An attempt to detect concealed information in a spatial cueing paradigm[1)]

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空間手がかり課題による隠匿情報検査の試み

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ABSTRACT

The concealed information test (CIT) is a technique that detects concealed knowledge related to criminal activity by presenting a series of questions to examinees and comparing their responses. Despite the active research in reaction time-based CIT (RT-CIT), its practical application has been limited to autonomic nervous system response-based CIT. This is due to methodological limitations inherent in the conventional RT-CIT paradigm, which restricts questions to known case facts. To address this limitation, we tested a novel RT-CIT task using the emergence of "inhibition of return" (IOR), whereby target detection is delayed when subsequent stimuli appear at the cued location in the spatial cueing paradigm. Participants were required to perform the task while holding a specific number in memory and keeping it concealed. Experiment 1 revealed that, in the exploratory analysis, IOR showed a partial reduction when the cue represented concealed information. However, this trend was not replicated in Experiment 2. We discuss the reasons for the low robustness of this effect and consider the potential for future advances. (168 words)

（和訳）

隠匿情報検査は被検査者に対して一連の質問群を提示し，それらに対する反応を比較することで，犯行に関連する隠匿情報を検出する技術である．反応時間に基づく隠匿情報検査研究は盛んに研究されているにもかかわらず，実務では自律神経系反応に基づく隠匿情報検査のみが採用されている．これは従来の反応時間による隠匿情報検査が既知の事件事実の質問に制限されてしまうという方法論的制約によるものである．この問題を解決するために，我々は，空間手がかり課題において手がかりが与えられた位置に後続する標的の検出が遅延する「復帰抑制」を利用した新しい反応時間に基づく隠匿情報検査課題を作成した．参加者は事前に指定された特定の数字を記憶・隠匿した状態で課題を行った．実験 1 では，探索的分析において，手がかりが隠匿情報の時に復帰抑制が一部消失することが示された．しかし，実験 2 では同様の傾向は再現されなかった．効果の頑健性が低い原因や今後の発展可能性について議論した．（417 語）

Key word

Concealed information test, Reaction time, Spatial cueing task, Inhibition of return, Attention

隠匿情報検査，反応時間，空間手がかり課題，復帰抑制，注意

The concealed information test (CIT) is a method of detecting hidden information by presenting multiple question items of the same category and comparing responses to a specific item with those to other items within the same questionnaire (Lykken, 1959; Meijer et al., 2014). The CIT has been used both in practical applications and research (Matsuda et al., 2019). For instance, in Japanese police organizations, the CIT using multiple autonomic nervous system responses including skin conductance, cardiovascular system and respiration (autonomic response-based CIT: AR-CIT) has been exclusively employed as a method of polygraph testing (Osugi, 2011). The AR-CIT assesses whether a target person has retained memory of case facts, with approximately 5,000 CIT examinations conducted annually nationwide (Osugi, 2018).

In practical polygraph testing, two subcategories of question method are employed: "known-solution" and "searching" questions, both of which are applicable to AR-CIT (Osugi, 2011). The known-solution question is utilized when the examiner possesses prior knowledge about the pertinent item related to the crime. For instance, in a theft case involving a stolen necklace, the question "What was the stolen item?" is presented, with options like "ring," "brooch," "earring," "necklace," and "bracelet." Responses to the critical item (necklace) are then compared with responses to the non-critical items (items other than the necklace) (Figure 1A, also refer to Osugi, 2018, Figure 5.1, Q1). On the other hand, the searching question is employed when the investigation is unaware of any items related to the crime. For example, when inquiring about the disposition of a necklace known solely to the perpetrator, potential responses like "handed it over," "hid it," "sold it," "deposited it," and "other (e.g., threw it away, buried it)" are presented within the context of "How did the criminal dispose of the item?" The objective here is to determine whether there is a distinct response to any one of the options as compared to the others (Figure 1B, also see Osugi, 2018, Figure 5.1, Q4). In situations where the searching question method is used, a sequence of questions must encompass all plausible scenarios, as they explore facts that are still unclear (Osugi, 2018). By using the known-solution and searching question methods together as needed, the AR-CIT addresses a wide variety of cases in practice.

The reaction time-based concealed information test (RT-CIT) has been actively studied since the early 2000s (Suchotzki et al., 2017). The stimulus set for the traditional RT-CIT comprises three distinct stimuli types termed as "probe," "target," and "irrelevant" (Seymour et al., 2000). Taking the earlier example of the necklace theft, the probe corresponds to the necklace, the target is, for example, the ring, and the irrelevant options encompass the brooch, earring, and bracelet (Figure 1C). Participants are instructed to press the YES key for the designated target (i.e., ring) and NO for the remaining stimuli (i.e., probe and irrelevant). Typically, participants who are concealing information regarding the probe show a longer response time to the probe stimulus than to the irrelevant stimuli. Based on this observation, the RT-CIT identifies concealed information by measuring the response latency to stimuli associated with the crime. The RT-CIT has potential real-world applications due to its cost-effectiveness, remote assessment capabilities, and ability to screen a large number of individuals simultaneously (Suchotzki, 2018).

However, the RT-CIT cannot effectively accommodate the searching question method because of the resulting methodological limitations. As mentioned above, the stimulus set for conventional RT-CIT includes three types of stimuli: probe, target, and irrelevant. In many previous RT-CIT studies, these stimuli were selected from the same category (e.g., Kleinberg & Verschuere, 2015, 2016; Koller et al., 2020; Lukács et al., 2017; Lukács & Ansorge, 2019, 2021, 2023; Seymuor et al., 2000; Verschuere & Kleinberg, 2016; Verschuere et al., 2015). This design derives from the principle underlying conventional RT-CIT, where manipulating the combination of stimulus type and response assignment produces differences in stimulus-response compatibility (Verschuere & De Houwer, 2011). In cases where participants conceal the probe, both the probe and the target are significant stimuli, while the irrelevant stimuli are not significant. Nevertheless, response allocation is distributed between the target and the other stimuli. A conflict arises because the probe is a significant stimulus but requires the same response as non-significant stimuli, resulting in a delayed response. A target in the same category as the probe and irrelevant stimuli is expected to increase the probe-irrelevant difference by inducing a conflict between the urge to press YES and the task demand to press NO for the probe (Schotzki et al., 2013; Verschuere et al., 2015).

The restriction that the same category of stimuli must be used for the question items and target may lead to inaccurate results in the searching question method. For instance, if the aforementioned searching question about the disposal of the necklace is included in the RT-CIT, with "handed it over" as the target for convenience, the CIT may not function accurately if this is indeed the concealed truth (Figure 1D). On the other hand, it has been reported that performing a conventional RT-CIT without distinct targets would require uniform responses to all stimuli, thereby eliminating any response time discrepancy between probe and irrelevant stimuli under such experimental conditions (Matsuda et al., 2009). Suppose the target is recruited from a different stimulus category than the other stimuli, the interplay between category and response allocation is seamless, resulting in no variance in stimulus-response compatibility across items. Consequently, the detection mechanism of the conventional RT-CIT appears ineffective (Figure 1E). Given its practical utility, the ability to incorporate both question methods within the same paradigm is desirable. Nevertheless, the current RT-CIT is limited to accommodating only the known-solution question method, necessitating the development of a new RT-CIT approach.

RT-CIT has a "single-probe protocol" in which only one category of questions is included in a single task, and a "multiple-probe protocol" in which multiple categories of questions are included, with the latter being observed to have a greater effect (Lukács et al., 2017; Lukács & Ansorge, 2019; Verschuere et al., 2015). On the other hand, the Japanese police, where practical CIT is widely used, use only the single-probe protocol, which is due to the fact that CIT in the Japanese police focuses on whether the examinee is aware of individual questions (question-focused judgment) rather than whether the examinee is a criminal or not (examinee-focused judgment) (Ogawa et al., 2015; Osugi, 2018). Question-focused CIT with a single-probe protocol is appropriate for practical situations where the number of questions that can be administered varies from case to case or where additional questions may be asked based on the progress of the investigation. Therefore, we believe that the development of RT-CIT, which can perform both known-solution and searching question methods using a single-probe protocol, is beneficial for practical use.

In this study, we have developed a novel RT-CIT applicable to both known-solution and searching questions. Our new task applies a spatial cueing task (Posner, 1980). Spatial cueing tasks typically manipulate two factors. The first is the relationship between the locations of the cue and the target. A trial in which the target appears at the cued location is called a valid trial, while a trial in which the target appears on the opposite side of the cued location is called an invalid trial. A trial in which attention is not direct to a particular location is called a neutral trial. The second is the timing of cue and target presentation, which is called stimulus onset asynchrony (SOA). By manipulating the SOA, the temporal dynamics of the visual attention process can be examined. It is known that when the SOA is shorter than 300 ms, the RT of valid trials is shorter than that of invalid trials, whereas when the SOA is longer than 300 ms, the RT of valid trials is conversely longer. This phenomenon is called inhibition of return (IOR); once attention is directed to a location, reorientation of attention to that location is inhibited (Klein, 2000; Posner & Cohen, 1984; Posner et al., 1985). In our method, the CIT question items (corresponding to probe and irrelevant items in conventional RT-CIT) are assigned to the cue and the subsequent target is distinctly separated by making it unrelated to the CIT items. Because RT-CIT using the spatial cueing task bypasses the use of stimulus-response compatibility, the category and attribute of the target can be manipulated without affecting the question items. This strategic reconfiguration allows for a comprehensive evaluation of the influence of each searching question item within an exhaustive array of questions on the observers' attention, as indicated by their reaction time to subsequent targets.

The influence of different properties of cue stimuli on IOR has been reported in previous studies using facial expression stimuli. Fox et al. (2002) compared the reaction time required to locate a subsequent black circle target using angry, happy, and neutral facial expressions as cues and reported that the IOR effect was eliminated only when an angry expression served as the cue. It is unclear whether CIT question items and emotional facial expressions have the same effect. Ogawa et al. (2007) were the first to apply a spatial cueing task to CIT, and they reported larger IOR in some experimental blocks when the cue was a critical item, compared to when it was a non-critical item. This finding is not consistent with Fox et al. (2002) in terms of the tendency for IOR to occur when a significant cue is presented, suggesting that the effects of critical questions of CIT and threat stimuli are different. However, both studies included only a single SOA condition and did not systematically examine the temporal dynamics of the cueing effects associated with SOA manipulations. Therefore, the present study introduces multiple SOA conditions, as in previous studies of IOR (e.g., Ponser & Cohen, 1984), and examines the cueing effects on IOR for critical and non-critical items. Spatial cueing tasks may be applicable to CIT if, as in Fox et al. (2002), we observe the phenomenon of reduced IOR when the cue is a critical item.

In addition, there have been recent attempts to apply eye movement indices to CIT (Lancry-Dayan et al., 2023; Nahari et al., 2019; Ono, 2019; Rosenzweig & Bonneh, 2020). Ono (2019) measured eye movements when a critical item was paired with a noncritical item and when two noncritical items were paired. Results showed that gaze was less directed to the critical item than to the non-critical item. Furthermore, the reaction time to first gaze at the non-critical item was measured for trials that included the critical item (critical trials) and trials that did not include the critical item (non-critical trials). The reaction time for the critical trials was significantly longer than that for the non-critical trials. Taken together, the results suggest that on critical trials, covert attention without eye movement is directed to the critical item, followed by overt attention with eye movement to the non-critical item. Based on the implications of this eye movement study, if attention is directed differently to critical and non-critical items in spatial cueing tasks, this may be reflected in the occurrence of IOR.

Several previous studies investigating IOR have found that differences in the nature of cues did not affect IOR (Lange et al., 2008; Niimi et al., 2017; Taylor & Therrien, 2005). However, some of them have reported that IOR occurred earlier than in typical experiments (Lange et al., 2008; Niimi et al., 2017). In light of these findings, whether or not the cue is a concealed information may influence the occurrence of IOR. Therefore, we believe that it is a useful attempt to systematically examine its effectiveness as a CIT in a spatial cueing task.

In summary, the current study investigates whether the concealed information in a spatial cueing task can be detected by differences in the occurrence of IOR when the cue is a critical item and when the cue is a non-critical item. We expect that reaction time to the target would be modulated by the preceding cue type (critical vs. non-critical items) because critical items are considered to be significant stimuli for the participants and hold their attention longer than non-critical items. Specifically, the IOR can be observed conventionally in the non-critical condition, but not in the critical condition. The current study consisted of two separate experiments conducted online. Experiment 1 aimed to elucidate the effect of concealed information presentation on IOR, achieved through manipulation of both the cue validity and SOA between the cue (question item) and the target. In Experiment 2, a direct follow-up assessment was conducted to test the robustness of the results revealed in the exploratory analysis of Experiment 1. In both experiments, participants memorized and concealed the number on the card they selected on the screen and performed a CIT using an application of the spatial cueing task. In this CIT task, a number is first presented as a cue in the context of the question "What was the number on the card?" to one of the white placeholders on the left, center, or right. Then, after an interval of 0 ms to 500 ms, one of the left and right placeholders turns red and the other turns green. These colors correspond to the answers to the question, and participants are told in advance that YES (“I know it.”) corresponds to green and NO (“I do not know it.”) corresponds to red. In other words, participants must locate the position of the red placeholder to hide the number on the card. We assessed IOR based on reaction times in valid trials in where the cue and target appeared on the same side and invalid trials where both appeared on the opposite side, and examined differences in IOR in critical and non-critical conditions. Note that we employed the known-solution question method because we have knowledge of the critical item in the experimental manipulation. However, because this task is separable between question and target categories, we can also perform CIT using the same paradigm, even in situations where we do not have knowledge of the critical item (i.e., a case of using the searching question method in practice).

Experiment 1

Method

Participants

We recruited a total of 56 participants (average age: 26.3 years; 28 females) through a staffing agency, providing them with a monetary compensation of 2,000 Japanese yen (approximately 17 US dollars at that time). The determination of the sample size was executed utilizing G*Power 3.1 (Faul et al., 2009). We opted for the ANOVA: Repeated measures, within factors choice within the F tests category. While our primary interest lay in investigating the interaction between cue validity and SOA as two factors, G*Power doesn't offer direct support for interactions within repeated measures designs. Thus, we defined the number of measurements (representing the count of levels within each repeated measures factor) as $(k_1\text{-}1) \times (k_2\text{-}1) +1$, where k_1 and k_2 denote the number of levels for each factor. We chose the "as in SPSS" option as the effect size specification, referencing the approach outlined by Watson et al. (2021). Given an alpha level of 0.05, statistical power of 0.80, and a medium effect size f(U) of 0.25 (group = 1, number of measurements = (3-1) × (6-1) +1 = 11: because our primary focus was the interaction between cue validity (3 levels) and SOA (6 levels) for each question item), the requisite sample size amounted to 28 participants. We doubled this size (= 56) to account for potential substantial variability inherent in data obtained from online experimentation (e.g., Kawashima & Amano, 2022).

From this total, one participant who used a monitor with a refresh rate of 35 Hz, two participants who answered incorrectly on the recognition test at the end of the experiment, and five participants whose overall task accuracy was near chance level were excluded from the data analysis. Therefore, we had available data on 48 participants for the statistical analyses, all of whom except for two were right-hand dominant and had normal or corrected-to-normal eyesight.

Ethics and consent

This experiment approved by the local ethics committee at Osaka University (HB021-116), and the experimental design was preregistered at https://osf.io/5ehkp. The informed consent statement was displayed on the monitor at the beginning of the online experiment, with a full description of the study purpose, authors identification, and that data would be stored privately with authors. Participants expressed their intention to participate in the experiment by pressing a predetermined key. All methods were performed in accordance with the relevant guidelines and regulations.

Stimuli and apparatus

Visual stimuli were presented via the Pavlovia.org platform, utilizing PsychoPy (v2021.1; Peirce et al., 2019) software. Following informed consent provided by the participants, a blank screen was displayed for a duration of 5 seconds, during which the refresh rate of each individual's monitor was computed. We then proceeded to calculate the logical pixel density (pixel/mm) of each participant's monitor using a card task, and ascertained their viewing distance using a blind spot task (Li et al., 2020). The blind spot task involved a minimum of three practice trials (which were allowed to be repeated if offered), followed by five experimental trials, and the data obtained were used to determine the visual angles of the presented stimuli. Participants were asked to sit facing the monitor and maintain their viewing distance throughout the experiment.

All stimuli were displayed on a black background. Prior to the RT-CIT task, participants completed a memory task where they were shown an animation involving two number cards (6 and 9) that were turned upside down and overlapped, and then the top card was turned over. They were instructed to remember the number on the face-up card and maintain it concealed during the subsequent RT-CIT task. Note that these numbers were selected to make the visual characteristics of critical and non-critical items as equivalent as possible for experimental control.

The RT-CIT task screen, as illustrated in Figure 2, consisted of three white placeholders (3.0° × 3.0°) in the center and positioned 9.0° away from the center towards the left and right. A question message in Japanese was displayed at the top, reading "What was the number on the card?". The cue stimuli were yellow numerals (font: Arial, height: 3.0°), presented for 150 ms in either placeholder. In half of the trials, the left placeholder turned red and the right one turned green at intervals of 0, 50, 100, 200, 300, and 500 ms after the presentation of the cue. On the other hand, in the remaining half of the trials, this color change occurred in the opposite manner, with the left placeholder becoming green and the right becoming red. In valid trials, the cue appeared in either the left or right placeholder, and the placeholder at the cued location turned red. In invalid trials, the placeholder opposite to the cued location (i.e., the left placeholder when the cue appeared at the right placeholder) turned red. In neutral trials, the cue appeared at the center placeholder and either the left or right placeholder turned red.

Procedure and design

The participants were given instructions to respond NO to the question regardless of whether the cue was the number they had memorized. The green and red colors of the placeholders were indicative of the participants' response to the question. They had to press the "f" key if the left placeholder turned red and the "j" key if the right one turned red as quickly and accurately as possible. The participants completed 36 practice trials before moving on to six blocks of 72 trials, totaling 432 experimental trials. In half of these trials, the cue stimuli were concealed information (critical condition), while in the other half, they were not (non-critical condition). Both the conditions contained three types of cue validity for the placeholder changing to red corresponding to NO (valid, invalid, and neutral), and six types of SOA (0, 50, 100, 200, 300, or 500 ms) in equal proportions. The trials were randomly intermixed. This task took approximately 20 minutes.

Data analysis

Trials with incorrect target localization responses or reaction times that were three standard deviations away from the mean were excluded from the data analysis, representing 3.6% of the critical condition and 4.6% of the non-critical condition. A repeated measures analysis of variance (ANOVA) was conducted for reaction times and accuracy in target localization, with 2 levels of the question item (critical, non-critical), 3 levels of cue validity (valid, invalid, neutral), and 6 levels of SOA (0 ms, 50 ms, 100 ms, 200 ms, 300 ms, 500 ms). We adjusted degrees of freedom using the Greenhouse-Geisser correction when the assumption of sphericity was violated, and used Shaffer's modified sequentially rejective Bonferroni procedure for *post hoc* multiple comparisons.

Results

There were no significant differences in target localization accuracy across conditions. The mean RTs for all conditions are shown in Table 1. A three-way (question item × cue validity × SOA) ANOVA showed significant main effects of cue validity (F (2, 94) = 14.4, $p < .001$, $\eta_p^2 = .24$) and SOA (F (2.15, 100.82) = 99.6, $p < .001$, $\eta_p^2 = .68$), and significant interaction of cue validity × SOA (F (6.88, 323.56) = 5.01, $p < .001$, $\eta_p^2 = .09$). However, a main effect of question item and any interactions including the factor of question item were not significant (all ps > .207).

With the aim of investigating the occurrence of IOR across different item conditions, we carried out an exploratory analysis to explore the patterns of IOR (Figure 3). We conducted separate two-way ANOVAs for each question item condition, focusing on the factors of cue validity (2 levels: valid, invalid) and SOA. For both the critical and non-critical item conditions, we observed significant main effects of cue validity (critical: F (1, 47) = 17.6, $p < .001$, $\eta_p^2 = .27$, non-critical: F (1, 47) = 26.3, $p < .001$, $\eta_p^2 = .36$) and SOA (critical: F (5, 235) = 55.0, $p < .001$, $\eta_p^2 = .54$, non-critical: F (5, 235) = 50.4, $p < .001$, $\eta_p^2 = .52$), as well as significant two-way interactions (critical: F (5, 235) = 2.80, $p = .018$, $\eta_p^2 = .06$, non-critical: F (5, 235) = 3.04, $p = .011$, $\eta_p^2 = .06$).

Upon conducting a simple effects analysis, we identified significant RT delays for valid trials (indicative of IOR occurrence) within the critical condition at SOAs of 100 ms, 200 ms and 500 ms (0 ms: p = .445, η_p^2 = .01, 50 ms: p = .078, η_p^2 = .06, 100 ms: p = .045, η_p^2 = .08, 200 ms: p < .001, η_p^2 = .22, 300 ms: p = .127, η_p^2 = .04, 500 ms: p = .024, η_p^2 = .10). On the other hand, in the non-critical condition, we observed significant RT delays for valid trials at SOAs of 50 ms, 100 ms, 200 ms and 300 ms (0 ms: p = .351, η_p^2 = .02, 50 ms: p = .034, η_p^2 = .09, 100 ms: p = .003, η_p^2 = .18, 200 ms: p < .001, η_p^2 = .24, 300 ms: p = .004, η_p^2 = .16, 500 ms: p = .053, η_p^2 = .08). An intriguing observation was made when the SOA was 300 ms: IOR occurred significantly in the non-critical condition but not in the critical condition.

While the three-way ANOVA did not reveal a significant effect of the question item factor, subsequent exploratory analyses showed that reaction time to the target is affected in part by whether the cue is concealed information or not. To further validate the robustness of this finding, we decided to conduct an additional experiment. Experiment 2 was designed as a direct replication of Experiment 1, wherein we pre-registered an identical analysis strategy as employed in the exploratory analysis. The primary aim was to test the hypothesis that IOR is reduced when the cue serves as concealed information, whereas it retains its usual manifestation when the cue does not contain concealed information.

Experiment 2

Method

Participants

A total of 64 participants were recruited (average age: 23.6 years; 36 females). The recruitment process involved SONA, a web-based recruitment system, and a staffing agency. Participants received monetary compensation of 500 Japanese yen (approximately 3.6 US dollars at that time) through SONA, while those from the staffing agency received 2,000 yen (approximately 14 US dollars at that time) in compliance with the agency's regulations.

Similar to Experiment 1, the determination of the sample size estimates was based on Watson et al. (2021). With an alpha level of 0.05, a statistical power of 80%, and an effect size f(U) of 0.244 (derived from the interaction effect size in the critical item condition of Experiment 1, where η_p^2 = .056), and considering group = 1 and a number of measurements = 6 (computed using the method outlined earlier: (2-1) × (6-1) +1), the requisite sample size was established at 46.

In Experiment 1, we initiated with a sample size of 56 participants, out of which 8 participants needed to be excluded (resulting in a 14.3% exclusion rate). These exclusions were attributed to issues specific to online experiments, such as misunderstandings of instructions or mismatches with monitor refresh rates. To account for anticipated data exclusions, the adjusted effective sample size was set at 52. However, we had to exclude six participants who were using monitors with incompatible refresh rates, three participants who answered the recognition test incorrectly at the conclusion of the experiment, and three participants whose overall task accuracy was close to chance level. These unexpectedly led to a higher number of data exclusions, ultimately resulting in a dataset consisting of only 40 valid entries. Consequently, we embarked on the recruitment of an additional 12 participants from the staffing agency to compensate for the shortfall. Following this, a total of 9 participants were incorporated after removing two participants with incompatible monitor refresh rates and one participant who demonstrated performance below chance level. Ultimately, we obtained data from 49 participants, which were utilized for the subsequent statistical analyses. Among these participants, all but four were right-hand dominant and exhibited either normal eyesight or corrected-to-normal eyesight.

Ethics and consent

This experiment approved by the local ethics committee at Osaka University (HB021-116R), and the experimental design was preregistered at https://osf.io/yh5zm. The procedure for informed consent was the same as in Experiment 1.

Stimuli, apparatus, procedure and design

All settings were the same as those in Experiment 1.

Data analysis

Trials with incorrect target localization responses or reaction times that were three standard deviations away from the mean were excluded from the data analysis, representing 4.8% of the critical condition and 4.6% of the non-critical condition. A repeated measures analysis of variance (ANOVA) was conducted for reaction times and accuracy in target localization, with 2 levels of the question item (critical, non-critical), 2 levels of cue validity (valid, invalid), and 6 levels of SOA (0 ms, 50 ms, 100 ms, 200 ms, 300 ms, 500 ms). We adjusted degrees of freedom using the Greenhouse-Geisser correction when the assumption of sphericity was violated, and used Shaffer's modified sequentially rejective Bonferroni procedure for *post hoc* multiple comparisons. This analysis design was identical to the exploratory analysis in Experiment 1.

Results

There were no significant differences in target localization accuracy across conditions. The mean RTs for each question item condition is shown in Table 2 and Figure 4. A two-way ANOVA was conducted independently for each question item condition, examining the factors of cue validity and SOA.

In the critical condition, significant main effects were observed for cue validity (F (1, 48) = 12.1, p = .001, η_p^2 = .20) and SOA (F (5, 240) = 69.2, p < .001, η_p^2 = .59), alongside a significant two-way interaction (F (5, 240) = 3.43, p = .005, η_p^2 = .07). Analysis of simple effects revealed noteworthy RT delays for valid trials at SOAs of 200 ms, 300 ms, and 500 ms (0 ms: p = .143, η_p^2 = .04, 50 ms: p = .528, η_p^2 = .01, 100 ms: p = .058, η_p^2 = .07, 200 ms: p = .006, η_p^2 = .15, 300 ms: p = .020, η_p^2 = .11, 500 ms: p = .004, η_p^2 = .16). Contrarily, within the non-critical condition, although main effects for cue validity (F (1, 48) = 6.92, p = .011, η_p^2 = .13) and SOA (F (5, 240) = 75.0, p < .001, η_p^2 = .61) were statistically significant, the interaction between the two factors (F (5, 240) = 1.59, p = .161, η_p^2 = .03) was not significant. This implies that, overall, responses to valid trials exhibited delays in comparison to invalid trials.

In contrast to the outcomes of Experiment 1, Experiment 2 showed robust IOR, even when the cue was concealed information. In essence, the hypothesis derived from Experiment 1 was not supported by the results of Experiment 2.

Discussion

The aim of this study was to investigate the feasibility of using the spatial cueing task to implement the CIT. Specifically, we compared the RTs for subsequent targets when the cue was a critical item and when it was a non-critical item. By manipulating the SOA between the cue and target stimuli, we focused on detecting potential differences in IOR based on the nature of the question items, namely critical and non-critical items. The underlying question was whether the occurrence of IOR would show variations depending on the specific characteristics of the stimuli. In particular, we focused our attention on cases in which the cue consisted of concealed information (critical condition), expecting that such a condition would affect IOR in a different way. This hypothesis was based on the previous research showing that significant stimuli to the observer, such as angry facial expressions, could abolish the IOR effect (Fox et al., 2002). With this premise in mind, we set out to investigate whether the presentation of concealed information as a cue of significant importance to the participant would result in the prolonged retention of attention at its point of appearance (manifesting as delayed attentional disengagement), thus potentially leading to the elimination of the conventional IOR phenomenon.

There was a degree of inconsistency in the results of the two experiments conducted in this study. Experiment 1 provided partial support for the hypothesis that concealed information could lead to a reduction in IOR. Within the critical condition, IOR was found to be incomplete, as there were no significant RT differences between valid and invalid trials at SOA of 300 ms. In contrast, the non-critical condition showed a significant RT difference between valid and invalid trials at the same SOA, confirming the occurrence of IOR. In order to establish the reliability of the results observed in Experiment 1, we decided to conduct Experiment 2. It aimed to provide a direct follow-up according to the pre-registered hypothesis that "IOR is reduced when the cue is concealed information, but remains consistent when the cue is not concealed information". However, Experiment 2 yielded different results; IOR was not reduced in the critical condition, thus failing to replicate the results of Experiment 1.

IOR was reliably observed in both experiments. These experiments were essentially localization tasks, and the occurrence of IOR in this type of task has been reported in previous research (Maylor, 1985). In both experiments, IOR was observed even under short SOA conditions. Several previous studies have reported similar phenomena (Lange et al., 2008; Niimi et al., 2017), and the timing of IOR occurrence appears to be influenced by several factors (Niimi et al., 2017). As a first step in a systematic investigation of CIT using IOR, we followed Posner and Cohen (1984) and used relatively short SOA conditions as variables in this study, whereas Fox et al. (2002) reported that the difference in cue was reflected in the occurrence of IOR in the longer SOA condition (960 ms). Therefore, it is necessary to examine the effect of concealed information cue on IOR under longer SOA conditions in future CIT studies.

The results of the two experiments support the conclusion that the influence of concealed information within the spatial cue paradigm is not consistently reliable. Several factors could contribute to this instability. In particular, the cue used in this study was a numerical value (6 or 9) that participants had to provide at the beginning of the experiment. The task itself used a form of peripheral cue presentation within the spatial cue task framework. Peripheral cues are generally characterized by their physical prominence, while lacking conceptual or meaningful content, such as simple flashes (e.g., Posner & Cohen, 1984). On the other hand, numbers and letters are more commonly used as conceptual central cues in related research (Müller & Rabbitt, 1989; Posner et al., 1985; Posner & Cohen, 1984). In the context of this study, the decision to use a peripheral cue task was driven by the intention to create a CIT that exploited IOR towards peripheral stimuli. Consequently, the results showed delayed responses to the target appearing at the cued location, demonstrating robust IOR effects in both experiments. However, although the peripheral stimuli were indeed processed within the specified durations and SOAs, these may not have been sufficient to effectively manifest the results of conceptual processing in terms of attention. In particular, peripheral cueing tasks are known to be resistant to interference from concurrent verbal working memory tasks. Jonides (1981) reported that the effect of central cues decreases with increasing working memory load, whereas the effect of peripheral cues is unaffected by working memory load. Although some models of response elicitation in CIT suggest that working memory is responsible for matching CIT items to memory representations (Nakayama, 1986, 2003), it is possible that even a high load of having to hide a critical item does not affect the effects of peripheral cues (i.e., the occurrence of IOR). This conclusion is consistent with previous findings that qualitative distinctions in prior stimuli are not influential in altering IOR outcomes (Lange et al., 2008; Niimi et al., 2017; Taylor & Therrien, 2005).

This study adopted a unique paradigm that differs from the conventional RT-CIT framework, as demonstrated by previous research (e.g., Seymour et al., 2000). In doing so, it became possible to incorporate a searching question approach that included a comprehensive set of questions, a feat that proves challenging within the confines of the conventional RT-CIT paradigm. However, this shift came at the cost of omitting stimulus-response compatibility, a facet often considered as the mechanism responsible for CIT effects in numerous RT-CIT investigations (Verschuere & De Houwer, 2011). Conventional RT-CIT requires separate responses for a critical item and a target of higher significance than the non-critical items: a NO response to the critical item and a YES response to the target. The non-critical items of low significance are given a NO response. This response assignment manipulates the stimulus-response compatibility between critical and non-critical items. In contrast, in the experimental task in the present study, the required response was the same for all stimuli (i.e., answer whether the stimulus appeared on the left or the right). This difference may have reduced the likelihood of response conflict for the critical item. We expected that the RT-CIT effect would be obtained by the orienting mechanism of attention even in the absence of response conflict derived from stimulus-response compatibility (see klein Selle et al., 2023). In particular, the concept of IOR has been established by a wealth of studies on visual attention over many years (Dukewich & Klein, 2015; Klein, 2000). We have attempted to use this robust phenomenon as a potential tool for CIT. However, the current study highlights the challenges of obtaining reliable CIT effects within the RT-CIT framework when using tasks that do not utilize stimulus-response compatibility. Interestingly, previous research has highlighted instances where RT-CIT has failed or yielded minimal effects even in tasks such as the Stroop task (Engelhard et al., 2003) and the dot-probe task (Verschuere et al., 2004). These tasks involve cognitive conflict without the presence of stimulus-response compatibility. One reason why the effect of CIT was not stable throughout this study may be that stimulus-response compatibility had little relevance to the procedures of the current study.

The involvement of orienting response mechanisms has been noted to underlie physiological responses in CIT (klein Selle et al., 2018; Lykken, 1974). Therefore, in the present study, we hypothesized that results similar to those of Fox et al. (2002), in which attention attracted to a critical item becomes difficult to shift to another location, might be observed. However, because the responses in CIT can be explained without emotional factors (klein Selle et al., 2018), it is unlikely that the effect of RT-CIT using IOR is based on exactly the same mechanism as in Fox et al. (2002) (see also Ogawa et al., 2007). As a result, the IOR was partially eliminated in the critical condition in our Experiment 1. Concerning this result, the significance of the critical item in RT-CIT may have led to a longer dwell time of attention at the cued location, similar to the threat stimuli of Fox et al. (2002), so that the subsequent target localization at the same location was not delayed. To our knowledge, no studies have yet directly compared IOR with threat stimuli and CIT items. If the direction of both effects is the same, it may be difficult to distinguish an emotional non-critical item from a neutral critical item based on the occurrence of IOR. In practice, however, because the critical and non-critical items should belong basically to the same category (Osugi, 2011), stimulus configurations in which only one item stands out in its emotional valence would be avoided. A recent study of AR-CIT also reported that the response of CIT is context-dependent (Ogawa et al., 2023). If the same is true for RT-CIT, it is possible that emotional stimuli that are unrelated to the context of the question have no effect on IOR. The relationship between the response to the critical item of CIT and the emotional valence of the stimulus itself awaits clarification by new studies that directly compare their effects using the same paradigm.

All experiments in this study were conducted online. IOR has been reported to occur robustly in online experiments (Crump et al., 2013; Majima, 2017). However, for CIT, there are reports that phenomena observed in face-to-face experiments could not be reproduced online (Matsuda et al., 2020; Matuda & Nittono, 2021). Matuda & Nittono (2021) suggest that online experiments may not be sufficient to increase arousal levels compared to laboratory experiments. In addition, most of the CIT experiments that have been successful online also had participants conceal their own identities (e.g., their own names and birthdays) (Kleinberg & Verschuere, 2015, 2016; Lukács et al., 2017; Lukács & Ansorge, 2019; Verschuere & Kleinberg, 2016). On the other hand, in the present study and in the studies by Matsuda and colleagues, stimuli presented for the first time during the encoding phase within the experiment were subject to concealment. A recent study also reported that the diagnostic accuracy of RT-CIT using cybercrime scenarios was lower than that using concealed identity scenarios (Lukács & Ansorge, 2023). Such differences in the nature of the information to be concealed may also affect the success or failure of online CIT.

Furthermore, it was difficult in our online experiments to strictly control the viewing distance or gaze of the participants in the experiment. Therefore, it cannot be denied that imperfect controls in these issues may have contributed to the discrepancies between the experimental results. A follow-up study with a face-to-face experiment is required to overcome this by strictly controlling the viewing distance and gazing. Another important limitation of this study is that we did not examine the non-encoding group. In the future, if the CIT effect is observed in the encoding group, the accuracy of the test should be confirmed by comparing it with the results of the non-encoding group (Lukács et al., 2017; Seymour et al., 2000).

The finding of this study doesn't rule out the possibility that future modifications of the task to make it more suitable for RT-CIT might yield more substantial CIT effects. The fact that the two experiments conducted in this study yielded different results in the critical and non-critical conditions, although the patterns were not entirely consistent, suggests that the variations in the question items have some impact on task performance. Consequently, if effective extensions are developed in subsequent studies, there's potential for this paradigm to become useful as a CIT tool. For example, recent research has shown that the effects of RT-CIT can be enhanced by introducing fillers (Lukács et al., 2017; Lukács & Ansorge, 2019, 2021, 2023). By exploiting differences in stimulus-response compatibility between well-designed fillers and question items, CIT effects could be preserved even in scenarios similar to search questions, where targets within the same category cannot be used. Other studies have shown that RT-CIT can be used to elicit intentions to engage in criminal activity in the near future, such as in counterterrorism investigations (Koller et al., 2020). This shows that the usefulness of exploratory question methods is gaining recognition not only in Japanese police practice, but also in other areas of research. In the coming years, further research in this area will require not only academic exploration, but also a practical approach to meet the real demands of the field.

Conflict of interest

The authors declare there are no conflicts of interest associated with this manuscript.

Data availability statement

All raw data are available via https://osf.io/5ajve and https://osf.io/pcdme.

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The manuscript was drafted using DeepL Write and OpenAI ChatGPT. The AI generated text was read, revised and proofed by the authors.

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Table

Table 1

Mean reaction times and 95% confidence intervals in Experiment 1.

	SOA (ms)											
	0		50		100		200		300		500	
	M	95% CI	*M*	95% CI	*M*	95% CI	*M*	95% CI	*M*	95% CI	*M*	95% CI
Critical item												
Valid	416	[403 , 430]	413	[401 , 426]	408	[396 , 420]	398	[389 , 407]	385	[375 , 394]	390	[380 , 400]
Invalid	419	[406 , 431]	408	[395 , 421]	401	[388 , 414]	384	[373 , 394]	380	[372 , 389]	381	[370 , 392]
Neutral	423	[410 , 436]	414	[403 , 426]	401	[391 , 411]	390	[379 , 400]	380	[372 , 388]	383	[374 , 392]
Non-critical item												
Valid	419	[405 , 432]	413	[401 , 424]	410	[401 , 419]	399	[390 , 409]	389	[379 , 400]	389	[379 , 399]
Invalid	422	[406 , 438]	405	[393 , 417]	398	[385 , 411]	387	[378 , 397]	378	[368 , 389]	383	[374 , 393]
Neutral	426	[412 , 440]	414	[403 , 426]	404	[392 , 416]	387	[377 , 398]	382	[372 , 392]	383	[374 , 392]

Table 2

Mean reaction times and 95% confidence intervals in Experiment 2.

	SOA (ms)											
	0		50		100		200		300		500	
	M	95% CI	*M*	95% CI	*M*	95% CI	*M*	95% CI	*M*	95% CI	*M*	95% CI
Critical item												
Valid	406	[393 , 418]	403	[391 , 415]	399	[388 , 411]	383	[374 , 393]	376	[365 , 387]	378	[367 , 390]
Invalid	411	[397 , 425]	400	[389 , 412]	392	[379 , 405]	374	[363 , 385]	367	[356 , 378]	368	[358 , 378]
Neutral	417	[403 , 431]	407	[393 , 420]	398	[383 , 413]	377	[365 , 388]	368	[359 , 378]	367	[357 , 377]
Non-critical item												
Valid	410	[394 , 426]	403	[392 , 415]	400	[388 , 411]	386	[375 , 396]	375	[365 , 384]	376	[365 , 386]
Invalid	413	[399 , 427]	398	[386 , 410]	394	[380 , 408]	377	[365 , 389]	364	[353 , 375]	370	[359 , 381]
Neutral	418	[402 , 433]	406	[393 , 419]	396	[384 , 408]	374	[364 , 385]	368	[357 , 380]	364	[356 , 373]

Figures

Figure 1

The field AR-CIT questionnaire example and its applicability to the typical RT-CIT. Example questions were taken from Osugi (2018).

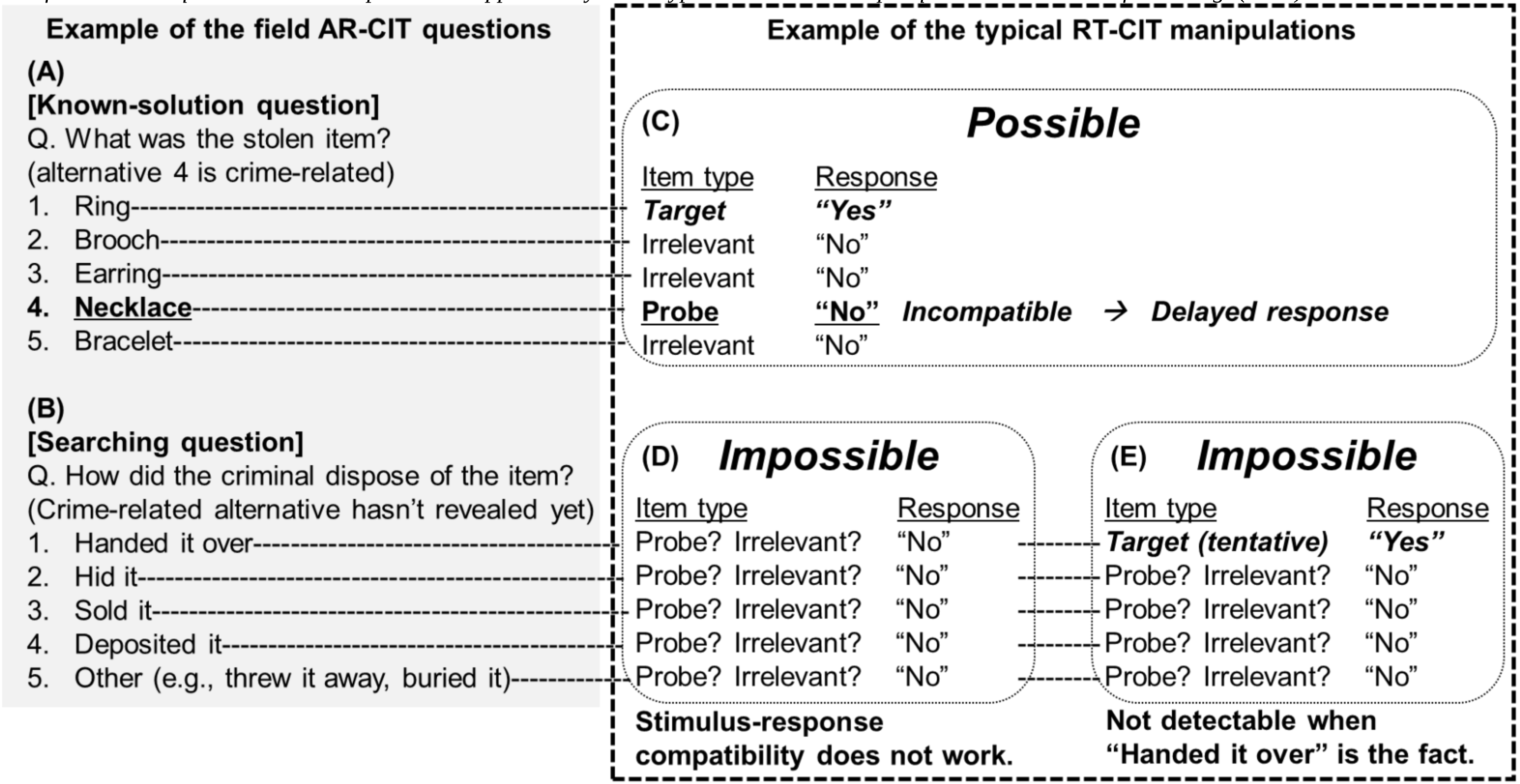

Figure 2

Schematic illustration of the experimental trials used in the study. At the top of the screen, the question text "What was the number on the card?" was presented in Japanese. The cue stimuli, either the numbers 6 or 9, were presented in equal frequency in the left, center, or right placeholders. In half of the trials, the left placeholder changed to red (shown in light gray) and the right to green (shown in dark gray), while in the other half, the color of the placeholders was vice versa.

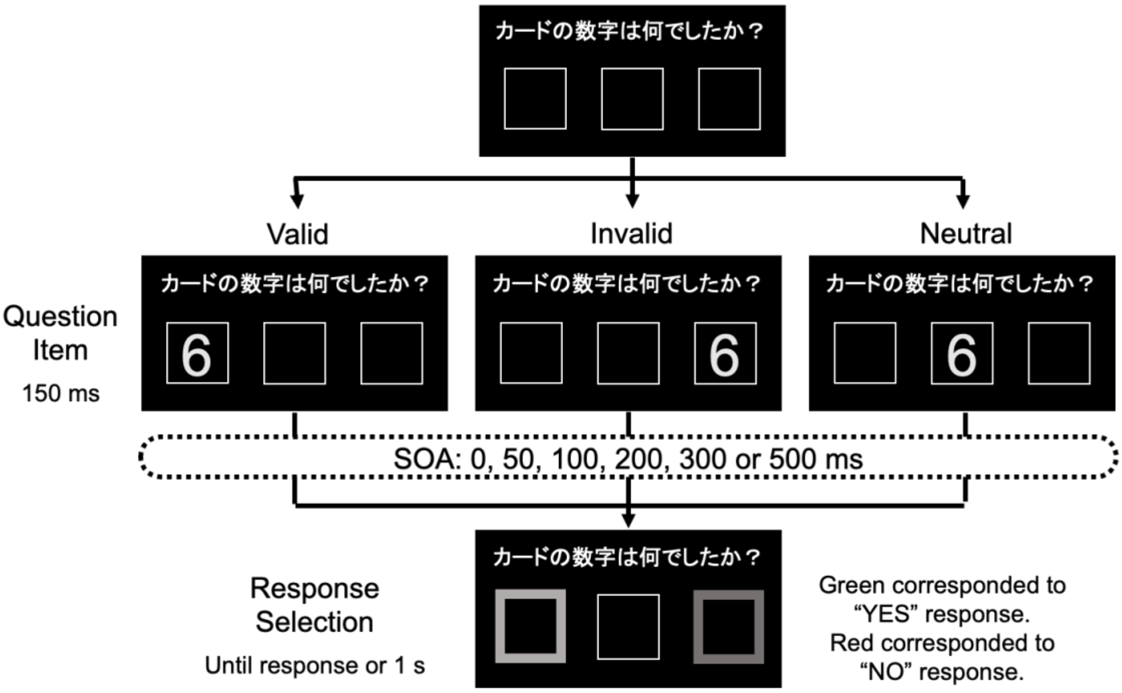

Figure 3

Mean reaction times for each cue and SOA condition when cue stimuli were critical questions (left) and non-critical questions (right) in Experiment 1. Error bars represent standard errors.

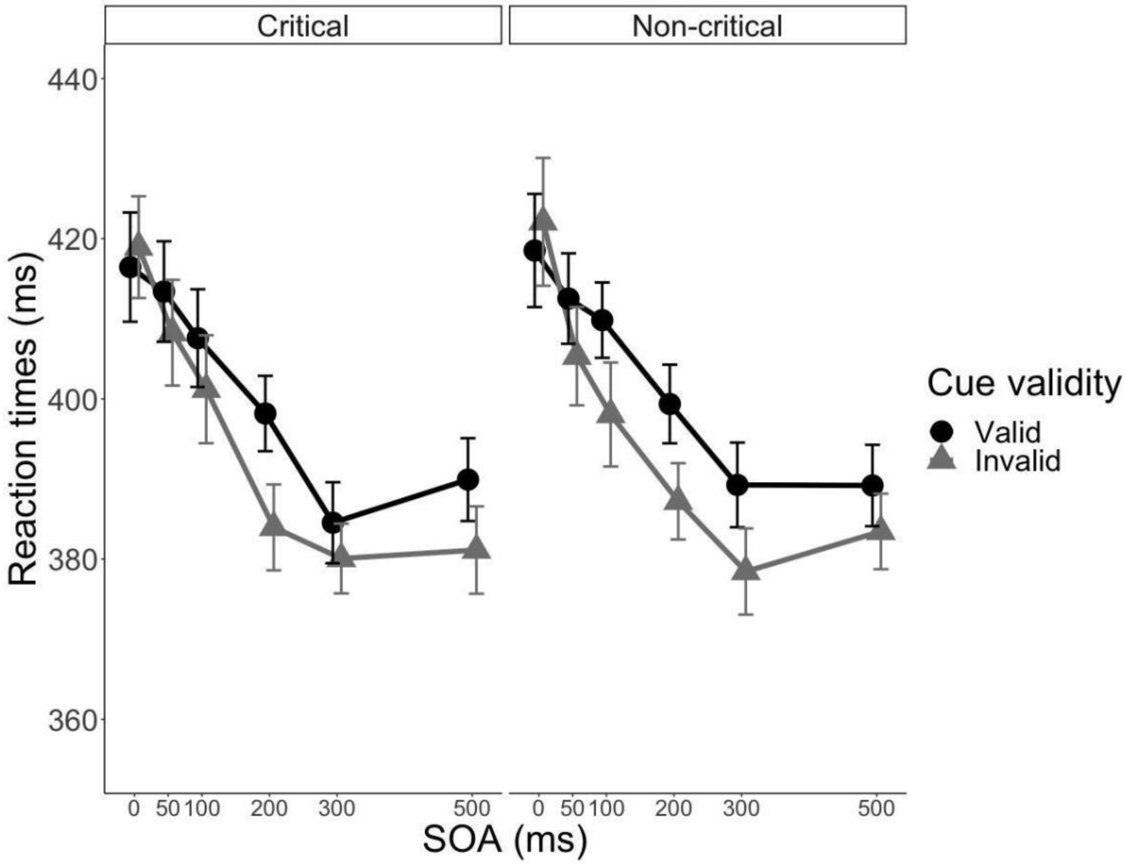

Figure 4

Mean reaction times for each cue and SOA condition when cue stimuli were critical questions (left) and non-critical questions (right) in Experiment 2. Error bars represent standard errors.