Effects of emotional arousal at memory encoding on the P300-based Concealed Information Test

（P300を用いた隠匿情報検査における符号化時の覚醒の効果）

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Declaration

The research in this thesis is the author's own original work. I hereby declare that this thesis has not been submitted, either in the same or different form, to any other University for a degree.

Akemi Osugi

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Abstract

The Concealed Information Test (CIT) is an information-detection technique used in forensic investigations. Previous studies have reported that the CIT is a reliable and powerful method for detecting information. However, the mechanisms underlying the CIT have not been fully elucidated. In particular, hardly any studies have examined effects of emotional arousal at memory encoding on physiological responses in the CIT. In this thesis, I manipulated the magnitude of emotional arousal at memory encoding in various ways and investigated its effects on physiological responses in the CIT. As an index of the detection of concealed information, I measured P300, a component of the event related potential (ERP), in the CIT.

Experiments 1 and 2 were aimed to examine whether emotional arousal at encoding influences P300 in the CIT. For this aim, participants were randomly assigned to either a High Arousal group or a Low Arousal group in both experiments. In Experiment 1, I attempted to manipulate emotional arousal by asking participants to enact different actions in a mock crime task. Participants in the High Arousal group were instructed to stab an "arm of a mannequin" with one sharp-edged tool selected out of five alternatives (e.g., kitchen knife or ice pick) in the mock crime task where participants were asked to harass a mannequin lying on a bed. Participants in the Low Arousal group were instructed to stab a "pillow" in the same experimental setting. After the mock crime task, all participants performed the P300-based CIT. I hypothesized that the High Arousal group would elicit greater P300 in responses to a probe (the picture of the sharp-edged tool used in the mock crime task) than the Low Arousal group. In addition, P300 in response to the probe would be greater than those in response to the irrelevant stimuli (the pictures of the sharp-edged tools that were not used in the mock crime task) in both groups. Results of Experiment 1 showed that there was a significant difference in P300 in response to the probe between the High and Low Arousal groups. P300 in response to the probe were significantly greater than those in response to the irrelevant stimuli in both groups: the detection of the probe was successful in both groups. Moreover, the differences in P300 between the probe and the irrelevant stimuli were larger in the High Arousal group than in the Low Arousal group: the detection was more efficient in the High Arousal group than in the Low Arousal group.

In Experiment 2, emotional arousal was manipulated before the mock crime task. According to the excitation-transfer theory, arousal can transfer to a temporally close emotion-eliciting event and amplify the intensity of emotional arousal caused by the event.

Based on this theory, emotionally arousing pictures were used. Viewing pictures was expected to arouse emotion at a high or a low level for each group respectively. Subsequently, all participants enacted the same mock crime task, in which they were instructed to stab a pillow with the edged tool. After that, the CIT was conducted. The hypothesis was the same as Experiment 1, and results of Experiment 2 were also consistent with those of Experiment 1: participants in the High Arousal group showed significantly greater P300 in response to the probe compared with the Low Arousal group. These results support the idea that emotional arousal influences P300 in the CIT and that emotional arousal enhances the detection efficiency of the CIT.

Although it was shown that emotional arousal plays a specific role in the CIT, mechanisms by which emotional arousal affects the CIT remained unclear. The main purpose of Experiment 3 was to assess how emotional arousal at encoding enhances P300 in the CIT. There were two possibilities here: enhanced P300 would derive either from top-down processing or from bottom-up processing. To elucidate the processing pathway for stimuli encoded with emotional arousal, the subliminal presentation method was applied. Here the same manipulation of emotional arousal and the same mock crime task as Experiment 2 were used. The CIT was conducted under both subliminal and supraliminal conditions. I hypothesized that the results obtained from the supraliminal condition would replicate those reported in Experiments 1 and 2, and the probe would be detected even under the subliminal condition by bottom-up processing. Results revealed a significantly greater difference in P300 between the probe and the irrelevant stimuli in the High Arousal group than in the Low Arousal group under both conditions. Whereas the detection of the probe was successful in both groups under the supraliminal condition, the detection under the subliminal condition was only successful in the High Arousal group. This result showed that the probe associated with high emotional arousal can be automatically processed via the bottom-up route in the CIT.

The present study was the first attempt to investigate the influence of emotional arousal on the CIT using P300 and the first empirical demonstration of effects of emotional arousal at encoding in the CIT. Results from three experiments provide strong evidence that emotional arousal at encoding plays a key role to detect the probe: emotional arousal can enhance P300 in response to the probe in the CIT, and the probe associated with high emotional arousal can be detected without conscious retrieval.

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Chapter 1

Introduction

1.1. Preface

Detecting lies has always been of interest to human society. To a greater or lesser extent, our everyday lives are flooded with lies. Some lies may facilitate human relationships, while others may pose serious problems. Especially in criminal investigations, lies are always disruptive and may obstruct justice. Detecting lies would be much simpler if people had Pinocchio's nose, a special wooden nose that elongated whenever Pinocchio lied; the real world however is far more complicated.

There is a long history in lie and deception detection (for a review, see Lykken, 1998). In early societies, torture was a popular technique and rituals on religious premises were believed to be effective for truth seeking. Ancient Hindu culture and the Roman Church used some alimentary techniques with rice or bread and cheese. These techniques have been identified as precursors of modern lie detectors because they used the person's salivation as an indicator of fear of being exposed lying. In the 19th century, criminologists and psychologists started to measure physiological indices such as those obtained with a plethysmograph and finger tremors to detect lies, but "lie detectors" or "polygraphs" acquired scientific aspects using measures of several physiological responses and were popularized in the next century.

The Comparison Question Test or the Control Question Test (CQT; Reid, 1947) was developed as one of most popular polygraph techniques using several physiological responses. This method was designed for lie detection and focuses on the examinee's emotional reactions when lying. In the CQT, responses to "relevant" questions regarding a suspect's involvement in a crime (e.g., Did you kill her?) are compared to responses to "control" questions that the suspect's answer will probably untrue (e.g., Have you ever stolen anything?). If the examinee elicits larger responses to the relevant questions than to the control questions, the examinee is assumed to be lying regarding the crime for which the questioning takes place. Although the CQT is broadly used in the field (Raskin and Honts, 2002), especially in the United States, Israel, and several European countries, the CQT has been severely criticized by psychophysiological researchers because of its lack of genuine control questions, signifying that the CQT is lacking scientific foundation (e.g., Ben-Shakhar, 2002; National Research Council, 2003).

The pursuit for a scientifically-sound method to detect lying has been persistent, but the problem comes down to that there is no single bodily response uniquely related to lying (Vrij, 2008). Therefore, alternatives to the emotional approach employed by instruments such as the CQT are required for lie detection. The Concealed Information Test (CIT) or the Guilty Knowledge Test (GKT) was proposed to this end by Lykken (1959) and was developed as a method of detecting information strongly related to an examinee's memory (Verschuere, Ben-Shakhar & Meijer, 2011); its main purpose is not detecting lies and deception. The CIT has been proven to be a reliable and powerful method for detecting information by numerous studies (for reviews, see Ben-Shakhar, 2012; Meijer, klein Selle, Elber & Ben-Shakhar, 2014; Verschuere et al., 2011) and applied in the field, i.e., in actual criminal investigations, in some countries such as Japan, Lithuania, and Slovenia (e.g., Hira & Furumitsu, 2002; Matsuda, Nittono, & Allen, 2013; Nakayama, 2002; Ogawa, Matsuda, Tsuneoka, & Verschuere, 2015; Osugi, 2011; Osugi, 2018; Zaitsu, 2016).

Despite these numerous studies and extensive application in Japan, the precise mechanisms by which the CIT detects concealed information have not yet been fully elucidated. In particular, the emotional aspects involved have been largely ignored by the CIT community for several decades in their effort to emphasize the differences between the CIT and the CQT, which is associated with fear, guilt, or other emotions. Indeed, little empirical attention has been focused on the role of emotional arousal at memory encoding in the CIT. However, it is natural to consider that experiences related to a crime are extraordinary for most people and probably associated with strong emotional arousal. Taking into account this emotional arousal factor may help further elucidate the mechanisms involved in the CIT.

The present study begins with an overview of CIT studies and studies related to emotional arousal and memory, especially using the P300, a component of the event related potential (ERP). Then, findings of CIT studies related to emotional arousal are reviewed, and their limitations are highlighted. Based on these problems, the specific goal of the present study is explained.

1.2. Concealed Information Test

The CIT has been extensively studied as a technique for detecting information, particularly crime-related memory. The CIT utilizes a series of multiple choice questions, in which there is one relevant alternative (labeled “probe” or “critical,” which is crime-related information in criminal investigations) and several non-relevant alternatives (labeled “irrelevant” or “non-critical”). Irrelevant stimuli are selected so that participants who have not committed an action (i.e., crime) will not be able to discriminate them from the probe. The core assumption of the CIT is that the correct answer (probe) has special meaning only for the participant who committed the action (i.e., criminal act in cases of criminal investigations). Only the knowledgeable person would be able to discriminate the probe stimulus from irrelevant stimuli. If the physiological responses to the probe are consistently larger than those to the irrelevant stimuli, the person would be judged as knowledgeable of the probe. In criminal investigations, it is important to implement the CIT using the probe which was not exposed to innocent individuals not to regard them as a guilty. Thus, the examiner removes the probe which the examinee insists he/she knows.

Here, some examples are introduced. In case of a murderer who strangled the victim with a belt in a hotel, questions could be formulated as follows when the examinee insists that he knows that the victim was strangled but does not know how the victim was strangled; “Did the criminal use (1) a rope, (2) a belt, (3) a necktie, (4) a towel, or (5) a scarf, to strangle the victim?” Here “a belt” is the probe and the other four alternatives are irrelevant. If it has not been publicized that the murder weapon was a belt, an innocent person would not be knowledgeable of the probe. Only a guilty person knows the probe, but he/she would pretend innocent to conceal his/her guilt. Thus, almost all examinees would answer “I don’t know.” As a result, the person who can discriminate the probe from the other irrelevant stimuli and elicit larger responses to the probe than to the irrelevant stimuli would be identified as a knowledgeable person. In a similar way, the examiner can ask the following questions in the case of a burglar who stole a necklace from a house, “Was the stolen item (1) a ring, (2) a brooch, (3) an earring, (4) a necklace, or (5) a bracelet?”, “Did the criminal steal the item from (1) wardrobe, (2) closet, (3) side table, (4) chest, or (5) bookshelf?”, and “Did the criminal use (1) a driver, (2) a crowbar, (3) a spanner, (4) a nipper, or (5) a hammer, for breaking into the house?”

In field applications in Japan, approximately 5–6 questions per examination are asked and the test lasts for approximately 2–3 hours (Osugi, 2011). The CIT has been officially and systematically applied for the last 50 years in Japan, and the results obtained using this method have been accepted as evidence in court since the 1960s (Matsuda et al., 2013). Approximately 5000 polygraph examinations are conducted annually by approximately 100 polygraph examiners at forensic science laboratories at prefectural police headquarters (Osugi, 2011). Details regarding the procedures and features related to the CIT in Japan appear in Osugi (2011) and Osugi (2018).

Although the probe stimulus is always derived from real crimes or accidents in the field, the probe stimulus in CIT studies is usually set in one of two ways: the personal-item paradigm and the mock-crime paradigm (Meijer et al., 2014). In the personal-item paradigm, the examinee's personal items such as first name, family name, date of birth, and hometown, are used as probes with several irrelevant stimuli belonging to the same categories (e.g., Maoz, Breska, & Ben-Shakhar, 2012; Noordraven & Verschuere, 2013; Verschuere, Crombez, Smolders, & De Clercq, 2009). In the mock-crime paradigm, participants always enact a mock crime task before the CIT, such as a mock theft in which they are supposed to steal money from a storeroom following specific instructions. The details of the mock crime such as the amount of stolen money and the location of the theft, are used as a probe along with several irrelevant stimuli (e.g., Ben-Shakhar & Dolev, 1996; Carmel, Dayan, Naveh, Raveh, & Ben-Shakhar, 2003; Nahari & Ben-Shakhar, 2011; Peth, Vossel, & Gamer, 2012). The former paradigm, especially using the participant's name, is often used in CIT studies because autobiographical information comprises robust and distinct stimuli. However, this type of information is reportedly processed differently from other information (Yang, Wang, Gu, Gao, & Zhao, 2013). The mock-crime paradigm is applied to assess the CIT effect closer to field application, in which the examinees' real experiences are asked.

1.2.1. Autonomic nervous system-based CIT

Studies on the CIT had already started in the early 40s and 50s using a single physiological measure, namely, the skin conductance response (SCR), and now the autonomic nervous system-based CIT (ANS-based CIT) is well established, as it has been shown that possessing knowledge of the probe results in larger SCR, respiratory suppression, heart rate (HR) deceleration, and reduction of pulse volume amplitude compared to responses to irrelevant stimuli (Gamer, 2011). The ANS-based CIT is implemented with relatively simple devices compared to the CIT using the central nervous system because these corresponding biosignals of the ANS are relatively easy to measure (Ambach & Gamer, 2018). Because several measures are typically recorded simultaneously and the results can be easily combined, which is likely to increase detection accuracy, we can consider that the ANS-based CIT is appropriate for use in the field (Meijer et al., 2014). Indeed, the CIT in the field is typically conducted using ANS measures. It is usually composed of two types of stimuli as mentioned above: one probe stimulus and several irrelevant stimuli. In one question, each stimulus is presented once within a set, and the set is repeated three to five times using different stimulus orders. The inter-stimulus interval (ISI) varies between 20 and 30 secs (e.g., Osugi, 2011).

1.2.2. P300-based CIT

The P300 component of the ERP has also been utilized in CIT studies since the late 80s because the P300 is a more direct index of stimulus processing at the neural level than ANS measures. Because the P300-based CIT requires numerous trials with shorter ISIs compared with the ANS-based CIT, it adopts a three-category oddball paradigm to focus participant attention on the test; one question consists of one target stimulus, one probe stimulus, and several irrelevant stimuli (e.g., Farwell & Donchin, 1988, 1991; Seymour, Seifert, Shafto, & Mosmann, 2000). The target stimulus also serves to identify the level of responsiveness to the probe stimulus expected by the participants, guarding against false negatives. Participants are usually asked to judge each stimulus as either a target or irrelevant by pressing one of two buttons. The probe stimulus is embedded among stimuli in the irrelevant category, as in the two-category oddball paradigm. Only participants who are knowledgeable of the probe are to realize that the various presented stimuli can be divided to three categories, whereas those who are not knowledgeable of the probe are to believe that the stimuli are just divided to two categories. For example, in case of the murderer who strangled the victim with a belt in a hotel, questions could be formulated as follows in this paradigm; “Did the criminal use (1) a rope, (2) a belt, (3) a necktie, (4) a towel, (5) a scarf, or (6) a power cord, to strangle the victim?" Here "a belt" is the probe as in the ANS-based CIT, but "a power cord" is added as a target (and the other four alternatives are irrelevant). Participants are required to press the right button for the target stimulus and the left button for the other stimuli including the probe and the irrelevant stimuli. Because the target stimulus is used only for the purposes mentioned above, it is sometimes excluded from the analysis (e.g., Matsuda, Nittono, & Allen, 2013). Usually, the focus of CIT studies is not on the target but on the differences between the probe and irrelevant stimuli; comparisons are always performed between the probe and irrelevant stimuli in the same way as in the ANS-based CIT.

Previous studies on the P300-based CIT have consistently reported that the probe elicited larger P300 amplitudes than the irrelevant stimuli (e.g., Allen & Iacono, 1997; Farwell & Donchin, 1991; Gamer & Berti, 2012; Johnson & Rosenfeld, 1992; Kubo & Nittono, 2009; Matsuda et al., 2013; Rosenfeld, Soskins, Bosh & Ryan, 2004). Although many studies have investigated the influence of various factors on the P300-based CIT, such as of concealment (e.g., Kubo & Nittono, 2009; Matsuda et al., 2013), countermeasures (e.g., Rosenfeld et al., 2004; Rosenfeld & Labkovsky, 2010), depth of processing (e.g., Gamer & Berti, 2012), and stimulus saliency (e.g., Leue, Clemens, Nieden, & Beauducel, 2017), the P300 has been typically seen as a positive wave with a scalp distribution along the midline of the head, in which it is largest parietally (Pz) and smallest frontally (Fz), acquiring intermediate values centrally (Cz). Previous P300-based CIT studies have also reported that the largest effect was shown at Pz (Rosenfeld, Shue, & Singer, 2007; Rosenfeld & Labkovsky, 2010). Thus, some studies have limited their analysis to the midline parietal scalp site, Pz.

The P300-based CIT has several advantages. First, the P300 is an index reflecting activity of the central nervous system, so it may be a useful tool to examine information processing in the human brain compared to ANS measurements (Hillyard & Kutas, 1983). Another advantage is that the P300 can be recorded relatively easily compared with other measurements of the central nervous system, and thus we can expect to obtain large amplitudes for detecting the probe even under experimental conditions and to examine information processing relatively easily. Moreover, an oddball task, which is a common paradigm used to measure the P300, is similar to the CIT, which strongly help to establish the P300-based CIT. Laboratory studies of the P300-based CIT have consistently shown that the P300 can be an effective indicator of the probe. According to a meta-analysis by Meijer et al. (2014), the effect sizes of the detection scores in the CIT are largest for the P300 (1.89), followed by the SCR (1.55), respiratory line length (RLL; 1.11), and HR (0.89).

1.3. Theories of the CIT

Despite numerous studies and extensive application in Japan, the underlying mechanism of the CIT have not yet been fully elucidated. Some researchers have conceptually confused the CIT with an instrument detecting lies or deception such as the CQT, and others have addressed the importance of a reality and have been too nervous to set their conditions closer to the real field examinations. These mistaken beliefs have so far prevented us from clearly and systematically revealing the underlying mechanism of the CIT.

Over the past several decades, researchers have attempted to elucidate the underlying mechanisms of concealed information and several theories have been proposed in CIT studies, which are broadly classified in two categories: early theories that emphasize emotional motivational factors, and later theories that emphasize cognitive factors (Verschuere & Ben-shakhar, 2011). Each approach is overviewed in the following section.

1.3.1. Emotional-motivational approaches

Early attempts to account for the CIT mechanism largely focused on emotional approaches involving emotional reactions to deceptive responses to the CIT. Davis (1961) proposed three possible theories: the conditioned response theory, the punishment theory, and the emotional conflict theory. The conditioned response theory holds that the crime-related (probe) stimulus plays the role of a conditioned stimulus and may evoke fear and arousal (i.e., conditioned response) as a criminal act or crime scene (i.e., unconditioned stimuli) evokes such emotions (i.e., unconditioned response). The punishment theory focuses on fear of punishment (consequences of the examinee’s failure to deceive) and holds that this fear enables detection of the probe. The emotional conflict theory holds that two incompatible reaction tendencies induce responses to the probe, emotional conflict between the urge to tell the truth and the need to lie to avoid detection. These early theories, however, appear to pertain to lie detection, and not to be specific to the CIT, because they focus on the emotions related to lying on the test. Moreover, limited empirical research has supported these theories in the context of the CIT (e.g., Elaad & Ben-Shakhar, 1989; klein Selle, Verschuere, Kindt, Meijer, & Ben-Shakhar, 2017; Verschuere et al., 2009).

Another theory focuses on the examinee's motivation to avoid detection, the motivation-impairment theory. Gustafson and Orne (1963) found that motivational instructions and financial incentive enhanced CIT detection efficiency. In their study, participants were told that only people who have superior intelligence and emotional control can successfully conceal information, and that they would receive a financial bonus if they avoided detection. While other studies have also reported the enhancement of detection efficiency through motivation (e.g. Elaad & Ben-Shakhar, 1989; Gustafson & Orne, 1965), several reports have failed to find such an effect of motivation to avoid detection (e.g., Furedy & Ben-Shakhar, 1991; Kugelmass & Lieblich, 1966). The meta-analysis by Meijer et al. (2014) revealed that motivation to conceal information surely increases detection efficiency, but also concluded that it is not a necessary condition for detecting concealed information: The core of the CIT is considered to underlie the other factors.

1.3.2. Cognitive approaches

Previous studies have largely supported cognitive approaches, which emphasize knowledge, rather than emotion, which is emphasized by the emotional-motivational approaches. Although several theories have derived from these approaches, such as the dichotomization theory (Ben-Shakhar, 1977, 1980; Lieblich, Kugelmass, & Ben-Shakhar, 1970) and the feature-matching theory (Ben-Shakhar & Gati, 1987; Gati & Ben-Shakhar, 1990), the orienting response (OR) theory provides the most influential account of the CIT effect (Verschuere & Ben-Shakhar, 2011). The OR is a complex of reactions evoked by a novel or significant stimulus (e.g., Sokolov, 1963; Siddle, 1991). According to Sokolov's theory (1963), each stimulus is capable of evoking an OR in principle.

Repeated presentations of the stimulus result in an internal representation of that stimulus input, named a “neuronal model.” Input information is always compared with existing neuronal models. If there is mismatch between the input and the model, an OR will be evoked. If the input matches the model, the OR will be inhibited and habituation will take place, which is a gradual decline in response magnitude with repeated stimulus presentation. Öhman (1979) interpreted the function of the OR improving Sokolov’s theory and proposed the information processing model as shown in Figure 1.1. In this model, autonomic concomitants of an OR denote a call initiating processing in a central capacity-limited channel, which can be identified with focal, conscious attention. It is assumed that there are two different routes for a stimulus to activate the common call for central processing, which are divided by pre-attentive mechanisms. The stimulus is compared with the neuronal model pre-attentively against the content of short-term memory storage, which is defined as an activated segment of long-term memory storage. When the pre-attentive mechanisms find mismatch to a model that is identified as “novel,” the stimulus can elicit an OR. Alternatively, when the pre-attentive mechanisms find a match to a model that has been primed as “significant,” the stimulus can also elicit an OR. These stimuli then enter the controlled central channel for further processing. When we contextualize this theory to the CIT, the probe stimulus is novel because of its conceptual frequency and has a special significance only for the knowledgeable person. According to Lykken (1974), such novelty and significance would tend to produce a stronger OR than the person shows toward the irrelevant stimuli. For innocent examinees, the probe does not have such significance or signal value, and thus all stimuli are equivalent and would evoke similar ORs for both the probe and irrelevant stimuli.

There are three main reasons why the OR theory is stressed in CIT studies. First, the physiological response pattern evoked by the probe in the CIT in knowledgeable persons is typical of the OR: increased SCR, respiratory suppression, HR deceleration, and reduction of pulse volume amplitude (e.g., Gamer, 2011). Second, the physiological responses to the probe have OR characteristics, such as habituation and generalization. Habituation has been shown in several CIT studies, in which the probe evoked a strong OR (e.g., Ben-Shakher, Lieblich, & Kugelmass, 1975). Generalization was also reported by Ben-Shakher, Frost, Gati, and Kresh (1996). They found that responses to stimuli presented verbally generalized to stimuli presented pictorially. Third, the findings of early CIT research that examined the emotional factors mentioned above (e.g., emotions related to lying, fear, and motivation to avoid detection) are considered to be integrated in the OR theory. Previous CIT studies have suggested that emotional factors can increase the degree of stimulus significance of the probe (Verschuere & Ben-Shakhar, 2011; Elaad & Ben-Shakhar, 1989) and reported strong relationships between stimulus significance and detection efficiency (e.g., Carmel et al., 2003). Taken together, a large body of evidence has generally supports the OR theory, although there are some challenges which need to be considered.

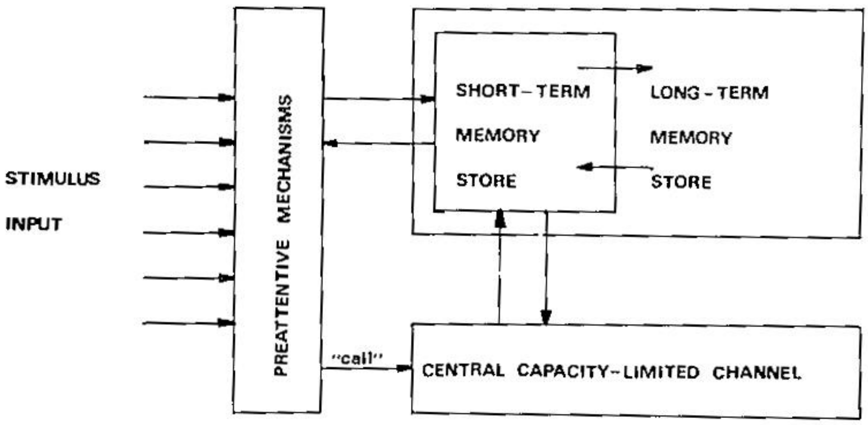

Figure 1.1. Schematic representation of the hypothetical information processing model proposed by Öhman (1979).

1.3.3. Issues with the existing theories regarding the CIT

The OR theory is the dominant account for the physiological responses obtained in the CIT, but several empirical findings of CIT studies are not fully explained by this theory. There are two main issues with previous CIT studies examining its mechanism. The first issue is that previous unitary approaches including the OR theory, which assume a single underlying mechanism, are considered inadequate to sufficiently explain what about the CIT. Recent research has summarized this evidence (klein Selle, Verschuere, Kindt, Meijer, & Ben-Shakhar, 2016, 2017; klein Selle, Verschuere, & Ben-Shakhar, 2018) and has added an alternative explanation of the CIT effect, namely the arousal inhibition (AI) theory. According to Miyake, Friedman, Emerson, Witzki, Howerter, and

Wager (2000), inhibition is defined as an executive function that enables an individual to deliberately and intentionally inhibit a dominant, automatic, prepotent response. In the CIT context, AI signifies an attempt of the knowledgeable person to inhibit proponent physiological arousal responses to the probe to not be detected by the CIT (klein Selle et al., 2016, 2017). In klein Selle et al.'s studies (2016, 2017), they investigated the independent contributions of the OR and AI to the responses in the CIT using role-playing scenarios (klein Selle et al., 2016) and autobiographical items (klein Selle et al., 2017) by contrasting two conditions: a "suspect" condition and a "witness" condition. In the suspect condition, participants were instructed to imagine that they are suspects of a crime and to successfully conceal the probe and avoid detection. On the other hand, in the witness condition, participants were instructed to imagine that they are witnesses of a crime and to successfully reveal the probe and to be detected. They found increased SCRs to the probe compared to the irrelevant stimuli in both conditions. In contrast, respiratory suppression and HR deceleration to the probe were only found in the suspect condition. Thus, they concluded that the different theories accounting for the CIT effect are based on different physiological measures; the SCR reflects pure OR, whereas respiratory measures and HR reflect AI. Although these findings require further experimental verification, their new proposal, the response fractionation theory, indicates that unitary approaches are inadequate and that we need to expand existing theory through combination or supplementation in order to elucidate the underlying mechanism of the CIT effect.

Note that it is unclear whether the P300 component in the CIT reflects the OR or inhibition (Donchin, Heffley, Hillyard, Loveless, Maltzman, Öhman, Rosler, Ruch-kin, & Siddle, 1984). Several previous studies have suggested that the CIT effect on the P300 was caused by the OR without inhibition (Matsuda, Nittono, & Ogawa, 2013; Rosenfeld, Ozsan, & Ward, 2017) in line with the SCR used by klein Selle et al. (2016, 2017). However, another study reported no CIT effect without inhibition (Kubo & Nittono, 2009) in line with the HR and respiration measures reported by klein Selle et al. (2016, 2017).

The second issue is related to emotional factors, which have been examined but have recently been regarded as less important in line with the commitment to accentuate cognitive factors in CIT studies. There is a key question here. Emotion and cognition are strongly related and they should be separately considered. In addition, the emotion examined in CIT studies were almost all related to lying or the conditions during the test. Emotional factors related to the CIT, however, are not limited to emotion during the test. It is important to also consider emotions elicited while the crime takes place, which are related to the CIT but are ordinarily neglected by the CIT community. It is natural to consider that experiences related to a crime are extraordinary for most people and probably associated with strong emotions; thus, emotion during a crime, that is emotion involved in memory encoding, may also potentially influence the CIT mechanism because the CIT is reportedly a memory detection test (Verschuere et al., 2011).

1.4. Effects of emotional arousal

In this study, we focused on emotional factors, especially emotional arousal at memory encoding. The CIT assesses the examinee's possession of crime-related memory by presenting a series of stimuli. Thus, we have to consider the influence of emotional arousal as divided in the following two phases: the memory acquisition phase and the test phase.

1.4.1. Effects of emotional arousal at encoding on memory processing

First, the effect of emotional arousal at encoding on memory acquisition is overviewed from the standpoint of studies having investigated the association between emotion and memory. Studies in the past several decades have provided considerable evidence suggesting that emotional arousal strongly influences memory (for reviews, see Christianson, 1992; Hamann, 2001; McGaugh, 2004). Bradley, Greenwald, Petry, and Lang (1992) reported that pictures rated as highly arousing were more accurately remembered than low-arousing ones. They obtained larger SCRs and concluded that long-term memory performance was mainly affected by arousal, but not valence. Other studies have revealed that arousing pictures generally elicit larger P300 amplitudes (Dolcos & Cabeza, 2002; Palomba, Angrilli, & Mini, 1997) than neutral or low-arousing pictures. These studies have also reported better memory performance in the subsequent memory test (e.g., recall test and recognition test); that is, emotionally arousing stimuli were remembered and retrieved better than low-arousing or neutral stimuli, even after long intervals (Dolcos, LaBar, & Cabeza, 2004).

Numerous studies have also indicated that there are neurobiological relationships between emotional arousal and memory (for reviews, see Cahill & McGaugh, 1998; McGaugh, 2004). Cahill, Haier, Fallon, Alkire, Tang, Keator, Wu, and McGaugh (1996) reported that amygdala activity assessed by positron emission tomography imaging scans obtained as participants viewed emotionally arousing films correlated highly with participant recall of the films 3 weeks later. McGaugh (2004) showed that no matter which emotion was aroused, regardless of the valence, hormonal and brain systems were activated and they regulated the consolidation of memories by emotional experiences. Hamann, Ely, Grafton, and Kilts (1999) and Dolcos, Graham, Labar, and Cabeza (2003) found that the activity levels of amygdala and hippocampal regions were correlated during the encoding of emotionally arousing stimuli.

According to the arousal-biased competition (ABC) theory proposed by Mather and Sutherland (2011), emotional arousal enhances memory of high priority stimuli which have subjective importance and perceptual salience. They also reported that emotional arousal prioritizes goal-relevant information and even memory binding between memories for the color, location, or visual details of emotionally arousing items of an event (e.g., a crime). Because probe stimuli which are supposed to be included in the CIT are basically high-priority ones and also strongly related to the examinee's goal, encoding of the probe is surely considered to be enhanced by emotional arousal at encoding.

Taken together, numerous studies have shown that, in the memory acquisition phase, emotional arousal at encoding enhances memory processing and induces physiological responses, which results in subsequent good memory performance.

1.4.2. Effects of emotional arousal at encoding on information processing

In contrast to the memory acquisition phase, attempts to identify the effect of emotional arousal at encoding on the test phase are more complicated. The influence of emotional arousal at encoding on the retrieval stage is overviewed based on previous memory studies from the perspective of the CIT being a memory detection test

(Verschuere et al., 2011). Then, information processing studies, especially affective processing studies, are also described because the CIT is at the same time an information detection technique presumably based on the OR theory.

Although many studies have supported the fact that emotional arousal at memory encoding influences physiological responses at the encoding stage as described in section 1.4.1., few studies have measured physiological responses at the memory retrieval stage and have shown how emotional arousal at memory encoding influences physiological responses at the retrieval stage. Some studies (Van Strien, Langeslag, Strekalova, Gootjes, & Franken, 2009; Xu, Zhang, Li, & Guo, 2015) measured ERPs at the retrieval stage, but they did not report whether there were differences in ERP amplitudes between old high-arousing items and old low-arousing items. Other previously mentioned studies (Dolcos & Cabeza, 2002; Palomba et al., 1997) have reported an arousal effect and subsequent memory effect, but ERP was measured only at the encoding stage, not the retrieval stage. Because these studies used the same emotionally-arousing stimuli in both the encoding and retrieval stages, it seems to be difficult to examine the emotional arousal effect without contamination by various factors. Thus, the effect of emotional arousal at encoding on physiological responses at the retrieval stage remains unclear.

Aside from the retrieval process, numerous studies have examined the effect of emotional arousal in the context of information or affective processing. According to affective ERP studies using emotionally arousing pictures (for a review, see Olofsson, Nordin, Sequeira, & Polich, 2008), arousing pictures generally elicit larger P300 amplitudes than neutral or low-arousing pictures (Johnson & Wang, 1991; Mini, Palomba, Angrilli, & Bravi, 1996). In studies which presented aversive stimuli such as fearful, threatening, and phobic stimuli, shorter reaction time (Öhman, Flykt, & Esteves, 2001) and stronger amygdala activation (Hariri, Tessitore, Mattay, Fera, & Weinberger, 2002) were also obtained. Moreover, these stimuli can elicit greater SCRs than neutral stimuli, even without conscious awareness (Van Den Hout, de Jong, & Kindt, 2000; Silvert, Delplanque, Bouwalerha, Verpoort, & Se-queira, 2004). Numerous fMRI studies have also shown that subliminal presentation of arousing stimuli automatically induces robust activation in the amygdala (see the meta-analysis by Brooks, Savov, Allzen, Benedict, Fredrilsson, & Schioth, 2012). Thus, it can be said that emotional-arousing stimuli have a distinct feature which strongly influences information processing.

Along these lines, several models of information processing of arousing stimuli have been proposed. Öhman (2008) introduced the emotion activation model as shown in Figure 1.2., based on the information processing model as mentioned above (Öhman, 1979). This model assumes two routes of pre-attentive processing: an automatic processing route (i.e., bottom-up or stimulus-driven) and a controlled processing route (i.e., top-down or knowledge-driven). In the former automatic route, a stimulus first makes contact with feature detectors, which detect potentially significant stimuli based on signal features. If the stimulus is identified as an evolutionarily-shaped significant signal, the arousal system is automatically activated and the significance evaluator receives feedback from the arousal system and becomes biased by the expectancy system, which induces the OR. These inputs are evaluated unconsciously by the significance evaluator, which then can call on a system of conscious perception for an elaborated analysis of the stimulus in interaction with both the arousal system and the expectancy system. Threatening stimuli or fear-related stimuli can be activated by former processing without conscious representation.

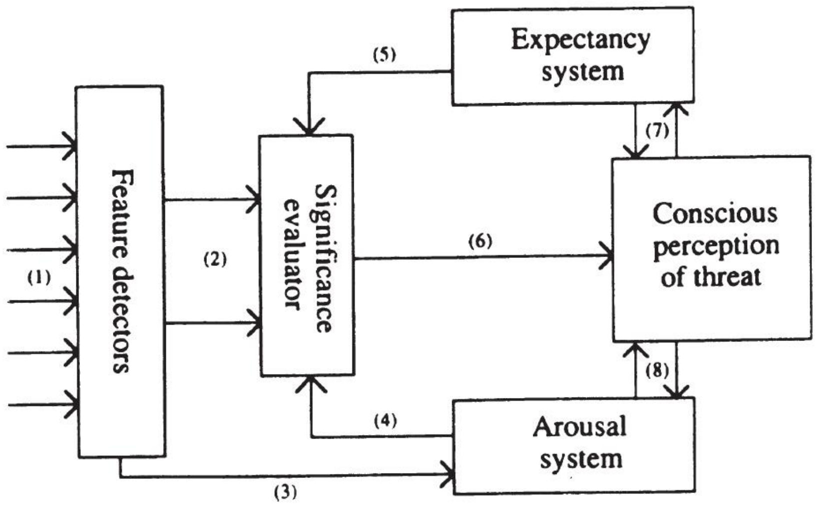

Figure 1.2. Schematic representation of the hypothetical emotion activation model proposed by Öhman (2008).

Similar to the notion proposed by Öhman (2008), LeDoux (1996) offered the dual-route model focusing on the function of the amygdala as shown in Figure 1.3. According to this model, emotional stimuli are processed using two parallel pathways to the amygdala from the sensory thalamus: the low road, a "quick and dirty" subcortical pathway for transferring rapid activity directly to the amygdala and the high road, providing slower but highly and elaborately processed cortical information. The low-road inputs are considered to initiate amygdala processing, and the high-road inputs are based on this initial processing. In dangerous situations, the low road allows us to begin responding to potentially dangerous stimuli before we consciously know what the stimulus is. This system offers evolutionary advantage to humans (LeDoux & Phelps, 2008).

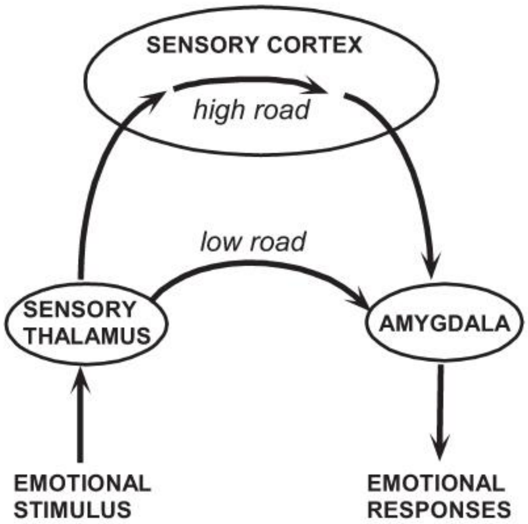

Figure 1.3. Schematic representation of the dual route model proposed by LeDoux (1996).

To sum up, emotionally arousing stimuli seem to be processed differently from neutral stimuli. Although the stimuli used in the CIT are typically not emotionally arousing pictures, that is originally neutral stimuli which would not be expected to elicit emotional arousal on their own without any experience, it may be possible that emotional arousal at memory encoding could influence these originally neutral stimuli through participant experience with the mock crime, causing the stimuli to function as emotionally-arousing stimuli. If so, the findings and theoretical views from these information-processing studies would help elucidate how emotional arousal at encoding influences P300 amplitudes in the CIT.

1.5. Previous findings and problems of CIT studies related to emotional arousal

Few previous studies have examined the role of emotional arousal, although it may seem natural that emotional arousal at memory encoding would influence the detection of crime-related information in the CIT. Several studies have investigated emotional arousal during retrieval in the CIT (Bradley & Janisse, 1981; Kugelmass & Lieblich, 1966; Verschuere, Meijer, & De Clercq, 2011), but little empirical attention has been focused on the role of emotional arousal at memory encoding in the CIT.

Two CIT studies have focused on emotional arousal. Peth, Vossel, and Gamer (2012) manipulated emotional arousal with a confederate who unexpectedly entered the storeroom in which the participants were enacting the mock crime task. Half of the guilty participants underwent induction of arousal during the mock crime task, and the autonomic responses of all participants were measured in the CIT. This study reported no significant differences in emotional arousal on the physiological responses between groups during the CIT. klein Selle, Verschuere, Kindt, Meijer, Nahari, and Ben-Shakhar (2017) also manipulated emotional arousal by showing a police case-file including emotionally arousing pictures and neutral pictures with a description of the crime in their study phase. They used the same pictures as the probe in the CIT and found that detection efficiency based on the SCR was better in the emotional-stimulus condition than in the neutral-stimulus condition.

The results from these studies appear inconsistent, but these experiments highlight three issues requiring further examination. The first relates to the manipulation of emotional arousal by Peth and colleagues (2012). In their experiment, the arousal manipulation was a brief interruption by a confederate. Although the intention was to induce emotional arousal, the manipulation may have introduced other confounding factors. For example, participant attention may have been affected by the interruption, as may have been participant attention on the mock crime task. Either of these possibilities could have influenced memory encoding for the probe item, which was the focus of questioning in the CIT. In addition, this manipulation was conducted only for the arousal induction group, not for the no-arousal group. Although the interruption may only have influenced the arousal induction group, its influence may have been contaminated by other factors that are relevant to CIT performance. The results indicated that participants in the arousal induction group were not able to recognize as many probe stimuli as were participants who were not disturbed during the mock crime task. To resolve these potential issues, a new method of emotional-arousal manipulation is needed.

The second issue is raised by klein Selle et al.'s (2017) study. Although they found an effect of emotional arousal on detection efficiency in the CIT, I suggest that their findings seemed to reflect the emotional arousal at encoding and at retrieval because they used the same emotional arousing stimuli not only at encoding but also in the CIT. In contrast, neutral stimuli were consistently used both at encoding and in the CIT in their neutral condition. To investigate the effect of emotional arousal at memory encoding without contamination of the emotional effect during the CIT (at retrieval), neutral stimuli have to be presented in the CIT for both the emotion-arousing condition and the non-arousing condition.

The last issue raised by both studies (klein Selle et al., 2017; Peth et al., 2012) is related to the physiological indices used. Because different findings were reported in these studies, the effect of emotional arousal on autonomic indices in CIT studies remains controversial. However, several previous studies have reported a relationship between the P300 and emotional arousal (for a review, see Olofsson et al., 2008). Several studies have also investigated the relationship between memory and emotional arousal using the P300, reporting that high-arousal pictures elicited greater P300 responses than neutral or low-arousal pictures at encoding (Dolcos & Cabeza, 2002; Palomba et al., 1997) and at recollection (Xu et al., 2015). These studies have established that an effect of emotional arousal can be found using the P300 in the CIT.

1.6. Purpose of the present study

The aim of the present study was to elucidate the effect of emotional arousal at memory encoding on the CIT. To accomplish this purpose, three experiments were designed to attempt to (1) examine whether emotional arousal at encoding influences physiological responses in the CIT (Experiment 1 and 2) and (2) assess how emotional arousal at encoding influences physiological responses in the CIT (Experiment 3). Eventually, the goal was to identify which present CIT theories may account for the findings and to provide a CIT model describing the relationship between emotional arousal and stimulus detection in the CIT.

For the first purpose, three different approaches were adopted in the present study to resolve fundamental deficiencies, which were related to the (i) manipulation of emotional arousal, (ii) presented stimuli, and (iii) measurement of the CIT. First, new methods of emotional arousal manipulation were applied. Two different methods derived from previous studies were employed in this study; the first was to manipulate emotional arousal by different actions between groups during a mock crime task, and the second was to manipulate emotional arousal before the mock crime task, which can influence the magnitude of emotional arousal at memory encoding during the mock crime task even though the same actions during the mock crime task were performed by all participants. The magnitude of emotional arousal at memory encoding was manipulated by emotionally arousing pictures, which were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999). Then, all participants enacted the same mock crime task after the manipulation. This procedure was based on the excitation-transfer theory (Zillmann 1978, 1979), which refers to the effect of arousal between two arousing events separated by a short period of time. According to this theory, arousal caused by the first event can transfer to a temporally close emotion-eliciting event (the second event) and amplify the intensity of emotional arousal caused by the second event. This effect seems to occur because arousal from the first event (e.g., viewing an erotic film or riding a stationary bicycle) can be misattributed to the second event (e.g., aggressive act or rating slides). Excitation transfer has been empirically demonstrated for several emotional reactions (e.g., Bunce, Larsen, & Cruz, 1993; Cantor, Zillmann, & Bryant, 1975); thus, this method was applied to this experiment. Following this theory, I assumed that the experience of viewing high or low emotionally arousing pictures (the manipulation of emotional arousal) would differentially affect the intensity of emotional arousal while the participant acted as a mock criminal (performing the mock crime task). This manipulation allowed me to investigate the influence of emotional arousal directly, without introducing differences in the action or other factors of the mock crime task.

Another limitation of the previous study was the stimuli used in the CIT. To prevent the effect of emotional arousal at encoding from contaminating by the influence of emotional arousal during the CIT, the same neutral picture of a sharp tool was used as the stimulus for both the High Arousal group and the Low Arousal group in this study. It should be noted that state arousal using affective pictures just before the mock crime task was manipulated, but the affective pictures were not used in the CIT. Neutral sharp tool pictures were used as stimuli for the CIT because the focus was on the effect of state arousal during the mock crime task, not on the effect of affective pictures in the CIT. To resolve the third issue, this study investigated emotional influence on the CIT using measurements of the P300. As described in the former section, the P300 component is a potential index of emotional arousal on memory or on information processing. The P300 is the most commonly used alternative approach for revealing the underlying mechanism of the CIT; thus, the P300-based CIT was adopted here.

The second purpose was to assess how emotional arousal at encoding influences physiological responses in the CIT. If the former experiments reveal the effect of emotional arousal at encoding on P300 in the CIT, the question would remain on how and why the P300 was enhanced in the CIT. There were two possibilities here: the enhanced P300 in response to the probe would derive either from knowledge-driven processing or from stimulus-driven processing. Because the stimuli used in the CIT were all originally neutral, emotional arousal could not have influenced the P300 without an antecedent emotional experience. The former assumes that a conscious retrieval process is needed to obtain an enhanced P300: the neutral stimulus allows the examinee to retrieve the emotional experience during the CIT and at that time emotional arousal is re-experienced during conscious retrieval. The latter assumes that the conscious retrieval process is unnecessary to obtain an enhanced P300; the neutral stimulus is strongly associated with emotional arousal at encoding, thus operates as an emotionally-arousing stimulus without conscious retrieval. To investigate which possibilities can clearly account for the enhancement of the P300, the subliminal presentation method was applied, which allowed me to investigate the influence of emotional arousal at encoding directly without conscious retrieval. The subliminal presentation method is described by Maoz et al. (2012). Here, subliminal presentation refers to a method in which the participants were aware that a stimulus was presented but were unable to discriminate which stimulus was presented. If the P300 is not enhanced under the subliminal condition, the probe stimulus may need to be processed via the top-down route (knowledge-driven processing). It would indicate that emotional arousal at encoding cannot directly influence the CIT without conscious retrieval. On the other hand, if P300 is enhanced even when the stimulus is subliminally presented, the probe stimulus may be processed via the bottom-up route (stimulus-driven processing). In that case, it is considered that emotional arousal at encoding enables the probe to be processed as an emotionally arousing stimulus.

1.7. Empirical studies for the present purpose

The first experiment was conducted to examine whether emotional arousal at encoding influences the P300 in the CIT. Participants were randomly assigned to either a high emotional arousal group (High Arousal group) or a low emotional arousal group (Low Arousal group), and I attempted to manipulate emotional arousal by prescribing different actions during a mock crime task. Participants in the High Arousal group were instructed to stab an "arm of a mannequin" with one sharp-edged tool of five choices (e.g., kitchen knife or ice pick) in the mock crime task as if harassing a mannequin lying on a bed, and those in the Low Arousal group were instructed to stab a "pillow" in the same way. Although the action involved in the mock crime task used in the previous studies has typically involved stealing an object (e.g., Carmel et al., 2003; Nahari & Ben-Shakhar, 2011; Peth et al., 2012; see meta-analysis, Meijer et al., 2014), a new type of action was adopted in the present study to ensure that the probe was strongly encoded. After the mock crime task, all participants performed the P300-based CIT. The hypothesis of this study was that the High Arousal group would be more emotionally aroused during the mock crime task than the Low Arousal group and would elicit greater P300 amplitudes in response to the probe (the picture of the sharp-edged tool used in the mock crime task) than the Low Arousal group. In addition, the P300 amplitudes in response to the probe would be greater than those in response to the irrelevant stimuli (the pictures of the sharp-edged tool, which were not related to the mock crime task) in both emotional arousal groups.

The second experiment was also conducted to examine whether emotional arousal at encoding influences the P300 in the CIT, but a different manipulation from the first experiment was applied. Here, emotional arousal was manipulated not during a mock crime task but before the mock crime task took place; in line with the assumptions of the excitation-transfer theory as mentioned before, emotionally arousing pictures were presented before the mock crime task. Participants were randomly assigned to either a High Arousal group or a Low Arousal group. Viewing pictures was expected to arouse emotion (as the first event) at a high or low level, respectively. Subsequently, all participants enacted the same mock crime task (as the second event), in which they were instructed to stab a "pillow" with a sharp-edged tool as if harassing a mannequin lying on a bed. After the antecedent emotional experience, the P300-based CIT was conducted. The same results as in the first experiment were expected; emotional arousal at encoding would enhance the responses to the probe and enlarge the difference between the responses to the probe and those to the irrelevant stimulus (i.e., detection efficiency) in the CIT.

The main purpose of Experiment 3 was to assess how emotional arousal at encoding influences the P300 in the CIT, that is to elucidate the processing pathway for stimuli encoded with emotional arousal in a mock crime task before the CIT. In this experiment, the same manipulation of emotional arousal and the same mock crime task as in Experiment 2 were adopted. That is, participants viewed emotionally arousing pictures before the mock crime task. Participants were assigned randomly to either a High or Low Arousal group; viewing pictures was expected to arouse emotion at a high or low level, respectively. Subsequently, all participants enacted the same mock crime task, in which they were instructed to stab a "pillow" with a sharp-edged tool as if to harass a mannequin lying on a bed. After that, a P300-based CIT was conducted using subliminal and supraliminal presentation methods. The hypothesis of this experiment was that the results obtained from both the supraliminal and subliminal conditions would replicate and extend those obtained from the former experiments. Although the detection of the probe would be successful regardless of the emotional arousal group under supraliminal conditions, the detection of the probe in the CIT would be successful only when the probe was encoded with high emotional arousal under the subliminal condition.

Chapter 2

Effects of emotional arousal manipulated by different actions in the mock crime task on the CIT (Experiment 1)

2.1. Introduction

The purpose of the present experiment was to investigate whether emotional arousal at memory encoding influences the P300 amplitudes in the CIT. Participants were randomly assigned to either a high emotional arousal group (High Arousal group) or a low emotional arousal group (Low Arousal group) in this experiment, and different actions in a mock crime task between groups were used to manipulate the magnitude of emotional arousal. Participants in the High Arousal group were instructed to stab the “arm of a mannequin” with a sharp-edged tool selected out of five choices (e.g., kitchen knife or ice pick) in the mock crime task as if harassing a mannequin lying on a bed. On the other hand, participants in the Low Arousal group were instructed to stab a “pillow” in the same way. Because stabbing an arm, even though it was a mannequin’s, was expected to be a quite extraordinary experience for participants and to induce feelings of guilt or hesitation against harming an innocent person compared with stabbing a pillow, the action in the High Arousal group was expected to induce higher emotional arousal than that in the Low Arousal group. According to previous memory studies, emotional arousal strongly influences memory (for a review, see Christianson, 1992; Hamann, 2001; McGaugh, 2004), and arousing pictures generally elicit larger P300 amplitudes (Dolcos & Cabeza, 2002; Palomba et al., 1997) than neutral or low-arousing pictures, which results in better memory performance. In a similar way, emotional arousal during the mock crime task may influence the P300 in the CIT.

The hypothesis of this experiment was that the High Arousal group would be more emotionally aroused during the mock crime task than the Low Arousal group and would elicit significantly greater P300 amplitudes in response to the probe (the picture of the sharp-edged tool used in the mock crime task) than the Low Arousal group. In addition, P300 amplitudes in response to the probe would be greater than those in response to the irrelevant stimuli (the pictures of the sharp-edged tools that were not related to the mock crime task) in both emotional arousal groups. Thus, I also hypothesized that detection of the probe would be easier in the High Arousal group than in the Low Arousal group.

2.2. Methods

2.2.1. Participants

Twenty-two undergraduates (nine men and 13 women) were recruited and participated in this experiment voluntarily. The mean age was 20.95 years (range 19–24 years). All participants were right-handed and had normal or corrected to normal vision and did not have any self-reported history of neurological disease. Participants were naive to the experimental design. They were assigned to either a high emotional arousal group (High Arousal group) or a low emotional arousal group (Low Arousal group) randomly in the participated order. This experiment was conducted in accordance with the ethical principles of the Declaration of Helsinki. All participants provided informed written consent to participate in the study, including in the mock crime task and the CIT using ERP recording.

2.2.2. Mock crime task

All participants were asked to choose one of five envelopes and memorize two keywords written on a sheet of paper inside the envelope. Keyword 1 was the name of a sharp-edged tool that would be used in the mock crime task (i.e., kitchen knife, box-cutter, ice pick, sickle, or saw). Keyword 2 was the name of the target in the mock crime task, "arm of the woman who lies on the bed" or "pillow." The former, "arm of the woman who lies on the bed," was to be stabbed with the sharp-edged tool named by Keyword 1 by the participants in the High Arousal group, and the latter, "pillow," was to be stabbed with sharp-edged tool named by Keyword 1 by the participants in the Low Arousal group. Unbeknownst to the participants, Keyword 1 items were counterbalanced. After choosing an envelope and engaging in the 1-minute memorization period, all participants performed a recall test, in which they wrote the two keywords five times to verify retention and enhance their memory. All participants then proceeded to the mock crime phase. They were instructed to move to a separate room and to look for the item indicated by Keyword 1 in that room. After finding the item, they were instructed to stab Keyword

2 with the Keyword 1 item a few times, as forcefully as possible as if intimidating an adult woman represented by the mannequin. The participants were also instructed to remain in the room for more than 10 minutes, and to smuggle the Keyword 1 item out of the room when they left, keeping the item in a bag they had been given, carefully covered with a towel.

2.2.3. Concealed Information Test

The P300-based CIT was then administered. Participants were informed that the experiment was designed to examine whether they had information on Keyword 1; the tool that was used in the mock crime task. They were also instructed to pretend to be innocent and to make an effort to avoid positive detection by the EEG. As a motivational incentive, the participants were informed that if they were not detected, they would receive a monetary reward. Before the actual CIT, participants were administered a card test to ensure that they understood the trial timing and to familiarize with it. The card test is typically used for all examinees in real-world practice in Japan to confirm their understanding of the procedure and assess their physiological response patterns, as well as to check the apparatus (Osugi, 2011). In the card test, the participants first chose one of five cards (i.e., 2, 3, 4, 5, or 6), and memorized the number written on the card. They were instructed to press the left button of a computer mouse when they saw number 1, as a target, and the right button of the mouse when they saw other numbers, including a number that had been chosen by the participants, which denoted the probe, and four irrelevant numbers. The practice session consisted of 60 trials. In the actual CIT, rather than asking “Did you use this tool in the mock crime task?,” six pictures of the sharp-edged tools, as described in detail below, were presented at constant intervals. Participants were required to press the response button with their right hand as quickly as possible when they recognized the stimulus, instead of saying “No.” To ensure that participants attended to the stimuli and performed the stimulus classification prerequisite for the elicitation of the P300, they were asked to press the left button of the mouse only in response to the target stimulus. They were also instructed to press the right button of the mouse when any of five other pictures were presented; these pictures included a probe and four irrelevant stimuli. The probe was the picture of the tool the participant had used in the mock crime task, and the four irrelevant stimuli were unrelated to the mock crime task.

2.2.3.1. Stimulus presentation

The six previously described pictures of sharp tools were used as stimuli. The scissors were always used as the target stimulus, and the other pictures, which were of a kitchen knife, box-cutter, ice pick, sickle, and saw, were used as the probe stimulus or irrelevant stimuli. The pictures were all 12.9 cm by 9.4 cm and were projected on a CRT display situated 1 m in front of the participants. Each trial began with a red fixation cross, presented for 1000 ms in the middle of the screen, followed by a gray fixation cross presented for 1400 ms. Subsequently, each sharp tool picture was presented for 300 ms, with a gray fixation cross appearing for 800 ms between each tool picture. The inter-stimulus interval was 3200 ms. The trial timing is shown in Figure 2.1. The participants were told not to blink when the sharp tool pictures and the gray fixation cross were presented. I used Presentation software Version 15.0 11.15.11 (Neurobehavioral Systems, Inc.; Berkeley, CA, USA) to control the stimulus presentation. Each tool picture was presented 20 times in a session in random order, and there were three sessions in total. Between sessions, participants were allowed a 2-minute break.

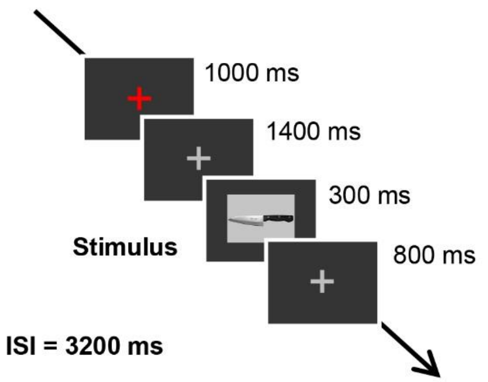

Figure 2.1. Trial timing of stimulus presentations.

2.2.3.2. Physiological responses

The EEG was recorded from Fz, Cz, and Pz, according to the international 10/20 system. The reference electrode was placed on the nose, and the forehead was grounded.

Electrooculograms (EOGs) were also recorded from electrodes placed supraorbitally to the left eye. Ag/AgCl electrodes were used, and electrode impedance did not exceed 5 kΩ. Signals were amplified with an MP100 system (BIOPAC Systems, Inc.; Goleta, CA, USA) with a 35-Hz low-pass filter and 0.1-Hz high-pass filter. Amplified EEG and EOG signals were digitized at a rate of 1000 points per second and recorded by EPLYZER II (Kissei Comtec Co., Ltd.; Matsumoto, Nagano, Japan). After recording, the EEG in the 1100-ms period between 100 ms prior to stimulus onset to 1000 ms after stimulus onset was analyzed with EPLYZER II (Kissei Comtec). The average amplitude of the 200-ms pre-stimulus interval was used as the baseline. In the averaging procedure, epochs in which the signal amplitudes exceeded ± 100 μV on any of the electrodes were removed by visual inspection. Only epochs with behavioral responses in the range of 200–800 ms were averaged with respect to each stimulus type: target, probe, and irrelevant. I used at least 30 artifact-free epochs per stimulus (one target, one probe, four irrelevant stimuli each) because Cohen and Polich (1997) reported that P300 amplitudes become statistically stable after 20 target trials are obtained and change to a very limited extent with 30 or more target trials.

2.2.4. Self-report

The Japanese version of the UWIST Mood Adjective Checklist, short version (JUMACL; Shirasawa, Ishida, Hakoda, & Haraguchi, 1999) was used in this study. The JUMACL comprises two subscales of 10 items each: Energetic Arousal (ranging from feeling sleepy to feeling awake) and Tense Arousal (ranging from feeling calm to feeling nervous). These subscales are sensitive to external stressors, and participants scoring high on Energetic Arousal tend to report feeling vigorous, bright, and active, while high Tense Arousal scores imply nervousness, jitters, and tenseness. The participants were instructed to rate the applicability of each adjective to their present mood using a four-choice symmetric format, as “definitely,” “slightly,” “slightly not,” or “definitely not.” Responses were scored from 4 for “definitely” to 1 for “definitely not.”

2.2.5. Procedure

All participants were informed before starting the experiment that they would be asked to enact a mock crime task and be administered the CIT, which involved an ERP measurement. Informed consent was obtained from all participants. After general instructions had been provided, all participants enacted the mock crime task. After the physiological recording equipment had been attached, the CIT was conducted. All participants were required to provide subjective ratings of their emotional arousal using the JUMACL at two time points, before the mock crime task (before mock crime) and after the mock crime task (after mock crime). At the end of the experiment, the participants were asked how they had felt during the mock crime task and the CIT, and their memory of the probe was confirmed with a short questionnaire.

2.3. Results

Repeated measures analyses of variance (ANOVAs) were conducted for the JUMACL scores and P300 amplitudes. The Greenhouse-Geisser correction was used to account for violation of sphericity, which is likely when repeated measures factors have more than two levels. The Bonferroni correction was used for *post hoc* comparisons in all cases, and effect sizes in ANOVA were shown using partial eta squared (ηp^2). These calculations were performed with PASW Statistics 18 (SPSS Inc., Chicago, IL, USA). Data from one participant were discarded because of excessive EOG artifacts in the ERP recording, leaving a final sample of 21 participants (High Arousal group, n = 11; Low Arousal group, n = 10).

2.3.1. Manipulation check

The mean scores on Energetic Arousal and Tense Arousal are shown in Figure 2.2. For each arousal scale, a GROUP (High, Low) × PERIOD (before the crime, after the crime) ANOVA was conducted. First, for Energetic Arousal, there was a marginally significant main effect of GROUP (F [1, 19] = 3.201, $p = .090$, $\eta p^2 = .144$), which showed that Energetic Arousal in the High Arousal group tended to be lower than in the Low Arousal group regardless of period. For Tense Arousal, a significant main effect of PERIOD (F [1, 19] = 46.108, $p < .001$, $\eta p^2 = .708$) was observed. This showed that Tense

Arousal after the mock crime task was significantly heightened compared with before the mock crime task. Contrary to my expectations, I did not obtain a significant interaction of GROUP × PERIOD in Tense Arousal. To confirm the difference in Tense Arousal between before the mock crime task and after the mock crime task separately in each arousal group, *t*-tests were conducted separately in each group. These *t*-tests showed a significant difference between before the mock crime task and after the mock crime task in the High Arousal group (t [10] = -5.685, $p < .001$, d = 1.45) and in the Low Arousal group (t [9] = -3.913, p = .004, d = 0.97). Although the effect size in the High Arousal group was larger than that in the Low Arousal group, I did not find a significant difference between groups after the mock crime task, which showed that my manipulation of emotional arousal was not successful.

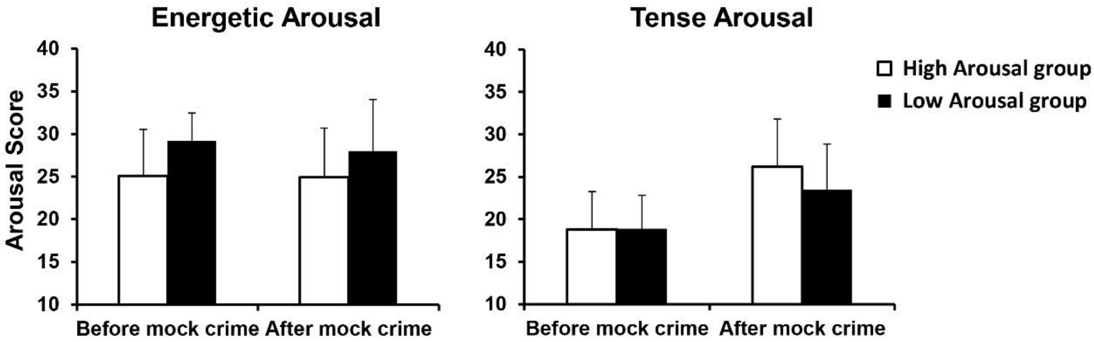

Figure 2.2. Mean scores for Energetic Arousal and Tense Arousal, by group.

2.3.2. ERP data

In the following analysis, the target stimulus was excluded because it differed from the other stimuli (i.e., the probe and irrelevant stimuli), in that the participants responded to the target and to the other stimuli by pressing different buttons during the CIT, and the focus of this study was not on the target but on the differences between the probe and irrelevant stimuli (see Matsuda, Nittono, & Allen, 2013 for a similar analysis).

The grand-averaged ERPs within categories of stimulus type for each group are shown in Figure 2.3. Visual inspection revealed prominent positive waves for both the High and Low Arousal groups. Because this component was parietally maximal and positive and appeared with a peak at approximately 400 ms, I assumed that the component was the P300. Some previous studies have investigated the P300 at Pz using the peak-peak (p-p) method, which computes the difference between the P300 peak and bottom peak from the P300 latency to approximately 1300 ms after stimulus onset and have emphasized the effectiveness of the P300-based CIT (e.g., Rosenfeld & Labkovsky, 2010; Soskins, Rosenfeld, & Niendam, 2001). However, in the present study I used the peak-amplitude method and did not limit my analysis to Pz because I focused on not only the difference in the P300 peak amplitude between the probe and irrelevant stimuli but also the effect of emotional arousal between the groups. Therefore, I calculated the largest positive peak in the range of 300–600 ms.

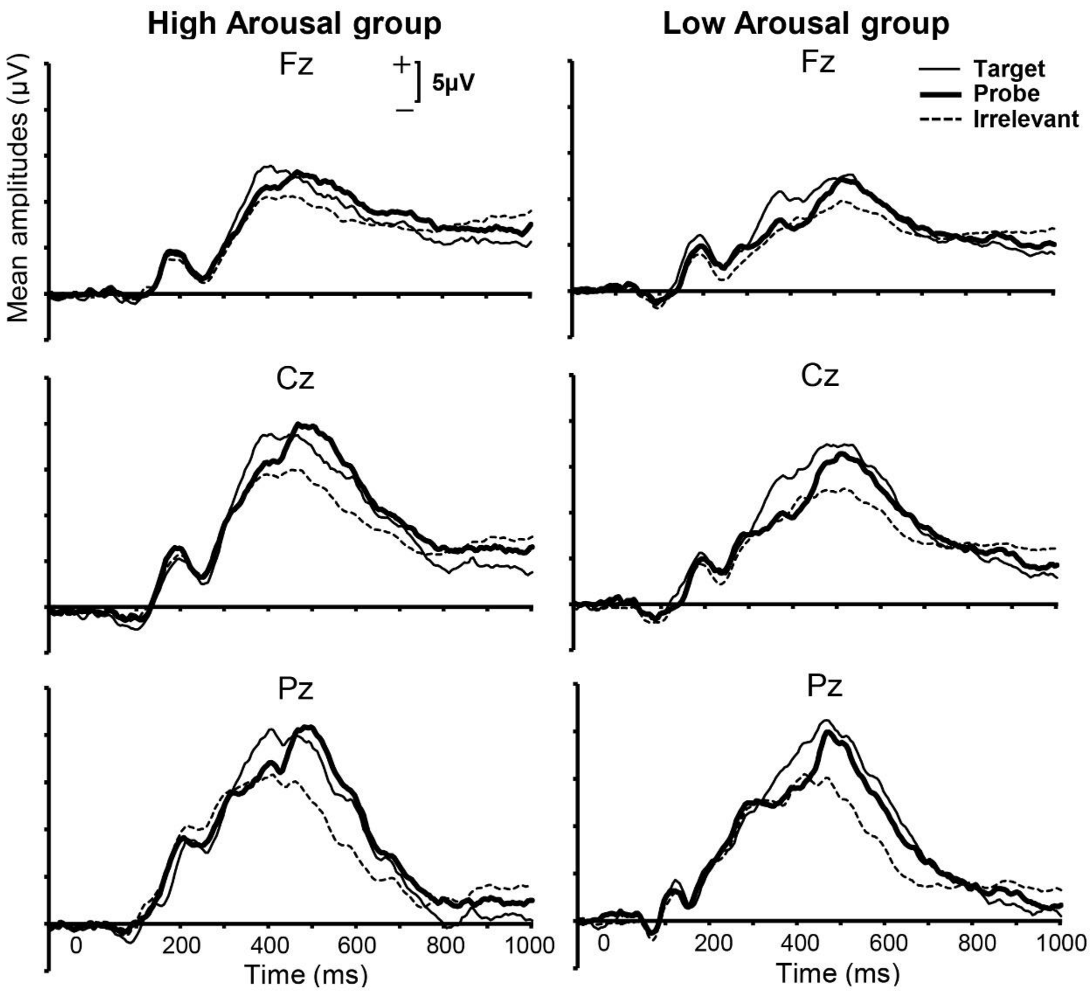

Figure 2.3. Grand-averaged ERPs for each group from 100 ms before to 1000 ms after stimulus presentation for midline electrodes and three stimulus categories

2.3.2.1. P300 amplitude

The peak amplitudes according to stimulus type at each site for each group are shown in Figure 2.4. A three-way ANOVA compared amplitudes for GROUP (High, Low) × STIMULUS TYPE (Probe, Irrelevant) × SITE (Fz, Cz, Pz). Consistent with the hypothesis, I found a significant GROUP × STIMULUS TYPE interaction (F [1, 19] = 4.950, p = .038, ηp^2 = .207) and also a significant main effect of STIMULUS TYPE (F [1, 19] = 46.691, p < .001, ηp^2 = .711). *Post hoc* comparisons of the GROUP × STIMULUS TYPE interaction showed that there was a marginally significant difference in the P300 amplitudes in response to the probe between the groups (p = .058), whereas P300 amplitudes in response to the irrelevant stimuli did not differ between the groups. *Post hoc* comparisons of the significant main effect of STIMULUS TYPE also revealed significantly larger P300 amplitudes in response to the probe compared with responses to the irrelevant stimuli in both groups (High Arousal group: p < .001, Low Arousal group: p = .005). I did not observe clear differences between the groups in response to the probe. Because I also found a significant main effect of SITE (F [2, 38] = 51.361, p < .001, ηp^2 = .730) and a marginally significant GROUP × STIMULUS TYPE × SITE interaction (F [2, 38] = 2.880, p = .090, ηp^2 = .132), the site appeared to significantly influence the differences between the groups for each stimulus type. Thus, I performed *post hoc* comparisons including SITE (i.e., *post hoc* comparisons of the GROUP × STIMULUS TYPE × SITE interaction). As shown in Figure 2.4, it was revealed that the amplitudes in response to the probe were significantly larger than those in response to irrelevant stimuli at all levels of SITE in both groups (High Arousal group: Fz; p < .001, Cz; p < .001, Pz; p < .001, Low Arousal group: Fz; p = .016, Cz; p = .014, Pz; p = .004). In addition, the amplitudes in response to the probe in the High Arousal group were significantly larger than those in the Low Arousal group at Cz (p = .034), although the amplitudes in response to the irrelevant stimuli were not different between the groups. These results indicated that the findings of the P300 amplitudes at Cz were consistent with the hypothesis.

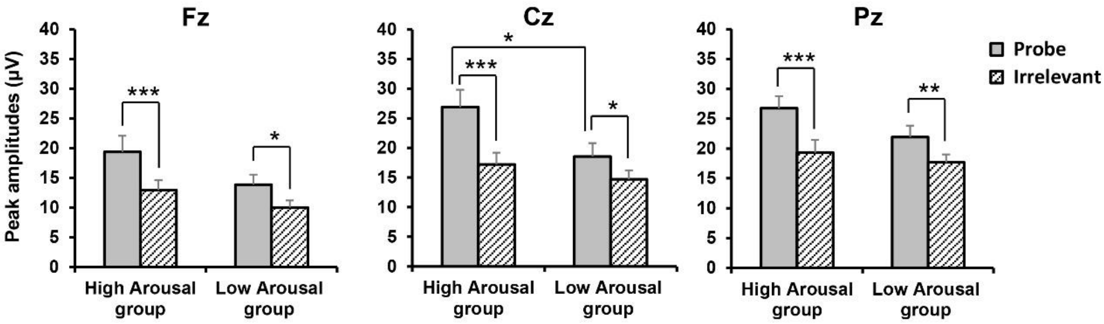

Figure 2.4. Peak amplitudes according to stimulus type, by group. Error bars indicate standard errors. †$p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$.

2.3.2.2. Differentiation of the P300 between the probe and irrelevant stimuli

Because the main consideration in CIT studies is whether there is a difference between responses to the probe and to the irrelevant stimuli (i.e., the CIT effect), I calculated and analyzed differences in P300 amplitude between the probe and irrelevant stimuli to reveal the detection efficiency in each group. These differences were 6.42 (SD = 5.54) µV at Fz, 9.67 (SD = 5.07) µV at Cz, and 7.43 (SD = 4.18) µV at Pz in the High Arousal group and 3.84 (SD = 2.75) µV at Fz, 3.36 (SD = 3.77) µV at Cz, and 4.26 (SD = 3.89) µV at Pz in the Low Arousal group. A two-way ANOVA compared the differences with GROUP (High, Low) × SITE (Fz, Cz, Pz). I found a significant main effect of GROUP (F [1, 19] = 4.950, $p = .038$, $\eta p^2 = .207$) and a marginally significant GROUP × SITE interaction (F [2, 38] = 2.880, $p = .090$, $\eta p^2 = .132$). *Post hoc* comparisons showed that differences between the probe and irrelevant stimuli in the High Arousal group were significantly larger than those in the Low Arousal group at Cz ($p = .008$), and marginally so at Pz ($p = .090$).

2.4. Discussion

The main objective of Experiment 1 was to investigate whether emotional arousal at encoding influences the CIT. For this purpose, I manipulated the magnitude of emotional arousal in the mock crime task using different actions between the groups and examined the effects of this manipulation on the CIT using P300 amplitudes. Consistent with the hypothesis, P300 amplitudes in response to the probe were larger in the High

Arousal group compared with the Low Arousal group, while amplitudes in response to the irrelevant stimuli were not different between the groups. There were also significant differences in P300 amplitude between the probe and irrelevant stimuli in both groups, and the differences were significantly greater in the High Arousal group than in the Low Arousal group.

The P300 amplitude differences in response to the probe between the groups suggest that emotional arousal was a modifying factor that enlarged the probe-vs.-irrelevant stimulus difference and enhanced the detection efficiency of the CIT. Previous CIT studies have suggested that emotional factors (e.g., emotions related to deception, fear, and motivation to avoid detection) can increase the degree of stimulus significance or stimulus salience of the probe (Elaad & Ben-Shakhar, 1989; Verschuere & Ben-Shakhar, 2011). In a similar way, emotional arousal at memory encoding may also increase stimulus significance or stimulus salience, potentially resulting in greater differentiation. In addition, the current finding is similar to the results of previous studies that examined the interaction of the ERP old/new effect with arousal (Van Strien et al., 2009; Xu et al., 2015). Xu et al. (2015) reported that the old/new differences for high-arousing pictures were larger than those for low-arousing pictures at the retrieval stage. They also found greater positivity for high-arousing pictures at the encoding stage. They suggested that this positivity reflected stronger encoding activity causing more accurate discrimination of old items compared with new items. Emotional arousal in the High Arousal group may help strengthen encoding of memories and facilitate the differentiation of the probe from the other CIT stimuli. As a result, emotional arousal might lead to enhancement of both the P300 amplitude and detection efficiency.

This emotional arousal effect is similar to the emotional effects obtained by numerous affective ERP studies using emotionally arousing pictures (for a review, see Olofsson et al., 2008). According to these studies, arousing pictures generally elicit larger P300 amplitudes than neutral or low-arousing pictures (Johnson & Wang, 1991; Mini et al., 1996). The current results appear to replicate the results of these studies. Although the stimuli used in the current study were not emotionally arousing pictures, the stimuli themselves were pictures of sharp tools, originally neutral stimuli which would not be expected to elicit emotional arousal on their own, emotional arousal at memory encoding might influence these originally neutral stimuli through participant experience with the mock crime task, causing the pictures to function as emotionally arousing stimuli. Alternatively, emotional arousal might otherwise influence the P300, for example by re-experiencing emotional arousal at retrieval in the CIT. It is still unclear how emotional arousal enhances P300 amplitudes in the CIT.

In this experiment, clear differences in P300 amplitude between the probe and irrelevant stimuli were observed, regardless of group. This finding supports the notion that emotional arousal was not an essential factor for producing differences in response to the probe and irrelevant stimuli. In line with the OR theory, it seems natural that I obtained a difference in P300 amplitude between the probe and irrelevant stimuli in both groups, allowing detection of the probes in the CIT, because the probe stimulus in both groups would be expected to have the same task relevance, subjective probability, and stimulus significance or salience (because of exclusive possession of information), which determine the OR and have been found to affect P300 amplitudes (for a review, see Kok, 2001). I used a short questionnaire at the end of the experiment to confirm that all participants in both groups possessed information regarding the probe. Taken together, the current results are not inconsistent with OR theory, and it is plausible that emotional arousal at encoding is not an essential factor. As it was not within the scope of this study to examine whether the AI theory may explain the P300 in the CIT, I did not control for any inhibition factors. Thus, the role of AI was not revealed here.

Regarding ERP components other than the P300, I did not obtain clear P200 or N200 components in grand-averaged ERPs in either group. The P200 has been observed in several previous studies (e.g., Meixner & Rosenfeld, 2010; Hu, Wu, & Fu, 2011), reporting larger P200 amplitudes in response to self-related information compared with other information. In addition, the N200 has also been reported in several CIT studies and has been suggested to reflect a process of orienting attentional resources or response monitoring demands (e.g., Gamer & Berti, 2010; Matsuda, Nittono, Hirota, Ogawa, & Takasawa, 2009; Matsuda et al., 2013). Because Crowley and Colrain (2004) suggested in their review that an increase in the level of attentiveness of a subject produces a decrease in P200 amplitude, the lack of a clear P200 peak in the current study might indicate the increased attentiveness of participants. Several previous studies have reported that the N200 was absent during correct responses (Holroyd, Pakzad-Vaezi, & Krigolson, 2008) and in responses to easily discriminable stimuli (Nieuwenhuis, Yeung, & Cohen, 2004). In the current study, the stimuli used in the CIT were discriminable and only epochs on correct trials were analyzed, potentially reducing the amplitude of the N200.

Although this experiment clearly showed the effect of emotional arousal at encoding on the P300, the study had an important limitation. Contrary to my expectation, it was revealed that the manipulation of emotional arousal by different actions was not successful in this experiment. The subjective ratings of Tense Arousal obtained by JUMACL were significantly higher after the mock crime task in both groups. This result showed that the procedure of the mock crime task could successfully evoke the participants' emotional arousal. However, the differences in Tense Arousal after the mock crime task were not significant between groups. Because individual differences in subjective ratings of the JUMACL seemed to be quite large regardless of group, these differences may have been response for the failure of the manipulation. To clearly identify the effect of emotional arousal at encoding on the CIT, an alternative method of emotional arousal manipulation was needed.

Chapter 3

Effects of emotional arousal manipulated by different arousing pictures before the mock crime task on the CIT (Experiment 2)

3.1. Introduction

The purpose of the present experiment was to investigate whether emotional arousal at memory encoding influences the P300 amplitudes in the CIT, as was the case in Experiment 1. Although clear differences between the High Arousal group and the Low Arousal group in P300 amplitudes in response to the probe in the CIT were obtained in Experiment 1, I did not find significant differences between groups in the subjective ratings of Tense Arousal after the mock crime task, which indicated that the manipulation of emotional arousal at encoding was not successful. One of the reasons why the subjective ratings were not significantly different is that individual differences in the subjective ratings of the JUMACL seemed to be quite large regardless of group. To identify the effect of emotional arousal at encoding on the CIT and provide persuasive accounts for the underlying mechanisms of the CIT, the manipulation of emotional arousal had to be changed to a highly controllable method to minimize individual differences.

In Experiment 2, I separated the manipulation of emotional arousal from the mock crime task by presenting emotionally arousing pictures before the crime task[1], which can influence the magnitude of emotional arousal at memory encoding during the mock crime task even if I prescribe the same actions during the mock crime task on all participants. Pictures were selected from the IAPS (Lang et al., 1999), and all participants enacted the same mock crime task after the manipulation; they were instructed to stab a "pillow" with a sharp-edged tool as if to harass a female mannequin lying on a bed. According to the excitation-transfer theory (Zillmann, 1978, 1979), which emphasizes the effect of arousal on emotional transfer, a temporally close emotion-eliciting event amplifies and energizes the experience of subsequent emotions, causing them to be experienced more intensely. Based on this theory, I assumed that the experience of

[1] Data of Experiment 2 were published in *Frontiers in Psychology* (Osugi & Ohira, 2018).

viewing high or low emotionally arousing pictures would differentially affect emotional arousal during the mock crime task. This manipulation allowed me to investigate the influence of emotional arousal directly, without introducing differences in the action or other factors involved in the mock crime task.

In the current experiment, the effects of emotional arousal at memory encoding in the P300-based CIT paradigm were investigated by manipulating participant emotional state beforehand and using an arousing mock crime task. The hypothesis of this experiment was that there would be a significant difference between responses to the probe and responses to the irrelevant stimuli regardless of the emotional arousal condition. I also hypothesized that P300 amplitudes elicited by the probe would differ by group, whereas those elicited by the irrelevant stimuli would not differ by group. I predicted that the High Arousal group would experience stronger emotional arousal during the mock crime task and would therefore elicit greater P300 amplitudes in response to the probe compared with the Low Arousal group, which would experience a lower level of emotional arousal. Thus, I hypothesized that detection of the probe would be easier in the High Arousal group than in the Low Arousal group.

3.2. Methods

3.2.1. Participants

Twenty-four undergraduates (12 men and 12 women) voluntarily participated in this experiment. Their mean age was 21.21 years (range 19–26 years). All were right-handed, had normal or corrected to normal vision, and had no self-reported history of neurological disease. Participants were randomly assigned to either a High Arousal group or a Low Arousal group. This experiment was conducted in accordance with the ethical principles of the Declaration of Helsinki, and I followed the necessary procedures. All participants provided informed written consent to participate in the study. The study was reviewed and approved by the Ethics Committee of the Graduate School of Environmental Studies, Nagoya University, Japan.

3.2.2. Manipulation of emotional arousal

The IAPS (Lang et al., 1999), a standardized collection of color pictures that arouse emotion, was used to manipulate participant emotional arousal. The IAPS has been rated by large groups of North American participants in terms of valence, dominance, and arousal. From the IAPS, 10 high emotionally arousing pictures (High Arousal pictures) and ten low emotionally arousing pictures (Low Arousal pictures)[2] were selected such that the mean arousal scores were significantly greater in the high emotionally arousing pictures condition than in the low emotionally arousing pictures condition (t [9] = 12.573, $p < .001$, $d = 4.85$)[3]. The mean valence scores were not significantly different between high and low emotionally arousing pictures (t [9] = −0.935, $p = .366$, $d = -0.32$), whereas the mean scores differed in the dominance dimension (t [9] = −2.444, $p = .037$, $d = -1.21$). Arousal and valence are the most important dimensions for this manipulation because they are considered to capture the global and basic elements of emotion. Thus, it is likely that the difference in the dominance dimension had little influence on this manipulation. All pictures were unrelated to the mock crime task in the present study and were used only for manipulation of emotional arousal. Each picture was projected for 10 s on a cathode ray tube (CRT) display situated 1 m in front of the participants' eyes. High Arousal pictures were presented to the High Arousal group, and Low Arousal pictures were presented to the Low Arousal group. The participants were instructed that 10 pictures would be presented and that they should attend to each picture for the entire time it appeared on the screen.

3.2.3. Mock crime task

The same method as in Experiment 1 was adopted except that Keyword 2 was fixed to "pillow" and all participants, regardless of group, enacted the same action in the mock crime task in this experiment. All participants were asked to choose one of five envelopes, in which two keywords were inserted. Participants were asked to memorize

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[2] The IAPS slide numbers were as follows: high emotionally arousing picture, 3005.1, 3400, 5972, 6260, 6550, 6831, 9300, 9600, 9635.1, 9921; low emotionally arousing picture, 2205, 2276, 2455, 3300, 9000, 9220, 9280, 9331, 9340, 9342.

[3] The mean arousal, valence, and dominance scores were as follows: high emotionally arousing pictures, 6.45, 2.42, and 3.29, respectively; low emotionally arousing pictures, 4.39, 2.58, and 4.01, respectively.

the two keywords inside for 1 minute. Keyword 1 was the name of a sharp-edged tool that was supposed to have been used in the mock crime task (choices were kitchen knife, box-cutter, ice pick, sickle, and saw). Keyword 2 was “pillow,” regardless of which envelope participants chose. Participants in both emotional arousal groups were instructed to stab the object represented by Keyword 2 with the object represented by Keyword 1. Unbeknownst to the participants, the Keyword 1 items were counterbalanced. A following recall test and the mock crime phase were the same as in Experiment 1; participants were instructed to stab Keyword 2 (pillow) with the Keyword 1 item a few times, as forcefully as possible, as if intimidating an adult woman represented by a mannequin that had been laid on a bed with its head on the pillow. Thus, participants were required to stab the pillow very close to the mannequin’s head. Participants were also instructed to remain in the room for more than 10 minutes and to smuggle the Keyword 1 item out of the room when they left, keeping the item in a bag they had been given, carefully covered with a towel.

3.2.4. Concealed Information Test

The P300-based CIT was then administered in the same manner as in Experiment 1. Participants were instructed that the experiment was designed to examine whether they had information regarding Keyword 1, the tool that was used in the mock crime task. They were also instructed to pretend to be innocent and to make an effort to avoid positive detection by the EEG. As a motivational incentive, the participants were informed that if they were not detected, they would receive a monetary reward. Before the actual CIT, participants were administered a card test to ensure that they understood the trial timing and had familiarized with it as described in Experiment 1. The actual CIT was also conducted in the same manner as in Experiment 1, using six pictures of the sharp-edged tools as described in detail below. Participants were required to press the left button of the mouse only in response to the target stimulus and the right button of the mouse when any of five other pictures were presented (these pictures included a probe and four irrelevant stimuli) with their right hand as quickly as possible when they recognized the stimulus. The probe was the picture of the tool that the participant had used in the mock crime task, and the four irrelevant stimuli were unrelated to the mock crime task.

3.2.4.1. Stimulus presentation

In Experiment 2, the same stimuli were used and presented as in Experiment 1. The six pictures of sharp tools were used as stimuli. The scissors were always used as the target stimulus, and the other pictures, which were a kitchen knife, box-cutter, ice pick, sickle, and saw, were used as the probe stimulus or irrelevant stimuli. The trial timing was also the same as in Experiment 1, as shown in Figure 3.1. Participants were instructed not to blink when the sharp tool pictures and the gray fixation cross were presented. I used Presentation software Version 15.0 11.15.11 (Neurobehavioral Systems) to control the stimulus presentation. Each tool picture was presented 20 times in a session in random order, and there were three sessions in total. Between sessions, participants were allowed a 2-minute break.

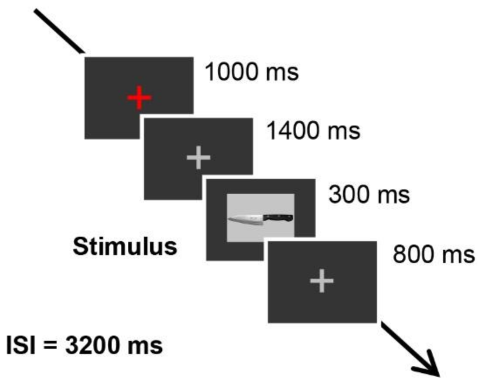

Figure 3.1. Trial timing of stimulus presentations.

3.2.4.2. Physiological responses

The recording procedure of Experiment 2 was the same as described in Experiment 1. The EEG was recorded from Fz, Cz, and Pz, according to the International 10/20 System. The reference electrode was placed on the nose, and the forehead was grounded. EOG was also recorded from electrodes placed supraorbitally to the left eye. Ag/AgCl electrodes were used, and electrode impedance did not exceed 5 kΩ. Signals were amplified with an MP100 system (BIOPAC Systems) with a 35-Hz low-pass filter and 0.1-Hz high-pass filter. Amplified EEG and EOG signals were digitized at a rate of 1000 points per second and recorded by EPLYZER II (Kissei Comtec). After recording, the EEG in the 1100-ms period between 100 ms prior to stimulus onset to 1000 ms after stimulus onset was analyzed with EPLYZER II (Kissei Comtec). The average amplitude of the 200-ms pre-stimulus interval was used as the baseline. The averaging procedure was also the same as described in Experiment 1.

3.2.5. Self-report

As in Experiment 1, I used the JUMACL (Shirasawa et al., 1999) in this experiment. All participants were instructed to rate their present mood using a four-choice symmetric format in the same manner as described in Experiment 1.

3.2.6. Procedure

The procedure was similar to that of Experiment 1, except for the manner used to manipulate emotional arousal. All participants were informed before starting the experiment that they would be asked to enact the mock crime task and be administered the CIT, which involved an ERP measurement. Informed consent was obtained from all participants. After general instructions had been provided, the manipulation of emotional arousal was conducted for each group. All participants then enacted the mock crime task. After the physiological recording equipment had been attached, the CIT was conducted. All participants were required to provide subjective ratings of their emotional arousal using the JUMACL at three time points, before the manipulation of emotional arousal (before IAPS), after the manipulation of emotional arousal (after IAPS), and after the mock crime task (after crime). At the end of the experiment, participants were asked how they had felt during the mock crime task and the CIT, and their memory of the probe was confirmed with a short questionnaire.

3.3. Results

Repeated measures ANOVAs were conducted for the JUMACL scores and P300 amplitudes. The Greenhouse-Geisser correction was used to account for violation of sphericity, which is likely when repeated measures factors have more than two levels. The Bonferroni correction was used for *post hoc* comparisons in all cases, and effect sizes in ANOVA were shown using partial eta squared (ηp^2). These calculations were performed with PASW Statistics 18. Data from three participants were discarded because of excessive EOG artifacts in the ERP recording, leaving a final sample of 21 participants (High Arousal group; n = 10, Low Arousal group; n = 11).

3.3.1. Manipulation check

The mean scores on Energetic Arousal and Tense Arousal are shown in Figure 3.2. For each arousal scale, a GROUP (High, Low) × PERIOD (before IAPS, after IAPS, after crime) ANOVA was conducted. First, for Energetic Arousal, there was a significant main effect of PERIOD (F [2, 38] = 12.116, $p < .001$, $\eta p^2 = .389$). *Post hoc* comparisons showed that Energetic Arousal was significantly lower after the crime than before the IAPS ($p = .001$) and also significantly lower after the IAPS than before the IAPS ($p = .039$) regardless of the group. In addition, Energetic Arousal showed a marginally significant decrease after the crime compared with after the IAPS ($p = .063$). For Tense Arousal, a significant interaction of GROUP × PERIOD (F [2, 38] = 5.943, $p = .006$, $\eta p^2 = .238$), a significant main effect of PERIOD (F [2, 38] = 24.262, $p < .001$, $\eta p^2 = .561$), and a significant main effect of GROUP (F [1, 19] = 7.024, $p = .016$, $\eta p^2 = .270$) were observed. According to *post hoc* comparisons, Tense Arousal in the High Arousal group was significantly heightened after the IAPS compared with before the IAPS ($p = .002$), and there was no difference between after the IAPS and after the crime. However, Tense Arousal in the Low Arousal group was significantly heightened after the crime compared with after the IAPS ($p < .001$), while there was no difference between before the IAPS and after the IAPS. More specifically, Tense Arousal was significantly higher in the High Arousal group than in the Low Arousal group after the IAPS ($p = .001$) and the difference between the two groups after the crime was marginally significant ($p = .095$).

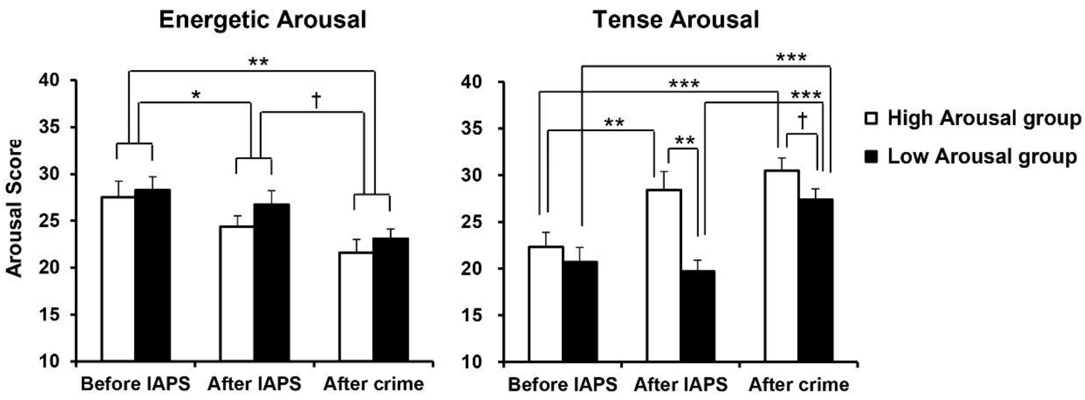

Figure 3.2. Mean scores for Energetic Arousal and Tense Arousal, by group. Error bars indicate standard errors. †$p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$.

3.3.2. ERP data

In the following analysis, the target stimulus was excluded as in the analysis in Experiment 1 (see Matsuda et al., 2013 for a similar analysis).

The grand-averaged ERPs within categories of stimulus type for each group are shown in Figure 3.3. Visual inspection revealed prominent positive waves for both the High and Low Arousal groups. Because this component was parietally maximal and positive and appeared with a peak at approximately 400 ms, I assumed that the component was the P300. Some previous studies have investigated the P300 at Pz using the p-p method as described in Experiment 1 (e.g., Rosenfeld & Labkovsky, 2010; Soskins et al., 2001). In the present study, however, I used the peak-amplitude method and did not limit my analysis to Pz because I focused on not only the difference in the P300 peak amplitude between the probe and irrelevant stimuli but also on the effect of emotional arousal between groups. Therefore, I calculated the largest positive peak in the range of 300–600 ms.

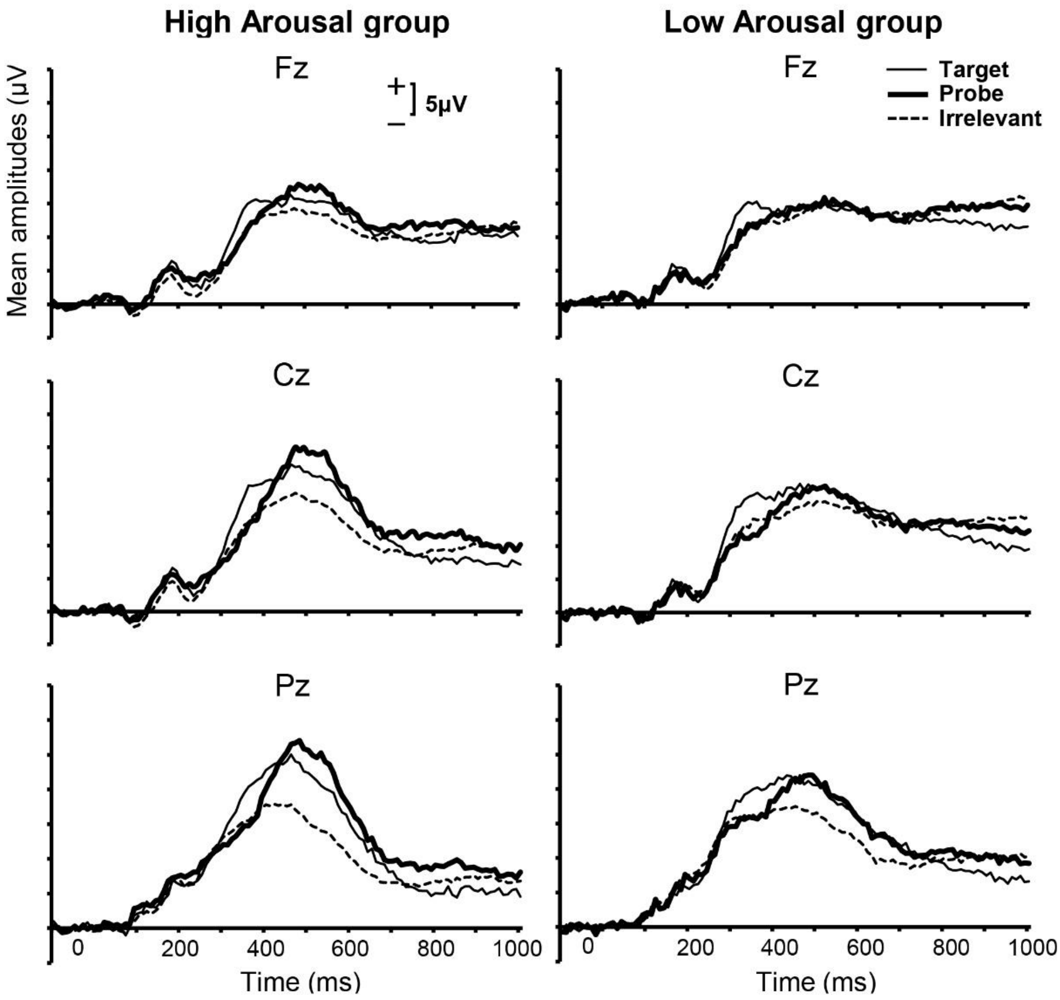

Figure 3.3. Grand-averaged ERPs for each group from 100 ms before to 1000 ms after stimulus presentation for midline electrodes and three stimulus categories.

3.3.2.1. P300 amplitude

The peak amplitudes according to stimulus type at each site for each group are shown in Figure 3.4. A three-way ANOVA compared amplitudes for GROUP (High, Low) × STIMULUS TYPE (Probe, Irrelevant) × SITE (Fz, Cz, Pz). Consistent with the hypothesis, I found a significant GROUP × STIMULUS TYPE × SITE interaction (F [2, 38] = 4.217, p = .037, ηp^2 = .182), a significant GROUP × STIMULUS TYPE interaction (F [1, 19] = 10.705, p = .004, ηp^2 = .360), a significant STIMULUS TYPE × SITE interaction (F [2, 38] = 21.015, p < .001, ηp^2 = .525), a significant main effect of STIMULUS TYPE (F [1, 19] = 53.962, p < .001, ηp^2 = .740), and a significant main effect of SITE (F [2, 38] = 24.495, $p < .001$, $\eta p^2 = .563$). *Post hoc* comparisons revealed that in the High Arousal group, the amplitudes in response to the probe were significantly larger than those in response to irrelevant stimuli at all levels of SITE (Fz; $p < .001$, Cz; $p < .001$, Pz; $p < .001$), while in the Low Arousal group there were significant differences between the probe and irrelevant stimuli at Cz and Pz (Cz; $p = .016$, Pz; $p = .002$) and a marginally significant difference at Fz ($p = .068$). In addition, the amplitudes in response to the probe in the High Arousal group were significantly larger than those in response to the probe in the Low Arousal group at Cz ($p = .039$), although the amplitudes in response to the irrelevant stimuli were not different between groups. At Pz, the difference in the responses to the probe between groups was marginally significant ($p = .060$). These results indicated that the findings regarding the P300 amplitudes at Cz were consistent with the hypothesis.

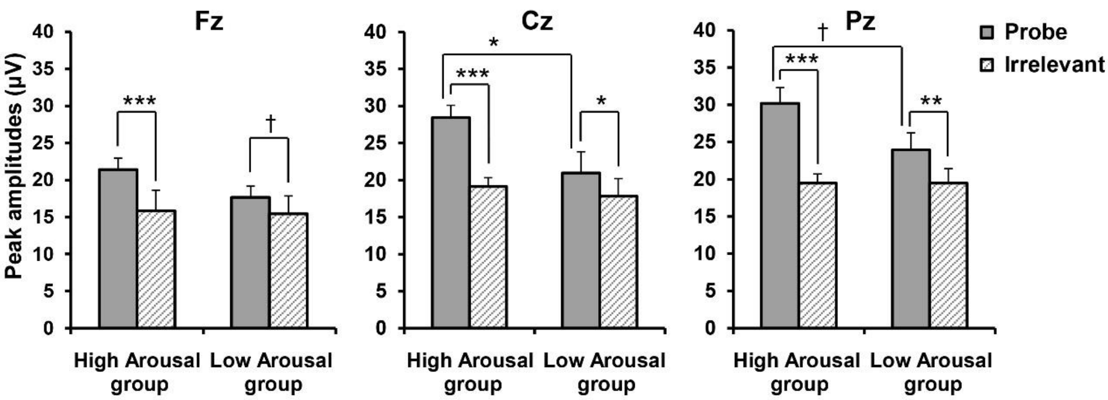

Figure 3.4. Peak amplitudes according to stimulus type, by group. Error bars indicate standard errors. †$p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$.

3.3.2.2. Differentiation of the P300 between the probe and irrelevant stimuli

To confirm the CIT effect, I calculated and analyzed differences in P300 amplitude between the probe and irrelevant stimuli to reveal the detection efficiency in each group. These differences were 5.59 (SD = 1.38) μV at Fz, 9.31 (SD = 1.55) μV at Cz and 10.72 (SD = 1.71) μV at Pz in the High Arousal group and 2.08 (SD = 1.09) μV at Fz, 2.95 (SD = 0.91) μV at Cz, and 4.62 (SD = 0.79) μV at Pz in the Low Arousal group. A two-way ANOVA compared the differences with GROUP (High, Low) × SITE (Fz, Cz, Pz). I found a significant GROUP × SITE interaction (F [2, 38] = 4.217, p = .037, ηp^2 = .182) and a significant main effect of GROUP (F [1, 19] = 10.705, p = .004, ηp^2 = .360) and SITE (F [2, 38] = 21.015, p < .001, ηp^2 = .525). *Post hoc* comparisons showed that differences between the probe and irrelevant stimuli in the High Arousal group were significantly larger than those in the Low Arousal group at Cz and Pz (Cz; p = .002, Pz; p = .003) and marginally so at Fz (p = .061).

3.4. Discussion

The main objective of Experiment 2 was to investigate whether emotional arousal at encoding influences the CIT as in Experiment 1. For this purpose, I manipulated the magnitude of emotional arousal before the mock crime task and examined the effects of this manipulation on the CIT using P300 amplitudes. Unlike Experiment 1, here, the manipulation of emotional arousal was successful. Consistent with the hypothesis, P300 amplitudes in response to the probe stimulus were larger in the High Arousal group than in the Low Arousal group, while amplitudes in response to the irrelevant stimuli were not different between the groups. There were also significant differences in P300 amplitude between the probe and irrelevant stimuli in both groups. These results almost replicated those obtained in Experiment 1.

In the current experiment, it was revealed that emotional arousal at encoding surely enhanced P300 amplitudes to the probe stimulus. It was suggested that emotional arousal was a modifying factor that enlarged the probe-vs.-irrelevant difference and enhanced the detection efficiency of the CIT and that emotional arousal was not an essential factor for producing differences in response to the probe and irrelevant stimuli. These findings related to emotional arousal are similar to the results of previous studies that examined the interaction of the ERP old/new effect with arousal (Van Strien et al., 2009; Xu et al., 2015) and also to the emotional effects obtained in numerous affective ERP studies using emotionally arousing pictures (for a review, see Olofsson et al., 2008). The question here is why and how the P300 was enlarged in the CIT in response to the probe in the High Arousal group. Because the only difference between the groups was the magnitude of emotional arousal at encoding by the manipulation, the enhanced P300 was sure to be somehow influenced by emotional arousal. As described in Chapter 1, numerous studies have shown that emotional arousal enhances encoding processing of the stimuli (Christianson, 1992; Hamann, 2001; Hamann et al., 1999; Mather & Sutherland, 2011; McGaugh, 2004), and it leads to better memory performance (Dolcos & Cabeza, 2002; Dolcos et al., 2003; Dolcos et al., 2004; Palomba et al., 1997). Therefore, it can be said that emotional arousal must enhance encoding of the related stimuli. The problem is the subsequent processing, that is what happens during the CIT.

To assess how emotional arousal at encoding influences P300 amplitudes in the CIT would provide the key to elucidating the effect of emotional arousal at encoding on the CIT. There are two possibilities for the mechanisms underlying the enhancement of P300 to the probe by emotional arousal here; enhanced P300 to the probe may be derived from knowledge-driven processing or from stimulus-driven processing. The former possibility assumes that emotional arousal at memory encoding enhances P300 amplitudes to the probe by knowledge-driven processing (via the top-down route) in the CIT. It is based on the notion that emotional arousal at encoding enhances P300 amplitudes by retrieving the probe and at that time arousal related to the probe is re-experienced accompanying the conscious retrieval in the CIT. Some neuroimaging studies have shown that the amygdala, which is activated at encoding of emotional arousing stimuli was also activated at retrieval (e.g., Dolan, Lane, Chua, & Fletcher, 2000; Smith, Stephan, Rugg, & Dolan, 2006), suggesting that emotional arousal at encoding is deeply related to later retrieval processing. The latter possibility assumes that emotional arousal at memory encoding enhances P300 amplitudes to the probe by stimulus-driven processing (via bottom-up route) in the CIT. It is based on the notion that emotional arousal at encoding is strongly associated with the probe during encoding and enables the probe stimulus to operate as an emotionally arousing stimulus. Here, enhanced P300 can be considered to be derived from stimulus-driven processing, suggesting that emotional arousal at encoding is deeply related to encoding processing, and is not directly related to retrieval processing.

To clarify which possibilities can fully explain the effect of emotional arousal at encoding on the CIT, the subliminal presentation method may be a useful tool because it can exclude the influence of conscious retrieval. Experiment 3, described in the next chapter, attempted to resolve this issue.

To my knowledge, the present experiment was the first attempt to investigate the influence of emotional arousal on the CIT using the P300, and the first empirical demonstration of the effect of emotional arousal on memory encoding in the CIT. Together with the results of Experiment 1, the findings support the notion that emotional arousal plays a key role in enhancing detection ability in the CIT.

Chapter 4

Effects of Emotional arousal on the subliminal CIT (Experiment 3)

4.1. Introduction

In Experiment 2, the effects of emotional arousal in the CIT were investigated by assessing the amplitudes of the P300 component. The results revealed that significantly larger P300 amplitudes were elicited in response to the probe, compared with irrelevant items, in participants who viewed highly emotionally arousing pictures before the mock crime task (High Arousal group) compared with participants who viewed pictures associated with relatively low levels of arousal (Low Arousal group). These findings suggest that emotional arousal plays a key role in enhancing the CIT effect, as revealed by the different scores between the probe and irrelevant stimuli, and the detection ability of the CIT. However, the mechanisms by which emotional arousal enhances P300 amplitudes in the CIT remain unclear. There are two possibilities as mentioned in the previous chapter. One possibility is that enhanced P300 reflects knowledge-driven processing (top-down processing) of emotional arousal at encoding, which signifies that participants consciously retrieve the probe and re-experience the arousal in the CIT. Another possibility is that enhanced P300 reflects stimulus-driven processing (bottom-up processing) of emotional arousal at encoding, which signifies that participants can unconsciously process the probe as well as general emotionally arousing stimuli. Top-down processes are mechanisms that enhance the neuronal processing of relevant sensory input, facilitating discrimination between signal and noise; in contrast, bottom-up processes are functions that are largely determined by the sensory salience of the stimulus (for a review, see Sarter, Givens, & Bruno, 2001).

The aim of the present experiment was to assess how emotional arousal at encoding influences P300 amplitudes in the CIT. In other words, which possibilities can offer plausible explanations to reveal the mechanisms involved in emotional arousal in the CIT[4]. For this purpose, I applied the subliminal presentation method, which allowed me to investigate the influence of emotional arousal at encoding directly without

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[4] Data of Experiment 3 were published in *Psychology* (Osugi & Ohira, 2017).

conscious retrieval. The subliminal presentation method was described by Maoz et al. (2012); the participants were aware that a stimulus was presented but were unable to discriminate which stimulus was presented. If P300 is not enhanced under the subliminal condition, the probe stimulus may need to be processed via the top-down route (knowledge-driven processing). This would indicate that emotional arousal at encoding cannot directly influence the CIT without conscious retrieval. On the other hand, if the P300 is enhanced even when the stimulus is subliminally presented, the probe stimulus may be processed via the bottom-up route (stimulus-driven processing). In that case, it is considered that emotional arousal at encoding enables the probe to be processed as an emotionally arousing stimulus.

The examination of these processes is also related to the two theories that have attempted to account for the P300 in the CIT: the OR theory and AI theory. As described in Chapter 1, it is unclear whether the P300 component in the CIT reflects the OR or inhibition (Donchin et al., 1984). Because inhibition is defined as an executive function that enables an individual to deliberately and intentionally inhibit a dominant, automatic, prepotent response (Miyake et al., 2000), it would not be possible to obtain the CIT effect without conscious, top-down processes if inhibition plays a crucial role in the P300. On the other hand, because the OR is evoked by stimulus novelty and stimulus significance (Verschuere & Ben-Shakhar, 2011), it may be possible to obtain the CIT effect without the involvement of conscious processes; that is, only bottom-up processes would be involved if the OR is responsible for the enhancement of the P300.

Two previous studies have investigated stimulus processing using subliminal presentation methods. Lui and Rosenfeld (2009) first applied subliminal presentation in the CIT using the P300, demonstrating a subliminal priming effect on CIT performance. However, because the priming protocol differed from the typical CIT paradigm, it remains unclear whether probe stimuli are automatically recognized and elicit responses through bottom-up processing in the CIT. Maoz et al. (2012) employed a subliminal presentation paradigm using the SCR, in which the probe was presented subliminally. The results suggested that probe stimuli might be processed automatically in the CIT. However, the probe in their study was the participant’s name, a type of information that is reportedly processed differently from other information (Yang et al., 2013). In the CIT, and in the field, crime-related stimuli are typically used, rather than self-referential stimuli. Thus, it remains unclear whether crime-related stimuli are also automatically recognized in the CIT, similar to self-referential stimuli.

Here, the effects of emotional arousal on the P300 wave amplitudes during the CIT were investigated under subliminal conditions. In line with Maoz et al. (2012), I determined the absence of correct discrimination using a two-alternative forced choice task (2AFC), confirming that the stimuli were subliminal via comparison with chance-level performance. To compare the results with the previous supraliminal CIT experiments (Experiments 1 and 2), a supraliminal condition was also used in this experiment. I followed the same procedure for the manipulation of emotional arousal as in Experiment 2 and hypothesized that the results obtained from both the supraliminal and subliminal conditions would replicate and extend those reported in Experiment 2.

4.2. Methods

4.2.1. Participants

Twenty-six undergraduates (16 men and 10 women) volunteered to participate in this experiment. Their mean age was 20.23 years (range 18–29 years). All participants were right-handed and had normal or corrected to normal vision and did not have any self-reported history of neurological disease. Participants were recruited from psychology classes at a local university and were offered monetary reward for participation. Participants were randomly assigned to either a High Arousal group or a Low Arousal group. This study was approved by the ethics committee of Nagoya University, and written informed consent was obtained from each participant prior to the experiment.

4.2.2. Manipulation of emotional arousal

The IAPS (Lang et al., 1999) was used to manipulate the participants' emotional arousal in the same way as described in Experiment 2. Ten High Arousal pictures and ten Low Arousal pictures were selected such that the mean arousal scores were significantly greater in the High Arousal pictures condition than in the Low Arousal pictures condition. Each picture was projected for 10 s on a CRT display situated 1 m in front of the participants' eyes. High Arousal pictures were presented to the High Arousal group, and

Low Arousal pictures were presented to the Low Arousal group. The participants were instructed that 10 pictures would be presented and that they should attend to each picture during the entire time it appeared on the screen.

4.2.3. Mock crime task

The mock crime procedure was also the same as that in Experiment 2. All participants were asked to choose one of five envelopes, each containing two keywords written on a sheet of paper. Keyword 1 was the name of a sharp-edged tool to be used in the mock crime task (i.e., kitchen knife, box-cutter, ice pick, sickle, or saw). Keyword 2 was "pillow" in every envelope and was to be stabbed by the participants in both emotional arousal groups with the object described by Keyword 1. Unknown to the participants, Keyword 1 items were counterbalanced, with each keyword arranged in order of participation, for each arousal group. After choosing one of five envelopes, each participant was asked to thoroughly memorize the two keywords for 1 minute. All participants then engaged in a recall test, in which they wrote the two keywords five times to confirm and reinforce their memory. This procedure was not realistic but was designed to ensure that participants remembered the probe because the purpose of the current study was to investigate the effects of emotional arousal, and lack of recognition of the probe caused by forgetting would contaminate the effects. All participants then enacted the mock crime task. Participants were instructed to move to a separate room and look for the item indicated by Keyword 1. After finding it, they were instructed to stab Keyword 2 (pillow) with the Keyword 1 item a couple of times, as forcefully as possible, as if to harass a female mannequin lying on a bed. The participants were also instructed to stay in the room for more than 10 minutes and to smuggle the Keyword 1 item out of the room, keeping the item in their bag carefully covered with a towel.

4.2.4. Concealed Information Test

The P300-based CIT was then administered, and participants were informed that the experiment was designed to examine whether they had remembered Keyword 1, which was the sharp-edged tool used in the mock crime task. They were also asked to pretend to be innocent and to make an effort to avoid positive detection by the EEG.

Motivational instructions were provided; participants were informed that if they were not detected they would receive a monetary reward. All participants were instructed that there were two conditions in this experiment; one in which they could see the stimuli easily (supraliminal condition) and one in which they could not (subliminal condition). The details of these conditions are described in the section below. Before commencing the CIT, the participants were administered a practice session for both conditions using six pictures of items of stationery. The order of these conditions was counterbalanced. In the practice session, the participants chose one of five cards and memorized the picture on the card. They were then required to press the left button in response to a picture of scissors as the target and the right button in response to the other pictures: ballpoint pen, ruler, staple, correction tape dispenser, and glue stick. The practice session consisted of 36 trials for each condition. In the CIT, six pictures of the sharp-edged tools were presented on the CRT at a constant interval representing the question, “Did you use this tool in the mock crime task?” They were required to press the button quickly and accurately with the right hand as the stimulus was presented, to indicate “No.” To ensure that participants attended to the stimuli and performed the stimulus classification prerequisite for the elicitation of the P300, they were asked to press the left button only to the target stimulus. They were instructed to press the right button when the other five pictures were presented, which included the probe and irrelevant stimuli. The buttons were counterbalanced between participants. The probe was a picture of the tool the participant used in the mock crime task and differed between participants. The other four pictures were irrelevant stimuli, which were not related to the mock crime task.

4.2.4.1. Stimulus presentation

Six 12.9 × 10.7 cm pictures of sharp-edged tools (i.e., scissors, kitchen knife, box-cutter, ice pick, sickle, and saw), were used as stimuli for the CIT. A picture of scissors was always used as the target stimulus, and the others were of the probe or irrelevant stimuli. The pictures were projected on a CRT display situated 1 m in front of the participants. Each trial began with a red fixation cross, presented in the middle of the screen for 1000 ms, and a gray fixation cross followed. After presentation of the gray fixation cross for 1000 ms, a pre-mask stimulus was presented for 15 ms. The following protocol differed in each condition as shown in Figure 4.1. In the supraliminal condition, all pictures of sharp-edged tools were presented for 300 ms after the pre-mask stimulus. This duration was sufficient for all participants to recognize the presented stimulus. The gray fixation cross was presented for 1000 ms again after each picture of a sharp-edged tool. In the subliminal condition, only the target stimulus was presented for 70 ms and the others for 30 ms. All tool pictures were masked by pre- and post-masks, which were presented for 230 ms for the target and 270 ms for the other stimuli. Participants could just recognize the target, but otherwise could not distinguish which sharp-edged tool picture was presented. The gray fixation cross was presented for 1000 ms once again after the tool picture, as in the supraliminal condition. The stimulus onset asynchrony between each picture of a sharp-edged tool was 3315 ms in both conditions. Participants were instructed not to blink when the tool picture and gray fixation cross were presented. Presentation software Version 15.0 11.15.11 (Neurobehavioral Systems) controlled the stimulus presentation via a personal computer (OPTIPLEX980; Dell Inc.; Round Rock, TX, USA). In both conditions, the target and probe stimuli were each presented 48 times and the irrelevant stimuli were presented 192 times, in a random order over four sessions. Between sessions, the participants were allowed a 2-min break. Each condition was conducted alternately for each session, and the order was randomized among participants.

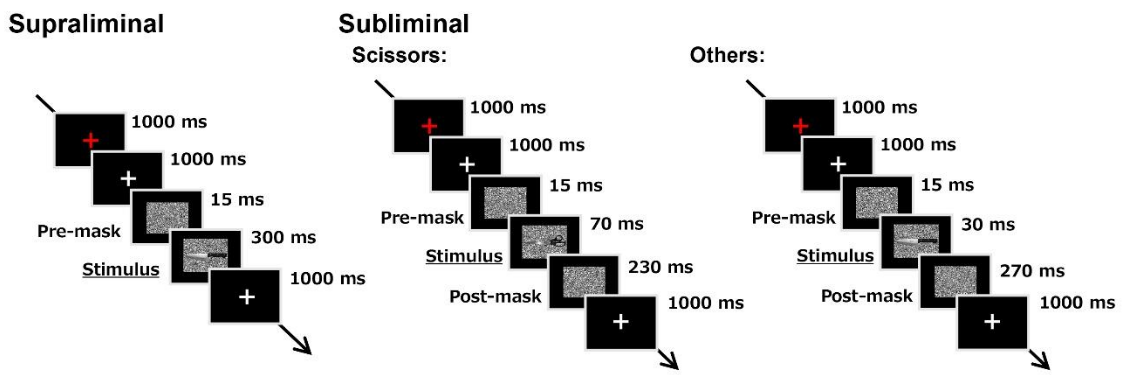

Figure 4.1. Timing of mask and stimulus presentations in each condition.

4.2.4.2. Physiological responses

In the CIT, EEG data were recorded. EEG data were recorded from 20 sites (Fp1/2, F3/4, F7/8, Fz, C3/4, T7/8, Cz, P3/4, P7/8, Pz, O1/2, and Oz) according to the extended 10-20 system. The reference electrode was placed on the nose and the forehead was grounded. EOG was also recorded from electrodes placed supraorbitally to the left eye. Electrocap (EASYCAP GmBH; Herrsching-Breitbrunn, Germany) and Ag/AgCl electrodes were used. Electrode impedance did not exceed 5 kΩ. Signals were amplified by Neurofax (Nihon Kohden, Inc.; Tokyo, Japan) with a 30-Hz high-cut filter and 0.1-Hz low-cut filter. Amplified EEG and EOG signals were digitized at a rate of 500 points per second and recorded. After recording, EEG data for 1200 ms, from 200 ms prior to stimulus onset to 1000 ms after stimulus onset, were analyzed. The average amplitude from 200–15 ms pre-stimulus was used as a baseline. In the averaging procedure, epochs in which the signal amplitudes exceeded ± 80 μV on any of the electrodes were removed.

4.2.5. Two-alternative forced choice task

To determine the lack of conscious awareness of each stimulus in the subliminal condition, a 2AFC was conducted. Excluding the picture of scissors, five pictures of the tools used in the CIT (i.e., kitchen knife, box-cutter, ice pick, sickle, and saw) and five pictures of stationery used in the practice session (i.e., ballpoint pen, ruler, staple, correction tape dispenser, and glue stick) were used. Each stimulus was presented for 30 ms between the pre- and post-masks, as in the subliminal condition, with the exception of the scissors, as shown in Figure 4.1. The stimuli were projected on a CRT display situated 1 m from the participants. All participants were required to judge whether the presented stimulus was a sharp-edged tool or an item of stationery. They pressed the left button for tools and the right button for stationery using the right hand as quickly as possible after the stimulus was presented. They were instructed that they had to press the left or right button without explicit consideration, even though they could not distinguish which picture was presented, and not to continually press only one button. It was assumed that lack of perception of the pictures would result in chance-level performance. The buttons were counterbalanced. Each stimulus was presented 10 times in random order, with 100 2AFC trials in total.

4.2.6. Self-report

As in Experiment 1 and Experiment 2, I used the JUMACL (Shirasawa et al., 1999) in this experiment. As mentioned before, the JUMACL comprises two subscales: Energetic Arousal and Tense Arousal. However, only Tense Arousal was used in Experiment 3 because it was revealed from Experiment 1 and Experiment 2 that Tense Arousal was quite appropriate to examine the effect of the manipulation of emotional arousal compared with Energetic Arousal (see Oue, Hakoda, Onuma, & Morikawa, 2001, for the same analysis). Matthews, Jones, and Chamberlain (1990) reported that these two scales have different features and only Tense Arousal is raised by both unpleasant physical and psychological stressors. The rating procedure of Tense Arousal was also the same as in Experiments 1 and 2.

4.2.7. Procedure

All participants were informed before starting the experiment that they would be required to enact the mock crime task and be administered the CIT with ERP measurements. After instructions were provided, emotional arousal was manipulated for each arousal group. All participants then enacted the mock crime task. After attaching the physiological assessment equipment, the CIT was conducted. Following the CIT, the 2AFC task was performed. All participants were required to provide subjective ratings of their emotional arousal using the JUMACL at five periods; before and after the manipulation of emotional arousal, after the mock crime task, and before and after the CIT. At the end of the experiment a short questionnaire was administered to ask participants how they felt during the mock crime task and the CIT and how they recognized the stimuli presented in both conditions. I also confirmed whether they consciously recognized the stimuli in the subliminal condition and remembered the probe.

4.2.8. Analysis

In the analyses in this experiment, target stimuli were excluded because of the following three reasons. First, the target was different to the probe and irrelevant stimuli in that participants pressed different buttons in the CIT only for the target. Second, participants only recognized the target in the subliminal condition because of its different duration. Third, the focus of this study was not on the target but on the differences between the probe and irrelevant stimuli (see Matsuda et al., 2013 for a similar analysis).

I calculated the JUMACL scores and difference scores of P300 amplitudes between the probe and the irrelevant stimuli and conducted repeated measures ANOVA for each. ANOVA *F*-statistics are positively biased, and the risk of Type I error increases when repeated-measures factors have more than two levels, as was the case here with periods. Thus, the *p*-values of all effects resulting from these factors were corrected toward conservative interpretation by reducing the degrees of freedom when Mauchly's test of sphericity was violated. This correction was performed by multiplying the original degrees of freedom by the Greenhouse-Geisser epsilon. Bonferroni correction was used for *post hoc* comparisons in all cases. Follow-up *t*-tests were also conducted for the P300 amplitudes to confirm each CIT effect. ANOVA effect sizes were calculated using partial eta squared (ηp^2) and those in *t*-tests were obtained using Cohen's *d*. These calculations were performed using PASW Statistics 18. Data from two participants were discarded due to low correct answer rates in the CIT (less than 80%), leaving a final sample of 24 participants (High Arousal group; n = 12, Low Arousal group; n = 12).

4.3. Results

4.3.1. Manipulation check

4.3.1.1. Arousal check

The mean scores and standard errors for Tense Arousal are shown in Figure 4.2. The mean arousal scores at the periods before and after the manipulation of emotional arousal were 17.75 (SD = 1.14) and 24.08 (SD = 0.82), respectively, in the High Arousal group and 18.41 (SD = 1.54) and 18.08 (SD = 1.70), respectively, in the Low Arousal group. The mean arousal score at the period after the mock crime task was 31.66 (SD = 1.09) in the High Arousal group and 27.66 (SD = 1.57) in the Low Arousal group. The mean arousal scores at the periods before and after the CIT were 18.00 (SD = 1.59) and 17.41 (SD = 0.67), respectively, in the High Arousal group and 15.58 (SD = 1.09) and 17.16 (SD = 1.29), respectively, in the Low Arousal group. A GROUP (High, Low) × PERIOD (before and after the manipulation of emotional arousal, after the mock crime task, and before and after the CIT) ANOVA was conducted. The analysis revealed a significant interaction of GROUP × PERIOD (F [4, 88] = 3.559, p = .01, ηp^2 = .139) and a significant main effect of PERIOD (F [4, 88] = 55.032, p < .001, ηp^2 = .714). According to *post hoc* comparisons, Tense Arousal scores were significantly higher in the High Arousal group than in the Low Arousal group after the manipulation of emotional arousal (p = .004), and after the mock crime task (p = .049), whereas there were no differences between both arousal groups before the manipulation of emotional arousal (p = .732), before the CIT (p = .224), and after the CIT (p = .866), indicating that the manipulation of emotional arousal in this study was successful. Here, in the High Arousal group, Tense Arousal scores were significantly heightened after the manipulation of emotional arousal compared with before the manipulation of emotional arousal (p < .001) and were also significantly higher after the mock crime task than after the manipulation of emotional arousal (p < .001). On the other hand, in the Low Arousal group, Tense Arousal was significantly heightened after the mock crime task compared with before the manipulation of emotional arousal (p < .001) and after the manipulation of emotional arousal (p < .001).

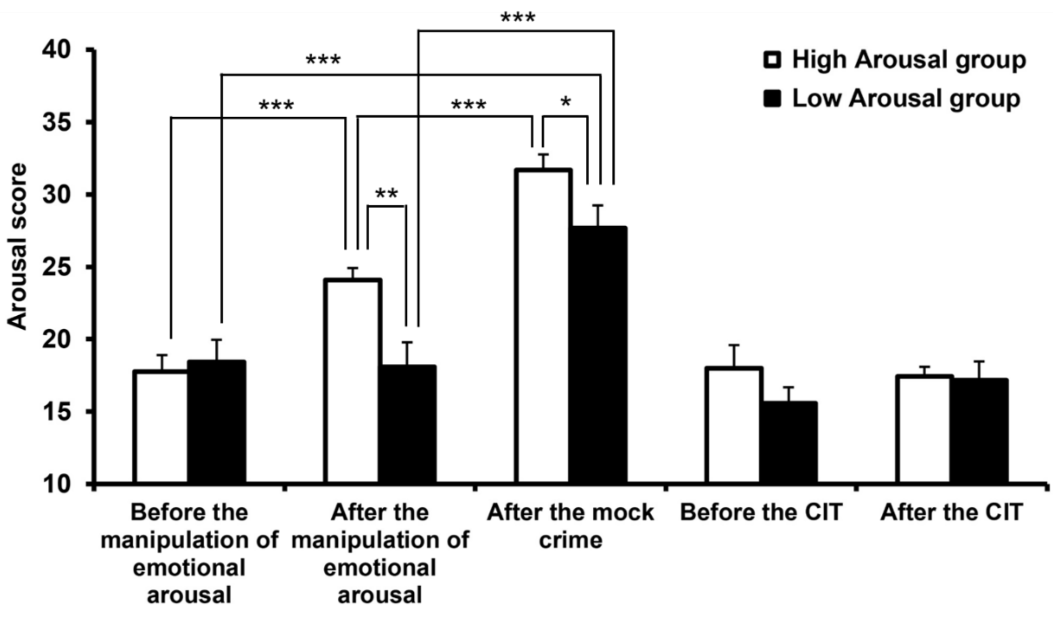

Figure 4.2. Mean scores of Tense Arousal in each group in each period. Error bars indicate standard errors. †p < .10, *p < .05, **p < .01, ***p < .001.

4.3.1.2. Awareness check

The thresholds reported by Maoz et al. (2012) were applied to confirm that each participant was not aware of the subliminally presented stimuli. I set a lower threshold of 45% and an upper threshold of 65% and eliminated participants whose scores were outside these thresholds because such high or low correct rates indicated that participants were subjectively aware of the stimuli. All correct rates were within these thresholds, and I confirmed that each participant was not subjectively aware of the subliminal stimuli. All data from included participants were used in the subsequent analysis. Participant self-reports also confirmed that they were unable to recognize which stimulus was presented in the subliminal condition, other than the target stimulus.

4.3.2. ERP data

The grand-averaged ERPs within the stimulus type categories (probe, irrelevant) for each group in each condition are shown in Figure 4.3. As prominent positive waves were found in both the High and Low Arousal groups, mainly in the supraliminal condition, this component was investigated as the P300 using the peak-amplitude method in the same way as Experiment 2. Several previous studies have investigated the P300 at Pz using the p-p method, which computes the difference between the P300 peak and the bottom peak from the beginning of the P300 latency to approximately 1300 ms after stimulus onset and have reported that the P300-based CIT method was effective (e.g., Soskins et al., 2001; Rosenfeld & Labkovsky, 2010; Rosenfeld, 2011). However, in the present study, I used the peak-amplitude method because clear negative peaks, which are usually obtained following P300 peaks in P300-based CIT studies, were not observed. This finding might be explained by previous reports that late positive potentials can be modulated in affective picture processing and motivated attentional processing (Matsuda & Nittono, 2015; Schupp, Cuthbert, Bradley, Cacioppo, Ito, & Lang, 2000). In addition, the analysis was confined to Pz, a midline parietal scalp site, as previous P300-based CIT studies have reported that the largest effect was shown at Pz and the researchers limited their analysis to this region (Rosenfeld et al., 2007; Rosenfeld & Labkovsky, 2010). Therefore, I calculated the largest positive peak in the range of 200–700 ms at Pz. To focus on a broad range of possibilities, I changed the time window to longer than that used in Experiments 1 and 2, in which the time window was 300–600 ms, in reference to previous studies which used the subliminal technique and measured ERP (Balconi & Lucchiani, 2007; Bowman, Filetti, Janssen, Su, Alsufyani, & Wyble, 2013; Lui & Rosenfeld, 2009).

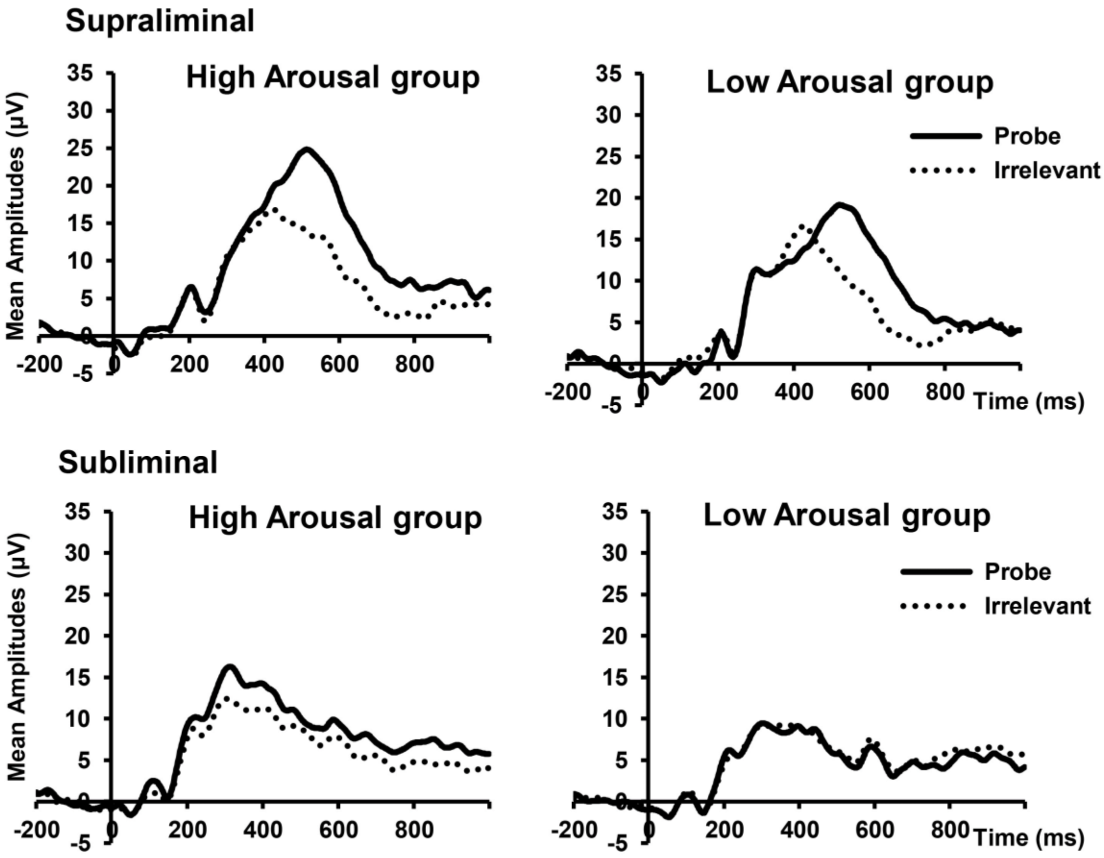

Figure 4.3. Grand average ERPs at Pz for each group in both conditions.

4.3.2.1. P300 amplitude

The mean amplitudes at Pz according to stimulus type for each group are shown in Figure 4.4. In the supraliminal condition, the mean amplitude in response to the probe stimuli was 27.45 (SD = 1.97) in the High Arousal group and 21.11 (SD = 1.98) in the Low Arousal group and the mean amplitude to the irrelevant stimuli was 18.68 (SD = 1.70) in the High Arousal group and 17.85 (SD = 1.95) in the Low Arousal group. In the subliminal condition, the mean amplitude in response to the probe stimuli was 17.64 (SD = 1.70) in the High Arousal group and 11.95 (SD = 1.75) in the Low Arousal group and the mean amplitude to the irrelevant stimuli was 14.28 (SD = 1.35) in the High Arousal group and 11.86 (SD = 1.56) in the Low Arousal group. Moreover, I calculated the difference scores of P300 amplitude between the probe and the irrelevant stimuli according to the presentation condition in each group. In the supraliminal condition, the difference score was 8.78 (SD = 1.05) in the High Arousal group and 3.25 (SD = 0.55) in the Low Arousal group, whereas in the subliminal condition the difference score was 3.35 (SD = 0.51) in the High Arousal group and 0.09 (SD = 0.92) in the Low Arousal group. A two-way ANOVA was used to compare the difference score with GROUP (High, Low) × PRESENTATION CONDITION (supraliminal, subliminal). I found a significant main effect of GROUP (F [1, 22] = 32.772, $p < .001$, $\eta p^2 = .598$) and a significant main effect of PRESENTATION CONDITION (F [1, 22] = 27.04, $p < .001$, $\eta p^2 = .551$). These results showed that the CIT effect was significantly greater in the High Arousal group than in the Low Arousal group and also significantly greater in the supraliminal condition than in the subliminal condition, regardless of group. A GROUP × PRESENTATION CONDITION interaction was not detected (F [1, 22] = 15.388, $p = .184$, $\eta p^2 = .079$).

As a follow-up analysis, I confirmed the CIT effect for each condition for each group using within-subjects t-test of the differentiation between the probe and irrelevant stimuli. The t-tests revealed that, in the supraliminal condition, the P300 amplitudes in response to the probe were significantly larger than those in response to irrelevant stimuli in both groups (High Arousal group; t [11] = 8.322, $p < .001$, $d = 2.402$, Low Arousal group; t [11] = 5.829, $p < .001$, $d = 1.683$). In the subliminal condition, the P300 amplitude in response to the probe was also significantly greater than those in response to irrelevant stimuli in the High Arousal group (t [11] = 6.506, $p < .001$, $d = 1.878$), although the amplitude in response to the probe in the Low Arousal group was not significantly different to responses to the irrelevant stimuli (t [11] = 0.099, $p = .923$, $d = 0.029$). In addition, the difference score in the supraliminal condition was significantly higher in the High Arousal group than in the Low Arousal group (t [22] = 4.632, $p < .001$, $d = 1.891$), which is consistent with that reported in Experiment 2. The difference score was also significantly higher in the High Arousal group than in the Low Arousal group in the subliminal condition (t [22] = 3.088, $p = .005$, $d = 1.261$).

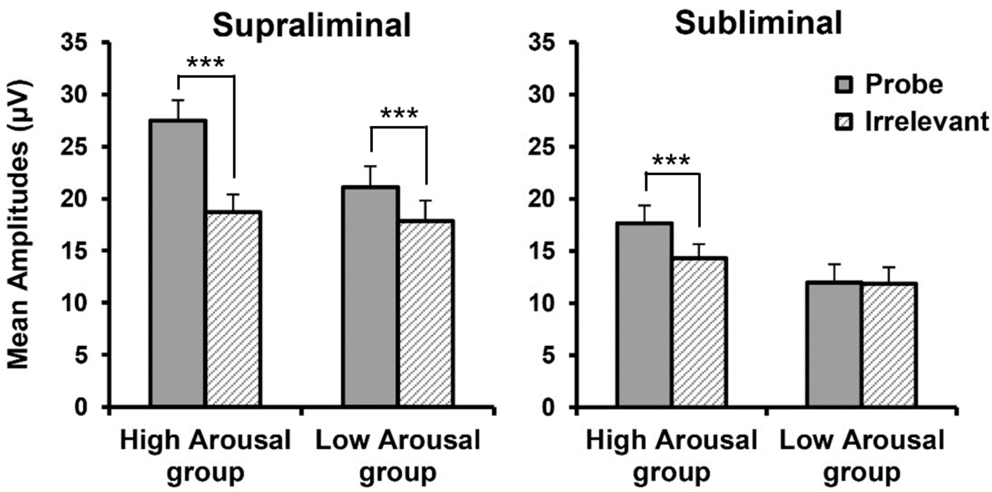

Figure 4.4. Mean amplitudes according to stimulus type in each group. Error bars indicate standard errors. †$p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$.

4.4. Discussion

The present experiment aimed to investigate whether stimuli encoded during emotional arousal are processed via the top-down or bottom-up route in the CIT. To this end, I tested participants on the CIT under both supraliminal and subliminal conditions. Consistent with the hypothesis, the CIT effect on P300 amplitude was significantly greater in the High Arousal group than in the Low Arousal group, under both conditions. However, the detection of the probe was successful only in the High Arousal group under the subliminal condition, while detection was successful in both groups under the supraliminal condition.

Importantly, the results revealed that the CIT effect was markedly larger in the High Arousal group than in the Low Arousal group in both presentation conditions. These results provide strong evidence that emotional arousal can influence the detection efficiency of the P300 in the CIT. These results are in strong agreement with the results of Experiment 1 and Experiment 2, in which it was revealed that emotional arousal significantly increased the differentiation between the P300 responses to the probe and irrelevant stimuli in the supraliminal CIT. In this experiment, I obtained the same results under the subliminal condition. Leiphart, Rosenfeld, and Gabrieli (1993) reported that the P300 amplitude was greater for subliminally presented old rather than new words and was no different between high emotional and low emotional words in the subliminal condition. However, because they did not select the emotional words based on arousal ratings, it is unclear whether the current results are consistent with this previous finding. Focused on affective processing, some studies have shown that highly emotionally arousing stimuli elicit more pronounced P300 waves than low emotionally arousing stimuli, even when these stimuli are presented without awareness (Feng, Wang, Liu, Zhu, Dai, Mai, & Luo, 2012; Rozenkrants, Olofsson, & Polich, 2008). These previous findings are in line with the results of the current experiment, confirming that emotional arousal increases P300 responses to probes in the CIT, regardless of conscious awareness.

Second, the probe encoded during high emotional arousal could be detected under the subliminal condition, while the probe encoded during low emotional arousal could not. This is the first report of subliminal effects in the typical CIT paradigm as assessed using P300 parameters, except for one study using the priming method (Lui & Rosenfeld, 2009). This suggests that the probe may be automatically processed via the bottom-up route in the CIT, but only when the probe was encoded during high emotional arousal. Under the subliminal condition, the participants could not discriminate which stimulus was presented, confirming that the subliminal stimuli were processed without conscious awareness. Thus, the CIT effect on the P300 under these conditions was presumably derived from stimulus-driven processing, suggesting that emotional arousal may have increased the significance of the stimulus at encoding and enable the probe to be processed as an emotionally arousing stimulus, potentially causing a greater CIT effect in the context of the OR. Similar to the results of previous studies using aversive or arousing stimuli (Silvert et al., 2004; Van Den Hout et al., 2000), this finding suggested that the OR could be elicited via bottom-up processing without conscious awareness and that inhibition did not play a crucial role in P300 in the CIT, that is, the P300 component in the CIT would not be explained by the AI theory.

Regarding P300 latencies, there were some additional considerations here, although no analysis was performed for these latencies because these were not the main consideration. In the supraliminal condition, P300 latencies to the probe appeared to be longer than those to the irrelevant stimuli in both groups. This seems to be consistent with the report that P300 latency for the self-relevant stimuli was longer than for the other stimuli (Gray, Ambady, Lowenthal, & Deldin, 2004). On the other hand, Kutas, McCarthy, & Donchin (1977) reported that the latency of the P300 corresponds to stimulus evaluation time. Because the probe must be a significant stimulus strongly related to the participants, these factors may have influenced the latencies under the supraliminal condition in this experiment. In an opposite way, the latencies of P300 in the subliminal condition appear to be shorter compared with those in the supraliminal condition. According to Olofsson et al (2008), processing occurring at approximately 200–300 ms latency reflects early stimulus discrimination and response selection processes. During affective picture viewing, arousal modulation can occur automatically in this early range, even when processing resource availability is limited. They indicated that this sensitivity for arousal level may reflect rapid affective amygdala processing of aversive information.

It should be noted that this study did not aim to investigate straightforward implementations of the subliminal CIT, although the results provide partial support for the application of the subliminal method. While few previous studies have examined the subliminal method within the CIT model, the present experiment is the first to examine the effect of emotional arousal in the subliminal CIT by assessing P300 amplitudes. The results revealed that emotional arousal enables powerful detection under supraliminal conditions and can even aid subliminal detection. These findings provide strong evidence that emotional arousal plays an important role in the CIT, providing new understanding of the CIT and its application.

Chapter 5

General discussion

To elucidate the effect of emotional arousal at memory encoding on the CIT, the present study manipulated the degree of emotional arousal and empirically examined its effect on the CIT with three empirical experiments. In this chapter, the main findings of the three experiments are summarized. Then, the contributions of their results are discussed in the context of previous CIT studies and a potential new model combining the effect of emotional arousal with information processing in the CIT is introduced. Finally, some of the limitations of the present study are acknowledged and future tasks are defined.

5.1. Summary of empirical findings in the present thesis

In Experiment 1 (Chapter 2), I investigated whether emotional arousal at encoding influences the P300 in the CIT by manipulating emotional arousal using different actions during a mock crime task. Participants in the High Arousal group were instructed to stab the “arm of a mannequin” with a sharp-edged tool in the mock crime task as if harassing a mannequin lying on a bed, and those in the Low Arousal group were instructed to stab a “pillow” in the same way. Results obtained in Experiment 1 were consistent with the hypothesis, in which there was a significant difference in P300 amplitudes in response to the probe between the High Arousal group and the Low Arousal group. In addition, P300 amplitudes in response to the probe were significantly greater than those to the irrelevant stimuli in both groups, which showed that the detection of the probe was successful in both groups. Moreover, the differentiations between the probe and irrelevant stimuli, namely the CIT effect, were larger in the High Arousal group than in the Low Arousal group. This signified that detection efficiency was better in the High Arousal group than in the Low Arousal group. Although clear differences were obtained in Experiment 1, the manipulation was not successful. The subjective ratings of Tense Arousal were not significantly different between the groups. Thus, another method of manipulating emotional arousal was needed to identify the effect of emotional arousal in the CIT.

In the following Experiment 2 (Chapter 3), I investigated whether emotional arousal at encoding influences the P300 in the CIT by manipulating the emotional state before a mock crime task. In line with the assumptions of the excitation-transfer theory, emotionally arousing pictures were presented to both arousal groups before the mock crime task; viewing pictures was expected to arouse emotion at a high or low level, respectively. Subsequently, all participants enacted the same mock crime task, in which they were instructed to stab a pillow with a sharp-edged tool as if harassing a mannequin lying on a bed. The participants in the High Arousal group showed significantly greater P300 amplitudes in response to a probe stimulus compared with the low arousal group as in Experiment 1. No differences were found between the groups in response to irrelevant stimuli. Thus, the CIT effect was greater in the High Arousal group than in the Low Arousal group. These results support the notion that emotional arousal influences the P300 in the CIT paradigm and that emotional arousal enhances its detection efficiency.

Experiment 3 (Chapter 4) was conducted to assess how emotional arousal at encoding influences the P300 in the CIT, i.e., to elucidate the processing pathway for stimuli encoded during emotional arousal in the CIT using the subliminal presentation method. The manipulation of emotional arousal and the procedure of the mock crime task were implemented in the same way as in Experiment 2. In the CIT, the subliminal and supraliminal conditions were set for all participants. The results revealed a significantly greater CIT effect on the P300 in the High Arousal group than in the Low Arousal group under both the supraliminal and subliminal conditions. The detection of the probe was successful only in the High Arousal group under subliminal conditions, whereas detection was successful regardless of the emotional arousal group under supraliminal conditions. These results provide strong evidence that emotional arousal can increase the P300 amplitude of responses to the probe in the CIT and suggested that the probe may be automatically processed via the bottom-up route in the CIT, but only when it is encoded during high emotional arousal.

5.2. Primary contributions of this study

5.2.1. Contributions of the present study in the context of previous studies

This section discusses the contributions of the present experiments in the context of previous CIT studies. Three main contributions may be derived from the three experiments, which may lead to new insight on the underlying mechanisms of the CIT.

First, through all experiments, it was clearly shown that emotional arousal at memory encoding enhances P300 amplitudes in response to the probe; that is, emotional arousal can enlarge the CIT effect (detection efficiency), which is the main consideration in CIT studies. The present study was the first attempt to investigate the influence of emotional arousal on the CIT using the P300 and the first empirical demonstration of the effect of emotional arousal on memory encoding in the CIT; such effects have not been reported by CIT studies using ANS measures (Peth et al, 2012). The fact that emotional arousal enhances P300 amplitudes is consistent with several findings from emotional memory studies using ERP, which have examined the interaction of the ERP old/new effect with arousal (Van Strien et al., 2009; Xu et al., 2015) and from affective processing studies using emotionally arousing pictures (for a review, see Olofsson et al., 2008). Contrary to these studies using emotionally arousing stimuli, the test stimuli were not emotionally arousing pictures in the present study; the stimuli themselves were pictures of sharp tools, so were originally neutral stimuli that were not expected to elicit emotional arousal on their own. Nevertheless, I obtained a similar emotional arousal effect throughout all experiments. It is a notable finding that emotional arousal at encoding may enable the originally neutral stimulus to act as an emotionally arousing stimulus in information processing.

Second, the CIT effect was confirmed in both arousal groups; that is, it was shown that the probe can be significantly detected even in low-arousal settings. Although many CIT researchers have expressed concern regarding the difference between arousal in the laboratory and in the field, the present study helps clarify the ecological validity of the CIT, revealing the connection between the two. Even when the test is conducted in a low-arousal setting in the laboratory, it can be said that the probe should be detectable using the CIT.

Third, detection of the probe was successful only in the High Arousal group under subliminal conditions, whereas the probe encoded during low emotional arousal could not be detected. That is, it was shown that emotional arousal enables subliminal detection of the probe. This is the first report of subliminal effects in the typical CIT paradigm as assessed using P300 parameters, except for one study using the priming method (Lui & Rosenfeld, 2009). Although there was a report which found that the subliminally presented probe of the participant's name was detected in the CIT using the SCR (Maoz et al., 2012), this study was also the first to detect the crime-related probe under subliminal conditions. This suggested that the probe encoded with high emotional arousal is automatically processed via the bottom-up route in the CIT; that is, the P300 was enhanced without conscious retrieval. This finding supported the notion that the probe was strongly associated with high emotional arousal and thus was operating as the emotionally arousing stimulus in the CIT, even though the probe itself was originally a neutral stimulus. In addition, this finding suggested that enhanced P300 in response to the probe in the CIT reflected the OR; detection of the probe can be successful by stimulus-driven processing without conscious retrieval. The results obtained here support the OR, not the AI, theory.

5.2.2. Hypothetical model of concealed information detection

Based on the previous results and the present findings, this section introduces a new hypothetical CIT model including the effect of emotional arousal on the CIT. Figure 5.1 depicts a scheme of the model.

The findings in the present study basically support the OR theory in line with numerous previous studies (e.g., Verschuere & Ben-Shakhar, 2011). In other CIT studies, however, the OR theory was always only used to account for the findings, and was not explained in detail with any interpretive model specifically constructed for the CIT. Here, a new hypothetical model of the CIT is proposed by applying a possible explanation provided from the information processing studies, especially in reference to the emotion activated model proposed by Öhman (2008) shown in Figure 5.1. As mentioned in Chapter 1, the emotion activation model is based on the information processing model as mentioned above (Öhman, 1979), and assumes two routes of pre-attentive processing: an automatic processing route (i.e., bottom-up or stimulus-driven) and a controlled processing route (i.e., top-down or knowledge-driven). In the former automatic route, a stimulus first (1) contacts feature detectors, which detect potentially significant stimuli based on signal features. If the stimulus is identified as an evolutionarily-shaped significant signal, information is passed on (2) to the significance evaluator and (3) the arousal system is automatically activated. Then, feedback (4) to the significance evaluator is provided, who is (5) biased by the expectancy system which relies on memory, which automatically induces the OR. After this processing, the significance evaluator calls on (6) conscious perception, which is integrated (7) with the expectancy system and (8) with the arousal system, that produced a strong OR via the latter controlled processing route.

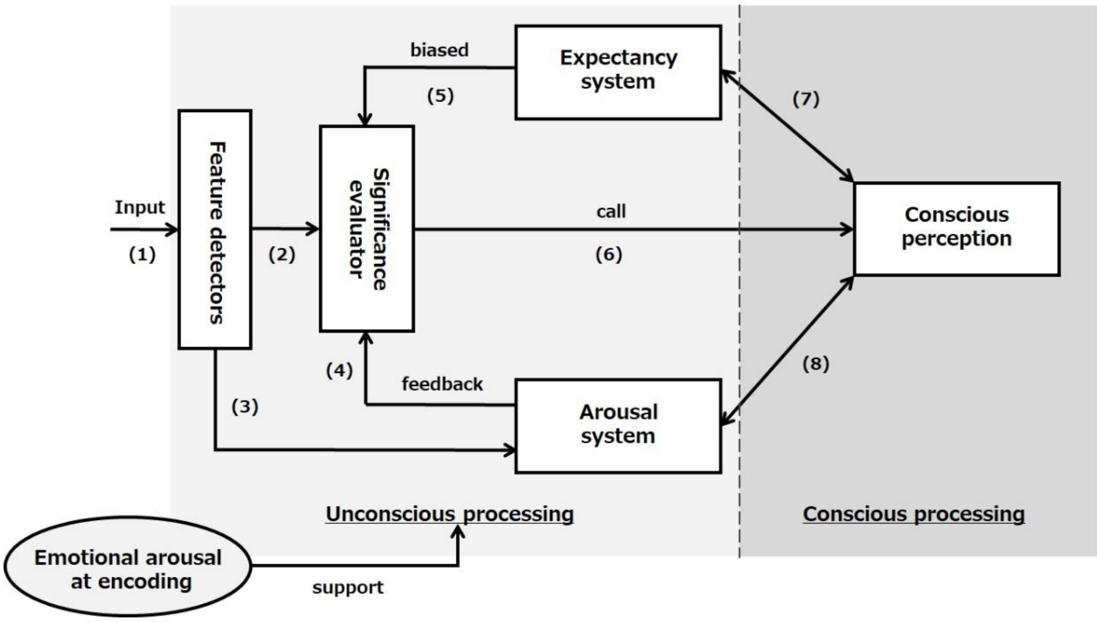

Figure 5.1. New hypothetical model based on the findings of the present study, as a modification of the emotion activation model by Öhman (2008).

In the CIT, the probe, which is ordinarily associated with relatively low emotional arousal would be processed via a controlled route, including all pathways from (1) to (8) shown in Figure 5.1. On the other hand, the probe associated with high emotional arousal would be processed via an automatic route, including only (1) through (5), as well as processing of emotionally arousing stimuli. This unconscious processing is proposed to be the same as the pre-attentive mechanisms proposed by Öhman (1979). In the CIT, two different processing routes can be assumed, which are determined by the magnitude of emotional arousal at encoding. Only when emotional arousal at encoding is sufficiently high to enable the probe to operate as an emotional arousing stimulus, it is supposed to support these interactions in the pre-attentive mechanisms in this hypothetical model.

This model may also offer another explanation related to activation of the amygdala referring to the dual route model proposed by LeDoux (1996). While the "low road" assumed in his model would apply to the unconscious processing part, which assumes a crucial role of the amygdala, the "high road" would apply to the conscious processing part, which is strongly related to the activation of the sensory cortex.

This hypothetical model is based on the assumption that the probe encoded with high emotional arousal works as a high emotional arousing stimulus, which has in all likelihood stimulus significance. The findings in the present study support this explanation, and enabling this unconscious processing is the key role of emotional arousal at encoding. I highlight here also that considering the role of emotional arousal in the CIT model is worthwhile based on this perspective.

5.2.3. Contributions of the present study to field applications

The present study may also contribute to the practical field, in which practical polygraph examinations using the CIT are utilized as a forensic science technique in actual criminal investigations. First, the findings of this study can help polygraph examiners to offer a persuasive and reliable explanation regarding the CIT mechanisms and the role of emotional arousal during a crime in court. Because there were no demonstrations revealing the effects of emotional arousal on the CIT before, it can be said that providing the first empirical demonstration of these effects is worthwhile contribution. In Japanese criminal courts, the results of the polygraph examination using the CIT method are admissible as evidence since 1968 (Osugi, 2011). The examiner's expert opinions have been admitted as evidence as needed, and sometimes they are asked to appear and state their opinion as witnesses in court. Nowadays scientific evidence based on empirical studies are in increasing demand.

Second contribution is related to the selection of the probe. Polygraph examiners always have to select most appropriate probes for each examination to investigate the examinee's knowledge in limited time. Usually one examination takes about 2 or 3 hours only to ask about approximately 5 or 6 probes. Because there are basically lots of probes in a crime as long as the probes are undisclosed, the examiners have to choose appropriate probes carefully from these potential probes (for detailed information about the selection of probes, see Osugi, 2011). However, there were few guiding principles endorsed by scientific demonstrations to select probes for clear and powerful detection. The present study adds a new component of emotional arousal at encoding to the mechanisms of the CIT and enables selection of the most appropriate probe for quick and powerful detection as an endorsed guiding principle. Such probes, which are likely to be highly arousing during a crime, may offer clear results on the test and lead to improved accuracy. On another front, it should be noted that here, the CIT effect was obtained even in the Low Arousal group. This shows that we can conduct the CIT even when a highly arousing probe cannot be identified.

The third contribution is related to the subliminal presentation. Because it was revealed that we can detect subliminally presented probes encoded with high emotional arousal, it is possible, as long as we can prepare such probes, to use the subliminal presentation method without special protocols as reported by Lui and Rosenfeld (2009) and Rosenfeld (2011) for countering the examinees' attempts to defeat the test or distort its results, which is a limitation of the conventional CIT paradigm. Subliminal CIT enables us to exclude the examinee's fantasy and supposition to specific stimuli, which prevents proper detection because the examinee cannot recognize which stimulus is presented during the subliminal CIT.

Finally, this study suggested that the P300 could be a worthwhile index to apply in the field, when there are problems with acquiring traditional ANS measures. Sometimes, we can encounter examinees who are non-SCR responders, or sometimes HR and NPV, which are considered to reflect arousal inhibition may not work well because of lack of arousal inhibition. Because it was revealed that the P300 component is a powerful index which reflects the OR, applying this index and then flexibly using appropriate indices depending on the situation may facilitate the detection of information.

5.3. Limitations and future tasks

The current study involved several limitations that should be considered, particularly regarding the number of the participants tested. Although I found significant effects of emotional arousal, suggesting the absence of type II errors regardless of the small sample size, it should be noted that the small sample size limits the generalizability of my conclusions. Because of the potential non-representativeness of the sample, the possibility of type I errors caused by individual differences, such as sex, age, and nationality, should be considered. Examining this effect in more detail will require further research with a larger sample size.

Another limitation is related to the manipulation of emotional arousal, in which only subjective self-reports were examined. The results revealed that the subjective arousal levels were significantly changed by the manipulation and mock crime task in this study. In addition, McCall, Hildebrandt, Bornemann, and Singer (2015) reported that subjective ratings in retrospect were in line with the physiological arousal during the original events. Thus, it is suggested that the present results did not suffer from this limitation. However, it is possible that physiological arousal levels were changed by the manipulation and mock crime task. To resolve this possibility in the future, it would be helpful to measure physiological responses during encoding.

Moreover, it is possible that the interaction between the two arousal tasks (emotional arousal manipulation task and mock crime task) also affected the current findings. Although I assumed that state arousal manipulated by affective pictures would not enhance the P300 solely without the mock crime procedure, state arousal may have influenced the P300 through the mock crime task. Future studies using other methods of manipulation may clarify this potential interaction. In addition, although I assumed that the effects of emotional arousal shown in this study were not due to the characteristics of the mock crime task, it is possible that the type of mock crime task used influenced the effects of emotional arousal. Because a new type of mock crime task was applied in this study, it would be helpful to investigate the effect using different types of mock crime tasks in future research.

The criterion for the awareness check of the subliminal presentation should be also considered in the limitations. The present study followed the previous study by Maoz et al. (2012) and confirmed that each participant was not aware of the subliminally presented stimuli by their thresholds. Although I assumed this criterion was plausible for the definition of "subliminal" in this study, it is suggested on the other side that the criterion and the definition should be more severe. Examining the effect of emotional arousal using different protocols of the subliminal presentation would be helpful for accurate understanding of subliminal condition.

Finally, it remains unclear whether emotional arousal effects are accurately reflected by the ANS measurements often used in CIT studies. Because the SCR appears to be based on the same OR theory with the P300 (klein Selle et al., 2016, 2017; Rosenfeld et al., 2017), I can assume that emotional arousal at encoding also influences the SCR in the CIT. Although previous studies have failed to find this effect on the SCR using different procedures from this study, there is still the possibility that emotional arousal at encoding influences the SCR as well as the P300. Investigating this issue with the procedure used in this study will help fully elucidate the effect of emotional arousal on the CIT.

5.4. Conclusion

In the present study, three experiments were conducted to elucidate the effect of emotional arousal at memory encoding on the CIT. By manipulation of the magnitude of emotional arousal at encoding, Experiments 1 and 2 revealed that the P300 amplitudes in response to the probe were larger in the High Arousal group compared with the Low Arousal group, and the differences between the probe and the irrelevant stimuli were significantly greater in the High Arousal group than in the Low Arousal group. These findings were the first empirical demonstration of the effect of emotional arousal at encoding in the CIT. To assess how emotional arousal at encoding enhances the P300 in the CIT, the subliminal presentation method was added to the ordinary supraliminal presentation in Experiment 3. The results showed that the CIT effect on the P300 amplitude was significantly greater in the High Arousal group than in the Low Arousal group under both conditions and that detection was successful in both groups under the supraliminal condition. On the other hand, the detection of the probe under the subliminal condition was only successful in the High Arousal group. These findings support the notion that the probe associated with high emotional arousal is processed without conscious perception, as is the case for highly emotionally arousing stimuli such as aversive, fearful stimuli. Because the P300 in the CIT was proven to reflect the OR, a hypothetical model was proposed taking into account the previous information processing models. The proposed model can explain how the probe is processed in the CIT and stress the key role of emotional arousal at encoding which works to determine one of two different processing routes, i.e., conscious and unconscious processing, in the CIT.

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