

## Case Study of the Increase of Normalized Pulse Volume to the Critical Item in the Laboratory Concealed Information Test

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This is the first detail report concerning the increase of normalized pulse volume (NPV) to the critical item in the laboratory Concealed Information Test (CIT). In CIT, NPV usually decreases in response to the critical item more than the non-critical item between 6 and 10 sec after the presentation of them and returns to its base level within 20 sec. In the present case, although NPV showed lower value to the critical item within 10 sec from the question onset, its value dramatically increased and became larger than its base level thereafter. In the discussion, some future prospects of the researches about this response were considered.

**Key words:** concealed information test, normalized pulse volume, sympathetic inhibition, laboratory setting

The concealed information test (CIT) is a psychophysiological method to examine whether an examinee recognizes crime-relevant information. CIT uses some question sets consisting of a crime-relevant information (the critical item) and several crime-irrelevant information (the non-critical items) which belong to the same category as the critical item and are not distinguishable from the critical item for innocent examinee. For example, in a case where a thief steals 50,000 yen, the critical item is 50,000 yen and the non-critical items are 10,000 yen, 20,000 yen, 30,000 yen, and 40,000 yen. If the examinee responds to a critical item differently from the non-critical items, the examiner determines the examinee has recognized the critical item. In this occasion, inhibition of respiration, occurrence of skin conductance response (SCR), deceleration of heart rate (HR), and decrease of normalized pulse volume (NPV) are likely to occur (Gamer, 2011; Hirota, Takasawa, Ogawa, & Matsuda, 2009; Kobayashi, Yoshimoto, & Fujihara, 2009; Matsuda, Nittono, & Allen, 2013; Osugi, 2011). These responses are known as the critical patterns in Japan (Osugi, 2011).

NPV is an index reflecting vascular sympathetic nerve activity, calculated from dividing pulse volume by blood volume (Sawada, Tanaka, & Yamakoshi, 2001; Tanaka, Sawada, & Yamakoshi, 2000; Tanaka, Sawada, Matsumura, Nagano, & Yamakoshi, 2002). When the sympathetic nerve activates, NPV decreases owing to vasoconstriction. On the other hand, when the sympathetic nerve deactivates, NPV increases owing to vasodilation. In the CIT, NPV usually decreases in response to critical item more than the non-critical item between 6 and 10 sec after the presentation of them and returns to its base level within 20 sec (Hirota, Sawada, Tanaka, Nagano, Matsuda, & Takasawa, 2003). This is the critical pattern of NPV. A

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present case, however, did not correspond to the critical pattern, which consistently showed a marked increase of NPV to the critical items in the laboratory CIT.

With regard to the field CIT, a few articles have reported NPV elevation cases so far. Yamamoto (2010) reported a case whose NPV started to increase 5 sec after the presentation of critical items and then marked significantly higher values than non-critical items. Kobayashi et al. (2009) also reported some NPV increase cases. They divided NPV data within 25 sec after the question onset into 5 epochs with 5 sec each and found that eight out of 38 examinees (21.1%) showed higher values to critical item than non-critical item in epoch 5 (21-25 sec). The mean values to critical item between 6 and 10 sec after the question onset were not lower than non-critical item in both cases. Increased NPV largely exceeded its base level in 20 or 25 sec.

As mentioned above, a few NPV elevation cases were reported in the field CIT so far. However, since almost all cases reported so far were based on the field CITs, it was not clear whether NPV elevation is specific to the field or not. The field CIT is assumed to be a different situation from laboratory CIT in terms of level of stress and motivation to avoid detection (Ben-Shakhar, 2012). Actually, state score of state-trait anxiety inventory (Kiriu, 2002) as well as physiological levels (Nakayama, 2010, 2011) of field examinees were higher than those of participants of laboratory experiments. Considering these peculiarity of field CITs, there is a possibility that NPV elevation is unique to the field CIT.

Meanwhile, increase of NPV in the laboratory experiment is indicated in Hirota et al. (2003). They showed epochs (4 epochs with 5 sec each) where statistical significance was obtained for each participant in their Table 1. According to it, three out of 28 participants seemed to show higher values to the critical item than non-critical item in epoch 3 or 4. However, since they did not refer to these responses at all, details are unknown. Thus, it has remained unclear whether NPV increases to critical item even in the laboratory CIT.

In this backdrop, a case which showed NPV elevations to critical items in the laboratory setting was obtained. The present case has higher credibility because the NPV elevations were seen across question sets, which means the responses are not the chance but actually occur. This is quite important for further researches and discussions because it suggests NPV increase is not specific to field CIT. Thus, details of this case are reported in the below. The corresponding responses of other indices (respiration, SCR, and HR) are also shown. This is the first detail report about NPV elevation in the laboratory CIT.

## Method

### *Participant*

A 30 years old healthy man who voluntarily took part in a CIT experiment on August, 2008 showed NPV elevation. He gave written informed consent. He did not have any disorders either currently or in the past.

### *Apparatus*

Respiration, SCR, HR, NPV were recorded using a portable polygraph device (PTH-347, TEAC, Tokyo). Recorded data were A/D converted with 1 kHz sampling rate and analyzed at offline.

Respiratory movement was recorded using respiratory pick-up (PP-C011-13, TEAC, Tokyo) placed around the participant's abdomen and amplified with a direct current. High-cut filter was set at 5 Hz.

SCR was measured using a 0.5 V constant voltage system (EDA unit, TEAC, Tokyo). Ag/AgCl disposable electrodes (Vitrode F-150S, Nihon Kohden, Tokyo) were attached on the distal phalanges of the index and middle fingers of the left hand. High-cut filter and time constant were set at 5 Hz and 5 sec, respectively.

An electrocardiogram was recorded from the right arm and both legs with Ag/AgCl disposable electrodes (Vitrode F-150U3, Nihon Kohden, Tokyo). A high-cut filter and time constant was set at 30 Hz and 0.1 sec, respectively. HR was calculated from the distance between R waves.

The changes of transmitted light volume were obtained divided into AC and DC component from a near infrared light-emitting diode (810 nm) attached on the nail of the left hand's ring finger and a phototransistor placed at the opposite side of the LED using an NPV measuring unit (MPN1001, Medisence, Saitama). AC component is equal to the pulse volume and DC component closely resembles to the blood volume. NPV was calculated by dividing amplitude of a pulse wave derived from AC component by the average voltage during within the same cardiac cycle derived from DC component. AC component was amplified 100 times with 0.3 sec time constant.

### *Procedure*

The participant was led to a chamber where the room temperature was kept at  $24 \pm 2$  °C and there the participant was given an explanation about the experiment. He agreed to the purpose of the experiment and signed the letter of consent. After that, a mock crime task was conducted. The participant was asked to choose one of five memory devices (SD card, USB memory, floppy disk, MO, PC card) and put it into one of five cases (envelope, plastic bag, paper box, cloth bag, plastic case). And then hide the case with memory device in it into one of five drawers labeling from "A" to "E". After these instructions, experimenter stood by at a separate room until the participant finished above mock crime task.

After finishing the task, the experimenter let the participant sit on a chair with arm chests and attached electrodes to him. First, a card test was conducted. In the field CIT, a card test is demonstrated to all examinees to confirm the examinee's understanding of the procedure and check their physiological response pattern, as well as to check the apparatus (Osugi, 2011). In the card test, the participant was told to pick up one of five cards (2, 3, 4, 5, and 6) without bringing it into experimenter's view and to memorize the number. The participant was also instructed to reply "no" to each question referring to card numbers and try to conceal the

number he selected during the card test. Each item was presented once in a random order in a block. This procedure was repeated five times in a question set. Inter-question intervals were 25 sec or more. After finishing the card test, the experimenter checked the card which the participant selected and confirmed that he had correctly memorized the number. Following that, question sets with regards to the mock crime were conducted.

Three question sets were used referring to the mock crime: those about memory device, case, and drawer. The participant was asked to keep on hiding the acts he had done in the mock crime in order to not allow them to be revealed to the experimenter. The order of the question sets was counterbalanced. In the present case, question set 1 was the questions about the case, question set 2 was about the drawer, and question set 3 was about the memory device. Questions were iterated five blocks with 25 sec or more inter-question interval as did in the card test.

After finishing all question sets, the experimenter asked the participant to tell what he had hidden in the mock crime in order to confirm that he had actually memorized the critical item correctly. Following his confession, experimenter opened the drawer and found the case and the memory device in it as he had said. Thus, it was confirmed that he had correctly recognized all critical items.

### *Analysis*

Respiration speed (RS) within 10 sec after the stimulus onset was analyzed. RS was a moving distance of respiration waveform in a certain time unit, calculated by dividing respiration line length in the object by the time at the same time window. SCR amplitude and the number of spontaneous SCRs were analyzed. SCR amplitude was defined as the peak change of skin conductance occurring within 0.5 to 5.0 sec after the question onset and log transformed after adding 1 to avoid being negative value. SCRs with amplitude of 0.05  $\mu$ S or more occurring 5 sec after the question onset were identified as the spontaneous SCRs, except those that elicited by artifacts. HR and NPV within 20 sec after stimulus onset were averaged 1 sec each. With respect to HR and NPV, averages in 20 sec were regarded as the response magnitude to the questions. Values of RS and SCR were standardized within whole blocks, and HR and NPV were within each block.

Five responses to the critical item in a question set were averaged. Four responses to non-critical items in a block were averaged and then further averaged between blocks. Considering small sampling numbers within an examinee, level of significance was set at 10 % when using *t* test. When the sample number was small and the statistical test should not be conducted, the differences of the response value itself were directly compared.

## **Results**

NPV elevations to the critical items were obtained in card test, question set 1, and question set 2. Therefore, results of these three question sets are described below.

### Reponses to critical and non-critical items

Table 1 shows mean values of three question sets including card test and two question sets (question set 1 and 2) for all indices. Although a decrease of RS, increase of SCR, and decrease of HR to the critical item were seen, there was no difference in NPV. Statistical analysis was not performed with regard to the results of Table 1 because of poor sample size (3 items each).

Table 1. Mean z-scores of each index for critical and non-critical items

	Critical	Non-Critical
RS	-1.16	0.29
SCR	0.80	-0.20
HR	-1.21	0.30
NPV	0.01	0.00

Then, the mean values of each question set were compared between critical and non-critical items for all indices. RS showed a significant decrease in all question sets ( $t(4) = -5.73$ ,  $p < .01$ ;  $t(4) = -5.12$ ,  $p < .01$ ;  $t(4) = -4.46$ ,  $p < .05$ , respectively). HR also showed a significant decrease in all question sets ( $t(4) = -10.53$ ,  $p < .001$ ;  $t(4) = -15.30$ ,  $p < .001$ ;  $t(4) = -3.10$ ,  $p < .05$ , respectively). SCR showed a significant increase in card test ( $t(4) = 3.26$ ,  $p < .05$ ) and question set 2 ( $t(4) = 9.19$ ,  $p < .005$ ). NPV showed no significant difference in all question sets.

Time series graph of HR and NPV were shown in Figure 1. Figure 1 shows mean values of three question sets during 20 sec after the question. HR decreased soon after the question onset. NPV to the critical item between 6 and 10 sec was lower than that to the non-critical item. But, after that, the former increased abruptly and largely exceeded onset value at 10 sec after and later. Initial decrease of NPV was consistent with the critical pattern, but the following increase was not. NPV started to increase 6 sec after the onset of critical item. No NPV elevation was seen to the non-critical item.

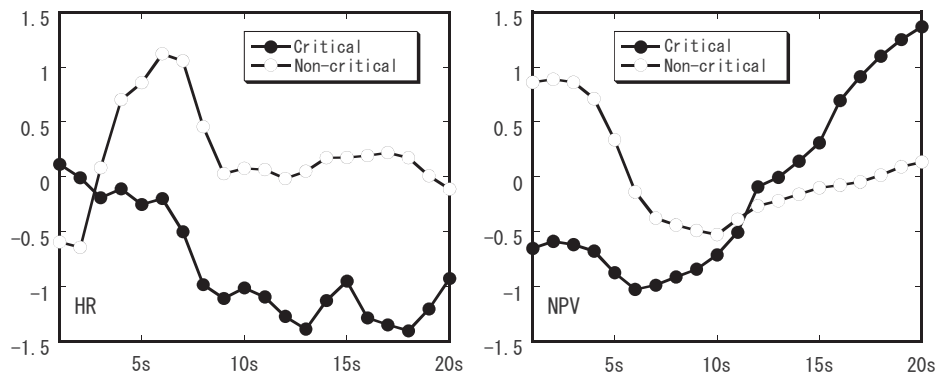
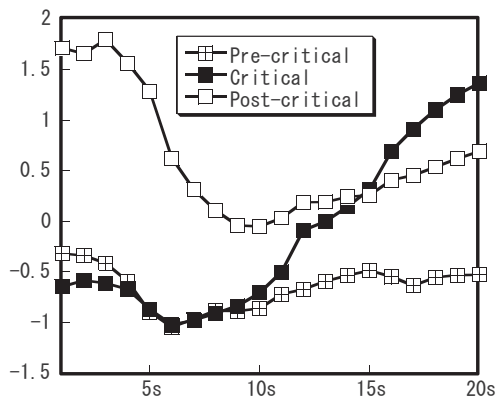


Figure 1. Time series graph of mean z-scores of HR (left) and NPV (right) for critical and non-critical items.

Mean NPV was not significantly different between critical and non-critical items in the present case. This did not support Yamamoto (2010)'s case. The reason for this lack of difference might be that NPV of the critical item largely exceeded non-critical item when 20 sec had passed from the question onset. Thus, NPV data were divided into 4 epochs with 5 sec each and compared the difference between critical and non-critical items of each question sets for each epoch. As a consequence, the value of the critical item was significantly lower than that of the non-critical item at epoch 1 ( $t(4) = -5.03, p < .01$ ;  $t(4) = -2.61, p < .10$ , respectively) and 2 ( $t(4) = -2.28, p < .10$ ;  $t(4) = -2.51, p < .10$ , respectively) in the card test and question set 1, and epoch 1 ( $t(4) = -3.45, p < .05$ ) in question set 2. On the other hand, the value of critical item was significantly higher than that of non-critical item at epoch 4 in question set 1 and 2 ( $t(4) = 3.07, p < .05$ ;  $t(4) = 3.30, p < .05$ , respectively). The value of critical item in card test also exceeded the one of non-critical item, but there was no significant differences ( $t(4) = 1.65, p = .18$ ).

In addition, because NPV to the critical item increased largely, NPV at the onset of the critical item might be lower than that of the non-critical item. Figure 2 shows time series graph of mean NPV for pre-critical, critical, and post-critical items. It is obvious that NPV of the post-critical item was higher than that of the pre-critical and critical item at the question onset. As the base level of post-critical item increased in whole after the NPV elevation to the critical item, NPV of the non-critical items presented followed by critical item might increase and the mean NPV of the non-critical items might render high.



*Figure 2.* Time series graph of mean z-scores of NPV for pre-critical, critical and post-critical items.

### *Frequency of SCRs after the presentation of critical items*

In Yamamoto's case (Yamamoto, 2010), spontaneous SCRs were not seen 7 sec or later after the presentations of critical items. Thus, frequencies of spontaneous responses after each question were investigated in order to ascertain whether the same phenomenon was also occurred in the present case (Figure 3). Figure 3 shows onset times of spontaneous

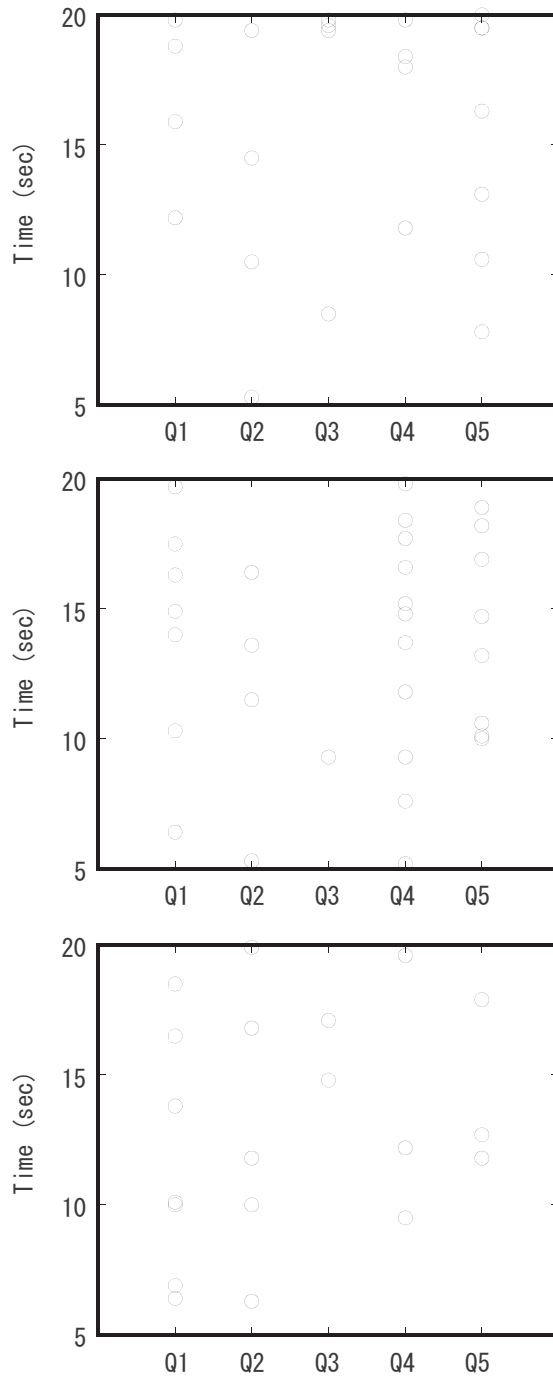


Figure 3. SCR onset times for card test (top), question set 1 (middle), and question set 2 (bottom) during 5 sec to 20 sec after the onset of questions.

SCRs occurred from 5 to 20 sec after the presentation of questions for each question set. The critical item was Q3 in all question sets. Frequencies of spontaneous responses of Q3 were smaller than other questions in all question sets, especially between 10 and 15 sec after the presentation of questions. Although there were no responses after 7 sec or later in Yamamoto's case (Yamamoto, 2010), a few spontaneous responses were observed just around the same time in the present case. But, because the frequency of the spontaneous responses after critical item was apparently lower than non-critical items, there is a possibility that the sympathetic nerve activity declined after the presentation of critical items.

### *SCRs to pre-critical and post-critical items*

SCRs to pre-critical and post-critical items were compared to investigate whether the sympathetic deactivations were actually occurred after the presentation of critical items. The mean SCR amplitudes of post-critical items were smaller than that of pre-critical items in all question sets. The mean SCR amplitudes of the pre-critical and post-critical items were  $-.13$  and  $-.51$  in the card test,  $.40$  and  $-.83$  in question set 1, and  $.17$  and  $-.71$  in question set 2, respectively. The averages of the three question sets were  $.14$  and  $-.68$ . These results support the idea that the sympathetic nerve activity was decreased after the presentation of critical items, though statistical tests were not performed on these results because of poor sampling numbers.

## **Discussion**

The case which showed an increase of NPV to the critical item in the laboratory CIT was reported. While critical patterns were seen in RS, SCR, and HR to the critical item, NPV showed a partially different response pattern to the critical item from the ones reported earlier (Hirota et al., 2003; Kobayashi et al., 2009). In the present case, NPV to the critical item between 6 and 10 sec after the question presentation decreased more than to the non-critical item, which corresponded to critical pattern. But, on the other hand, the NPV increased markedly thereafter, although in general, the temporally decreased NPV gets back to its base level in 20 sec (Hirota et al., 2003). In the present case, however, NPV largely exceeded its base level even though 20 sec had passed. This is not consistent with the critical pattern. When the sympathetic nerve activates, NPV decreases owing to vasoconstriction. On the other hand, when the sympathetic nerve deactivates, NPV increases owing to vasodilation. Thus, the increase of NPV to the critical item might be derived from the decrease of vascular sympathetic activation. This idea was supported by the results that spontaneous SCRs were diminished after the presentation of critical items. In addition, the amplitudes of post-critical items were smaller than that of pre-critical items. These results corresponded to Yamamoto's case (Yamamoto, 2010). Therefore, in the present case, as with Yamamoto's case (2010), NPV might be increased by the decrease of sympathetic activation after the temporal activation of it when the critical item was presented.



Note that differing from Kobayashi et al. (2009) or Yamamoto (2010), NPV to the critical item decreased more than to the non-critical item in epoch 1 and 2 in the present case. The main cause of this inconsistency might be brought by NPV elevation itself. That is, because NPV continued increasing from 5 sec after the presentation of the critical item, the base level of post-critical item was forced up. Therefore, the average of non-critical item would take relatively high value. In fact, mean NPV at the onset of post-critical item was much higher than that of the critical and pre-critical items (Figure 2).

The present case is quite interesting because NPV elevation was obtained in the laboratory experiment. Since almost all reports related to NPV elevation were based on the field CIT so far, it was unclear whether NPV elevation is specific to the field CIT or not. The fact that the increase of NPV was consistently obtained in the laboratory experiment suggests that this response is not limited to the field.

Only one study indicates the possibility of NPV elevation in the laboratory setting. Hirota et al. (2003) divided 20 sec time series data of NPV into 4 epochs with 5 sec each and investigated the differences between critical and non-critical items in each epoch for every participant. Although they did not refer to NPV elevation at all, table 1 in Hirota et al. (2003) indicated there were a few participants whose NPV significantly increased to a critical item in epoch 3 or 4. Three out of 28 participants (12.5 %) showed NPV elevation. Two of them showed in epoch 4 only, and the rest did in epoch 3 and 4. These results are quite similar to present and earlier reports.

If the above mentioned results of Hirota et al. (2003) should be the same with the present case, the percentage of the participants who showed NPV elevation in their experiment would be 12.5 %. Comparing with 21.1 % obtained from field data (Kobayashi et al., 2009), 12.5 % is rather low. But, the ratio is still more than 10 %. This indicates the possibility that some participants have certain characteristics related to NPV elevation such as personality or genetic factor. On the other hand, considering the difference of the ratio between laboratory and field, field specificity might also have some influence on the NPV elevation. It would be worth to consider some characteristics or field specificity to investigate the mechanism of this response.

As discovered through the reports of recent articles (Fujihara, Kobayashi, Yoshimoto, & Yamamoto, 2010; Tominaga & Yamamoto, 2012), NPV elevation is recognized as a rare critical pattern especially among the field examiners. It is obvious from the present case and previous reports that there are some examinees and participants who show an increase of NPV in the field and laboratory CIT. In addition, preceding research indicated the existence of a certain number of examinees and participants who show this response. Given these facts in consideration, there is worth to positively obtain the response in one of the critical pattern. However, since the mechanism of NPV elevation still remains unclear, the response has not been regarded as positive evidence for the judgment in the field. The present case indicates the possibility to be able to evoke the response experimentally in the laboratory. If it could succeed and the psychophysiological mechanism of NPV elevation elucidate, this response

would be a new critical pattern. But now, there is much about NPV elevation that continues to remain unclear. Thus, multidimensional approaches such as collecting similar cases, examining the characteristics of examinees and participants related to NPV elevation, considering field specificity and succeeding to elicit this response in the laboratory experiment are needed in future research.

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