true effect in our specific case (e.g., providing a power of .81 for the conventional medium effect size of 0.5). Five hundred and four participants started the experiment, but 265 participants dropped out at some point. Of the 239 participants finishing the experiment, 21 were excluded due to excessive error rates (ERs; the exclusion criterion was an ER above 50% for any item type). Comprehensive information about dropouts, exclusions in each group and final sample (sex, age) is presented in Table 2.

Adult participants were recruited through Social Media and advertisements at universities and high schools. No reward was offered. All participants provided informed consent before the experiment.

<<Insert table 2 about here>>

Procedure

The experimental tasks (consideration of an imaginary scenario involving either committing a crime or visiting a museum, and participation in concealed information tests) were prepared with PsychoPy software and run on the pavlovia.org platform (Bridges et al., 2020). At the end of the experiment, participants were transferred to the Qualtrics platform to complete a memory check test.³ The entire study was conducted in Polish.

After opening a link enclosed in an advertisement for the study, participants were transferred to a study web page containing detailed instructions, and where they also consented to the terms of participation. Next, they were randomly assigned to guilty or innocent⁴ conditions, and S-CIT or E-CIT protocol.

Participants in the guilty groups were requested to imagine that they were committing a theft. The imaginary crime scenario was based on a study by Suchotzki et al. (2019). Participants were asked to imagine that they went to a doctor's surgery and were alone in a *waiting room*. Suddenly, they noticed that someone had left a *handbag*. They took the opportunity and looked inside it. They found a black *telephone* and decided to take it. Subsequently, they left the waiting room quickly. Each step of the scenario was supported with a photograph of a waiting room, a handbag, and a telephone, respectively. Subsequently, participants were provided with a summary of their actions ("You were in a *waiting room*. You took a black *telephone* from a *handbag*.") They were requested to memorize the course of the crime, especially the three crucial details (written in italics in the preceding text), which

³ Participants were asked to recall probe items. Out of all participants who completed the test, 14 did not recall all the items correctly, and 5 of these also met the criterion for exclusion due to an excessive error rate. The exclusion of the remaining 9 participants made no notable (i.e., only very small, nominal) differences to the results obtained.

⁴ Of course, both guilt and innocence were only simulated, and the CIT itself implies recognition rather than guilt. Nonetheless, we consider the terms "guilty" and "innocent" to be simpler and more intuitive than alternatives such as "knowledgeable" and "naive."

were written in capital letters in the summary. They were encouraged to repeat the details several times, and even to write them down. They were also informed that they would be tested as to whether they remembered these details correctly at the end of the study. The three crime details were used as probes in the CITs.

At the same stage of the experiment, participants in the innocent groups were requested to imagine visiting a museum. Thus, they were asked to imagine that they went to a *museum*. They were there with a couple of visitors, and suddenly they spotted a *painting* on the wall. They took the opportunity to look closer and noticed a small *village* next to a beach. Then they left the museum quickly. Again, participants in these groups were provided with a summary of their visit ("You were at a *museum*. You saw a *painting* with a small *village* next to a beach."). Further instructions were the same as for the guilty groups. However, the details mentioned to the innocent groups were not used in any of the CITs.

Before RT-CITs, participants were informed that they were suspected of having committed the offense of theft. They were told that their task was to prove that they did not possess any information about the crime committed, and, even if they acquired some knowledge, they should hide this during the RT-CIT, which came next.

RT – CITs – reaction time-based Concealed Information Tests

The S-CIT. For the S-CIT, participants were informed that they would see words referring to different items in the center of their computer screen, and that their task was to categorize these as recognized or not recognized. They were told that pressing the "K" key on their keyboard meant "YES, I recognize this word" and that pressing the "D" key meant "NO, I do not recognize this word". During each part of the S-CIT, one word was chosen as a TARGET, and participants were instructed that their task was to press the "K " key ("YES, I recognize this word") each time they saw it on the screen. In the case of the rest of the words, participants were told to press the "D" key ("NO, I do not recognize this word").

Before each part (every S-CIT), participants completed three practice rounds. During the first two practice rounds, participants saw the question: "Do you recognize this word?" on the top of their screen, and response guidance: "D – NO" on the left part of the screen, and "K – YES" on the right. This information was not presented during the third practice round and the main task. During the first practice round, each word was presented without a time limit: the next word was not presented until participants pressed either key. If participants gave an incorrect response, the message "WRONG" written in red was shown for 200 ms, after which the next stimulus was presented. During the second round, the time limit for responding was 1,500 ms. If participants did not respond within this time, "TOO SLOW" written in red was presented below the stimulus for 200 ms. The inter-stimulus interval was randomized within the range 500 to 1,000 ms (in all practice rounds and in the main task). If participants failed to complete either of the first or second practice rounds correctly, they were not repeated. During the third practice round, the response time limit was shortened to 1,000 ms, as it was in the subsequent main task, and this round was repeated twice (regardless of a participant's error rate). In each practice round, all six of the stimuli (probe, target, and 4 irrelevant items – see Table 3) were randomly presented once. During the main task, each stimulus was presented 20 times – 120 stimuli for each part (20 x probe, 20 x target, 80 x irrelevant – 4 irrelevant items 20 times each). The order of stimuli was randomized in groups of six (one probe, one target, and four irrelevant). The specific main items (one probe, one target, four irrelevants) belonging to each category (waiting room, handbag, and telephone), were presented always within one block only (single-probe protocol). The order of categories (blocks) was randomized for each participant.

The E-CIT. Instructions for the enhanced version were very similar to the S-CIT. However, instead of categorizing words as recognized or not, participants were informed that they should categorize them as important (by pressing the "K" key) or unimportant (by

pressing the "D" key). They were told that they should press "K " for the target word as well as important fillers, and press "D" for other words including unimportant fillers. Other information was identical to that for the S-CIT. As to the practice rounds and main tasks, the only differences concerned: (1) questions presented during the first two practice rounds ("Is it significant for you?" instead of "Do you recognize this word?"⁵), and; (2) the number of items presented during practice rounds and main tasks. Here, in each practice round participants saw each stimulus once in a random order (1 probe, 1 target, 4 irrelevant items, 3 important fillers, 6 unimportant fillers – 15 in total).⁶ During each main task, the probe, target and each irrelevant item were presented 20 times (120 presentations in total), and, additionally, each important and unimportant filler was presented six times (54 presentations in total; see also Tables 3 and 4). As in the S-CIT, the categories were presented in separate blocks. The pseudo-random order of stimuli within each block followed restrictions proposed by Lukács, Kleinberg, et al. (2017): a filler trial was never followed by another filler trial, and each of the nine fillers (three familiarity-related, six unfamiliarity-related) preceded each of the four probes, four targets, and 16 irrelevant items exactly one time. The block order was randomized. However, the order of the stimuli within each category was fixed and the same for each participant.

<<Insert table 3 and table 4 about here>>

Results

⁵ Previous studies showed that header does not significantly influence the results (Lukács, Kleinberg, et al., 2017; Lukács & Ansorge, 2019). Furthermore, during the main task there was no header in either of our protocols.

⁶ The smaller proportion (3 to 6) of important relative to unimportant fillers is intended to keep “target-side” items (i.e., the target and items to be categorized with the same key as the target) less frequent than the rest of the items, thereby keeping the target (or all target-side items) more rare or even unique among all used items, since this relative rarity is assumed to contribute to the response conflict in case of probes: For more detailed explanation and empirical evidence, see Lukács & Ansorge (2021).

The main measure compared during analyses was the RT-CIT effect: the difference in reaction times to probe and irrelevant stimuli. Only data for errorless trials were analyzed, and trials with reaction times below 150 ms or above 1,000 ms were also excluded.

Bayes factors (BFs) are reported using the default r-scale of 0.707 (default uninformed prior using Cauchy distribution as implemented by Morey & Rouder, 2018), and, in the case of ANOVAs, we use inclusion BFs based on matched models (Makowski et al., 2019). To assess the classification accuracy of concealed information detection at the individual level (i.e., the efficiency of discriminating guilty from innocent participants), we calculated areas under the receiver operating characteristic curve (AUCs; see National Research Council, 2003, pp. 342–344). Using a given predictor variable (here: the probe-irrelevant RT differences), the receiver operating characteristic curve depicts the true positive rates (TPR; ratio of guilty participants correctly classified as guilty) and true negative rates (TNR; ratio of innocent participants correctly classified as innocent) at all possible cut-off points. The corresponding AUC gives an averaged value of all TPRs and TNRs that can range from 0 to 1 (where .5 is chance level and 1 is perfect classification). All analyses were performed in R (R Core Team, 2019) using packages designed by Kelley (2018), Lukács (2021), Morey and Rouder (2018; for BF tests), and Robin et al. (2011; for AUC calculations and tests). All tests were preregistered except where explicitly noted otherwise. The preregistration, all data, and analysis scripts are available via https://osf.io/5thpe/?view_only=e73679fee08041e497160ce8ced356b4. Mean reaction times, mean error rates and classification accuracies are presented in Table 5.

<<Insert table 5 about here>>

Reaction times

A two-way between-subjects ANOVA (condition: guilty vs. innocent, and RT-CIT protocol: S-CIT vs E-CIT) on probe-irrelevant RT mean differences showed significant main effects of condition (larger values in case of guilty groups), $F(1, 212) = 33.93, p < .001, \eta_p^2 = .138$, 90% CI [.073, .209], $\eta_G^2 = .138$, $BF_{10} = 1.54 \times 10^5$, and RT-CIT protocol (larger values in case of E-CIT), $F(1, 212) = 7.92, p = .005, \eta_p^2 = .036$, 90% CI [.006, .085], $\eta_G^2 = .036$, $BF_{10} = 4.66$. Most importantly, there was a significant interaction between Condition and RT-CIT protocol, $F(1, 212) = 18.04, p < .001, \eta_p^2 = .078$, 90% CI [.030, .141], $\eta_G^2 = .078$, $BF_{10} = 562.18$ (Figure 2). A follow-up one-sided t -test (as preregistered) comparing protocols in guilty groups showed that, as expected, probe-irrelevant differences in the E-CIT were significantly larger than in the S-CIT, with a difference of 16.8 ms, 90% CI [11.7, ∞], $t(91.3) = 4.28, p < .001, d = 0.83$, 90% CI [0.50, ∞], $BF_{10} = 1189.29$. Correspondingly, areas under the curve (AUC) for the E-CIT proved significantly larger than those for the S-CIT via a one-sided DeLong test, with a difference of .247, 95% CI [.109, .385], $D(198.4) = 3.56, p < .001$ (see Figure 3).

<<Insert figure 2 about here>>

<<Insert figure 3 about here>>

Error rates

For probe-irrelevant ER differences, an analogous two-way between-subjects ANOVA showed a significant main effect of condition, $F(1, 212) = 16.37, p < .001, \eta_p^2 = .072$, 90% CI

[.025, .133], $\eta_G^2 = .072$, $BF_{10} = 133.59$, but not of RT-CIT protocol, $F(1, 212) = 3.68$, $p = .056$, $\eta_p^2 = .017$, 90% CI [0, .056], $\eta_G^2 = .017$, $BF_{01} = 1.37$. While there was a significant interaction between Condition and RT-CIT protocol, $F(1, 212) = 17.05$, $p < .001$, $\eta_p^2 = .074$, 90% CI [.027, .136], $\eta_G^2 = .074$, $BF_{10} = 438.27$, surprisingly, this interaction was the reverse of what was expected. Thus, while the difference between probe and irrelevant ERs was practically negligible for the S-CIT, in the case of the E-CIT the ERs for irrelevants were higher than for probes (and were therefore also not diagnostic of guilt in the conventional probe-minus-irrelevant form; see Table 5). However, ERs were generally very low (all below 3%), and therefore a substantial speed-accuracy tradeoff seems unlikely. In any case, ERs are not generally used as diagnostic data in the RT-CIT.

Exploratory analyses: dropout rate differences and adjusted exclusion criteria

For the present data, Pearson's chi-square tests and independent multinomial contingency table BFs both provided evidence for the similarity of dropout rates between the E-CIT and S-CIT protocols when only the guilty conditions were included, with a nominal difference of a mere 0.8%, 95% CI [-13.3, 11.8], $\chi^2(1) < .01$, $p = .993$, $BF_{01} = 6.60$, and when both the guilty and innocent conditions were included, the difference here being 0.5%, 95% CI [-9.7, 8.6], $\chi^2(1) < .01$, $p = .977$, $BF_{01} = 8.93$.

All ER-based exclusions in the present study were due to ERs that were too high for targets or importance-related fillers. But, even for these, none of the participants had ERs that were high enough to indicate a complete absence of attention (e.g., zero correct responses). Therefore, we repeated all the analyses with all 239 participants who completed the tests included (i.e., with no ER-based exclusions). All the results remained statistically significant with no notable changes. In the interests of brevity, here we report only the results for the most relevant test: the AUC comparison. Thus, for the S-CIT without exclusions the AUC

was .561, 95% CI [.455, .667], while for the E-CIT without exclusions the AUC was .773, 95% CI [.690, .855], with DeLong's test again showing very strong evidence for a difference (.211, 95% CI [.075, .347]), $D(218.8) = 3.08$, $p = .001$ (see Figure 3).

Discussion

Deception detection researchers will probably always seek methods which are effective, useful and easy to conduct in practice. It is hard to imagine a more useful or easier method than the RT-CIT since it requires only a computer or just a smartphone (Lukács, Kleinberg, Kunzi, & Ansorge, 2020). However, as mentioned in the Introduction, the effectiveness of the RT-CIT is still debatable. The current study allowed us to establish at least three important findings: (1) adding importance-related fillers significantly improves RT-CIT accuracy in the case of episodic information; (2) in contrast to the standard version (S-CIT), the enhanced RT-CIT (E-CIT) can be effective even where information is of low salience, and; (3) there are no substantial differences in dropout between the two versions of the RT-CIT, and the imposition of less strict exclusion criteria does not affect the main results obtained.

The enhanced RT-CIT can be effective even for information of low salience.

The classification accuracy for S-CIT did not differ significantly from the chance level. This is somewhat surprising, although not unprecedented in case of the S-CIT (Eom et al., 2016; Matsuda, Nittono, & Allen, 2013; Lukács, Kleinberg, et al., 2017), especially when attempting to detect the possession of information which is of low salience (Verschuere, Kleinberg, & Theocharidou, 2015; Kleinberg & Verschuere, 2015), which is also typical of crime details (as opposed to autobiographical details). In fact, to our knowledge, this is the first study that found a significant probe-irrelevant difference (and AUC significantly above

chance) using a single-probe protocol in a crime scenario (cf., Eom et al., 2016; Matsuda et al., 2013). This was achieved using importance-related fillers in the E-CIT.

The imaginary crime scenario used in our research was based on a study by Suchotzki et al. (2019). In this scenario, no crime is actually committed. From a participant's point of view this information is only relevant because it is part of an experimental task. It is not personally meaningful (unlike their date of birth or name), and it can be assumed that it is not associated with high, or even moderate, emotional arousal, unlike information about a real crime that has been committed. Even compared to information acquired during a mock crime, where participants perform real actions (for example, touching and feeling objects), information about an imaginary crime can be considered to have very low salience (despite the lack of realism in encouraging participants to remember the details). These possibilities are supported by the fact that 14 of the participants who completed the whole experimental procedure failed to recall the probes correctly.

Importance-related versus familiarity-related fillers

In this study we again demonstrated the enhancing influence of fillers, and we successfully introduced importance-related fillers, which seem applicable in a broad range of situations. Importance-related fillers seem to have strong advantages over familiarity-related fillers from a practical point of view. They are more generalizable, more intuitive, and easier to explain (for examiners) and follow (for participants) in crime related cases than familiarity-related fillers. For example, if the probe is the stolen item, it cannot be considered as belonging to the suspect, and therefore it would make no sense to use the familiarity-referring filler "MINE", or the opposing unfamiliarity-referring fillers "THEM" or "THEIRS" (which did however make sense in case of autobiographical details). At the same time, all kinds of probes in any RT-CIT are IMPORTANT, SIGNIFICANT or RECOGNIZED, and none of them are UNIMPORTANT, NEUTRAL, and so forth.

Which types of fillers work best (e.g., more specific, familiarity-related, or crime-related fillers, such as “stolen,” or more general fillers, such as those used in the present study) remains to be explored in future research. To note, in the present study we used single-probe protocol S-CIT only. The (single-probe) E-CIT has been shown to outperform the multiple-probe S-CIT protocol too, in two separate previous experiments (Lukács, Kleinberg, et al., 2017). However, as explained above, the multiple-probe protocol has very low viability for real-life use, and, therefore, replicating this latter finding seemed of low priority.

Dropout or exclusion rates are not important for enhanced results

Another important finding concerns dropout and exclusion rates. Some authors have stressed that the E-CIT (as introduced by Lukács, Kleinberg, et al., 2017) has a notable limitation in that higher dropout and ER-based exclusion rates are observed compared to the S-CIT and other protocols (Koller et al., 2020; Suchotzki et al., 2018). However, these observations have been made exclusively from online studies, where, for one, dropout rates are completely normal and to be expected. Reviewing 27 online studies, Musch and Reips (2000) reports that, on average, ca. 32% of the participants who access the first page of an online experiment do not proceed further, and that the total dropout rate can be at times as high as 93%, depending on various factors: for example, unpaid studies, such as ours, result in much higher dropouts than paid studies (86% vs. 55%; Musch & Reips, 2000; regarding the reasons, see Zhou and Fishbach, 2016, p. 495).⁷

The results of this online study showed that, unlike the previous online studies (e.g., Lukács, Kleinberg, et al., 2017), the dropout rate did not differ significantly between the two protocols. It is very probable that the differences in dropout rate in the former studies was due

⁷ A more thorough explanation of why dropout and exclusion rates make no difference regarding the enhancement can be found in the Online Appendix via

https://osf.io/5thpe/?view_only=e73679fee08041e497160ce8ced356b4.

to their very strict criteria for passing practice round in E-CIT, especially in comparison to those for their S-CIT group.

Furthermore, in the previous studies (and also in this one) exclusion criteria for excessive error rates were all arbitrarily set at a “minimum 50% ER for each item type,” which is far stricter for the E-CIT (5 different items types) than for the S-CIT (only 3 different item types). In the current study, we have shown that even without any exclusion of participants, the results remained practically the same. To provide even more proof in this regard, we reanalyzed the S-CIT and E-CIT data of Lukács, Kleinberg, et al. (2017; Experiment 1 only – since the other experiments contained no “innocent” control data), and no matter which specific exclusion criterion we chose, the key results were the same. For simplicity we again report the outcomes when all participants completing the tests are included in an analysis ($N = 314$). For the 2017 S-CIT data without exclusions the AUC was .627, 95% CI [.548, .706], while for the 2017 E-CIT data without exclusions the AUC was .849, 95% CI [.780, .918], DeLong’s test once again showing very strong evidence for a difference, $D(310.2) = 4.14, p < .001$.

Limitations and further studies

Some limitations of the present study should be noted. First, the study employed an imaginary crime scenario. While this was advantageous in that it allowed a study involving episodic information to be conducted via the Internet, it has to be acknowledged that an imaginary crime scenario is probably less similar to a real crime than mock-crime scenarios because participants only imagined taking part in a crime, without any real action. Moreover, they were provided with text, photos, and encouraged to repeat words or even write them down, which also is far from a real crime situation.

Second, RT-CITs were administrated immediately after the encoding phase, while in real-life such tests are administrated usually after a long time after the crime. Ideally, future studies should take into account the time delay between the encoding phase and E-CIT administration.

Third, , the online setting of our experiment may allow more noise in the data than strictly controlled lab experiments. However, there have been numerous studies that explored the reliability of online RT research (e.g., Hilbig, 2016; Pronk et al., 2020) – all of which unanimously conclude that results obtained in this environment closely reflect those obtained in strictly controlled laboratory conditions.

Conclusions

The practical implication of increasing the diagnostic efficiency of the RT-CIT is straightforward: it would lead to more correct classification of real-world suspects as to whether they have recognized a given probe item. While familiarity-related fillers have been repeatedly shown to provide such an enhancement in efficiency for autobiographical details, the present paper is the first to show that importance-related fillers can also be of great benefit, and shows that such fillers are highly generalizable to different types of scenario.

We have also shown, for the first time, that neither dropout rates nor ER-based exclusions pose a limitation to the enhancement in efficiency achieved. Thus, to our knowledge, the E-CIT, while repeatedly proven to outperform the S-CIT, has no notable limitations in comparison to any other RT-CIT protocol.

References

- 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(1), 131.
- Bridges, D., Pitiot, A., MacAskill, M. R., & Peirce, J. W. (2020). The timing mega-study: Comparing a range of experiment generators, both lab-based and online. *PeerJ*, 8, e9414. <https://doi.org/10.7717/peerj.9414>
- Eom, J.-S., Sohn, S., Park, K., Eum, Y.-J., & Sohn, J.-H. (2016). Effects of Varying Numbers of Probes on RT-based CIT Accuracy. *International Journal of Multimedia and Ubiquitous Engineering*, 11(2), 229–238. <https://doi.org/10.14257/ijmue.2016.11.2.23>
- Greenwald, A. G., Poehlman, T. A., Uhlmann, E. L., & Banaji, M. R. (2009). Understanding and using the Implicit Association Test: III. Meta-analysis of predictive validity. *Journal of Personality and Social Psychology*, 97(1), 17–41. <https://doi.org/10.1037/a0015575>
- Hilbig, B. E. (2016). Reaction time effects in lab- versus web-based research: Experimental evidence. *Behavior Research Methods*, 48(4), 1718–1724. <https://doi.org/10.3758/s13428-015-0678-9>
- Hu, X., Evans, A., Wu, H., Lee, K., & Fu, G. (2013). An interfering dot-probe task facilitates the detection of mock crime memory in a reaction time (RT)-based concealed information test. *Acta Psychologica*, 142(2), 278–285. <https://doi.org/10.1016/j.actpsy.2012.12.006>
- Iacono, W. G., & Ben-Shakhar, G. (2019). Current status of forensic lie detection with the comparison question technique: An update of the 2003 National Academy of Sciences report on polygraph testing. *Law and human behavior*, 43(1), 86.

- Kelley, K. (2018). *MBESS: The MBESS R Package*. R package version 4.4.3.
<https://CRAN.R-project.org/package=MBESS>
- Kleinberg, B., & Verschuere, B. (2015). Memory detection 2.0: The first web-based memory detection test. *PloS one*, *10*(4), e0118715.
- Koller, D., Hofer, F., & Verschuere, B. (2020). *Different target modalities improve the single-probe protocol of the response time-based Concealed Information Test*.
<https://doi.org/10.31219/osf.io/385pd>
- Krapohl, D. J. (2011). Limitations of the Concealed Information Test in criminal cases. In B. Verschuere, G. Ben-Shakhar, & E. Meijer (Eds.), *Memory detection: Theory and application of the concealed information test* (pp. 151–170). Cambridge, UK: Cambridge University Press.
- Lukács, G. (2021). neatStats: An R package for a neat pipeline from raw data to reportable statistics in psychological science. *The Quantitative Methods for Psychology*, *17*(1), 7–23. <https://doi.org/10.20982/tqmp.17.1.p007>
- Lukács, G., & Ansorge, U. (2019). Information leakage in the response time-based Concealed Information Test. *Applied Cognitive Psychology*, *33*(6), 1178-1196.
- Lukács, G., & Ansorge, U. (2021). The mechanism of filler items in the response time concealed information test. *Psychological Research*. <https://doi.org/10.1007/s00426-020-01432-y>
- Lukács, G., Gula, B., Szegedi-Hallgató, E., & Csifcsák, G. (2017). Association-based Concealed Information Test: A novel reaction time-based deception detection method. *Journal of Applied Research in Memory and Cognition*, *6*(3), 283–294.
<https://doi.org/10.1016/j.jarmac.2017.06.001>
- Lukács, G., Kleinberg, B., Kunzi, M., & Ansorge, U. (2020). Response time concealed information test on smartphones. *Collabra: Psychology*, *6*(1).

- Lukács, G., Kleinberg, B., & Verschuere, B. (2017). Familiarity-related fillers improve the validity of reaction time-based memory detection. *Journal of Applied Research in Memory and Cognition*, 6(3), 295–305. <https://doi.org/10.1016/j.jarmac.2017.01.013>
- Lykken, D. T. (1959). The GSR in the detection of guilt. *Journal of Applied Psychology*, 43(6), 385.
- Lykken, D. T. (1960). The validity of the guilty knowledge technique: The effects of faking. *Journal of Applied Psychology*, 44(4), 258.
- Makowski, D., Ben-Shachar, M., & Lüdtke, D. (2019). bayestestR: Describing effects and their uncertainty, existence and significance within the Bayesian framework. *Journal of Open Source Software*, 4(40), 1541. <https://doi.org/10.21105/joss.01541>
- Matsuda, I., Nittono, H., & Ogawa, T. (2013). Identifying concealment-related responses in the concealed information test. *Psychophysiology*, 50(7), 617–626. <https://doi.org/10.1111/psyp.12046>
- Meijer, E. H., Klein Selle, N., Elber, L., & Ben-Shachar, G. (2014). Memory detection with the Concealed Information Test: A meta analysis of skin conductance, respiration, heart rate, and P300 data. *Psychophysiology*, 51(9), 879–904. <https://doi.org/10.1111/psyp.12239>
- Morey, R. D., & Rouder, J. N. (2018). *BayesFactor: Computation of Bayes factors for common designs* (Version 0.9.12-4.2). Retrieved from <https://CRAN.R-project.org/package=BayesFactor>
- Musch, J., & Reips, U.-D. (2000). A brief history of Web experimenting. In *Psychological experiments on the Internet* (pp. 61–87). Academic Press. <https://doi.org/10.1016/B978-012099980-4/50004-6>

- National Research Council (2003). The polygraph and lie detection. Committee to review the scientific evidence on the polygraph. Division of behavioral and social sciences and education. Washington, DC: The National Academies Press
- Olson, J., Rosenfeld, J. P., & Perrault, E. (2020). Familiarity-related filler items enhance the RT CIT, but not the P300 CIT: Episodic vs. Semantic memory protocols. *International Journal of Psychophysiology*, 158, 370–379.
<https://doi.org/10.1016/j.ijpsycho.2020.10.001>
- Podlesny, J. A. (2003). A paucity of operable case facts restricts applicability of the Guilty Knowledge Technique in FBI criminal polygraph examinations. *Forensic Science Communications*, 5(3). Retrieved from: <https://archives.fbi.gov/archives/about-us/lab/forensic-science-communications/fsc/july2003/podlesny.htm>
- Pronk, T., Wiers, R. W., Molenkamp, B., & Murre, J. (2020). Mental chronometry in the pocket? Timing accuracy of web applications on touchscreen and keyboard devices. *Behavior Research Methods*, 52(3), 1371–1382. <https://doi.org/10.3758/s13428-019-01321-2>
- R Core Team. (2019). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. Retrieved from <https://www.R-project.org/>
- Robin, X., Turck, N., Hainard, A., Tiberti, N., Lisacek, F., Sanchez, J.-C., & Müller, M. (2011). pROC: an open-source package for R and S+ to analyze and compare ROC curves. *BMC Bioinformatics*, 12(1), 77. <https://doi.org/10.1186/1471-2105-12-77>
- Rosenfeld, J. P. (2020). P300 in detecting concealed information and deception: A review. *Psychophysiology*, 57(7), e13362.

- Seymour, T. L., Seifert, C. M., Shafto, M. G., & Mosmann, A. L. (2000). Using response time 668 measures to assess “guilty knowledge”. *Journal of Applied Psychology*, 85(1), 30–37. 669 <https://doi.org/10.1037//0021-9010.85.1.30>
- Suchotzki, K., De Houwer, J., Kleinberg, B., & Verschuere, B. (2018). Using more different and more familiar targets improves the detection of concealed information. *Acta Psychologica*, 185, 65–71. <https://doi.org/10.1016/j.actpsy.2018.01.010>
- Suchotzki, K., Kakavand, A., & Gamer, M. (2019). Validity of the reaction time Concealed Information Test in a prison sample. *Frontiers in psychiatry*, 9, 745.
- 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(7), 991-1002.
- Verschuere, B., & De Houwer, J. (2011). *Detecting concealed information in less than a second: Response latency-based measures*. In B. Verschuere, G. Ben-Shakhar, & E. Meijer (Eds.), *Memory detection: Theory and application of the Concealed Information Test* (p. 46–62). Cambridge University Press. <https://doi.org/10.1017/CBO9780511975196.004>
- Verschuere, B., Kleinberg, B., & Theocharidou, K. (2015). RT-based memory detection: Item saliency effects in the single-probe and the multiple-probe protocol. *Journal of Applied Research in Memory and Cognition*, 4(1), 59-65.
- Verschuere, B., Meijer, E., & De Clercq, A. (2011). Concealed information under stress: A test of the orienting theory in real-life police interrogations. *Legal and criminological psychology*, 16(2), 348-356.
- Verschuere, B., Rosenfeld, J. P., Winograd, M. R., Labkovsky, E., & Wiersema, R. (2009). The role of deception in P300 memory detection. *Legal and Criminological Psychology*, 14(2), 253-262.

Visu-Petra, G., Varga, M., Miclea, M., & Visu-Petra, L. (2013). When interference helps:

Increasing executive load to facilitate deception detection in the Concealed

Information Test. *Frontiers in Psychology*, 4.

<https://doi.org/10.3389/fpsyg.2013.00146>

Zhou, H., & Fishbach, A. (2016). The pitfall of experimenting on the web: How unattended

selective attrition leads to surprising (yet false) research conclusions. *Journal of*

Personality and Social Psychology, 111(4), 493–504.

<https://doi.org/10.1037/pspa0000056>

Table 1

Concealed Information Test - summarize of stimuli types

				Stimuli types in each protocol		
Stimuli types	Description	Example	Response	S-CIT	E-CIT with familiarity related fillers	E-CIT with importance related fillers
Probe	Item relevant to the crime or other important information to detect.	RIFLE	Eg. "E" button (In S-CIT meaning "I don't recognize"; In E-CIT "Not familiar word/object"/"Not important word/object")	+	+	+
Irrelevant	From 4 to 5 items (per test) from the same category as the probe but unrelated to the crime.	GUN, PISTOL etc.	Eg. "E" button (In S-CIT meaning "I don't recognize"; In E-CIT "Not familiar word/object"/"Not important word/object")	+	+	+

Target	Irrelevant item, unrelated to the crime, which required a specific response.	KNIFE	Eg. "I" button (In S-CIT meaning "I do recognize"; In E-CIT "Familiar word/object"/"I mportant word/object"	+	+	+
	Filler items that refer to the familiarity context and requiring specific response (same as to target)	FAMILIAR, MINE, RECOGNIZED	Eg. "I" button (meaning "Familiar word/object")	-	+	-
Unfamiliar-related-fillers	Filler items that refer to the unfamiliarity context	"UNFAMILIAR," "UNKNOWN," "OTHER," "THEIRS," "THEM," and "FOREIGN"	Eg. "E" button (meaning "Not familiar")	-	+	-
	Filler items that refer to importance context and	"IMPORTANT," "SIGNIFICANT," and "RECOGNIZED"	Eg. "I" button (meaning "Important word/object"	-	-	+

requiring
specific
response
(same as to
target)

Unimportance -related-fillers	Filler items	“UNIMPORTANT”,	Eg. “E” button (meaning “Not important”)	-	-	+
	that refer to	“INSIGNIFICANT”,				
	unimportanc	“UNKNOWN”,				
	e context	“REGULAR”,				
		“NEUTRAL”,				
		“UNFAMILIAR”				

Table 2

Comprehensive information about participants in each group

	Group			
	S-CIT – Innocent	S-CIT – Guilty	E-CIT Innocent	E-CIT Guilty
Initial <i>n</i>	108	131	123	142
Dropout	55 (50.9%)	70 (53.4%)	63 (51.2%)	77 (54.2%)
Exclusion – excessive error rate	2 (3.8%)	4 (6.6%)	5 (8.3%)	12 (18.5%)
Final sample	51	57	55	53
	(age = 22.8 years, ±3.8 years; 13 males, 37 females	(age = 23.3 years, ±4.4 years [1	(age = 22.9 years, ±5.1 years; 14	(age = 24.7 years, ±7.7 years; 21

[1 unknown])	unknown]; 15	males, 41	males, 29
	males, 41	females).	females [3
	females [1		unknown])
	unknown])		

Note. Initial numbers of participants include all participants, even those who only read experimental instructions. Consequently, dropout numbers reflect the numbers of participants who aborted their participation at any stage (e.g., while simply reading the initial instructions or toward the end of their experimental task). Exclusion denotes the number of participants who were excluded based on an excessive error rate (all participants). Percentages in parentheses indicate changes as compared to: (a) in the case of dropouts, all participants, and; (b) in the case of ER-based exclusions, participants remaining after dropouts.

Table 3*Items used in the RT-CIT*

	Category		
	Stolen item	Premises	Container
Probe	Telephone (<i>Telefon</i>)	Waiting room (<i>Poczekalnia</i>)	Handbag (<i>Torebka</i>)
Irrelevants	Wallet, Money, Camera, Documents (<i>Portfel,</i> <i>Pieniądze, Aparat,</i> <i>Dokumenty</i>)	Bathroom, Shop, Cafe, Cloakroom (<i>Łazienka, Sklep,</i> <i>Kawiarnia, Szatnia</i>)	Basket, Briefcase, Jacket, Suitcase (<i>Koszyk, Teczka,</i> <i>Kurtka, Walizka</i>)
Target	Computer (<i>Komputer</i>)	Office (<i>Biuro</i>)	Backpack (<i>Plecak</i>)
Important fillers (only E-CIT)	Important, Significant, Known (<i>Ważny, Istotny, Znany</i>)		
Unimportant fillers (only E-CIT)	Unimportant, Insignificant, Unknown, Regular, Neutral, Unfamiliar (<i>Nieważny,</i> <i>Nieistotny, Nieznany, Zwykły, Obojętny, Obcy</i>)		

Note: The Polish words that were actually used in the experiment are shown in parentheses.

Table 4

The number of stimuli presented per item type for each RT-CIT version.

	S-CIT	E-CIT
Probes	20	20
Irrelevant	80	80
Target	20	20
“Important” filler	-	18
"Unimportant" filler	-	36
TOTAL	120	192

Table 5*Response Times and AUCs*

	Probe	Irrelevant	Target	Filler- NT	Filler-T	P – I	AUC [95% CI]	TPR	TNR
<i>S-CIT RT</i>									
Guilty	405±54	404±49	485±48			1.1±16.1	.562	.42	.78
Innocent	404±52	407±47	494±71			-2.8±14.0	[.453, .671]		
<i>E-CIT RT</i>									
Guilty	522±73	506±63	579±59	543±78	621±55	16.0±26.9	.810	.93	.62
Innocent	490±59	496±55	571±50	545±71	618±52	-6.3±15.8	[.728, .891]		
<i>S-CIT ER</i>									
Guilty	1.7±3.3	1.6±3.5	19.7±14.5			0.08±1.85	.529	.25	.88
Innocent	1.1±1.7	1.2±2.0	20.3±12.3			-0.05±1.28	[.420, .638]		
<i>E-CIT ER</i>									
Guilty	2.1±3.2	3.8±4.8	22.9±18.8	5.8±5.0	30.3±23.4	-1.70±3.49	.231		
Innocent	2.7±5.1	2.2±5.2	21.9±15.7	7.1±5.3	28.0±18.0	0.49±1.43	[.143, .319]		

Note. Means and *SDs* for individual RT means (ms) and ERs (%) for different item types, and for probe-irrelevant differences (P – I), and, most importantly, corresponding AUCs (95% CIs in brackets). TPR: true positive rates (ratio of correctly detected ‘guilty’ participants), TNR: true negative rates (ratio of correctly detected ‘innocent’ participants), using arbitrary optimal cutoffs (maximal Youden’s index) for classification. Filler-T: “target-side” important fillers; Filler-NT: “nontarget-side” unimportant fillers. AUC: area under the curve.

Figure 1

Multiple-Probe Protocol versus Single-Probe Protocol

Note. In case of the multiple-probe protocol (left panel), all items (probes, targets, irrelevants) in all categories are randomly mixed in each block, while in case of the single-probe protocol (right panel), the items of each category are presented separately within separate blocks. Each category involves one probe (here: “RIFLE” among weapons, and “30 APRIL” among dates), one target (HERE: “ROPE” and “25 MARCH”), and several, usually four irrelevant items (e.g. “KNIFE” and “14 JULY”).

Figure 2

Probe-irrelevant RT and ER differences per RT-CIT Protocol

Note. Means (with 95% CIs) of individual probe-irrelevant RT and ER mean differences; per each RT-CIT protocol (S-CIT or E-CIT) and condition (Guilty or Innocent).

Figure 3

Receiver operating characteristic curves

Note. True positive and true negative rates at all possible cutoff points for S-CIT and E-CIT probe-irrelevant RT mean predictors, for data after ER-based exclusions (left panel), and for all data without any exclusions (right panel). The black circles mark TPRs and TNRs at optimal cutoff points, corresponding those reported in Table 5. Note that, due to the bending of the curve, in case of E-CIT, the cutoffs that provide best accuracies (largest sums of TPR and TNR) also provide relatively higher TPR as compared to TNRs. In contrast, in case of the S-CIT, the best cutoffs provide higher TNRs than TPRs. However, the choice of the optimal cutoff point is rather arbitrary and is only highlighted for illustration. For a balanced assessment of the general diagnostic performance of a method, the AUC is preferred, which takes into account all possible cutoff points.