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嚼食檳榔對睡眠剝奪者之有效視覺區之影響

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李碩衡、施雅羚、王威中

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中　華　民　國　98　年　9　月　15　日

前言

今年之研究計畫總共撰寫成兩篇論文，目前均正在審稿當中。這兩篇論文之標題分別為 Can Betel Nut Chewing Affect the UFOV Size? 以及 Betel nut chewing effect on contour and object masking。前者是由今年之計畫以及去年之計畫之研究成果，合併寫成。目前正在期刊 Ergonomics 審稿中。後者是由今年之成果撰寫而成，目前正在 British Journal of Psychology 審稿中。以下分別列出這兩篇論文之英文摘要與論文全文，以供參考。

Can Betel Nut Chewing Affect the UFOV Size?

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Abstract

Betel nut is a common stimulant in many Asian countries. However, few behavioral studies reported the betel nut chewing effects on cognition. We examined the effects of betel nut chewing on the useful field of view (UFOV) under deprived sleep and normal sleep conditions. After one night of normal sleep or deprived sleep, habitual chewers and non-chewers chew either betel nut or gum before proceeding to the UFOV subtests. In the UFOV subtests, participants need to identify the central target, divide their attention to the peripheral target, and detect the peripheral target embedded in the distractors while identifying the central target. We reported that betel nut chewing can affect the UFOV of the habitual betel nut chewers when their sleep was deprived for one night. The implication for people often chewing betel nut for refreshment during long-hour working is discussed.

Key Words: betel nut, areca, sleep deprivation, useful field of view

In Taiwan, betel nuts (also known as areca) is a common refreshment for people working at night shifts. For example, many long-distance overnight bus and truck drivers chew betel nuts for refreshment. About 1.5 million Taiwanese are betel nut users, with about 30% of these users are chewing betel nuts for refreshment purpose (Directorate-General of Budget, Accounting and Statistic, 1999). People place a whole betel nut into their mouth and macerate it by biting for approximately two to three minutes; they then spit out the red chewing saliva of the betel nut.

A betel nut usually consists of three major ingredients: a raw areca nut, slaked lime, and piper betel flower. The slaked lime, which is handled in the form of a paste, is either white lime or red lime. Red lime betel nut, containing green areca fruit, piper betel inflorescence and red lime paste, is the main method of areca consumption in Taiwan (about 70% of all betel nuts). The primary chemical ingredients in betel nuts are alkaloids (i.e., arecoline, arecaidine, guvaeoline, guvacine, and acolidine), polyphenolic compounds, safrole, eugenol, and hydroxychavicol.

Betel nuts have long been chewed by people as a stimulant because of their physiological effects, which include: increased stamina, a general feeling of well-being (Nieschulz, 1967), sweating, salivation, stimulation, cardioacceleration, a slightly drunk feeling and warming of the body, and mouth cavity (Hwang, Wang, & Kao, 1993). Many studies have shown that betel nut chewing can heighten the state of alertness (e.g., Cawte, 1985; Chu, 1993, 1994a, 1994b, 2001; Chu & Chang, 1994; Haubrich, & Watson, 1972; Molinengo, Fundaro, & Cassone, 1988; Rinaldi, & Himwich, 1955; Wyatt, 1996); additionally, such effects occur only for habitual betel nut chewers. According to Chu and Chang's survey, the first three effects experienced by the new chewers were dizziness, hot sensation, and palpitation. Contrarily, the first three effects for habitual chewers were: heightened alertness, hot sensation, and palpitation.

Evidence that supports the refreshment effect of betel nut chewing comes primarily from physiological studies. In general, the physiological effects of betel nut chewing may result from the chemical effects of the betel nut ingredients on the autonomic and central nervous systems (for a review, refer to Chu, 2001). Chu (1994a) conducted an electroencephalographic (EEG) study on the effects of betel nut chewing. Results showed an increase in both beta (associated with alertness) and alpha (associated with relaxation) activities and a decrease in theta (associated with drowsiness) activity. Both an increase in beta and a decrease in theta indicated an increase in the state of alertness, whereas an increase in alpha indicated a relaxation or calmness while chewing betel nut. In addition, these EEG changes were restricted mainly to posterior areas (particularly the occipital areas) for alpha activity, but were more widespread for theta and beta activities.

Chu (1993) investigated the time course of betel nut chewing effect by measuring three groups of participants' (chronic, occasional and non-chewers) cardiovascular changes (heart rate and blood pressure). Both heart rate and blood pressure were measured 5 minutes before betel nut chewing and every 2 to 5 minutes during and after chewing, lasting for about one hour. The chewing effects on heart rates in three groups were immediate and reached a peak within 4 to 6 minutes of chewing. The cardio-accelerating responses lasted for an average of 16.8 minutes. However, neither systolic nor diastolic blood pressures were affected in chronic and occasional groups. Only the non-chewers showed a significant increase solely in systolic blood pressures.

Contrary to the fruitful literatures on the physiological effects of betel nut, very few studies focusing on the behavioral measures of betel nut chewing effects were reported. In addition, results of these behavioral studies were mixed (e.g., Chu, 1994b, Stricherz & Pratt, 1976; Wyatt, 1996). Stricherz and Pratt employed a simple reaction time task and found a lengthened reaction time (RT) within the initial five minutes of the ingestion of a betel nut. Chu investigated betel nut effects on both simple and choice RT tasks for the habitual betel nut chewers. Participants performed RT tasks before and during betel nut chewing. Only the choice RT was found to be shorter during betel nut chewing than that before chewing. Wyatt investigated betel nut chewing effects on habitual chewer's performances on a variety of behavioral and physiological measures (the choice RT, eye-hand coordination, digit span, pulse rate and blood pressure). The pulse rate was the only measure reported increment after betel nut chewing.

In the current study, we do not intend to disentangle the mixed results of betel nut effects on behavioral studies. We aim to focus on whether betel nut chewing could improve visual attention under normal and deprived sleep. To our knowledge, no studies have provided behavioral data on the betel nut chewing effect on visual attention under sleep deprivation. One of the important indexes of visual attention is the useful field of view (UFOV). The UFOV refers to a spatial area that is functional or useful for the ongoing task(s) (Sanders, 1970). Attentional resources are allocated to this spatial area in order to process the incoming information. Any stimuli within the UFOV would receive further processing; however, any stimuli falling outside of the UFOV would receive only basic preattentive processing (e.g., physical properties, viz., color and texture). That is, when the size of the UFOV shrinks, fewer stimuli within the UFOV are processed further.

Measures of the UFOV typically involve three well-documented components: speed of identifying a central target alone (hereafter *processing speed*), dividing attention between central and peripheral targets presented simultaneously (hereafter *divided attention*), and localization of a peripheral target embedded in distractors while identifying a central target (hereafter *selective attention*) (for a review, see Ball, Roenker, & Bruni, 1990; Sekuler & Ball, 1986). The size of the UFOV varies across situations. The size of the UFOV is decreased by the slowing of visual information processing (Ball, Beard, Miller, & Roenker, 1987; Leibowitz & Appelle, 1969). When the central task demand increases (Chan & Courtney, 1993, 1994; Rantanen & Goldberg, 1999; Sekuler & Ball, 1986; William, 1982), a peripheral target localization or detection will be impaired. The UFOV size deteriorates when the peripheral target is embedded in the background distractors (Drury & Clement, 1978; Scialfa, Kline, & Layman, 1987; Sekuler & Ball, 1986). Furthermore, when the similarity of a peripheral target and the background distractors increase, the size of UFOV will be further reduced (Ball, Roenker, & Bruni, 1990).

The size of the UFOV also varies across individuals. Individuals with more impaired components of the UFOV (i.e., processing speed, divided attention and selective attention) suffer from further reduction of the UFOV size (Ball & Owsley, 1992). Many have shown that sleep deprivation deteriorates the components that determine the UFOV size (e.g., Pilcher & Huffcutt, 1996; Rogé, Pébayle, Hannachi & Muzet, 2003; Williamson & Feyer, 2000). For example, sleep deprivation decreases participants' ability to identify a critical signal in the central visual field (Williamson & Feyer, 2000). In addition, the divided attention task was impaired and reached levels equivalent to the maximum alcohol dosage given to participants (Williamson & Feyer, 2000). Moreover, the UFOV, rather than eye health and visual sensory function, has direct effects on accident frequency (Clay, et al., 2005; Cross, et al., 2009; Owsley & McGwin, 1999; Leat & Lovie-Kitchin, 2006). Additionally, visual sensory function and eye health have indirect effects on car crash frequency mediated by UFOV.

Because many habitual chewers chew betel nut for refreshment when they need to stay awake overnight, and previous studies have shown that sleep deprivation reduces the UFOV, we test whether betel nut chewing could affect the UFOV size under deprived sleep. A normal sleep condition (without sleep deprivation) was included as a baseline. Physiological studies have reported that the ingredients of betel nuts are able to increase stamina and alertness for the chewers (e.g., Chu, 2001). Thus, we hypothesize that betel nut chewing can affect the UFOV size measured in terms of the three well-developed components (processing speed, divided attention and selective attention). Further, since previous studies showed that sleep deprivation could deteriorate UFOV, we hypothesize a larger betel nut chewing effect under the sleep deprivation condition in comparison to the normal sleep condition. Finally, because previous survey (e.g., Chu & Chang, 1994) showed different chewing experiences for the new chewers and habitual chewers, we hypothesize that these betel nut effects on the UFOV might only occur to the habitual betel nut chewers, rather than the non-chewers.

Method

Participants

Four different groups of participants were recruited: deprived sleep/chewer (DepCh), deprived sleep/non-chewer (DepNch), normal sleep/chewer (NorCh), and normal sleep/non-chewer (NorNch). All participants had a low level of drowsiness (scores < 11) in daily life on the Epworth sleepiness scale (ESS; Johns, 1991, 1992). All participants were morning (scores between 59 and 86) or intermediate people (scores between 42 and 58) types on the Morning-Evening Questionnaire (MEQ; Horne & Ostberg, 1976). All participants have normal or corrected-to-normal vision. None of them work night shifts. All had had a normal night of sleep before the experiment. All non-chewers had never chewed betel nuts. Participants with deprived sleep had not used betel nut or any food or drink containing alcohol or caffeine during the night in the laboratory. Participants with normal sleep had not used betel nut or any food or drink containing alcohol or caffeine during the daytime.

Apparatus

We used an IBM-compatible PC with a 17 inch touch screen CRT desktop monitor (refresh rate = 60 Hz).

Design and Procedure

Each participant underwent two conditions of experiments (chewing gum and betel nut conditions); these conditions were counterbalanced across participants so that half of the participants took part in the chewing gum condition first, and the remaining half took part in the betel nut condition first. The chewing gum condition was adopted in order to control for the effect of mere chewing. These two conditions were separated by about one week. The laboratory prepared the betel nuts and chewing gum so that all the participants chewed the same type of betel nuts and chewing gum.

For the sleep deprivation groups (both DepCh and DepNch groups), participants were requested to stay awake all night in the company of the experimenter. Each participant arrived at the laboratory at about 22h00, the night before the UFOV test. Participants could bring quiet activities with them; the luminance in the laboratory was 310 lux. After the participants arrived at the laboratory, they needed to fill out the Verran and Snyder-Halpern sleep scale (VSS; Simpson, Lee & Cameron, 1996; Snyder-Halpern & Verran, 1987) in order to evaluate their sleep quality the night before the experiment. In order to evaluate participants' sleepiness degree overnight, the Stanford sleepiness scale (SSS; Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973) was administered every hour from 22h00 to 7h00. The following morning at about 7h00, each participant chewed either a betel nut or a chewing gum before the UFOV test. In either the betel nut or chewing gum condition, participants chewed one material (betel nut or chewing gum) for 3 minutes and then spit it out before they began the UFOV test.

For the normal sleep groups (both NorCh and NorNch groups), each participant arrived at the laboratory at about 18h00. After the participants arrived at the laboratory, they needed to fill out the VSS. Then each participant chewed either a betel nut or a chewing gum before the UFOV test. Participants chewed one material (betel nut or chewing gum) for 3 minutes and then spit it out before they began the UFOV test.

The functional field of view was assessed by the UFOV software (Visual Awareness, Inc., Birmingham, AL), consisting of three subtests that measure the processing speed (Subtest 1), divided attention (Subtest 2) and selective attention (Subtest 3) respectively. These three subtests were presented sequentially (Subtest 1 first, then Subtest 2, and finally Subtest 3). The UFOV test was administered in a dim room where each participant leaned his/her chin on a chinrest with a fixed viewing distance of 50 cm from the monitor.

Subtest 1 consisted of a sequence of stimuli in which the central outlined rectangle (3.3° in width and 4° in height) was presented, followed by a single target (a silhouette of either a car or a truck with 2.3° in width and 1.7° in height) with varied presentation time from 16 to 500 ms, which was followed by a 1-s random dot mask, the size of the display screen. The mask was proceeding with a response screen in which both the car and truck icons were presented always to the right and left of fixation. Participants were instructed to discriminate between these two possible targets and responded to the target by touching the stimulus icon displayed on the touch monitor without time pressure.

For each subtest, the UFOV software adjusts the length of stimulus presentation in milliseconds if needed. This adjustment procedure is a "two up, one down" adaptive staircase in which two successive correct responses to the central target in Subtest 1 (or both central and peripheral targets in Subtests 2 and 3) result in a shortened stimulus presentation duration for the next trial; an incorrect response (to either a central or peripheral target) results in a lengthened stimulus presentation duration for the next trial. The procedure of adjusting the perceptual threshold was continued until a stable estimate of 75% correct rate was calculated. Scores yielded from each subtest of the UFOV were expressed in terms of *stimulus presentation time*. Longer stimulus presentation time (i.e., stimulus is displayed on the screen for a longer period of time for correct responses) indicates that more time is needed to process the stimuli to reach the performance criteria.

In Subtest 2, in addition to identifying the central target as Subtest 1, participants needed to detect a simultaneously presented peripheral target, which was always a silhouette of a car. The center-to-center distance between the central and peripheral targets was 13.5°. This peripheral target appeared randomly at one of eight different peripheral locations along eight radial spokes (4 cardinal and 4 oblique). The center-to-center distance between two nearest peripheral locations was 9.1°. As Subtest 1, participants responded by touching the monitor first to discriminate which target was seen in the center. Then, they needed to localize the peripheral target; the identification of this target was unimportant. The response screen for localization judgment consisted of eight boxes at the eight possible peripheral target locations linked to the central box by eight radial lines. Participants were instructed to touch one of the eight boxes on the monitor display to indicate its location.

The tasks in Subtest 3 were the same as those in Subtest 2 (i.e., central target discrimination and peripheral target localization tasks); however, distractors (upside-down outlined triangles with each side length of 2.3°) were added to the remaining area of the screen. These distractors were arranged in three imaginary circles with three different radii (4.3°, 8.8°, and 12.8°). In each imaginary circle, the center-to-center distance between two nearest triangles was 3.8°. There were 8 distractors in the inner circle and 16 in the middle circle. The peripheral target was presented in one of eight locations (as Subtest 2) in the outer circle, resulting in 23 distractors in the outer circle. In each subtest, four practice trials were presented before the formal trials. In general, the UFOV test lasts for about 15 minutes or less.

The UFOV test used in the current study differed from the previous paradigm (e.g., Sekuler & Ball, 1986) in that the current test did not manipulate the spatial distance between the central and peripheral targets, and the response time was not the primary dependant variable. The current UFOV test has been shown to have high test-retest reliability (r = .735) and high correlation with the previous paradigm manipulating spatial distance and recording response time (r = .746) (Edwards, Vance, Wadley, Cissell, Roenker, & Ball, 2005). Also, the current UFOV test takes less time (15 minutes or less) than the past paradigm (about 20 to 30 minutes). The un-speeded response in the current UFOV test also allows controlling for the possible confounds from post-perceptual stages (e.g., decision making and motor function). Thus, the current UFOV test is appropriate to assess participants' functional field of view.

Results and Discussion

Demographic Characteristics

Demographic characteristics are shown in Table 1. An analysis of variance (ANOVA) on the frequency and number of betel nut chewing showed that the chewers in the normal sleep condition have more months of betel nut chewing history ($p < .0001$, partial η^2=.544) and more days per week of chewing ($p < .05$, partial η^2=.210) than those in the sleep deprivation condition. The average number of betel nuts chewed per day between these two conditions was marginally significant ($p = .061$, partial η^2=.129). To examine whether these differences are critical for the UFOV performances, the average months of chewing, the average days per week of chewing and the number of betel nuts chewed per day are correlated to the three UFOV subtests in the betel nut condition and in the gum condition. Analysis showed that the frequency and number of betel nut chewing are not sufficient to account for the UFOV performance in our case. Only the average months of chewing is weakly correlated to Subtest 2 (divided attention) in the gum condition ($p = .049$, Pearson's $r = -.375$). We will discuss these findings in General Discussion. None of other variables (age, ESS, and MEQ) showed between-group differences.

Insert Table 1 about here

Sleepiness Scores

For the DepCh group, regression analysis showed that SSS scores increased as the hours that participants stayed awake in the laboratory increased in both conditions (in chewing gum condition, $\beta = .718$; in betel nut condition, $\beta = .694$; both p's < .0001). In both conditions, the mean SSS score was 1 ("feeling active and vital; alert; wide awake") at 22h00 (in betel nut condition, SD = .7; in chewing gum condition, SD = .6) and was 5 ("fogginess; beginning to lose interest in remaining awake; slowing down") at 7h00 (in betel nut condition, SD = 1.5; in chewing gum condition, SD = 1.3).

For the DepNch group, regression analysis showed that SSS increased as the hours that participants stayed awake in the laboratory increased in both conditions (in the chewing gum condition, β= .745; in the betel nut condition, β= .691; both p's < .0001). In the betel nut condition, the mean SSS score was 1 ("feeling active and vital; alert; wide awake") at 22h00 (SD = .7) and was 5 ("fogginess; beginning to lose interest in remaining awake; slowing down") at 7h00 (SD = 1.6). In the chewing gum condition, the mean SSS score was 2 ("functioning at a high level, but not at peak; able to concentrate") at 22h00 (SD = 1.1) and was 6 ("sleepiness; prefer to be lying down; fighting sleep; woozy") at 7h00 (SD = 1.3).

The mean VSS scores for all four groups are shown in Table 2. An ANOVA of 2 (sleep condition: deprived sleep or normal sleep) × 2 (betel nut use: chewer or non-chewer) × 2 (treatment: betel nut or gum) on VSS showed interactions of sleep condition x treatment ($p < .05$, partial η^2=.092) and betel nut use x treatment ($p < .005$, partial η^2=.161). Further analysis on the sleep condition x treatment revealed no VSS difference between betel nut and gum conditions for both deprived sleep and normal sleep groups (all p's > .1). On the other hand, analysis on the betel nut use x treatment showed a VSS difference between betel nut and gum conditions for the non-chewers (p < .05). This VSS difference indicates that non-chewers had better sleep quality the night before the experiment in which they chewed betel nut than before they chewed gum.

To assess whether the VSS is critical for the UFOV performances, the VSS in the betel nut condition is correlated to three UFOV subtests in the betel nut condition. Also, the VSS in the gum condition is correlated to three UFOV subtests in the gum condition as well. None of these correlations reach the significant level (all *p*'s > .05). That is to say, in the current study, the VSS is not crucial to account for the UFOV performance.

Insert Table 2 about here

UFOV Scores

The mean stimulus presentation times are shown in Table 3. In terms of the data, betel nut chewing might affect participants in normal sleep and deprived sleep conditions differently. That is, it appears that betel nut chewing effect may be larger in sleep deprivation condition, particularly for habitual chewers. To emphasize this difference, we conducted an ANOVA of 2 (treatment: betel nut or gum) × 3 (UFOV test: processing speed, divided attention and selective attention) × 2 (betel nut use: chewer or non-chewer) in each sleep condition[1]. The first two variables (treatment and UFOV test) were within-subject variables, and the last was a between-subject variable.

Insert Table 3 about here

For the sleep deprivation condition, the main effect of UFOV test and treatment × betel nut use interaction were obtained. The main effect of UFOV test [$F(2,48) = 55.52$, $MSE = 5018.7$, $p < .0001$, partial $\eta^2 = .698$] showed that more processing time was required for more complex tasks. Namely, the average stimulus presentation time of Subtest 1 (29 ms) was shorter than Subtest 2 (74 ms), which was shorter than Subtest 3 (176 ms) (all *p*'s < .0001). Most critically and intriguingly, the interaction of treatment × betel nut use [$F(1,24) = 4.24$, $MSE = 9879.1$, $p < .05$, partial $\eta^2 = .150$] has revealed a betel nut chewing effect for the habitual chewers when their sleep was deprived for one night. That is, for the chewers, the average stimulus presentation time when they chewed betel nuts (69 ms) was significantly shorter than that when they chewed gums (123 ms) ($p < .05$, partial $\eta^2 = .127$). When the chewers chewed betel nut, they could quickly identify the central target presented alone, divide their attention to the peripheral target, and detect the peripheral target embedded in the distractors while identifying the central target. However, for the non-chewers, the average stimulus presentation time in the betel nut condition (97 ms) did not differ significantly from that in the gum condition (83 ms) ($p > .4$, partial $\eta^2 = .054$).

For the normal sleep condition, only main effect of UFOV test [$F(2,44) = 68.90$, $MSE = 2642.4$, $p < .0001$, partial $\eta^2 = .758$] was obtained. The average stimulus presentation time of

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[1] We also did an ANOVA of 2 (treatment) × 3 (UFOV test) × 2 (betel nut use) × 2 (sleep condition) to assess betel nut chewing effect. The main effect of UFOV test and two two-way interactions (UFOV × betel nut use and treatment × betel nut use) were obtained. Sleep condition was not found to involve in any interactions. However, the data shown in Table 3 indicates a possibility of larger betel nut chewing effect for habitual chewers with deprived sleep, but not with normal sleep. Not ignoring this important information, we conducted 2 × 3 × 2 ANOVA in each sleep condition.

Subtest 1 (19 ms) was shorter than Subtest 2 (37 ms), which was shorter than Subtest 3 (133 ms) (all p's < .05). That is, when participants (both habitual chewers and non-chewers) had normal sleep, betel nut chewing did not have effect on the UFOV.

To examine whether the chewers reporting at least one withdrawal symptom performed differently from those not reporting withdrawal symptoms, we conducted an ANOVA of 2 (withdrawal symptom: yes or no) × 2 (treatment: betel nut or gum) × 3 (UFOV test: processing speed, divided attention and selective attention) for habitual chewers with deprived sleep. Importantly, the analysis did not show main effect and interactions involved withdrawal symptom (all p's > .4), indicating that betel nut chewing was effective for chewers with deprived sleep reporting and not reporting withdrawal symptoms. The main effects of treatment and UFOV were significant. The main effect of treatment showed that stimulus presentation time was shorter in the betel nut condition than that in the gum condition ($p < .05$). The main effect of UFOV showed that stimulus presentation time increased with the complexity of the UFOV subtests (all p's < .05).

To conclude, betel nut chewing can affect the UFOV size for the habitual betel nut chewers when their sleep was deprived for one night. Betel nut chewing has no effect on the UFOV performance of non-chewers with normal sleep or deprived sleep.

General Discussion

We examined whether betel nut chewing could influence the UFOV size for both habitual chewers and non-chewers in normal and deprived sleep conditions. Our results indicated that betel nut chewing could affect the UFOV size for the habitual chewers (with and without reporting withdrawal symptom) whose sleep was deprived for one night, but not for the non-chewers.

Some possibilities could account for the betel nut chewing effects on the UFOV that found only among habitual chewers in the sleep deprivation condition. First, the expectancy effect of betel nut chewing may be larger in the chewers. In Taiwan, it is thought to be a common knowledge that chewing betel nut has a refreshing effect. Possibly, the habitual chewers are more anticipative of betel nut's refreshment effect, thus causing better performance while chewing betel nut. However, because many physiological studies have reported the refreshment effect of betel nut chewing, it is unlikely that this effect is merely due to habitual chewer's expectations. Further, if the betel nut chewing effect is merely due to expectations, this effect should also be found among habitual chewers in normal sleep condition. However, we did not found such effect in normal sleep condition. A mixed effect of physiological contributions and expectations may be more likely the case. It is of importance to include a placebo control to examine how physiological effect alone or their interaction influence habitual chewer's or non-chewer's behavior.

Second, previous surveys have shown that the initial feelings of chewing betel nut are: dizziness, hot sensations, and palpitation (Chu & Chang, 1994). Such uncomfortable feelings may result from an increase in systolic blood pressure after chewing betel nut expecially for the non-chewers, but not the habitual chewers (Chu, 1993). It is possible that the selective effect of betel nut chewing on blood pressure for non-chewers and habitual chewers resulted in different performances in both groups. Future study can examine the possible link between online physiological and behavioral measures.

Some research limitations should be mentioned. First, the three UFOV subtests were always presented sequentially; thus, one may discern about the interaction between the time course of betel nuts and subtest sequence. However, this concern may be minor. The lack of UFOV- and treatment-related interactions (e.g., treatment × UFOV, partial η^2= .002, treatment × UFOV × sleep condition, partial η^2=.011, and treatment × UFOV x betel nut use, partial η^2=.029), and the significant treatment × betel nut use have shown betel nut chewing effect for the habitual chewers with deprived sleep, but not the non-chewers, in regardless of types of UFOV subtests. In other words, betel nut chewing shortened the stimulus presentation durations in all three UFOV subtests for the habitual chewers. Although the effects of betel nut chewing were constrained by its time course (an average of about 16.8 minutes; Chu, 1993), betel nut chewing indeed affected habitual chewer's performances in the UFOV tests. It is difficult to investigate the interaction between the time course of betel nut chewing effect and the UFOV subtests with current experimental design. However, the whole story remains clear; that is, betel nut chewing can affect habitual chewer's functional fields of views assessed by UFOV tests.

Second, the frequency and number of betel nut chewed for the chewers in the normal sleep group differ from those in the deprived sleep group. This may influence their UFOV performances. However, the correlation analysis showed that only the average month of chewing is weakly (p = .049) correlated to Subtest 2 (divided attention) in the gum condition. It is unclear why the average month of chewing was correlated to Subtest 2. A random error may cause this weak effect. Generally, the frequency and number of betel nut chewed are not sufficient to account for the UFOV performance in our case. Future studies could emphasize on how the frequency and number of betel nut chewing affect visual attention and other cognitive functions.

The current study has important implication for people who often chew betel nut for refreshment during long-hour working. Since betel nut chewing could improve chewer's attentional system in general (e.g., processing speed, divided attention and selective attention in the current case), it is expected that many working errors could be prevented because of this improved attentional system. However, the betel nut chewing is only effective for the habitual chewers. For example, sleep deprivation could raise the likelihood of car accidents, mediated through the deteriorated UFOV (Clay, et al., 2005; Cross, et al., 2009; Owsley & McGwin, 1999; Leat & Lovie-Kitchin, 2006; Rogé, Pébayle, Hannachi & Muzet, 2003). An overnight truck driver could chew betel nut to improve their UFOV, which could reduce the likelihood of car accidents. After chewing betel nut, this truck driver could process information ahead more quickly (processing speed), notice a fast passing car (divided attention), and ignore the distracting billboards near the road (selective attention). What causes fatigue (e.g., sleep deprivation in our case) may not be critical for obtaining betel nut chewing effect, whereas the extent of fatigue may be important. The betel nut chewing may be effective for people with some degree of fatigue, no matter what causes this fatigue. Future studies could test this hypothesis by manipulating sources that cause fatigue.

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Table 1. Demographic characteristics in the current study. Standard deviations are shown in the parenthesis. DepCh = Deprived sleep/Chewer, DepNch = Deprived sleep/Non-chewer, NorCh = Normal sleep/Chewer, NorNch = Normal sleep/Non-chewer.

	DepCh	DepNch	NorCh	NorNch	
N	16	10	12	12	
Average age (years)	35 (10)	38 (14)	36 (7)	41 (14)	n.s.
Number of female	1	3	1	1	
ESS	6 (3)	6 (3)	5 (3)	7 (3)	n.s.
MEQ	52 (7)	53 (7)	54 (11)	54 (11)	n.s.
Average months of chewing	46 (46)	none	154 (73)	none	DepCh < NorCh ($p < .0001$, partial η^2=.544)
Average days per week of chewing	5 (2)	none	7 (1)	none	DepCh < NorCh ($p < .05$, partial η^2=.210)
Average numbers of	22 (15)	none	50 (52)	none	n.s. ($p = .061$,

betel nuts chewed per day	partial η^2=.129)

Table 2. Mean VSS scores the night before the experiment in which participants chewed betel nut or gum. in the current study. Standard deviations are shown in the parenthesis.

	DepCh	DepNch	NorCh	NorNch
Betel nut	94.3	102.13	92.50	96.67
	(23.6)	(36.37)	(29.35)	(29.13)
Gum	94.14	80.56	103.00	91.42
	(24.65)	(30.62)	(30.07)	(22.63)

Table 3. Mean stimulus presentation time (in ms) in three UFOV subtests for habitual chewers and non-chewers when they chewed betel nut or gum in deprived or normal sleep conditions. Standard errors of mean are shown in the parenthesis.

		UFOV subtest				
		Deprived sleep			Normal sleep	
		1	2	3	1	2
Chewers	Betel nut	19	55	134	18	31
		(2)	(17)	(24)	(2)	(20)
	Gum	50	125	193	22	26
		(13)	(26)	(27)	(15)	(30)
on-chewers	Betel nut	23	74	194	18	46
		(3)	(22)	(30)	(2)	(20)
	Gum	24	43	182	17	44
		(17)	(33)	(34)	(15)	(30)

Betel nut chewing effect on contour and object masking

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Abstract

Betel nut is a common stimulant in many Asian countries, including Taiwan. In the current study, we employ the masking task developed by Enns and Di Lollo (1997) to investigate the effect of betel nut chewing on sensory and attentional processing. The habitual chewers and non-chewers chewed either betel nut or gum before proceeding to the masking task. In the masking task, participants needed to identify a target that was masked by either a contour mask or an object mask. Results show that while betel nut chewing could influence habitual chewers' and non-chewers' attentional processing, it has little effect on sensory processing. More specifically, betel nut chewing concentrates the non-chewers' attentional resources locally on the central target. On the other hand, betel nut chewing could improve the habitual chewers' parafoveal vision, but at the cost of worse central vision. The implications of the results are discussed.

Key Words: betel nut; areca; masking; contour; object

In Taiwan, betel nuts (also known as areca) are common refreshment for people working night shifts. About 1.5 million Taiwanese are betel nut users, with about 30% of these users chewing betel nuts for refreshment purpose (Directorate-General of Budget, Accounting and Statistic, 1999). People place a whole betel nut into their mouths and macerate it by biting for approximately two to three minutes; they then spit out the red chewing saliva of the betel nut.

A betel nut usually consists of three major ingredients: a raw areca nut, slaked lime, and piper betel flower. The slaked lime, which is handled in the form of a paste, is either white lime or red lime. Red lime betel nut, containing green areca fruit, piper betel inflorescence and red lime paste, is the main method of areca consumption in Taiwan (about 70% of all betel nuts). The primary chemical ingredients in betel nuts are alkaloids (i.e., arecoline, arecaidine, guvaeoline, guvacine, and acolidine), polyphenolic compounds, safrole, eugenol, and hydroxychavicol.

Betel nuts have long been chewed by people as a stimulant because of their physiological effects, which include: increased stamina, a general feeling of well- being (Nieschulz, 1967), sweating, salivation, stimulation, cardioacceleration, a slightly drunk feeling and warming of the body and mouth cavity (Hwang, Wang, & Kao, 1993). In general, the physiological effects of betel nut chewing could result from the chemical effects of the betel nut ingredients on the autonomic and central nervous systems (for review, refer to Chu, 2001). For example, Chu (1994a) conducted an electroencephalographic (EEG) study on the effects of betel nut chewing. He showed an increase in both beta and alpha activities and a decrease in theta activity. Both an increase in beta and a decrease in theta indicated an increase in the state of alertness, whereas an increase in alpha indicated relaxation or calmness while chewing betel nut. In addition, these EEG changes were restricted mainly to posterior areas (particularly the occipital areas) for alpha activity, but were more widespread for theta and beta activities.

The changes observed in the central nervous system owing to betel nut chewing plausibly suggest changes in visual information processing. However, as far as we know, very few studies focus on how betel nut chewing influences visual information processing (e.g., Chu, 1994b, Ho & Wang, 2009; Stricherz & Pratt, 1976; Wyatt, 1996). These studies investigate how betel nut chewing influences information processing speed (e.g., Chu, 1994b, Ho & Wang, 2009; Stricherz & Pratt, 1976; Wyatt, 1996) and attentional processing (e.g., Ho & Wang, 2009). Stricherz and Pratt employed a simple reaction time task and found a lengthened reaction time (RT) within the initial five minutes following the ingestion of a betel nut. Chu investigated betel nut effects on both simple and choice RT tasks for the habitual betel nut chewers. Participants performed RT tasks before and during betel nut chewing. Only the choice RT was found to be shorter during betel nut chewing than that before chewing. Wyatt investigated betel nut chewing effects on habitual chewers' performances on a variety of behavioral and physiological measures (the choice RT, eye-hand coordination, digit span, pulse rate and blood pressure). The pulse rate was the only measure reporting an increment after betel nut chewing. Recently, Ho and Wang (2009) examined the effects of betel nut chewing on the useful field of view (UFOV) under sleep deprivation and normal sleep conditions. They reported that betel nut chewing could influence the UFOV size for the habitual chewers, but not for the non-chewers.

Visual information processing refers to a series of stages or modules from the lower level (e.g., the mangocellular and parvocellular pathways) to higher level (e.g., the extrastriate and frontal areas) to process visual stimuli in the real world. In general, these stages or modules form bottom-up sensory processing and top-down attentional processing (Egeth & Yantis, 1997). Previous studies on betel nut chewing effect usually did not distinguish between both processes (e.g., Chu, 1994b; Stricherz & Pratt, 1976; Wyatt, 1996) or only emphasizes the attentional process (e.g., Ho & Wang, 2009). In the current study, our aim was to investigate how betel nut chewing influences sensory processing and attentional processing.

According to the visual information processing hierarchy, sensory processing consists of a series of the lower levels of processing, which could feed-forward the instantaneous and detailed sensory inputs to the higher levels. For example, the retinal ganglion cells, the neurons in lateral geniculate nucleus (LGN) of thalamus and the primary visual cortex can process various visual features of the incoming stimuli (e.g., contrast, location, motion, color, texture and orientation). The visual features extracted by such sensory processes form the sensory representations which we are not consciously aware, easily updated by the instantaneous incoming changes. Two primary pathways, mangocellular and parvocellular pathways (M-pathway and P-pathway hereafter), from the retinal ganglion cells, LGN to the primary visual cortex, have different sensitivity to different physical properties (see Zeki, 1993 for a review). For instance, the M-pathway is sensitive to contrast, motion and orientation; whereas the P-pathway is sensitive to location, color and texture. These two pathways in early vision could interact with each other and transfer visual information to higher-level processing for identification, recognition and action.

The incoming stimuli are not identified and recognized without any limitation. The top-down attentional processing could determine, to a large extent, the degree to which the bottom-up sensory information could be processed to influence thought and behavior (Egeth & Yantis, 1997). For example, the selected sensory representation could benefit from better representational qualities (e.g., contrast, e.g., Carrasco, Ling, & Read, 2004), which result in better recognition (Enns, 2004). The top-down attentional process is closely associated to the notion of working memory capacity (WMC) (for review, refer to Barrett, Tugade, & Engle, 2004; Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005). It has been shown that people with larger WMC could allocate attention more flexibly than do people with lower WMC (Bleckley, Durso, Crutchfield, Engle, & Khanna, 2003).

How does betel nut chewing affect the sensory processing and attentional processing? To investigate this, one must adopt an appropriate task in order to distinguish, to some extent, between the processing of these two. One of the tasks with which to achieve this goal is visual masking (e.g., Atchley, Grobe, & Fields, 2002; Breitmeyer & Öğmen, 2006; Enns, 2004; Enns & Di Lollo, 1997). Visual masking refers to "the reduction of the visibility of one stimulus, called the target, by a spatiotemporally overlapping or contiguous second stimulus, called the mask" (Breitmeyer & Öğmen, 2006, p.2). In this study, we primarily employed two types of masks: contour and object masks, to investigate sensory and attentional processing, respectively.

A contour mask refers to a mask that appears temporally before or after the target stimulus and that forms a contour around the target stimulus, but does not occupy the same spatial positions. Contour masking could be influenced by a variety of physical attributes such as proximity (Enns & Di Lollo, 1997), contrast (Macknik & Livingstone, 1998), and background luminance (Stewart & Purcell, 1974). When the target and mask are in close temporal proximity and when attention is directed to a single target, contour masking is insensitive to attentional distribution. Enns (2004) compared target identification performance when the target appearing randomly at one of eight locations was not cued, cued simultaneously with 100% validity, or was preceded by a pre-cue with 100% validity. The masking effects in the three cue conditions (no-cue, simultaneous cue and pre-cue) were comparable in the range of target-to-mask interval between -50 (mask precedes target) and +50 ms (target precedes mask); thus the focus of attention prior to the target onset (i.e., distributed attention in the no-cue condition, or focused attention in the simultaneous cue and pre-cue conditions) had little influence on these masking effects. The contour masking could be accounted for by the interactions of activity in P-pathway and M-pathway. Inhibitory activity both within pathways and between pathways contributes to such masking (Breitmeyer & Öğmen, 2006).

On the other hand, the object mask refers to a mask that does not act as a mask when used in the manner of a contour mask, but acts as a powerful mask under the spatial uncertainty condition (Enns & Di Lollo, 1997). In the spatial uncertainty condition, the target appears in one of multiple possible locations; thus attention needs to be distributed over all the possible locations in expectation of the target. The object mask is even simpler than the contour mask: for example, the four dots surrounding the target stimulus usually serve as an object mask. Enns and Di Lollo suggested that the representation of four dots substitutes itself for the representation of the target and becomes the focus of object recognition (Brehaut, Enns, & Di Lollo, 1999; Giesbrecht & Di Lollo, 1998). Such object substitution is relatively late in the visual information processing and is a higher-level, attentional processing (Enns, 2004).

The classic study by Enns and Di Lollo (1997; Experiment 1) compared the contour and the object masks and found several important differences. They presented either a contour or an object mask randomly at various values of stimulus onset asynchrony (SOA), ranging from -300 ms (mask preceded target) to +300 ms (target preceded mask). The target is a diamond with a missing corner either on the left or right side. Participants were instructed that their responses should correspond to the missing corner. In one condition, the mask and target were always at the center of the display, called one-location condition; in the other condition, the mask and target could each randomly appear centrally or parafoveally (either left or right side of the center), called three-location condition. The latter condition created spatial uncertainty.

Enns and Di Lollo found that these two masks differ in regard to temporal characteristics, particularly in the one-location condition. In the one-location condition, when a contour mask precedes or is presented simultaneously with a target, the target visibility is still good. When a contour mask trails by 0 to 100 ms, the target visibility decreases; although it increases again when the mask trail durationis lengthened. On the other hand, the object mask did not reduce target visibility in the one-location condition. In the three-location condition (spatial uncertainty), the contour mask reduced target visibility when the target was presented centrally (at the central fixation) and parafoveally (near the central fixation). However, the object mask impaired target visibility only when the target was parafoveal. Degraded attentional distribution at the parafoveal location might make target recognition less efficient (e.g., more comparisons between low-level sensory inputs and top-down re-entrant perceptual hypothesis are needed for correct recognition); the masking thereby occurs when the four dots substitute themselves for the decaying target representation before the target recognition has been completed.

The contour mask is sensitive to the spatial separation of the target and the contour (Breitmeyer & Öğmen, 2006; Growney, Weisstein, & Cox, 1977). Enns and Di Lollo (1997; Experiment 2) manipulated the proximity of the target and the surrounding mask to examine the proximity effect on both types of masks. The contour mask was found to be sensitive to proximity; however the object mask was relatively insensitive to the proximity manipulation. They (Experiment 3) further examined the effect of attentional distribution on masking by manipulating the number of targets. That is, one target could appear on one of three locations (as in the three-location condition in Experiments 1 and 2), or three targets could appear at all three locations. In the latter condition, one mask (either contour or object mask) appeared on one of three targets, indicating which of the three targets required response. Enns and Di Lollo discovered that the target number (one or three) had little effect on the contour masking; however, the object masking was more effective (particularly when the foveal target was reported) when the target number increased to three. When attention was distributed widely over the three targets in the three-target condition, the object masking was obtained when the target was foveal and parafoveal. However, in the three-location condition (only one target appeared), attention was distributed in a gradient mode with more attention at the foveal location and less at the parafoveal locations; thus, the object masking was obtained only in parafoveal target.

In the current study, we applied the masking paradigm used in Enns and Di Lollo (1997; Experiment 1) to examine how betel nut chewing affects chewers' sensory and attentional processing. Atchley, Grobe and Fields (2002) applied the masking paradigm to investigate smoker's sensory and attentional processing; they suggested that nicotine (provided by smoking) could increase the contour masking effect possibly by increasing transient channel activities (e.g., M-pathway); whereas nicotine was not found to influence attention processing. Since the previous studies (e.g., Ho & Wang, 2009) have shown the betel nut chewing effect on attentional processing (e.g., UFOV) for habitual chewers, we hypothesized a reduced object masking for habitual chewers after they chew betel nut. That is, after chewing betel nut, the habitual chewers' attentional resources could be distributed to all of the possible target locations more effectively, thus reducing the object masking.

As for contour masking, if betel nut chewing increases the sensitivity of sensory processing, then the contour masking is increased. For example, the high sensitivity of sensory processing improves the sensory representations of target and mask, leading to stronger inhibition within, and between, P- and M-pathways. On the other hand, it is also possible that betel nut chewing decreases the sensitivity of sensory processing, reducing contour masking. That is, low sensitivity of sensory processing degrades the sensory representations of target and mask, weakening the inhibition within, and between, P- and M-pathways.

Method

Participants

Twelve habitual betel nut chewers (all males) (mean age = 32 years old, SD = 8 years, range = 24 - 51 years old) and 12 non-chewers (three females) (mean age = 31 years old, SD = 8 years, range = 24 - 52 years old) participated in this study. There was no age difference between these two groups ($p > .8$). For the chewers, the average months of chewing betel nut were 74 (SD = 65, range = 3 - 240). The average days per week of chewing were 4 (SD = 2, range = 1 - 7). The average numbers of betel nuts chewed per day were 9 (SD = 7, range = 1 - 30). All participants have normal or corrected-to-normal vision.

Apparatus

We used an IBM-compatible PC with a 17 inch CRT desktop monitor (refresh rate = 85 Hz).

Design

The stimuli were derived from those used by Enns and Di Lollo (1997). All the stimuli were black on the white background (Figure 1). The target was a diamond (0.62˚ in vertical axis) with a missing corner (0.17˚) on either the right or left side. The contour mask was a frame (0.20˚ in width) surrounding the target (1 pixel from the target). The object mask consisted of four squares (0.20˚) that were placed on a notional square (1.0˚ on each side). The minimum separation between neighboring contours in the target and mask was 0.35˚. Two short vertical lines (2.0˚ above and below the location of the central stimulus) served as fixation point.

Insert Figure 1 about here

Each participant underwent two conditions (gum and betel nut conditions) that were counterbalanced across participants so that half of the participants took part in the gum condition first, and the remaining half took part in the betel nut condition first. The gum condition was adopted in order to control for the effect of mere chewing. These two conditions were separated by at most about one week. The laboratory prepared the betel nuts and chewing gum so that all of the participants chewed the same type of betel nuts and chewing gum.

Each participant underwent three tasks in sequence. The tasks were administered in a dim room where each participant leaned his/her chin on a chinrest with a fixed viewing distance of 50 cm from the monitor. In the first task (*target identification* hereafter), the single target was presented centrally on the screen to familiarize the participants with the identification task. There were 36 trials in the first task. In the second task (*one-location condition* hereafter), the target and mask were presented centrally. The contour and object masks appeared equally often and were randomly assigned across trials. There were 160 trials in the second task (10 trials per SOA and mask type). In the third task (*three-location condition* hereafter), the target and mask were each equally often and randomly assigned to three horizontally arrayed locations, one central and two parafoveal (3.0° left and right of center). The target and the mask appeared in the same location on one third of the trials and in the different locations on two thirds of the trials. There were 288 trials in the third task (when both the target and mask are co-located, there are 2 and 4 trials per SOA and mask type for the central and parafoveal target conditions, respectively). The duration of the target and mask was 32 ms in all tasks. The mask was presented at one of eight SOAs (-150, -100, -50, 0, 50, 100, 150, or 300 ms relative to the target). Before each task, there were 20 practice trials.

Procedure

In all tasks, participants were instructed to press the mouse button corresponding to the missing corner of the target (left or right) which flashed briefly. They were also instructed to respond as accurately as possible, without worrying about the response speed. They were allowed to make their best guess if they were not sure of the correct answer. Participants were instructed to fixate at the central location between the vertical lines at the beginning of each trial. In addition to the general instruction, task-specific instructions were provided. In the second task, participants were informed that in addition to the target, one other figure would appear briefly. In the third task, participants were informed that the target and one other figure would each appear randomly at three locations. In each task: after instruction and practice and before the formal trials, participants were required to chew either gum or betel nut for three minutes. After they spit out the gum or betel nut, the formal trials began.

Results and Discussion

Target identification

The analysis of variance (ANOVA) of group (habitual chewers or non-chewers) × treatment (betel nut or gum) was conducted to assess the target identification performance. There were no main or interaction effects, indicating an equivalent ability to identify the target for both groups in both treatments. The accuracy rate for the habitual chewers in betel nut, and gum condition were both .94 and for the non-chewers in betel nut it was .96 and in gum condition, .99.

One-location condition

Accuracy rates are shown in Figure 2. In the following analysis, we computed Cohen's *d* (Cohen, 1988) to estimate the masking effects (Atchley, Grobe & Fields, 2002). To do so, the data from SOAs < 0 was collapsed to serve as a baseline. There is no forward masking when SOA < 0 in the current study, which is similar to the previous study (e.g., Enns & Di Lollo, 2000). Additionally, the previous studies (e.g., Atchley, Grobe & Fields, 2002; Enns, 2004; Enns & Di Lollo, 1997, 2000) have shown maximum masking effects (contour and object masks) at target-to-mask SOA = 50 ms. Therefore, the effect sizes of masking at 50-ms SOA for each chewer group (habitual chewers and non-chewers), each mask type (contour and object masks) and each treatment (betel nut and gum) are reported in the current study (Figure 3). In general, effect size of about 0.3 is regarded as small; 0.5, medium; and 0.8, large.

Insert Figure 2 about here

Insert Figure 3 about here

The contour mask produced strong masking effect in the gum control condition for both habitual chewers (*d* = 2.99) and non-chewers (*d* = 3.25) as observed in the previous studies. The masking effects in the gum control were larger than those observed in Atchley, Grobe and Fields (2002). They found moderate effect for the non-smokers (*d* =.56) and the deprived smokers (*d* =.51), and large effect for the non-deprived smokers (*d* =.83). This discrepancy may be caused by the mean accuracy difference between the baseline and the 50-ms SOA condition. The mean accuracy difference in our case is about 30%, but in Atchley et al. it was about 10% (non-smokers and deprived smokers) to 20% (non-deprived smokers). In effect, our data is more similar to Enns and Di Lollo (1997; Experiment 1), in which the mean difference is about 35%. After participants chewed betel nut, the contour masking effect became smaller among the habitual chewers (*d* = 2.14) and the non-chewers (*d* = 2.05). Although betel nut chewing could reduce the contour masking effect to a small extent, these masking effects were still strong. Therefore, we suggest that betel nut chewing only has small effect on sensory processing.

On the other hand, the object mask produced large masking effects in the gum condition for the non-chewers (*d* = 1.01) and for the habitual chewers (*d* = 1.14). Previous study (e.g., Atchley, Grobe & Fields, 2002) also found object masking in one-location condition, but with medium effect size. The accuracy in their study was similar to that in the current study (about 85-100%), thus the large effect size in our study may be due to the relatively small standard deviations in the current case. Moreover, betel nut chewing reduced the object masking for the non-chewers (*d* = 0.35) and for the habitual chewers (*d* = 0.66). After chewing betel nut, participants could allocate their attentional resources on target location more effectively, thus reducing the object masking. This effect is more profound for the non-chewers.

Three-location condition

Accuracy rates are shown in Figures 4 and 5. In the three-location condition, the data, in which the target and the mask were at different locations, served as the baseline (e.g., Atchley, Grobe & Fields, 2002; Enns & Di Lollo, 1997). That is, when the target and the mask were at different locations, the accuracy rates were collapsed across all SOAs. The univariate F test showed comparable accuracy rates across SOAs when target and mask were at different locations. Baseline performance across groups, mask types, target locations and treatments are shown in Table 1. Effect sizes (Cohen's *d*) of masking were estimated in each condition of group × mask type × target location × treatment. That is, performance in each masking condition (when the target and mask were at the same location at target-to- mask SOA = 50 ms) was compared with the same condition when the target and the mask were at different locations (i.e., baseline). Once again, maximum masking effects were expected at target-to-mask SOA = 50 ms (e.g., Atchley, Grobe & Fields, 2002; Enns, 2004; Enns & Di Lollo, 1997, 2000).

Insert Figure 4 about here

Insert Figure 5 about here

Insert Table 1 about here

To examine the baseline performance difference, the ANOVA of group (habitual chewers or non-chewers) × mask type (contour mask or object mask) × target location (central or parafoveal target) × treatment (betel nut or gum) on accuracy was conducted; the main effects of mask type and target location and interaction effect of group × treatment were obtained. Baseline performance was better for object mask than for contour mask [$F(1,22) = 13.28$, MSe = .004, $p < .001$]. Also, baseline performance was better in central target location than in the parafoveal target location [$F(1,2) = 467.23$, MSe = .007, $p < .0001$]. The group × treatment interaction [$F(1,22) = 4.75$, MSe = .007, $p < .05$] showed that the mean accuracy difference (i.e., accuracy rate in the gum condition minus that in the betel nut condition) was larger among the habitual chewers than in the non-chewers.

The effect sizes of masking at 50-ms SOA are shown in Figure 6. The non-chewers showed small to moderate object masking effects in the gum control condition for the central target ($d = 0.38$) and the parafoveal target ($d = 0.56$). After the non-chewers chewed betel nuts, the object masking effect became negative for the central target ($d = -0.19$) and large for the parafoveal target ($d = 1.04$). On the other hand, the habitual chewers showed about moderate to large object masking effects in the gum control condition for the central target ($d = 0.41$) and the parafoveal target ($d = 1.20$). After chewing betel nut, the habitual chewers showed increased masking effect for the central target ($d = 0.90$) and decreased masking effect for the parafoveal target ($d = 0.64$).

Insert Figure 6 about here

Betel nut chewing improves habitual chewers' attentional distribution in the parafoveal location; however, it deteriorates non-chewers' attentional distribution in the parafoveal location. In the gum control condition, the habitual chewers experience a large object masking effect parafoveally. That is to say, when betel nut is unavailable (gum control), the habitual chewers have fewer attentional resources distributed parafoveally. In contrast, the non-chewers may distribute their attentional resources more effectively across central and parafoveal targets in the gum control condition. After the betel nut is consumed, the habitual chewers could distribute more resources parafoveally (therefore reducing the masking effect parafoveally), but with a cost of fewer resources distributed centrally (therefore increasing the masking effect centrally). In contrast, after the betel nut is consumed, the non-chewers concentrate attentional resources centrally, causing little masking effect centrally and a large masking effect parafoveally. Specifically, when the non-chewers chewed betel nuts, the object masking effect became negative (d = -0.19) for the central target, indicating a better performance in the masking condition. It is unclear why target identification in the masking condition is better than that in the baseline condition, after chewing betel nut. Perhaps, the later mask in the different location from the target (i.e., baseline) quickly diverts participants' attention from the target, leading to worse target identification.

The non-chewers showed moderate to large contour masking effects in the gum control condition for the central target (d = 0.62) and the parafoveal target (d = 1.10). After the non-chewers chewed betel nuts, the contour masking effects became large for the central target (d = 1.16) and the parafoveal target (d = 0.80). The habitual chewers showed large contour masking effect in the gum control condition for the central target (d = 1.34) and the parafoveal target (d = 1.13). After chewing betel nut, the habitual chewers showed large effects for the central target (d = 1.48) and small effects for the parafoveal target (d = 0.38).

A trend of moderate to large contour masking effects was obtained in the gum control condition for the non-chewers and the habitual chewers for the central and parafoveal locations. Interestingly, after chewing betel nut, the contour masking effect for the parafoveal target for the habitual chewers decreased from large to small effect. Recall that the object masking effect for the parafoveal target for habitual chewers also became smaller in the betel nut condition. Possibly, the contour masking is sensitive to attentional distribution to some degree; therefore, the decreased contour masking after chewing betel nut is also due to increased attentional distribution in the parafoveal locations.

In the three-location condition in the current study, attention is primarily allocated in the central location and decays in the parafoveal locations (therefore better target identification in central target location). This gradient attentional distribution might influence the contour masking, particularly when the target is in the parafoveal location, where fewer attentional resources are distributed. For example, Enns (2004; Experiment 1) manipulated attentional distribution by presenting one, four or seven letters in any of eight locations on an imaginary circle. A mask was presented close to one of the target letters and at SOAs between -150 ms to + 600 ms. The target letter denoted by the mask was reported. Enns showed that target identification accuracy decreased with the display size in all forms of backward masking, including the contour mask. That is, when attention is divided among multiple target locations in target expectation, the target representation is likely to be replaced with the incoming mask prior to the completion of target identification, leading to worse target identification (i.e., masking effect). Since attentional distribution among multiple locations could cause the masking effect (e.g., Enns, 2004), it is reasonable to suggest that an increment of attentional resources should reduce the likelihood of masking; recall the finding in the object masking in the three-location condition that attentional resources are increased on the parafoveal locations after habitual chewers consumed betel nuts. Possibly, this increment of attentional resources could also reduce the contour masking effect. Note that attentional distribution in the three-location condition was unable to exclusively account for the contour masking effect (Enns, 2004; Enns & Di Lollo, 1997); otherwise, the contour masking should be simply the same as the object masking. The contour masking in the spatial uncertainty condition (e.g., the three-location condition in our case and the multiple target locations in Enns' (2004) case) is influenced by both sensory and attentional processing (Enns, 2004).

Finally, we examined whether there was forward masking or facilitation in the current study when mask preceded target. The accuracy rates from the negative SOA condition were collapsed for the baseline (the target and mask locations were different) and masking (the target and mask locations were the same) conditions. These two conditions (baseline and masking) were then compared in each condition of group × mask type × target location × treatment. There was no forward masking or facilitation for the habitual chewers and the non-chewers.

General Discussion

In the current study, we applied the masking paradigm (e.g., Atchley, Grobe & Fields, 2002; Enns & Di Lollo, 1997) to investigate how betel nut chewing influences sensory and attentional processing. Sensory processing is assessed primarily by examining target identification in the contour mask condition when the target is presented only centrally (one-location condition). When attention is directed to a single target and when the target and mask are in close temporal proximity, contour masking is insensitive to attentional distribution (Enns, 2004). Attentional processing is assessed primarily by examining target identification in the object mask condition when the target is presented randomly in central and parafoveal locations (three-location condition). Object masking is sensitive to attentional distribution in the three-location condition, particularly the degraded attentional distribution in the parafoveal locations (Enns & Di Lollo, 1997).

There are several important conclusions drawn in the present study. First, both the habitual chewers and the non-chewers have similar and strong contour masking effects in the gum control condition. This indicates that chewing betel nut may have little (if any) long-term effect on sensory processing. Second, betel nut chewing has little immediate effect on sensory processing. Betel nut chewing reduces the contour masking effects to some extent, but these effects are still strong (Cohen's *d* is around two in the betel nut condition).

Third, chewing betel nut has a long-term effect on habitual chewers' attentional processing. In the gum control condition, the habitual chewers have a large object masking effect in the parafoveal location, indicating fewer resources allocated parafoveally. In contrast, the non-chewers could divide attentional resources for both central and parafoveal locations, leading to similar object masking effects. There are at least two possibilities that could account for the object masking effect in the gum condition. The first possibility is that the habitual chewers have fewer total attentional resources when the betel nut is unavailable, thus causing fewer resources distributed parafoveally. On the other hand, it is also possible that the habitual chewers have smaller WMC (Barrett, Tugade, & Engle, 2004; Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005), causing less flexible attentional allocation on the possible target locations (e.g., Bleckley, Durso, Crutchfield, Engle, & Khanna, 2004). These two accounts (fewer total attentional resources and smaller WMC) may not be mutually exclusive of each other. For example, people with smaller WMC may have fewer attentional resources. Future studies could measure habitual chewers' and non-chewers' WMC before and after chewing betel nut and gum to examine whether WMC is modulated by long-term and/or immediate betel nut chewing.

Finally, betel nut chewing has an immediate effect on attentional processing for both habitual chewers and non-chewers. Moreover, betel nut chewing influences parafoveal and central locations differently. In the parafoveal locations, the effect of object masking for the habitual chewers in the betel nut condition (d = 0.64) is similar to that for the non-chewers in the gum control condition (d = 0.56). Also, in the parafoveal locations, the effect of object masking for the habitual chewers in the gum control condition (d = 1.20) is similar to that for the non-chewers in the betel nut condition (d = 1.04). It indicates that betel nut chewing could immediately improve the habitual chewers' parafoveal vision to the extent equivalent to the non-chewers' parafoveal vision in the gum control. This also suggests a possibility that betel nut chewing only raises habitual chewers' parafoveal vision back to, rather than beyond, the level of non-chewers in the gum control. On the other hand, betel nut chewing immediately impairs the non-chewers' parafoveal vision to the extent equivalent to the habitual chewers' parafoveal vision in the gum control.

In the central location, the effects of object masking for both habitual chewers and non-chewers are similar in the gum control condition. Nevertheless, after chewing betel nut, the object masking effect in the central location becomes larger for the habitual chewers, and smaller for the non-chewers, i.e. betel nut chewing immediately enhances the non-chewers' central vision but impairs the habitual chewers' central vision. The object masking in the one-location condition also supports this result. Betel nut chewing reduces the object masking to the small effect for the non-chewers (d = 0.35) and to the moderate effect for the habitual chewers (d = 0.66). After chewing betel nut, the non-chewers' central vision could be enhanced.

The current study and Ho and Wang's (2009) both suggest that betel nut chewing could enhance the habitual chewers' processing of visual stimuli away from the central fixation (i.e., the parafoveal target in the current study and the peripheral target in Ho and Wang (2009)). Ho and Wang (2009) found that betel nut chewing could influence habitual chewers' (but not the non-chewers') UFOV after one night of sleep deprivation. When the habitual chewers chewed betel nut after one night of sleep deprivation, they could quickly identify the central target presented alone, divide their attention to include the peripheral target, and detect the peripheral target embedded in the distracters while identifying the central target. Namely, the habitual chewers could process peripheral information more effectively after chewing betel nut, in relation to the gum condition. In the three-location condition in the present study, the habitual chewers' parafoveal vision was enhanced in the betel nut condition, also suggesting more effective parafoveal information processing.

However, Ho and Wang (2009) found the betel nut chewing effect only in the sleep deprivation condition, not in the normal sleep condition, as in the current study did. The different distances of the target from the central fixation in these two studies may account for this difference. The peripheral target in Ho and Wang (2009) was distanced 13.5° away from the central fixation, and the parafoveal target in the current study was 3.0° away. Betel nut chewing may enhance the visual field in a gradient mode, with more attentional resources locally surrounding the central fixation (i.e., parafoveal vision) and fewer attentional resources distributed far away from it (i.e., peripheral vision). When the habitual chewers have normal sleep, the extent of the parafoveal target enhancement is larger than that of the peripheral target, thus it is easier to detect the attentional distribution on the parafoveal, rather than the peripheral, target.

To conclude, betel nut chewing could influence the chewers' attentional processing, but only has little effect on sensory processing. Furthermore, chewing betel nut concentrates the non-chewers' attentional resources locally on the central target, suggesting possible tunnel vision. Therefore, after chewing betel nut, the non-chewers may pay more attention to the foveal information (e.g., the car ahead of the driver) and ignore the parafoveal information (e.g., a fast passing car), which may raise the likelihood of an accident. On the other hand, chewing betel nut could improve the habitual chewers' parafoveal vision, but at the cost of worse central vision. Therefore, after chewing betel nut, t habitual chewers could pay more attention to the parafoveal information, reducing the likelihood of accidents occurring. However, although betel nut chewing improves the habitual chewers' parafoveal vision, it only raises their parafoveal vision back to the level of non-chewers in the gum control.

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Table 1: Baseline performance (accuracy rate) across groups, mask types, target locations and treatments. Standard deviations are shown in the parenthesis.

	Contour				Object			
	Betel		Gum		Betel		Gum	
	Central	Peripheral	Central	Peripheral	Central	Peripheral	Central	Peripheral
Habitual chewers	0.89 (0.10)	0.59 (0.08)	0.93 (0.07)	0.64 (0.07)	0.92 (0.07)	0.67 (0.08)	0.92 (0.10)	0.68 (0.08)
Non-chewers	0.93 (0.07)	0.67 (0.08)	0.87 (0.08)	0.66 (0.08)	0.94 (0.06)	0.70 (0.12)	0.90 (0.10)	0.70 (0.08)

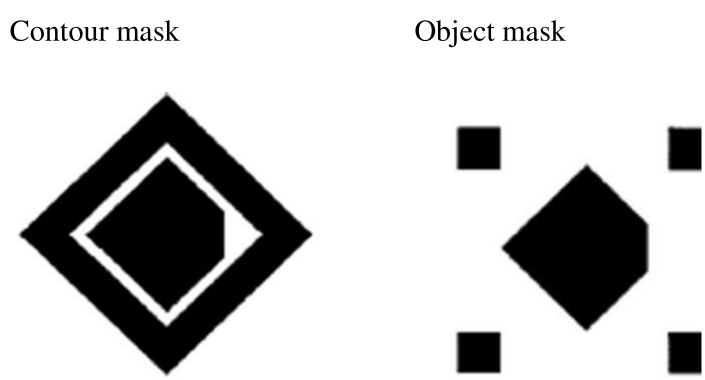
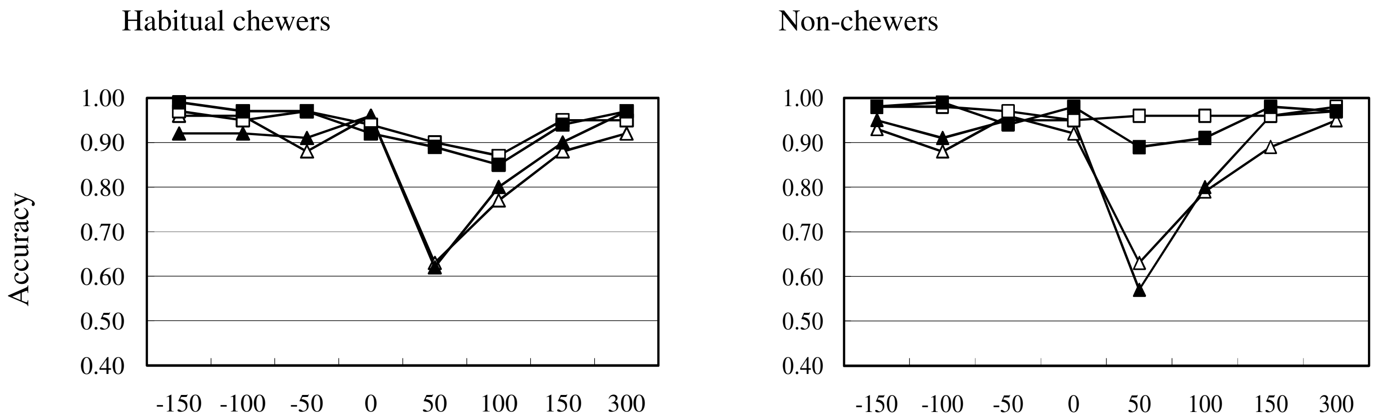


Figure 1: The contour and object masks in the current study. The target is a central diamond with a missing corner.



Target-to-Mask SOA (ms)

Figure 2: Accuracy rate for each chewer group, each mask type and each treatment in the one-location condition. Diamond. Triangles represent the contour masking and rectangles represent the object masking. The open symbols represent the betel nut condition and the closed symbols represent the gum condition.

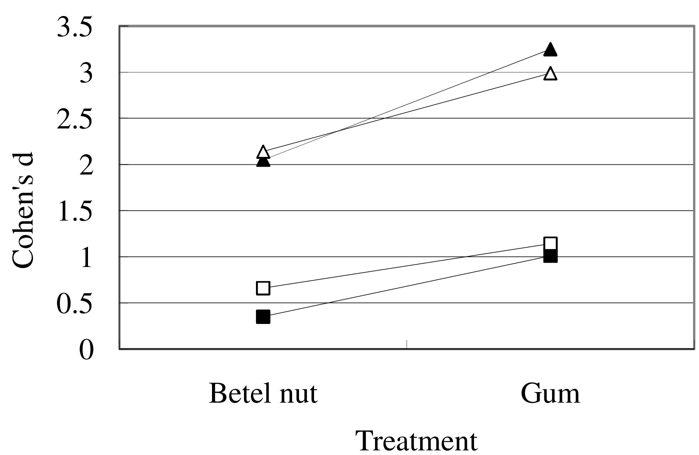


Figure 3: Effect sizes of masking at 50-ms SOA for each chewer group, each mask type and each treatment. Triangles represent the contour masking and rectangles represent the object masking. The open symbols represent the habitual chewers and the closed symbols represent the non-chewers.

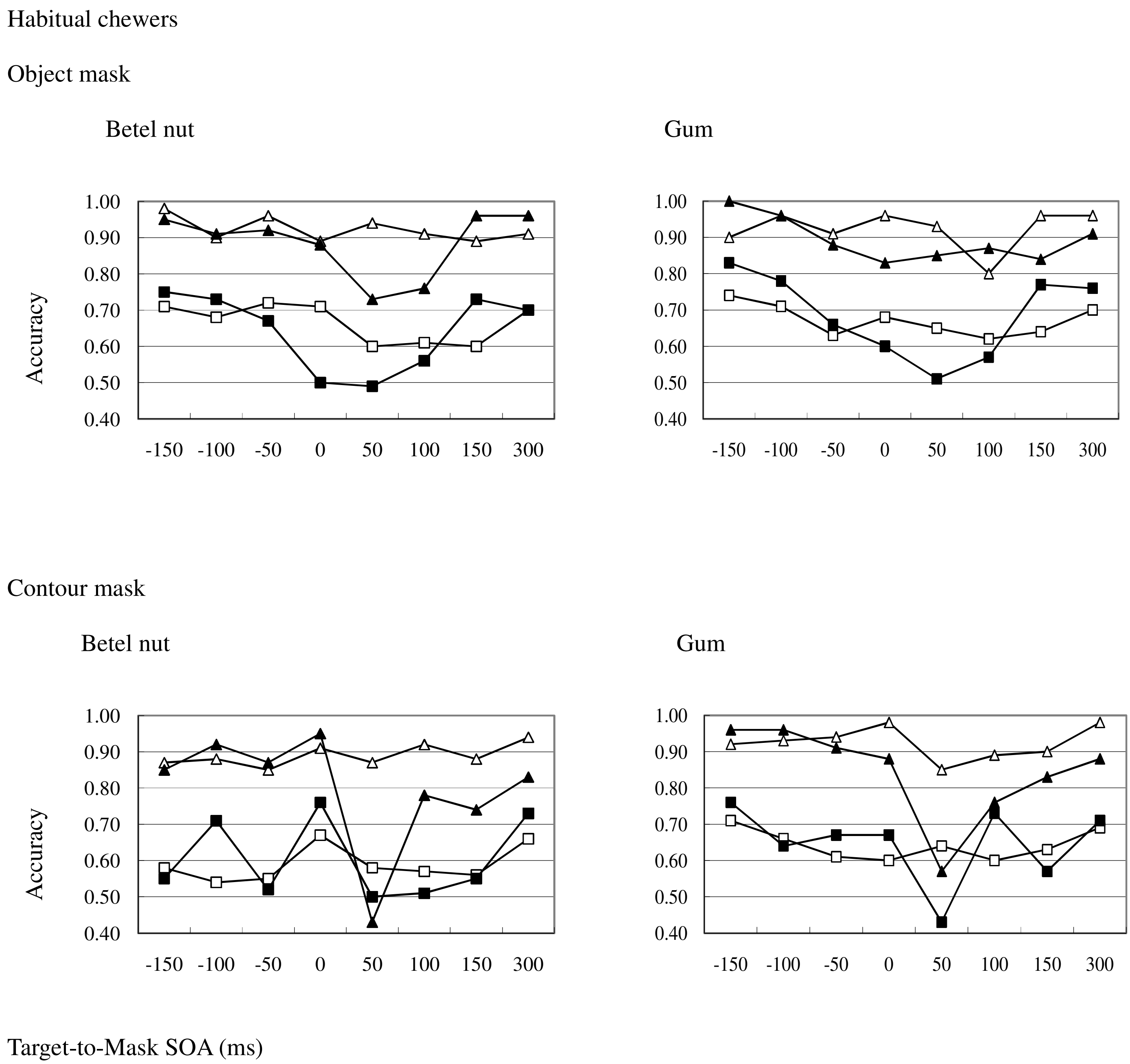
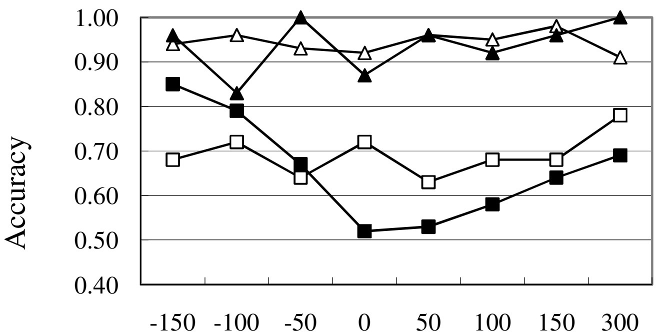


Figure 4: Accuracy rate for the habitual chewers for each mask type and each treatment in the three-location condition. Triangles represent the central target and rectangles represent the peripheral target. The open symbols represent the performance when the target and mask are in different locations and the closed symbols represent the performance when the target and mask are in the same locations.

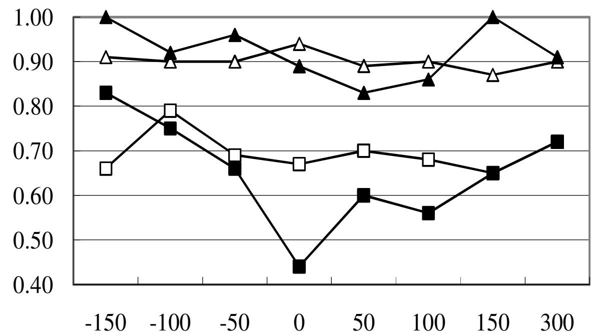
on-chewers

bject mask

Betel nut

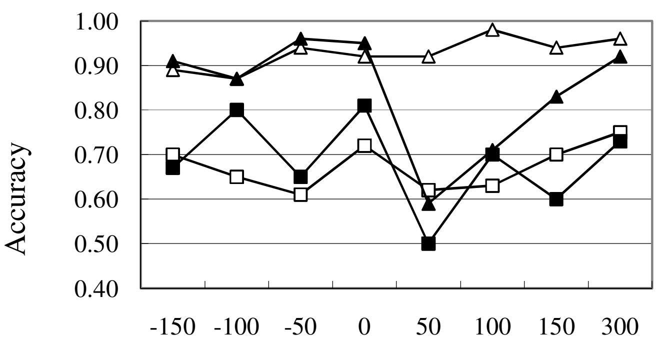


Gum

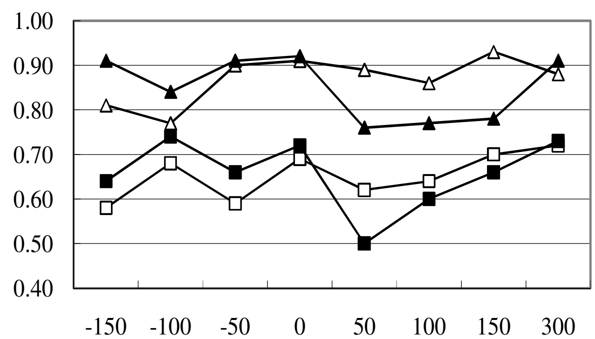


ontour mask

Betel nut



Gum



arget-to-Mask SOA (ms)

igure 5: Accuracy rate for the non-chewers for each mask type and each treatment in the three-location condition. ıngles represent the central target and rectangles represent the peripheral target. The open symbols represent the formance when the target and mask are in different locations, and the closed symbols represent the performance en the target and mask are in the same locations.

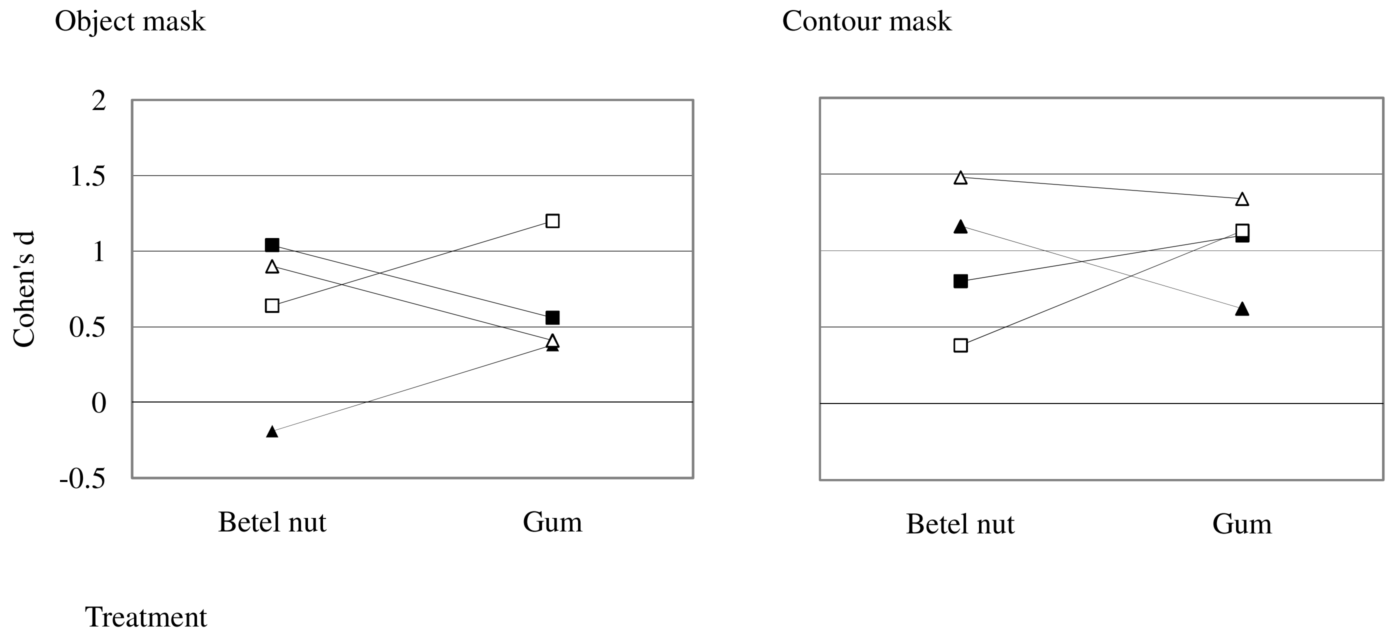


Figure 6: Effect sizes of masking at 50-ms SOA for each chewer group, each mask type, each target location, and each treatment. Triangles represent the central target and rectangles represent the parafoveal target. The open symbols represent the habitual chewers and the closed symbols represent the non-chewers.

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計畫成果自評

本研究已經依照計畫內容，完成所有實驗，已經達到預期目標。更進一步，計畫內容中的實驗一（與去年計畫合併）與實驗二已經寫成兩篇英文論文。本研究提供重要且缺乏的行為實證資料，來支持檳榔對注意力之影響（例如慣嚼檳榔者會因為嚼檳榔而能夠更有效率地注意到周遭之視覺訊息)。而對從未嚼食者來說，檳榔反而會使其注意力效率下降。未來，我們希望能夠增加生理指標（例如血壓、心跳、皮膚電阻等)來客觀地量測嚼食檳榔所導致的生理改變以及其視覺注意力之改變(例如有效視覺區的改變等)。更宏觀地說，我們希望未來能夠探討嚼食檳榔對視覺注意力與視知覺各面向的影響。我們已經申請到 2009-2012 的三年國科會經費（檳榔嚼食者之注意力系統：導向、抑制與持續性注意力，98-2410-H-040-005-MY3），希望能更檢驗重要但沒有行為實證資料的議題。

參加 2009 年 European Congress of Psychology (ECP) 的三篇摘要

Can betel nut chewing affect the UFOV size after sleep deprivation?

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Betel nut is a common refreshment in Taiwan. However, few behavioral studies focusing on the betel nut chewing effects were reported. Two experiments examined the effects of betel nut chewing on the useful field of view (UFOV) under sleep deprivation. The UFOV refers to a spatial area that is functional or useful for the ongoing task(s). Attentional resources are allocated to this spatial area in order to process the incoming information. When the size of the UFOV shrinks, fewer stimuli within the UFOV are further processed. The size of the UFOV can be determined by the speed of information processing, proficiency in dividing attention, and ability to ignore irrelevant distractions. We reported that betel nut chewing could broaden the UFOV size for the habitual chewers, but not for the non-chewers. Specifically, betel nut chewing can facilitate the ability to ignore irrelevant distractions under sleep deprivation conditions for the habitual chewers.

Key Words: betel nut, areca, sleep deprivation, useful field of view

Betel nut chewing effect on sensory and attentional masking

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Betel nut is a common refreshment in Taiwan. We examined if betel nut chewing could affect chewers' lower-level sensory (e.g., precortical M- and P-pathway) and/or higher-level attentional processings (e.g., cortical signal feedback). We adopted contour and object masks to investigate sensory and attentional processings respectively (e.g., Atchley, Grobe & Fields, 2002). Contour masking is sensitive to proximity, but insensitive to attentional distribution. However, the object masking is not sensitive to proximity, but sensitive to attentional distribution. Betel nut chewers showed weak and comparable object masking after they chew betel nut or gum. Also, betel nut chewers showed weak contour masking after they chew betel nut. However, after they chew chewing gum, they showed strong contour masking when target-mask SOA was over 50 ms. We suggested that betel nut might not increase attentional resources, whereas might reduce the sensory processing. Future study will examine the chronic effect of betel nut chewing.

Key Words: betel nut, areca, contour, object, masking

Betel nut chewing effect on UFOV and sustained attention

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Betel nut is a common refreshment in many countries, including Taiwan. Betel nut plays a role in central nervous system associated to many aspects of attention. We investigated if betel nut chewing influences the useful field of view (UFOV) and sustained attention (SA). The UFOV is a spatial area that is functional or useful for the ongoing task. The UFOV consists of three dimensions: processing speed, divided attention, and selective attention. SA refers as the ability to self-sustain mindful, conscious processing of stimuli whose repetitive, non-arousing qualities would lead to habituation and distraction to other stimuli. We adopted sustained attention to response task (SART) to assess sustained attention. We reported that chewing betel nut could reduce the UFOV in comparison to chewing gum. However, chewing gum or betel nut leads to equivalent performance in SA. Future study will compare the non-chewers to examine the chronic effect of betel nut chewing.

Key Words: betel nut, areca, useful field of view, sustained attention

出席國際學術會議心得報告

第 11 屆歐洲心理學研討會是由 EFPA (The European Federation of Psychologists Association)贊助，由 Norwegian Psychological Association 主辦，於 7 月 7 日至 10 日在挪威 Oslo 舉辦。此研討會為每兩年舉辦一次，上次（2007）是在捷克舉辦，下次（2011）之舉辦地點為土耳其的 Istanbul。此研討會內容涵蓋心理學各個領域，從生理、社會、知覺，一直到諮商、臨床等。此研討會邀請多位演講者以及 symposia，除了以上，尚有多個口頭以及海報場次，讓人目不暇給。以監獄實驗著名的社會心理學家 Zimbardo 也蒞臨演講，甚為有趣。

由於研討會資訊繁多，我主要挑選與我近來研究主軸相關的研究，來進一步瞭解，我的研究主軸主要在選擇性注意力、情緒與注意力以及短期記憶與注意力。注意力與記憶之間的關係，長久以來一直是視知覺研究之重點，這次研討會也以此為主題探討了視覺的 repetition priming。演講很精彩，可惜知名以色列學者 Dominique Lamy 因故取消無法參加。Campana 以 TMS 發現 prime 之特徵（e.g., motion direction 和 spatial location）在大腦中相關的區域處理，例如 motion direction 就在 motor area 處理。除了這些以廣為人之的腦區外，其他與作業有關的腦區也會激發。此外，他們也發現 priming 可能夠發生在更高階的處理歷程，例如 size of attentional focus。Sneve 以 event-related fMRI 發現 V1 對 visual short-term memory 之重要性。受試者在做 spatial frequency discrimination task 的同時，需要記憶一個無關的 mask 的 spatial frequency。當 mask spatial frequency 與 discrimination task 中的 target spatial frequency 類似時，作業的正確率下降（memory mask effect）。而同時 V1 的血流量也下降。作者推論當 retrieve mask from visual STM，V1 會產生側抑制，去抑制競爭的 target spatial frequency。

行政院國家科學委員會補助專題研究計畫 ■ 成 果 報 告
□期中進度報告

嚼食檳榔對睡眠剝奪者之有效視覺區之影響

計畫類別：■ 個別型計畫　　□ 整合型計畫
計畫編號：NSC 97-2410-H-040-010-
執行期間：97 年 8 月 1 日至 98 年 7 月 31 日

計畫主持人：何明洲
共同主持人：王進崑
計畫參與人員：
李碩衡、施雅羚、王威中

成果報告類型(依經費核定清單規定繳交)：■精簡報告　□完整報告

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執行單位：中山醫學大學

中　華　民　國　98　年　9　月　15　日

前言

今年之研究計畫總共撰寫成兩篇論文，目前均正在審稿當中。這兩篇論文之標題分別為 Can Betel Nut Chewing Affect the UFOV Size? 以及 Betel nut chewing effect on contour and object masking。前者是由今年之計畫以及去年之計畫之研究成果，合併寫成。目前正在期刊 Ergonomics 審稿中。後者是由今年之成果撰寫而成，目前正在 British Journal of Psychology 審稿中。以下分別列出這兩篇論文之英文摘要與論文全文，以供參考。

Can Betel Nut Chewing Affect the UFOV Size?

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Abstract

Betel nut is a common stimulant in many Asian countries. However, few behavioral studies reported the betel nut chewing effects on cognition. We examined the effects of betel nut chewing on the useful field of view (UFOV) under deprived sleep and normal sleep conditions. After one night of normal sleep or deprived sleep, habitual chewers and non-chewers chew either betel nut or gum before proceeding to the UFOV subtests. In the UFOV subtests, participants need to identify the central target, divide their attention to the peripheral target, and detect the peripheral target embedded in the distractors while identifying the central target. We reported that betel nut chewing can affect the UFOV of the habitual betel nut chewers when their sleep was deprived for one night. The implication for people often chewing betel nut for refreshment during long-hour working is discussed.

Key Words: betel nut, areca, sleep deprivation, useful field of view

報告內容

In Taiwan, betel nuts (also known as areca) is a common refreshment for people working at night shifts. For example, many long-distance overnight bus and truck drivers chew betel nuts for refreshment. About 1.5 million Taiwanese are betel nut users, with about 30% of these users are chewing betel nuts for refreshment purpose (Directorate-General of Budget, Accounting and Statistic, 1999). People place a whole betel nut into their mouth and macerate it by biting for approximately two to three minutes; they then spit out the red chewing saliva of the betel nut.

A betel nut usually consists of three major ingredients: a raw areca nut, slaked lime, and piper betel flower. The slaked lime, which is handled in the form of a paste, is either white lime or red lime. Red lime betel nut, containing green areca fruit, piper betel inflorescence and red lime paste, is the main method of areca consumption in Taiwan (about 70% of all betel nuts). The primary chemical ingredients in betel nuts are alkaloids (i.e., arecoline, arecaidine, guvaeoline, guvacine, and acolidine), polyphenolic compounds, safrole, eugenol, and hydroxychavicol.

Betel nuts have long been chewed by people as a stimulant because of their physiological effects, which include: increased stamina, a general feeling of well-being (Nieschulz, 1967), sweating, salivation, stimulation, cardioacceleration, a slightly drunk feeling and warming of the body, and mouth cavity (Hwang, Wang, & Kao, 1993). Many studies have shown that betel nut chewing can heighten the state of alertness (e.g., Cawte, 1985; Chu, 1993, 1994a, 1994b, 2001; Chu & Chang, 1994; Haubrich, & Watson, 1972; Molinengo, Fundaro, & Cassone, 1988; Rinaldi, & Himwich, 1955; Wyatt, 1996); additionally, such effects occur only for habitual betel nut chewers. According to Chu and Chang's survey, the first three effects experienced by the new chewers were dizziness, hot sensation, and palpitation. Contrarily, the first three effects for habitual chewers were: heightened alertness, hot sensation, and palpitation.

Evidence that supports the refreshment effect of betel nut chewing comes primarily from physiological studies. In general, the physiological effects of betel nut chewing may result from the chemical effects of the betel nut ingredients on the autonomic and central nervous systems (for a review, refer to Chu, 2001). Chu (1994a) conducted an electroencephalographic (EEG) study on the effects of betel nut chewing. Results showed an increase in both beta (associated with alertness) and alpha (associated with relaxation) activities and a decrease in theta (associated with drowsiness) activity. Both an increase in beta and a decrease in theta indicated an increase in the state of alertness, whereas an increase in alpha indicated a relaxation or calmness while chewing betel nut. In addition, these EEG changes were restricted mainly to posterior areas (particularly the occipital areas) for alpha activity, but were more widespread for theta and beta activities.

Chu (1993) investigated the time course of betel nut chewing effect by measuring three groups of participants' (chronic, occasional and non-chewers) cardiovascular changes (heart rate and blood pressure). Both heart rate and blood pressure were measured 5 minutes before betel nut chewing and every 2 to 5 minutes during and after chewing, lasting for about one hour. The chewing effects on heart rates in three groups were immediate and reached a peak within 4 to 6 minutes of chewing. The cardio-accelerating responses lasted for an average of 16.8 minutes. However, neither systolic nor diastolic blood pressures were affected in chronic and occasional groups. Only the non-chewers showed a significant increase solely in systolic blood pressures.

Contrary to the fruitful literatures on the physiological effects of betel nut, very few studies focusing on the behavioral measures of betel nut chewing effects were reported. In addition, results of these behavioral studies were mixed (e.g., Chu, 1994b, Stricherz & Pratt, 1976; Wyatt, 1996). Stricherz and Pratt employed a simple reaction time task and found a lengthened reaction time (RT) within the initial five minutes of the ingestion of a betel nut. Chu investigated betel nut effects on both simple and choice RT tasks for the habitual betel nut chewers. Participants performed RT tasks before and during betel nut chewing. Only the choice RT was found to be shorter during betel nut chewing than that before chewing. Wyatt investigated betel nut chewing effects on habitual chewer's performances on a variety of behavioral and physiological measures (the choice RT, eye-hand coordination, digit span, pulse rate and blood pressure). The pulse rate was the only measure reported increment after betel nut chewing.

In the current study, we do not intend to disentangle the mixed results of betel nut effects on behavioral studies. We aim to focus on whether betel nut chewing could improve visual attention under normal and deprived sleep. To our knowledge, no studies have provided behavioral data on the betel nut chewing effect on visual attention under sleep deprivation. One of the important indexes of visual attention is the useful field of view (UFOV). The UFOV refers to a spatial area that is functional or useful for the ongoing task(s) (Sanders, 1970). Attentional resources are allocated to this spatial area in order to process the incoming information. Any stimuli within the UFOV would receive further processing; however, any stimuli falling outside of the UFOV would receive only basic preattentive processing (e.g., physical properties, viz., color and texture). That is, when the size of the UFOV shrinks, fewer stimuli within the UFOV are processed further.

Measures of the UFOV typically involve three well-documented components: speed of identifying a central target alone (hereafter *processing speed*), dividing attention between central and peripheral targets presented simultaneously (hereafter *divided attention*), and localization of a peripheral target embedded in distractors while identifying a central target (hereafter *selective attention*) (for a review, see Ball, Roenker, & Bruni, 1990; Sekuler & Ball, 1986). The size of the UFOV varies across situations. The size of the UFOV is decreased by the slowing of visual information processing (Ball, Beard, Miller, & Roenker, 1987; Leibowitz & Appelle, 1969). When the central task demand increases (Chan & Courtney, 1993, 1994; Rantanen & Goldberg, 1999; Sekuler & Ball, 1986; William, 1982), a peripheral target localization or detection will be impaired. The UFOV size deteriorates when the peripheral target is embedded in the background distractors (Drury & Clement, 1978; Scialfa, Kline, & Layman, 1987; Sekuler & Ball, 1986). Furthermore, when the similarity of a peripheral target and the background distractors increase, the size of UFOV will be further reduced (Ball, Roenker, & Bruni, 1990).

The size of the UFOV also varies across individuals. Individuals with more impaired components of the UFOV (i.e., processing speed, divided attention and selective attention) suffer from further reduction of the UFOV size (Ball & Owsley, 1992). Many have shown that sleep deprivation deteriorates the components that determine the UFOV size (e.g., Pilcher & Huffcutt, 1996; Rogé, Pébayle, Hannachi & Muzet, 2003; Williamson & Feyer, 2000). For example, sleep deprivation decreases participants' ability to identify a critical signal in the central visual field (Williamson & Feyer, 2000). In addition, the divided attention task was impaired and reached levels equivalent to the maximum alcohol dosage given to participants (Williamson & Feyer, 2000). Moreover, the UFOV, rather than eye health and visual sensory function, has direct effects on accident frequency (Clay, et al., 2005; Cross, et al., 2009; Owsley & McGwin, 1999; Leat & Lovie-Kitchin, 2006). Additionally, visual sensory function and eye health have indirect effects on car crash frequency mediated by UFOV.

Because many habitual chewers chew betel nut for refreshment when they need to stay awake overnight, and previous studies have shown that sleep deprivation reduces the UFOV, we test whether betel nut chewing could affect the UFOV size under deprived sleep. A normal sleep condition (without sleep deprivation) was included as a baseline. Physiological studies have reported that the ingredients of betel nuts are able to increase stamina and alertness for the chewers (e.g., Chu, 2001). Thus, we hypothesize that betel nut chewing can affect the UFOV size measured in terms of the three well-developed components (processing speed, divided attention and selective attention). Further, since previous studies showed that sleep deprivation could deteriorate UFOV, we hypothesize a larger betel nut chewing effect under the sleep deprivation condition in comparison to the normal sleep condition. Finally, because previous survey (e.g., Chu & Chang, 1994) showed different chewing experiences for the new chewers and habitual chewers, we hypothesize that these betel nut effects on the UFOV might only occur to the habitual betel nut chewers, rather than the non-chewers.

Method

<u>Participants</u>

Four different groups of participants were recruited: deprived sleep/chewer (DepCh), deprived sleep/non-chewer (DepNch), normal sleep/chewer (NorCh), and normal sleep/non-chewer (NorNch). All participants had a low level of drowsiness (scores < 11) in daily life on the Epworth sleepiness scale (ESS; Johns, 1991, 1992). All participants were morning (scores between 59 and 86) or intermediate people (scores between 42 and 58) types on the Morning-Evening Questionnaire (MEQ; Horne & Ostberg, 1976). All participants have normal or corrected-to-normal vision. None of them work night shifts. All had had a normal night of sleep before the experiment. All non-chewers had never chewed betel nuts. Participants with deprived sleep had not used betel nut or any food or drink containing alcohol or caffeine during the night in the laboratory. Participants with normal sleep had not used betel nut or any food or drink containing alcohol or caffeine during the daytime.

<u>Apparatus</u>

We used an IBM-compatible PC with a 17 inch touch screen CRT desktop monitor (refresh rate = 60 Hz).

Design and Procedure

Each participant underwent two conditions of experiments (chewing gum and betel nut conditions); these conditions were counterbalanced across participants so that half of the participants took part in the chewing gum condition first, and the remaining half took part in the betel nut condition first. The chewing gum condition was adopted in order to control for the effect of mere chewing. These two conditions were separated by about one week. The laboratory prepared the betel nuts and chewing gum so that all the participants chewed the same type of betel nuts and chewing gum.

For the sleep deprivation groups (both DepCh and DepNch groups), participants were requested to stay awake all night in the company of the experimenter. Each participant arrived at the laboratory at about 22h00, the night before the UFOV test. Participants could bring quiet activities with them; the luminance in the laboratory was 310 lux. After the participants arrived at the laboratory, they needed to fill out the Verran and Snyder-Halpern sleep scale (VSS; Simpson, Lee & Cameron, 1996; Snyder-Halpern & Verran, 1987) in order to evaluate their sleep quality the night before the experiment. In order to evaluate participants' sleepiness degree overnight, the Stanford sleepiness scale (SSS; Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973) was administered every hour from 22h00 to 7h00. The following morning at about 7h00, each participant chewed either a betel nut or a chewing gum before the UFOV test. In either the betel nut or chewing gum condition, participants chewed one material (betel nut or chewing gum) for 3 minutes and then spit it out before they began the UFOV test.

For the normal sleep groups (both NorCh and NorNch groups), each participant arrived at the laboratory at about 18h00. After the participants arrived at the laboratory, they needed to fill out the VSS. Then each participant chewed either a betel nut or a chewing gum before the UFOV test. Participants chewed one material (betel nut or chewing gum) for 3 minutes and then spit it out before they began the UFOV test.

The functional field of view was assessed by the UFOV software (Visual Awareness, Inc., Birmingham, AL), consisting of three subtests that measure the processing speed (Subtest 1), divided attention (Subtest 2) and selective attention (Subtest 3) respectively. These three subtests were presented sequentially (Subtest 1 first, then Subtest 2, and finally Subtest 3). The UFOV test was administered in a dim room where each participant leaned his/her chin on a chinrest with a fixed viewing distance of 50 cm from the monitor.

Subtest 1 consisted of a sequence of stimuli in which the central outlined rectangle (3.3° in width and 4° in height) was presented, followed by a single target (a silhouette of either a car or a truck with 2.3° in width and 1.7° in height) with varied presentation time from 16 to 500 ms, which was followed by a 1-s random dot mask, the size of the display screen. The mask was proceeding with a response screen in which both the car and truck icons were presented always to the right and left of fixation. Participants were instructed to discriminate between these two possible targets and responded to the target by touching the stimulus icon displayed on the touch monitor without time pressure.

For each subtest, the UFOV software adjusts the length of stimulus presentation in milliseconds if needed. This adjustment procedure is a "two up, one down" adaptive staircase in which two successive correct responses to the central target in Subtest 1 (or both central and peripheral targets in Subtests 2 and 3) result in a shortened stimulus presentation duration for the next trial; an incorrect response (to either a central or peripheral target) results in a lengthened stimulus presentation duration for the next trial. The procedure of adjusting the perceptual threshold was continued until a stable estimate of 75% correct rate was calculated. Scores yielded from each subtest of the UFOV were expressed in terms of *stimulus presentation time*. Longer stimulus presentation time (i.e., stimulus is displayed on the screen for a longer period of time for correct responses) indicates that more time is needed to process the stimuli to reach the performance criteria.

In Subtest 2, in addition to identifying the central target as Subtest 1, participants needed to detect a simultaneously presented peripheral target, which was always a silhouette of a car. The center-to-center distance between the central and peripheral targets was 13.5°. This peripheral target appeared randomly at one of eight different peripheral locations along eight radial spokes (4 cardinal and 4 oblique). The center-to-center distance between two nearest peripheral locations was 9.1°. As Subtest 1, participants responded by touching the monitor first to discriminate which target was seen in the center. Then, they needed to localize the peripheral target; the identification of this target was unimportant. The response screen for localization judgment consisted of eight boxes at the eight possible peripheral target locations linked to the central box by eight radial lines. Participants were instructed to touch one of the eight boxes on the monitor display to indicate its location.

The tasks in Subtest 3 were the same as those in Subtest 2 (i.e., central target discrimination and peripheral target localization tasks); however, distractors (upside-down outlined triangles with each side length of 2.3°) were added to the remaining area of the screen. These distractors were arranged in three imaginary circles with three different radii (4.3°, 8.8°, and 12.8°). In each imaginary circle, the center-to-center distance between two nearest triangles was 3.8°. There were 8 distractors in the inner circle and 16 in the middle circle. The peripheral target was presented in one of eight locations (as Subtest 2) in the outer circle, resulting in 23 distractors in the outer circle. In each subtest, four practice trials were presented before the formal trials. In general, the UFOV test lasts for about 15 minutes or less.

The UFOV test used in the current study differed from the previous paradigm (e.g., Sekuler & Ball, 1986) in that the current test did not manipulate the spatial distance between the central and peripheral targets, and the response time was not the primary dependant variable. The current UFOV test has been shown to have high test-retest reliability ($r = .735$) and high correlation with the previous paradigm manipulating spatial distance and recording response time ($r = .746$) (Edwards, Vance, Wadley, Cissell, Roenker, & Ball, 2005). Also, the current UFOV test takes less time (15 minutes or less) than the past paradigm (about 20 to 30 minutes). The un-speeded response in the current UFOV test also allows controlling for the possible confounds from post-perceptual stages (e.g., decision making and motor function). Thus, the current UFOV test is appropriate to assess participants' functional field of view.

Results and Discussion

Demographic Characteristics

Demographic characteristics are shown in Table 1. An analysis of variance (ANOVA) on the frequency and number of betel nut chewing showed that the chewers in the normal sleep condition have more months of betel nut chewing history ($p < .0001$, partial η^2=.544) and more days per week of chewing ($p < .05$, partial η^2=.210) than those in the sleep deprivation condition. The average number of betel nuts chewed per day between these two conditions was marginally significant ($p = .061$, partial η^2=.129). To examine whether these differences are critical for the UFOV performances, the average months of chewing, the average days per week of chewing and the number of betel nuts chewed per day are correlated to the three UFOV subtests in the betel nut condition and in the gum condition. Analysis showed that the frequency and number of betel nut chewing are not sufficient to account for the UFOV performance in our case. Only the average months of chewing is weakly correlated to Subtest 2 (divided attention) in the gum condition ($p = .049$, Pearson's $r = -.375$). We will discuss these findings in General Discussion. None of other variables (age, ESS, and MEQ) showed between-group differences.

Insert Table 1 about here

Sleepiness Scores

For the DepCh group, regression analysis showed that SSS scores increased as the hours that participants stayed awake in the laboratory increased in both conditions (in chewing gum condition, $\beta = .718$; in betel nut condition, $\beta = .694$; both p's < .0001). In both conditions, the mean SSS score was 1 ("feeling active and vital; alert; wide awake") at 22h00 (in betel nut condition, SD = .7; in chewing gum condition, SD = .6) and was 5 ("fogginess; beginning to lose interest in remaining awake; slowing down") at 7h00 (in betel nut condition, SD = 1.5; in chewing gum condition, SD = 1.3).

For the DepNch group, regression analysis showed that SSS increased as the hours that participants stayed awake in the laboratory increased in both conditions (in the chewing gum condition, β= .745; in the betel nut condition, β= .691; both p's < .0001). In the betel nut condition, the mean SSS score was 1 ("feeling active and vital; alert; wide awake") at 22h00 (SD = .7) and was 5 ("fogginess; beginning to lose interest in remaining awake; slowing down") at 7h00 (SD = 1.6). In the chewing gum condition, the mean SSS score was 2 ("functioning at a high level, but not at peak; able to concentrate") at 22h00 (SD = 1.1) and was 6 ("sleepiness; prefer to be lying down; fighting sleep; woozy") at 7h00 (SD = 1.3).

The mean VSS scores for all four groups are shown in Table 2. An ANOVA of 2 (sleep condition: deprived sleep or normal sleep) × 2 (betel nut use: chewer or non-chewer) × 2 (treatment: betel nut or gum) on VSS showed interactions of sleep condition x treatment ($p < .05$, partial η^2=.092) and betel nut use x treatment ($p < .005$, partial η^2=.161). Further analysis on the sleep condition x treatment revealed no VSS difference between betel nut and gum conditions for both deprived sleep and normal sleep groups (all p's > .1). On the other hand, analysis on the betel nut use x treatment showed a VSS difference between betel nut and gum conditions for the non-chewers (p < .05). This VSS difference indicates that non-chewers had better sleep quality the night before the experiment in which they chewed betel nut than before they chewed gum.

To assess whether the VSS is critical for the UFOV performances, the VSS in the betel nut condition is correlated to three UFOV subtests in the betel nut condition. Also, the VSS in the gum condition is correlated to three UFOV subtests in the gum condition as well. None of these correlations reach the significant level (all *p*'s > .05). That is to say, in the current study, the VSS is not crucial to account for the UFOV performance.

Insert Table 2 about here

UFOV Scores

The mean stimulus presentation times are shown in Table 3. In terms of the data, betel nut chewing might affect participants in normal sleep and deprived sleep conditions differently. That is, it appears that betel nut chewing effect may be larger in sleep deprivation condition, particularly for habitual chewers. To emphasize this difference, we conducted an ANOVA of 2 (treatment: betel nut or gum) × 3 (UFOV test: processing speed, divided attention and selective attention) × 2 (betel nut use: chewer or non-chewer) in each sleep condition[1]. The first two variables (treatment and UFOV test) were within-subject variables, and the last was a between-subject variable.

Insert Table 3 about here

For the sleep deprivation condition, the main effect of UFOV test and treatment × betel nut use interaction were obtained. The main effect of UFOV test [$F(2,48) = 55.52$, $MSE = 5018.7$, $p < .0001$, partial $\eta^2 = .698$] showed that more processing time was required for more complex tasks. Namely, the average stimulus presentation time of Subtest 1 (29 ms) was shorter than Subtest 2 (74 ms), which was shorter than Subtest 3 (176 ms) (all *p*'s < .0001). Most critically and intriguingly, the interaction of treatment × betel nut use [$F(1,24) = 4.24$, $MSE = 9879.1$, $p < .05$, partial $\eta^2 = .150$] has revealed a betel nut chewing effect for the habitual chewers when their sleep was deprived for one night. That is, for the chewers, the average stimulus presentation time when they chewed betel nuts (69 ms) was significantly shorter than that when they chewed gums (123 ms) ($p < .05$, partial $\eta^2 = .127$). When the chewers chewed betel nut, they could quickly identify the central target presented alone, divide their attention to the peripheral target, and detect the peripheral target embedded in the distractors while identifying the central target. However, for the non-chewers, the average stimulus presentation time in the betel nut condition (97 ms) did not differ significantly from that in the gum condition (83 ms) ($p > .4$, partial $\eta^2 = .054$).

For the normal sleep condition, only main effect of UFOV test [$F(2,44) = 68.90$, $MSE = 2642.4$, $p < .0001$, partial $\eta^2 = .758$] was obtained. The average stimulus presentation time of

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[1] We also did an ANOVA of 2 (treatment) × 3 (UFOV test) × 2 (betel nut use) × 2 (sleep condition) to assess betel nut chewing effect. The main effect of UFOV test and two two-way interactions (UFOV × betel nut use and treatment × betel nut use) were obtained. Sleep condition was not found to involve in any interactions. However, the data shown in Table 3 indicates a possibility of larger betel nut chewing effect for habitual chewers with deprived sleep, but not with normal sleep. Not ignoring this important information, we conducted 2 × 3 × 2 ANOVA in each sleep condition.

Subtest 1 (19 ms) was shorter than Subtest 2 (37 ms), which was shorter than Subtest 3 (133 ms) (all p's < .05). That is, when participants (both habitual chewers and non-chewers) had normal sleep, betel nut chewing did not have effect on the UFOV.

To examine whether the chewers reporting at least one withdrawal symptom performed differently from those not reporting withdrawal symptoms, we conducted an ANOVA of 2 (withdrawal symptom: yes or no) × 2 (treatment: betel nut or gum) × 3 (UFOV test: processing speed, divided attention and selective attention) for habitual chewers with deprived sleep. Importantly, the analysis did not show main effect and interactions involved withdrawal symptom (all p's > .4), indicating that betel nut chewing was effective for chewers with deprived sleep reporting and not reporting withdrawal symptoms. The main effects of treatment and UFOV were significant. The main effect of treatment showed that stimulus presentation time was shorter in the betel nut condition than that in the gum condition ($p < .05$). The main effect of UFOV showed that stimulus presentation time increased with the complexity of the UFOV subtests (all p's < .05).

To conclude, betel nut chewing can affect the UFOV size for the habitual betel nut chewers when their sleep was deprived for one night. Betel nut chewing has no effect on the UFOV performance of non-chewers with normal sleep or deprived sleep.

General Discussion

We examined whether betel nut chewing could influence the UFOV size for both habitual chewers and non-chewers in normal and deprived sleep conditions. Our results indicated that betel nut chewing could affect the UFOV size for the habitual chewers (with and without reporting withdrawal symptom) whose sleep was deprived for one night, but not for the non-chewers.

Some possibilities could account for the betel nut chewing effects on the UFOV that found only among habitual chewers in the sleep deprivation condition. First, the expectancy effect of betel nut chewing may be larger in the chewers. In Taiwan, it is thought to be a common knowledge that chewing betel nut has a refreshing effect. Possibly, the habitual chewers are more anticipative of betel nut's refreshment effect, thus causing better performance while chewing betel nut. However, because many physiological studies have reported the refreshment effect of betel nut chewing, it is unlikely that this effect is merely due to habitual chewer's expectations. Further, if the betel nut chewing effect is merely due to expectations, this effect should also be found among habitual chewers in normal sleep condition. However, we did not found such effect in normal sleep condition. A mixed effect of physiological contributions and expectations may be more likely the case. It is of importance to include a placebo control to examine how physiological effect alone or their interaction influence habitual chewer's or non-chewer's behavior.

Second, previous surveys have shown that the initial feelings of chewing betel nut are: dizziness, hot sensations, and palpitation (Chu & Chang, 1994). Such uncomfortable feelings may result from an increase in systolic blood pressure after chewing betel nut expecially for the non-chewers, but not the habitual chewers (Chu, 1993). It is possible that the selective effect of betel nut chewing on blood pressure for non-chewers and habitual chewers resulted in different performances in both groups. Future study can examine the possible link between online physiological and behavioral measures.

Some research limitations should be mentioned. First, the three UFOV subtests were always presented sequentially; thus, one may discern about the interaction between the time course of betel nuts and subtest sequence. However, this concern may be minor. The lack of UFOV- and treatment-related interactions (e.g., treatment × UFOV, partial η^2= .002, treatment × UFOV × sleep condition, partial η^2=.011, and treatment × UFOV x betel nut use, partial η^2=.029), and the significant treatment × betel nut use have shown betel nut chewing effect for the habitual chewers with deprived sleep, but not the non-chewers, in regardless of types of UFOV subtests. In other words, betel nut chewing shortened the stimulus presentation durations in all three UFOV subtests for the habitual chewers. Although the effects of betel nut chewing were constrained by its time course (an average of about 16.8 minutes; Chu, 1993), betel nut chewing indeed affected habitual chewer's performances in the UFOV tests. It is difficult to investigate the interaction between the time course of betel nut chewing effect and the UFOV subtests with current experimental design. However, the whole story remains clear; that is, betel nut chewing can affect habitual chewer's functional fields of views assessed by UFOV tests.

Second, the frequency and number of betel nut chewed for the chewers in the normal sleep group differ from those in the deprived sleep group. This may influence their UFOV performances. However, the correlation analysis showed that only the average month of chewing is weakly (p = .049) correlated to Subtest 2 (divided attention) in the gum condition. It is unclear why the average month of chewing was correlated to Subtest 2. A random error may cause this weak effect. Generally, the frequency and number of betel nut chewed are not sufficient to account for the UFOV performance in our case. Future studies could emphasize on how the frequency and number of betel nut chewing affect visual attention and other cognitive functions.

The current study has important implication for people who often chew betel nut for refreshment during long-hour working. Since betel nut chewing could improve chewer's attentional system in general (e.g., processing speed, divided attention and selective attention in the current case), it is expected that many working errors could be prevented because of this improved attentional system. However, the betel nut chewing is only effective for the habitual chewers. For example, sleep deprivation could raise the likelihood of car accidents, mediated through the deteriorated UFOV (Clay, et al., 2005; Cross, et al., 2009; Owsley & McGwin, 1999; Leat & Lovie-Kitchin, 2006; Rogé, Pébayle, Hannachi & Muzet, 2003). An overnight truck driver could chew betel nut to improve their UFOV, which could reduce the likelihood of car accidents. After chewing betel nut, this truck driver could process information ahead more quickly (processing speed), notice a fast passing car (divided attention), and ignore the distracting billboards near the road (selective attention). What causes fatigue (e.g., sleep deprivation in our case) may not be critical for obtaining betel nut chewing effect, whereas the extent of fatigue may be important. The betel nut chewing may be effective for people with some degree of fatigue, no matter what causes this fatigue. Future studies could test this hypothesis by manipulating sources that cause fatigue.

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Table 1. Demographic characteristics in the current study. Standard deviations are shown in the parenthesis. DepCh = Deprived sleep/Chewer, DepNch = Deprived sleep/Non-chewer, NorCh = Normal sleep/Chewer, NorNch = Normal sleep/Non-chewer.

	DepCh	DepNch	NorCh	NorNch	
N	16	10	12	12	
Average age (years)	35 (10)	38 (14)	36 (7)	41 (14)	n.s.
Number of female	1	3	1	1	
ESS	6 (3)	6 (3)	5 (3)	7 (3)	n.s.
MEQ	52 (7)	53 (7)	54 (11)	54 (11)	n.s.
Average months of chewing	46 (46)	none	154 (73)	none	DepCh < NorCh ($p < .0001$, partial η^2=.544)
Average days per week of chewing	5 (2)	none	7 (1)	none	DepCh < NorCh ($p < .05$, partial η^2=.210)
Average numbers of	22 (15)	none	50 (52)	none	n.s. ($p = .061$,

betel nuts chewed per day	partial η^2=.129)

Table 2. Mean VSS scores the night before the experiment in which participants chewed betel nut or gum. in the current study. Standard deviations are shown in the parenthesis.

	DepCh	DepNch	NorCh	NorNch
Betel nut	94.3	102.13	92.50	96.67
	(23.6)	(36.37)	(29.35)	(29.13)
Gum	94.14	80.56	103.00	91.42
	(24.65)	(30.62)	(30.07)	(22.63)

Table 3. Mean stimulus presentation time (in ms) in three UFOV subtests for habitual chewers and non-chewers when they chewed betel nut or gum in deprived or normal sleep conditions. Standard errors of mean are shown in the parenthesis.

		UFOV subtest				
		Deprived sleep			Normal sleep	
		1	2	3	1	2
Chewers	Betel nut	19	55	134	18	31
		(2)	(17)	(24)	(2)	(20)
	Gum	50	125	193	22	26
		(13)	(26)	(27)	(15)	(30)
on-chewers	Betel nut	23	74	194	18	46
		(3)	(22)	(30)	(2)	(20)
	Gum	24	43	182	17	44
		(17)	(33)	(34)	(15)	(30)

Betel nut chewing effect on contour and object masking

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Abstract

Betel nut is a common stimulant in many Asian countries, including Taiwan. In the current study, we employ the masking task developed by Enns and Di Lollo (1997) to investigate the effect of betel nut chewing on sensory and attentional processing. The habitual chewers and non-chewers chewed either betel nut or gum before proceeding to the masking task. In the masking task, participants needed to identify a target that was masked by either a contour mask or an object mask. Results show that while betel nut chewing could influence habitual chewers' and non-chewers' attentional processing, it has little effect on sensory processing. More specifically, betel nut chewing concentrates the non-chewers' attentional resources locally on the central target. On the other hand, betel nut chewing could improve the habitual chewers' parafoveal vision, but at the cost of worse central vision. The implications of the results are discussed.

Key Words: betel nut; areca; masking; contour; object

In Taiwan, betel nuts (also known as areca) are common refreshment for people working night shifts. About 1.5 million Taiwanese are betel nut users, with about 30% of these users chewing betel nuts for refreshment purpose (Directorate-General of Budget, Accounting and Statistic, 1999). People place a whole betel nut into their mouths and macerate it by biting for approximately two to three minutes; they then spit out the red chewing saliva of the betel nut.

A betel nut usually consists of three major ingredients: a raw areca nut, slaked lime, and piper betel flower. The slaked lime, which is handled in the form of a paste, is either white lime or red lime. Red lime betel nut, containing green areca fruit, piper betel inflorescence and red lime paste, is the main method of areca consumption in Taiwan (about 70% of all betel nuts). The primary chemical ingredients in betel nuts are alkaloids (i.e., arecoline, arecaidine, guvaeoline, guvacine, and acolidine), polyphenolic compounds, safrole, eugenol, and hydroxychavicol.

Betel nuts have long been chewed by people as a stimulant because of their physiological effects, which include: increased stamina, a general feeling of well- being (Nieschulz, 1967), sweating, salivation, stimulation, cardioacceleration, a slightly drunk feeling and warming of the body and mouth cavity (Hwang, Wang, & Kao, 1993). In general, the physiological effects of betel nut chewing could result from the chemical effects of the betel nut ingredients on the autonomic and central nervous systems (for review, refer to Chu, 2001). For example, Chu (1994a) conducted an electroencephalographic (EEG) study on the effects of betel nut chewing. He showed an increase in both beta and alpha activities and a decrease in theta activity. Both an increase in beta and a decrease in theta indicated an increase in the state of alertness, whereas an increase in alpha indicated relaxation or calmness while chewing betel nut. In addition, these EEG changes were restricted mainly to posterior areas (particularly the occipital areas) for alpha activity, but were more widespread for theta and beta activities.

The changes observed in the central nervous system owing to betel nut chewing plausibly suggest changes in visual information processing. However, as far as we know, very few studies focus on how betel nut chewing influences visual information processing (e.g., Chu, 1994b, Ho & Wang, 2009; Stricherz & Pratt, 1976; Wyatt, 1996). These studies investigate how betel nut chewing influences information processing speed (e.g., Chu, 1994b, Ho & Wang, 2009; Stricherz & Pratt, 1976; Wyatt, 1996) and attentional processing (e.g., Ho & Wang, 2009). Stricherz and Pratt employed a simple reaction time task and found a lengthened reaction time (RT) within the initial five minutes following the ingestion of a betel nut. Chu investigated betel nut effects on both simple and choice RT tasks for the habitual betel nut chewers. Participants performed RT tasks before and during betel nut chewing. Only the choice RT was found to be shorter during betel nut chewing than that before chewing. Wyatt investigated betel nut chewing effects on habitual chewers' performances on a variety of behavioral and physiological measures (the choice RT, eye-hand coordination, digit span, pulse rate and blood pressure). The pulse rate was the only measure reporting an increment after betel nut chewing. Recently, Ho and Wang (2009) examined the effects of betel nut chewing on the useful field of view (UFOV) under sleep deprivation and normal sleep conditions. They reported that betel nut chewing could influence the UFOV size for the habitual chewers, but not for the non-chewers.

Visual information processing refers to a series of stages or modules from the lower level (e.g., the mangocellular and parvocellular pathways) to higher level (e.g., the extrastriate and frontal areas) to process visual stimuli in the real world. In general, these stages or modules form bottom-up sensory processing and top-down attentional processing (Egeth & Yantis, 1997). Previous studies on betel nut chewing effect usually did not distinguish between both processes (e.g., Chu, 1994b; Stricherz & Pratt, 1976; Wyatt, 1996) or only emphasizes the attentional process (e.g., Ho & Wang, 2009). In the current study, our aim was to investigate how betel nut chewing influences sensory processing and attentional processing.

According to the visual information processing hierarchy, sensory processing consists of a series of the lower levels of processing, which could feed-forward the instantaneous and detailed sensory inputs to the higher levels. For example, the retinal ganglion cells, the neurons in lateral geniculate nucleus (LGN) of thalamus and the primary visual cortex can process various visual features of the incoming stimuli (e.g., contrast, location, motion, color, texture and orientation). The visual features extracted by such sensory processes form the sensory representations which we are not consciously aware, easily updated by the instantaneous incoming changes. Two primary pathways, mangocellular and parvocellular pathways (M-pathway and P-pathway hereafter), from the retinal ganglion cells, LGN to the primary visual cortex, have different sensitivity to different physical properties (see Zeki, 1993 for a review). For instance, the M-pathway is sensitive to contrast, motion and orientation; whereas the P-pathway is sensitive to location, color and texture. These two pathways in early vision could interact with each other and transfer visual information to higher-level processing for identification, recognition and action.

The incoming stimuli are not identified and recognized without any limitation. The top-down attentional processing could determine, to a large extent, the degree to which the bottom-up sensory information could be processed to influence thought and behavior (Egeth & Yantis, 1997). For example, the selected sensory representation could benefit from better representational qualities (e.g., contrast, e.g., Carrasco, Ling, & Read, 2004), which result in better recognition (Enns, 2004). The top-down attentional process is closely associated to the notion of working memory capacity (WMC) (for review, refer to Barrett, Tugade, & Engle, 2004; Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005). It has been shown that people with larger WMC could allocate attention more flexibly than do people with lower WMC (Bleckley, Durso, Crutchfield, Engle, & Khanna, 2003).

How does betel nut chewing affect the sensory processing and attentional processing? To investigate this, one must adopt an appropriate task in order to distinguish, to some extent, between the processing of these two. One of the tasks with which to achieve this goal is visual masking (e.g., Atchley, Grobe, & Fields, 2002; Breitmeyer & Öğmen, 2006; Enns, 2004; Enns & Di Lollo, 1997). Visual masking refers to "the reduction of the visibility of one stimulus, called the target, by a spatiotemporally overlapping or contiguous second stimulus, called the mask" (Breitmeyer & Öğmen, 2006, p.2). In this study, we primarily employed two types of masks: contour and object masks, to investigate sensory and attentional processing, respectively.

A contour mask refers to a mask that appears temporally before or after the target stimulus and that forms a contour around the target stimulus, but does not occupy the same spatial positions. Contour masking could be influenced by a variety of physical attributes such as proximity (Enns & Di Lollo, 1997), contrast (Macknik & Livingstone, 1998), and background luminance (Stewart & Purcell, 1974). When the target and mask are in close temporal proximity and when attention is directed to a single target, contour masking is insensitive to attentional distribution. Enns (2004) compared target identification performance when the target appearing randomly at one of eight locations was not cued, cued simultaneously with 100% validity, or was preceded by a pre-cue with 100% validity. The masking effects in the three cue conditions (no-cue, simultaneous cue and pre-cue) were comparable in the range of target-to-mask interval between -50 (mask precedes target) and +50 ms (target precedes mask); thus the focus of attention prior to the target onset (i.e., distributed attention in the no-cue condition, or focused attention in the simultaneous cue and pre-cue conditions) had little influence on these masking effects. The contour masking could be accounted for by the interactions of activity in P-pathway and M-pathway. Inhibitory activity both within pathways and between pathways contributes to such masking (Breitmeyer & Öğmen, 2006).

On the other hand, the object mask refers to a mask that does not act as a mask when used in the manner of a contour mask, but acts as a powerful mask under the spatial uncertainty condition (Enns & Di Lollo, 1997). In the spatial uncertainty condition, the target appears in one of multiple possible locations; thus attention needs to be distributed over all the possible locations in expectation of the target. The object mask is even simpler than the contour mask: for example, the four dots surrounding the target stimulus usually serve as an object mask. Enns and Di Lollo suggested that the representation of four dots substitutes itself for the representation of the target and becomes the focus of object recognition (Brehaut, Enns, & Di Lollo, 1999; Giesbrecht & Di Lollo, 1998). Such object substitution is relatively late in the visual information processing and is a higher-level, attentional processing (Enns, 2004).

The classic study by Enns and Di Lollo (1997; Experiment 1) compared the contour and the object masks and found several important differences. They presented either a contour or an object mask randomly at various values of stimulus onset asynchrony (SOA), ranging from -300 ms (mask preceded target) to +300 ms (target preceded mask). The target is a diamond with a missing corner either on the left or right side. Participants were instructed that their responses should correspond to the missing corner. In one condition, the mask and target were always at the center of the display, called one-location condition; in the other condition, the mask and target could each randomly appear centrally or parafoveally (either left or right side of the center), called three-location condition. The latter condition created spatial uncertainty.

Enns and Di Lollo found that these two masks differ in regard to temporal characteristics, particularly in the one-location condition. In the one-location condition, when a contour mask precedes or is presented simultaneously with a target, the target visibility is still good. When a contour mask trails by 0 to 100 ms, the target visibility decreases; although it increases again when the mask trail durationis lengthened. On the other hand, the object mask did not reduce target visibility in the one-location condition. In the three-location condition (spatial uncertainty), the contour mask reduced target visibility when the target was presented centrally (at the central fixation) and parafoveally (near the central fixation). However, the object mask impaired target visibility only when the target was parafoveal. Degraded attentional distribution at the parafoveal location might make target recognition less efficient (e.g., more comparisons between low-level sensory inputs and top-down re-entrant perceptual hypothesis are needed for correct recognition); the masking thereby occurs when the four dots substitute themselves for the decaying target representation before the target recognition has been completed.

The contour mask is sensitive to the spatial separation of the target and the contour (Breitmeyer & Öğmen, 2006; Growney, Weisstein, & Cox, 1977). Enns and Di Lollo (1997; Experiment 2) manipulated the proximity of the target and the surrounding mask to examine the proximity effect on both types of masks. The contour mask was found to be sensitive to proximity; however the object mask was relatively insensitive to the proximity manipulation. They (Experiment 3) further examined the effect of attentional distribution on masking by manipulating the number of targets. That is, one target could appear on one of three locations (as in the three-location condition in Experiments 1 and 2), or three targets could appear at all three locations. In the latter condition, one mask (either contour or object mask) appeared on one of three targets, indicating which of the three targets required response. Enns and Di Lollo discovered that the target number (one or three) had little effect on the contour masking; however, the object masking was more effective (particularly when the foveal target was reported) when the target number increased to three. When attention was distributed widely over the three targets in the three-target condition, the object masking was obtained when the target was foveal and parafoveal. However, in the three-location condition (only one target appeared), attention was distributed in a gradient mode with more attention at the foveal location and less at the parafoveal locations; thus, the object masking was obtained only in parafoveal target.

In the current study, we applied the masking paradigm used in Enns and Di Lollo (1997; Experiment 1) to examine how betel nut chewing affects chewers' sensory and attentional processing. Atchley, Grobe and Fields (2002) applied the masking paradigm to investigate smoker's sensory and attentional processing; they suggested that nicotine (provided by smoking) could increase the contour masking effect possibly by increasing transient channel activities (e.g., M-pathway); whereas nicotine was not found to influence attention processing. Since the previous studies (e.g., Ho & Wang, 2009) have shown the betel nut chewing effect on attentional processing (e.g., UFOV) for habitual chewers, we hypothesized a reduced object masking for habitual chewers after they chew betel nut. That is, after chewing betel nut, the habitual chewers' attentional resources could be distributed to all of the possible target locations more effectively, thus reducing the object masking.

As for contour masking, if betel nut chewing increases the sensitivity of sensory processing, then the contour masking is increased. For example, the high sensitivity of sensory processing improves the sensory representations of target and mask, leading to stronger inhibition within, and between, P- and M-pathways. On the other hand, it is also possible that betel nut chewing decreases the sensitivity of sensory processing, reducing contour masking. That is, low sensitivity of sensory processing degrades the sensory representations of target and mask, weakening the inhibition within, and between, P- and M-pathways.

Method

Participants

Twelve habitual betel nut chewers (all males) (mean age = 32 years old, SD = 8 years, range = 24 - 51 years old) and 12 non-chewers (three females) (mean age = 31 years old, SD = 8 years, range = 24 - 52 years old) participated in this study. There was no age difference between these two groups ($p > .8$). For the chewers, the average months of chewing betel nut were 74 (SD = 65, range = 3 - 240). The average days per week of chewing were 4 (SD = 2, range = 1 - 7). The average numbers of betel nuts chewed per day were 9 (SD = 7, range = 1 - 30). All participants have normal or corrected-to-normal vision.

Apparatus

We used an IBM-compatible PC with a 17 inch CRT desktop monitor (refresh rate = 85 Hz).

Design

The stimuli were derived from those used by Enns and Di Lollo (1997). All the stimuli were black on the white background (Figure 1). The target was a diamond (0.62˚ in vertical axis) with a missing corner (0.17˚) on either the right or left side. The contour mask was a frame (0.20˚ in width) surrounding the target (1 pixel from the target). The object mask consisted of four squares (0.20˚) that were placed on a notional square (1.0˚ on each side). The minimum separation between neighboring contours in the target and mask was 0.35˚. Two short vertical lines (2.0˚ above and below the location of the central stimulus) served as fixation point.

Insert Figure 1 about here

Each participant underwent two conditions (gum and betel nut conditions) that were counterbalanced across participants so that half of the participants took part in the gum condition first, and the remaining half took part in the betel nut condition first. The gum condition was adopted in order to control for the effect of mere chewing. These two conditions were separated by at most about one week. The laboratory prepared the betel nuts and chewing gum so that all of the participants chewed the same type of betel nuts and chewing gum.

Each participant underwent three tasks in sequence. The tasks were administered in a dim room where each participant leaned his/her chin on a chinrest with a fixed viewing distance of 50 cm from the monitor. In the first task (*target identification* hereafter), the single target was presented centrally on the screen to familiarize the participants with the identification task. There were 36 trials in the first task. In the second task (*one-location condition* hereafter), the target and mask were presented centrally. The contour and object masks appeared equally often and were randomly assigned across trials. There were 160 trials in the second task (10 trials per SOA and mask type). In the third task (*three-location condition* hereafter), the target and mask were each equally often and randomly assigned to three horizontally arrayed locations, one central and two parafoveal (3.0° left and right of center). The target and the mask appeared in the same location on one third of the trials and in the different locations on two thirds of the trials. There were 288 trials in the third task (when both the target and mask are co-located, there are 2 and 4 trials per SOA and mask type for the central and parafoveal target conditions, respectively). The duration of the target and mask was 32 ms in all tasks. The mask was presented at one of eight SOAs (-150, -100, -50, 0, 50, 100, 150, or 300 ms relative to the target). Before each task, there were 20 practice trials.

<u>Procedure</u>

In all tasks, participants were instructed to press the mouse button corresponding to the missing corner of the target (left or right) which flashed briefly. They were also instructed to respond as accurately as possible, without worrying about the response speed. They were allowed to make their best guess if they were not sure of the correct answer. Participants were instructed to fixate at the central location between the vertical lines at the beginning of each trial. In addition to the general instruction, task-specific instructions were provided. In the second task, participants were informed that in addition to the target, one other figure would appear briefly. In the third task, participants were informed that the target and one other figure would each appear randomly at three locations. In each task: after instruction and practice and before the formal trials, participants were required to chew either gum or betel nut for three minutes. After they spit out the gum or betel nut, the formal trials began.

<u>Results and Discussion</u>

Target identification

The analysis of variance (ANOVA) of group (habitual chewers or non-chewers) × treatment (betel nut or gum) was conducted to assess the target identification performance. There were no main or interaction effects, indicating an equivalent ability to identify the target for both groups in both treatments. The accuracy rate for the habitual chewers in betel nut, and gum condition were both .94 and for the non-chewers in betel nut it was .96 and in gum condition, .99.

One-location condition

Accuracy rates are shown in Figure 2. In the following analysis, we computed Cohen's *d* (Cohen, 1988) to estimate the masking effects (Atchley, Grobe & Fields, 2002). To do so, the data from SOAs < 0 was collapsed to serve as a baseline. There is no forward masking when SOA < 0 in the current study, which is similar to the previous study (e.g., Enns & Di Lollo, 2000). Additionally, the previous studies (e.g., Atchley, Grobe & Fields, 2002; Enns, 2004; Enns & Di Lollo, 1997, 2000) have shown maximum masking effects (contour and object masks) at target-to-mask SOA = 50 ms. Therefore, the effect sizes of masking at 50-ms SOA for each chewer group (habitual chewers and non-chewers), each mask type (contour and object masks) and each treatment (betel nut and gum) are reported in the current study (Figure 3). In general, effect size of about 0.3 is regarded as small; 0.5, medium; and 0.8, large.

Insert Figure 2 about here

Insert Figure 3 about here

The contour mask produced strong masking effect in the gum control condition for both habitual chewers (*d* = 2.99) and non-chewers (*d* = 3.25) as observed in the previous studies. The masking effects in the gum control were larger than those observed in Atchley, Grobe and Fields (2002). They found moderate effect for the non-smokers (*d* =.56) and the deprived smokers (*d* =.51), and large effect for the non-deprived smokers (*d* =.83). This discrepancy may be caused by the mean accuracy difference between the baseline and the 50-ms SOA condition. The mean accuracy difference in our case is about 30%, but in Atchley et al. it was about 10% (non-smokers and deprived smokers) to 20% (non-deprived smokers). In effect, our data is more similar to Enns and Di Lollo (1997; Experiment 1), in which the mean difference is about 35%. After participants chewed betel nut, the contour masking effect became smaller among the habitual chewers (*d* = 2.14) and the non-chewers (*d* = 2.05). Although betel nut chewing could reduce the contour masking effect to a small extent, these masking effects were still strong. Therefore, we suggest that betel nut chewing only has small effect on sensory processing.

On the other hand, the object mask produced large masking effects in the gum condition for the non-chewers (*d* = 1.01) and for the habitual chewers (*d* = 1.14). Previous study (e.g., Atchley, Grobe & Fields, 2002) also found object masking in one-location condition, but with medium effect size. The accuracy in their study was similar to that in the current study (about 85-100%), thus the large effect size in our study may be due to the relatively small standard deviations in the current case. Moreover, betel nut chewing reduced the object masking for the non-chewers (*d* = 0.35) and for the habitual chewers (*d* = 0.66). After chewing betel nut, participants could allocate their attentional resources on target location more effectively, thus reducing the object masking. This effect is more profound for the non-chewers.

Three-location condition

Accuracy rates are shown in Figures 4 and 5. In the three-location condition, the data, in which the target and the mask were at different locations, served as the baseline (e.g., Atchley, Grobe & Fields, 2002; Enns & Di Lollo, 1997). That is, when the target and the mask were at different locations, the accuracy rates were collapsed across all SOAs. The univariate F test showed comparable accuracy rates across SOAs when target and mask were at different locations. Baseline performance across groups, mask types, target locations and treatments are shown in Table 1. Effect sizes (Cohen's *d*) of masking were estimated in each condition of group × mask type × target location × treatment. That is, performance in each masking condition (when the target and mask were at the same location at target-to- mask SOA = 50 ms) was compared with the same condition when the target and the mask were at different locations (i.e., baseline). Once again, maximum masking effects were expected at target-to-mask SOA = 50 ms (e.g., Atchley, Grobe & Fields, 2002; Enns, 2004; Enns & Di Lollo, 1997, 2000).

Insert Figure 4 about here

Insert Figure 5 about here

Insert Table 1 about here

To examine the baseline performance difference, the ANOVA of group (habitual chewers or non-chewers) × mask type (contour mask or object mask) × target location (central or parafoveal target) × treatment (betel nut or gum) on accuracy was conducted; the main effects of mask type and target location and interaction effect of group × treatment were obtained. Baseline performance was better for object mask than for contour mask [$F(1,22) = 13.28$, MSe = .004, $p < .001$]. Also, baseline performance was better in central target location than in the parafoveal target location [$F(1,2) = 467.23$, MSe = .007, $p < .0001$]. The group × treatment interaction [$F(1,22) = 4.75$, MSe = .007, $p < .05$] showed that the mean accuracy difference (i.e., accuracy rate in the gum condition minus that in the betel nut condition) was larger among the habitual chewers than in the non-chewers.

The effect sizes of masking at 50-ms SOA are shown in Figure 6. The non-chewers showed small to moderate object masking effects in the gum control condition for the central target ($d = 0.38$) and the parafoveal target ($d = 0.56$). After the non-chewers chewed betel nuts, the object masking effect became negative for the central target ($d = -0.19$) and large for the parafoveal target ($d = 1.04$). On the other hand, the habitual chewers showed about moderate to large object masking effects in the gum control condition for the central target ($d = 0.41$) and the parafoveal target ($d = 1.20$). After chewing betel nut, the habitual chewers showed increased masking effect for the central target ($d = 0.90$) and decreased masking effect for the parafoveal target ($d = 0.64$).

Insert Figure 6 about here

Betel nut chewing improves habitual chewers' attentional distribution in the parafoveal location; however, it deteriorates non-chewers' attentional distribution in the parafoveal location. In the gum control condition, the habitual chewers experience a large object masking effect parafoveally. That is to say, when betel nut is unavailable (gum control), the habitual chewers have fewer attentional resources distributed parafoveally. In contrast, the non-chewers may distribute their attentional resources more effectively across central and parafoveal targets in the gum control condition. After the betel nut is consumed, the habitual chewers could distribute more resources parafoveally (therefore reducing the masking effect parafoveally), but with a cost of fewer resources distributed centrally (therefore increasing the masking effect centrally). In contrast, after the betel nut is consumed, the non-chewers concentrate attentional resources centrally, causing little masking effect centrally and a large masking effect parafoveally. Specifically, when the non-chewers chewed betel nuts, the object masking effect became negative (d = -0.19) for the central target, indicating a better performance in the masking condition. It is unclear why target identification in the masking condition is better than that in the baseline condition, after chewing betel nut. Perhaps, the later mask in the different location from the target (i.e., baseline) quickly diverts participants' attention from the target, leading to worse target identification.

The non-chewers showed moderate to large contour masking effects in the gum control condition for the central target (d = 0.62) and the parafoveal target (d = 1.10). After the non-chewers chewed betel nuts, the contour masking effects became large for the central target (d = 1.16) and the parafoveal target (d = 0.80). The habitual chewers showed large contour masking effect in the gum control condition for the central target (d = 1.34) and the parafoveal target (d = 1.13). After chewing betel nut, the habitual chewers showed large effects for the central target (d = 1.48) and small effects for the parafoveal target (d = 0.38).

A trend of moderate to large contour masking effects was obtained in the gum control condition for the non-chewers and the habitual chewers for the central and parafoveal locations. Interestingly, after chewing betel nut, the contour masking effect for the parafoveal target for the habitual chewers decreased from large to small effect. Recall that the object masking effect for the parafoveal target for habitual chewers also became smaller in the betel nut condition. Possibly, the contour masking is sensitive to attentional distribution to some degree; therefore, the decreased contour masking after chewing betel nut is also due to increased attentional distribution in the parafoveal locations.

In the three-location condition in the current study, attention is primarily allocated in the central location and decays in the parafoveal locations (therefore better target identification in central target location). This gradient attentional distribution might influence the contour masking, particularly when the target is in the parafoveal location, where fewer attentional resources are distributed. For example, Enns (2004; Experiment 1) manipulated attentional distribution by presenting one, four or seven letters in any of eight locations on an imaginary circle. A mask was presented close to one of the target letters and at SOAs between -150 ms to + 600 ms. The target letter denoted by the mask was reported. Enns showed that target identification accuracy decreased with the display size in all forms of backward masking, including the contour mask. That is, when attention is divided among multiple target locations in target expectation, the target representation is likely to be replaced with the incoming mask prior to the completion of target identification, leading to worse target identification (i.e., masking effect). Since attentional distribution among multiple locations could cause the masking effect (e.g., Enns, 2004), it is reasonable to suggest that an increment of attentional resources should reduce the likelihood of masking; recall the finding in the object masking in the three-location condition that attentional resources are increased on the parafoveal locations after habitual chewers consumed betel nuts. Possibly, this increment of attentional resources could also reduce the contour masking effect. Note that attentional distribution in the three-location condition was unable to exclusively account for the contour masking effect (Enns, 2004; Enns & Di Lollo, 1997); otherwise, the contour masking should be simply the same as the object masking. The contour masking in the spatial uncertainty condition (e.g., the three-location condition in our case and the multiple target locations in Enns' (2004) case) is influenced by both sensory and attentional processing (Enns, 2004).

Finally, we examined whether there was forward masking or facilitation in the current study when mask preceded target. The accuracy rates from the negative SOA condition were collapsed for the baseline (the target and mask locations were different) and masking (the target and mask locations were the same) conditions. These two conditions (baseline and masking) were then compared in each condition of group × mask type × target location × treatment. There was no forward masking or facilitation for the habitual chewers and the non-chewers.

General Discussion

In the current study, we applied the masking paradigm (e.g., Atchley, Grobe & Fields, 2002; Enns & Di Lollo, 1997) to investigate how betel nut chewing influences sensory and attentional processing. Sensory processing is assessed primarily by examining target identification in the contour mask condition when the target is presented only centrally (one-location condition). When attention is directed to a single target and when the target and mask are in close temporal proximity, contour masking is insensitive to attentional distribution (Enns, 2004). Attentional processing is assessed primarily by examining target identification in the object mask condition when the target is presented randomly in central and parafoveal locations (three-location condition). Object masking is sensitive to attentional distribution in the three-location condition, particularly the degraded attentional distribution in the parafoveal locations (Enns & Di Lollo, 1997).

There are several important conclusions drawn in the present study. First, both the habitual chewers and the non-chewers have similar and strong contour masking effects in the gum control condition. This indicates that chewing betel nut may have little (if any) long-term effect on sensory processing. Second, betel nut chewing has little immediate effect on sensory processing. Betel nut chewing reduces the contour masking effects to some extent, but these effects are still strong (Cohen's *d* is around two in the betel nut condition).

Third, chewing betel nut has a long-term effect on habitual chewers' attentional processing. In the gum control condition, the habitual chewers have a large object masking effect in the parafoveal location, indicating fewer resources allocated parafoveally. In contrast, the non-chewers could divide attentional resources for both central and parafoveal locations, leading to similar object masking effects. There are at least two possibilities that could account for the object masking effect in the gum condition. The first possibility is that the habitual chewers have fewer total attentional resources when the betel nut is unavailable, thus causing fewer resources distributed parafoveally. On the other hand, it is also possible that the habitual chewers have smaller WMC (Barrett, Tugade, & Engle, 2004; Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005), causing less flexible attentional allocation on the possible target locations (e.g., Bleckley, Durso, Crutchfield, Engle, & Khanna, 2004). These two accounts (fewer total attentional resources and smaller WMC) may not be mutually exclusive of each other. For example, people with smaller WMC may have fewer attentional resources. Future studies could measure habitual chewers' and non-chewers' WMC before and after chewing betel nut and gum to examine whether WMC is modulated by long-term and/or immediate betel nut chewing.

Finally, betel nut chewing has an immediate effect on attentional processing for both habitual chewers and non-chewers. Moreover, betel nut chewing influences parafoveal and central locations differently. In the parafoveal locations, the effect of object masking for the habitual chewers in the betel nut condition ($d = 0.64$) is similar to that for the non-chewers in the gum control condition ($d = 0.56$). Also, in the parafoveal locations, the effect of object masking for the habitual chewers in the gum control condition ($d = 1.20$) is similar to that for the non-chewers in the betel nut condition ($d = 1.04$). It indicates that betel nut chewing could immediately improve the habitual chewers' parafoveal vision to the extent equivalent to the non-chewers' parafoveal vision in the gum control. This also suggests a possibility that betel nut chewing only raises habitual chewers' parafoveal vision back to, rather than beyond, the level of non-chewers in the gum control. On the other hand, betel nut chewing immediately impairs the non-chewers' parafoveal vision to the extent equivalent to the habitual chewers' parafoveal vision in the gum control.

In the central location, the effects of object masking for both habitual chewers and non-chewers are similar in the gum control condition. Nevertheless, after chewing betel nut, the object masking effect in the central location becomes larger for the habitual chewers, and smaller for the non-chewers, i.e. betel nut chewing immediately enhances the non-chewers' central vision but impairs the habitual chewers' central vision. The object masking in the one-location condition also supports this result. Betel nut chewing reduces the object masking to the small effect for the non-chewers ($d = 0.35$) and to the moderate effect for the habitual chewers ($d = 0.66$). After chewing betel nut, the non-chewers' central vision could be enhanced.

The current study and Ho and Wang's (2009) both suggest that betel nut chewing could enhance the habitual chewers' processing of visual stimuli away from the central fixation (i.e., the parafoveal target in the current study and the peripheral target in Ho and Wang (2009)). Ho and Wang (2009) found that betel nut chewing could influence habitual chewers' (but not the non-chewers') UFOV after one night of sleep deprivation. When the habitual chewers chewed betel nut after one night of sleep deprivation, they could quickly identify the central target presented alone, divide their attention to include the peripheral target, and detect the peripheral target embedded in the distracters while identifying the central target. Namely, the habitual chewers could process peripheral information more effectively after chewing betel nut, in relation to the gum condition. In the three-location condition in the present study, the habitual chewers' parafoveal vision was enhanced in the betel nut condition, also suggesting more effective parafoveal information processing.

However, Ho and Wang (2009) found the betel nut chewing effect only in the sleep deprivation condition, not in the normal sleep condition, as in the current study did. The different distances of the target from the central fixation in these two studies may account for this difference. The peripheral target in Ho and Wang (2009) was distanced 13.5° away from the central fixation, and the parafoveal target in the current study was 3.0° away. Betel nut chewing may enhance the visual field in a gradient mode, with more attentional resources locally surrounding the central fixation (i.e., parafoveal vision) and fewer attentional resources distributed far away from it (i.e., peripheral vision). When the habitual chewers have normal sleep, the extent of the parafoveal target enhancement is larger than that of the peripheral target, thus it is easier to detect the attentional distribution on the parafoveal, rather than the peripheral, target.

To conclude, betel nut chewing could influence the chewers' attentional processing, but only has little effect on sensory processing. Furthermore, chewing betel nut concentrates the non-chewers' attentional resources locally on the central target, suggesting possible tunnel vision. Therefore, after chewing betel nut, the non-chewers may pay more attention to the foveal information (e.g., the car ahead of the driver) and ignore the parafoveal information (e.g., a fast passing car), which may raise the likelihood of an accident. On the other hand, chewing betel nut could improve the habitual chewers' parafoveal vision, but at the cost of worse central vision. Therefore, after chewing betel nut, t habitual chewers could pay more attention to the parafoveal information, reducing the likelihood of accidents occurring. However, although betel nut chewing improves the habitual chewers' parafoveal vision, it only raises their parafoveal vision back to the level of non-chewers in the gum control.

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Table 1: Baseline performance (accuracy rate) across groups, mask types, target locations and treatments. Standard deviations are shown in the parenthesis.

	Contour				Object			
	Betel		Gum		Betel		Gum	
	Central	Peripheral	Central	Peripheral	Central	Peripheral	Central	Peripheral
Habitual chewers	0.89 (0.10)	0.59 (0.08)	0.93 (0.07)	0.64 (0.07)	0.92 (0.07)	0.67 (0.08)	0.92 (0.10)	0.68 (0.08)
Non-chewers	0.93 (0.07)	0.67 (0.08)	0.87 (0.08)	0.66 (0.08)	0.94 (0.06)	0.70 (0.12)	0.90 (0.10)	0.70 (0.08)

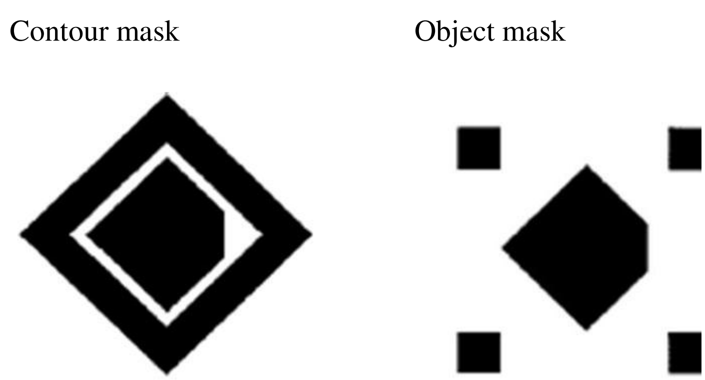


Figure 1: The contour and object masks in the current study. The target is a central diamond with a missing corner.

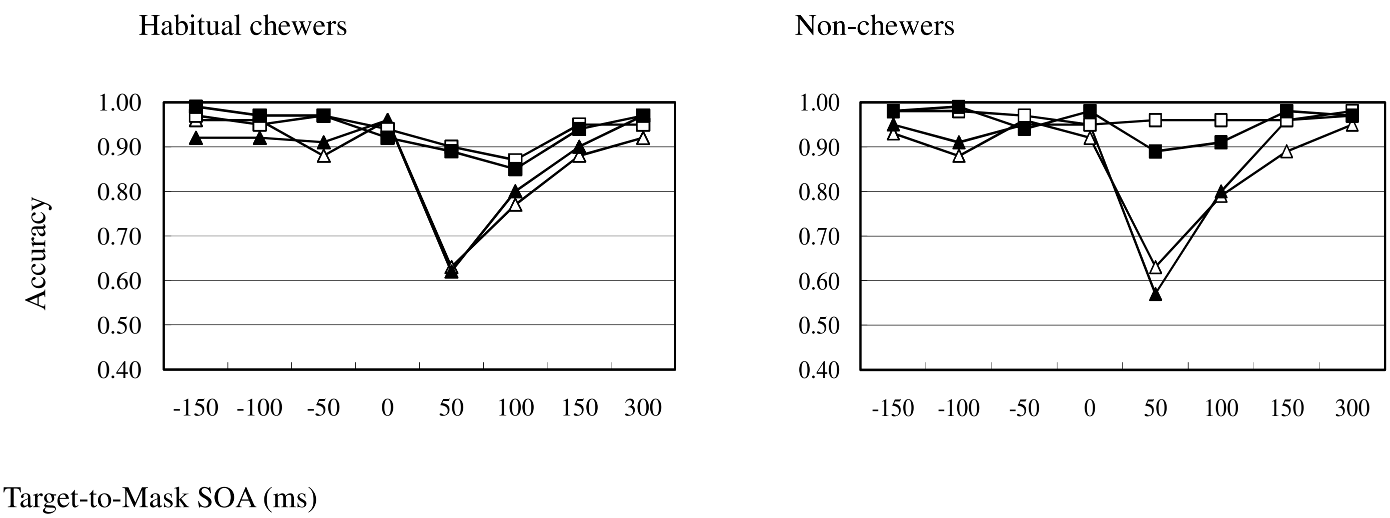


Figure 2: Accuracy rate for each chewer group, each mask type and each treatment in the one-location condition. Diamond. Triangles represent the contour masking and rectangles represent the object masking. The open symbols represent the betel nut condition and the closed symbols represent the gum condition.

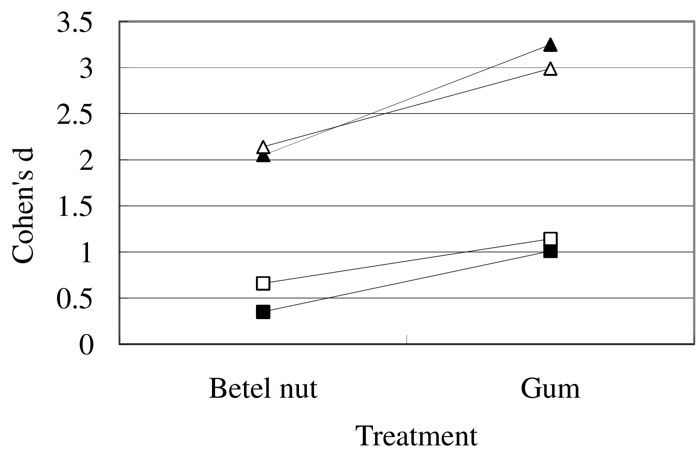
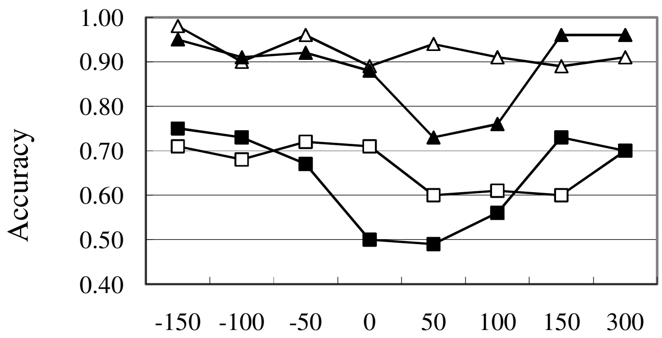


Figure 3: Effect sizes of masking at 50-ms SOA for each chewer group, each mask type and each treatment. Triangles represent the contour masking and rectangles represent the object masking. The open symbols represent the habitual chewers and the closed symbols represent the non-chewers.

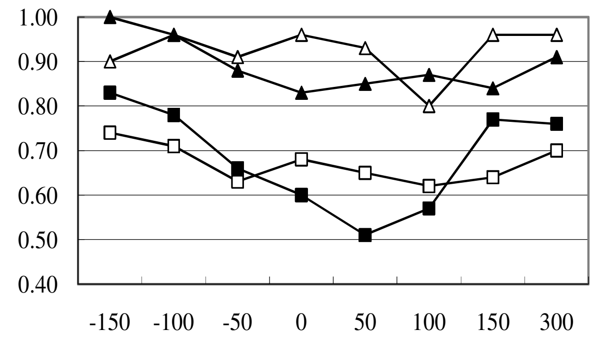
Habitual chewers

Object mask

Betel nut

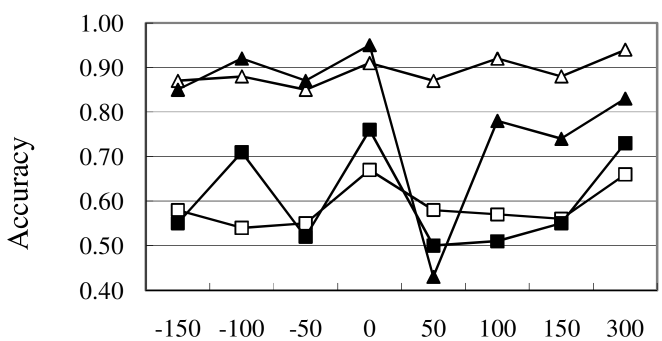


Gum

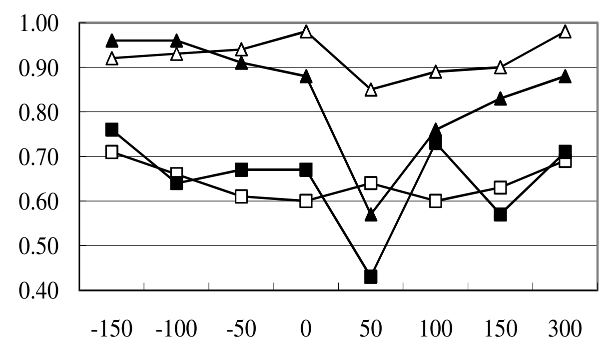


Contour mask

Betel nut



Gum



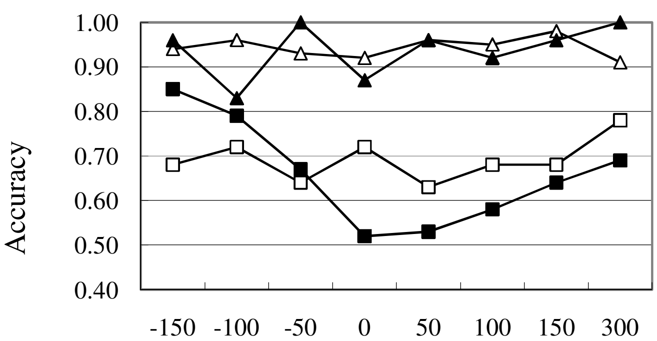
Target-to-Mask SOA (ms)

Figure 4: Accuracy rate for the habitual chewers for each mask type and each treatment in the three-location condition. Triangles represent the central target and rectangles represent the peripheral target. The open symbols represent the performance when the target and mask are in different locations and the closed symbols represent the performance when the target and mask are in the same locations.

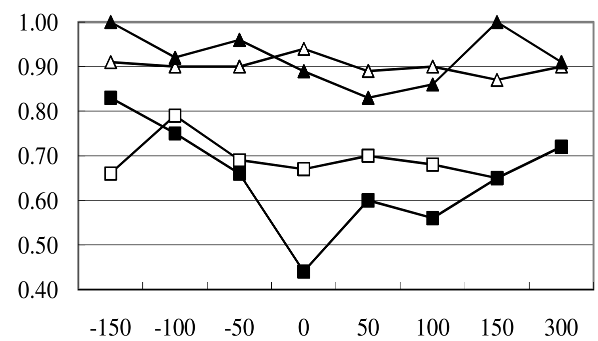
lon-chewers

bject mask

Betel nut

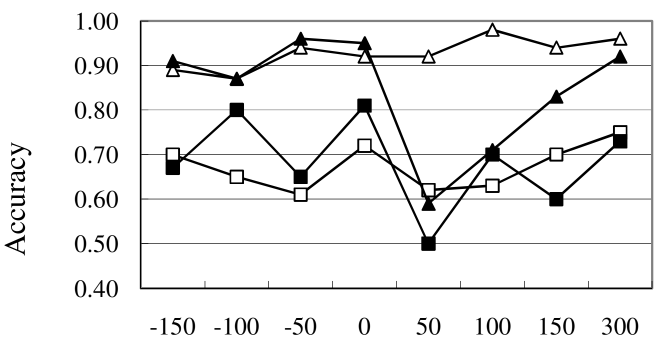


Gum

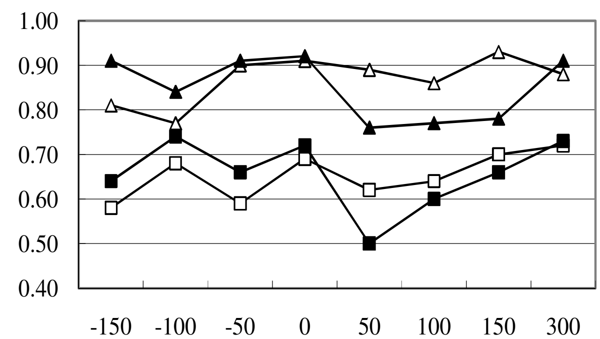


ontour mask

Betel nut



Gum



arget-to-Mask SOA (ms)

igure 5: Accuracy rate for the non-chewers for each mask type and each treatment in the three-location condition. ngles represent the central target and rectangles represent the peripheral target. The open symbols represent the formance when the target and mask are in different locations, and the closed symbols represent the performance en the target and mask are in the same locations.

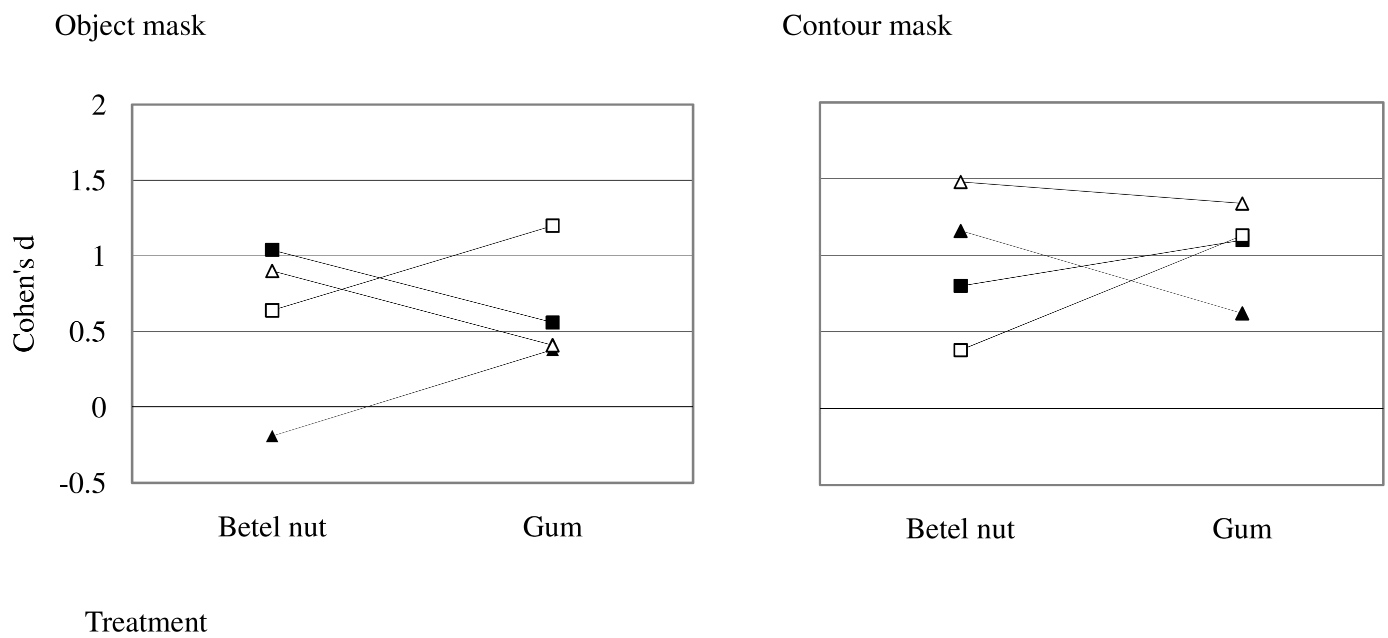


Figure 6: Effect sizes of masking at 50-ms SOA for each chewer group, each mask type, each target location, and each treatment. Triangles represent the central target and rectangles represent the parafoveal target. The open symbols represent the habitual chewers and the closed symbols represent the non-chewers.

Acknowledgement

This study was supported by NSC-97-2410-H-040-010 from the National Science Council. We thank Shuo-Heng Li, Ya-Ling Shih, Wei-Chung Wang, and Wan-Ting Hsieh for their assistance with the current study.

計畫成果自評

本研究已經依照計畫內容，完成所有實驗，已經達到預期目標。更進一步，計畫內容中的實驗一（與去年計畫合併）與實驗二已經寫成兩篇英文論文。本研究提供重要且缺乏的行為實證資料，來支持檳榔對注意力之影響（例如慣嚼檳榔者會因為嚼檳榔而能夠更有效率地注意到周遭之視覺訊息)。而對從未嚼食者來說，檳榔反而會使其注意力效率下降。未來，我們希望能夠增加生理指標（例如血壓、心跳、皮膚電阻等)來客觀地量測嚼食檳榔所導致的生理改變以及其視覺注意力之改變(例如有效視覺區的改變等)。更宏觀地說，我們希望未來能夠探討嚼食檳榔對視覺注意力與視知覺各面向的影響。我們已經申請到 2009-2012 的三年國科會經費（檳榔嚼食者之注意力系統：導向、抑制與持續性注意力，98-2410-H-040-005-MY3），希望能更檢驗重要但沒有行為實證資料的議題。

參加 2009 年 European Congress of Psychology (ECP) 的三篇摘要

Can betel nut chewing affect the UFOV size after sleep deprivation?

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[2]School of Nutrition, Chung-Shan Medical University

Betel nut is a common refreshment in Taiwan. However, few behavioral studies focusing on the betel nut chewing effects were reported. Two experiments examined the effects of betel nut chewing on the useful field of view (UFOV) under sleep deprivation. The UFOV refers to a spatial area that is functional or useful for the ongoing task(s). Attentional resources are allocated to this spatial area in order to process the incoming information. When the size of the UFOV shrinks, fewer stimuli within the UFOV are further processed. The size of the UFOV can be determined by the speed of information processing, proficiency in dividing attention, and ability to ignore irrelevant distractions. We reported that betel nut chewing could broaden the UFOV size for the habitual chewers, but not for the non-chewers. Specifically, betel nut chewing can facilitate the ability to ignore irrelevant distractions under sleep deprivation conditions for the habitual chewers.

Key Words: betel nut, areca, sleep deprivation, useful field of view

Betel nut chewing effect on sensory and attentional masking

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[2]School of Nutrition, Chung-Shan Medical University

Betel nut is a common refreshment in Taiwan. We examined if betel nut chewing could affect chewers' lower-level sensory (e.g., precortical M- and P-pathway) and/or higher-level attentional processings (e.g., cortical signal feedback). We adopted contour and object masks to investigate sensory and attentional processings respectively (e.g., Atchley, Grobe & Fields, 2002). Contour masking is sensitive to proximity, but insensitive to attentional distribution. However, the object masking is not sensitive to proximity, but sensitive to attentional distribution. Betel nut chewers showed weak and comparable object masking after they chew betel nut or gum. Also, betel nut chewers showed weak contour masking after they chew betel nut. However, after they chew chewing gum, they showed strong contour masking when target-mask SOA was over 50 ms. We suggested that betel nut might not increase attentional resources, whereas might reduce the sensory processing. Future study will examine the chronic effect of betel nut chewing.

Key Words: betel nut, areca, contour, object, masking

Betel nut chewing effect on UFOV and sustained attention

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[2]School of Nutrition, Chung-Shan Medical University

Betel nut is a common refreshment in many countries, including Taiwan. Betel nut plays a role in central nervous system associated to many aspects of attention. We investigated if betel nut chewing influences the useful field of view (UFOV) and sustained attention (SA). The UFOV is a spatial area that is functional or useful for the ongoing task. The UFOV consists of three dimensions: processing speed, divided attention, and selective attention. SA refers as the ability to self-sustain mindful, conscious processing of stimuli whose repetitive, non-arousing qualities would lead to habituation and distraction to other stimuli. We adopted sustained attention to response task (SART) to assess sustained attention. We reported that chewing betel nut could reduce the UFOV in comparison to chewing gum. However, chewing gum or betel nut leads to equivalent performance in SA. Future study will compare the non-chewers to examine the chronic effect of betel nut chewing.

Key Words: betel nut, areca, useful field of view, sustained attention

出席國際學術會議心得報告

第 11 屆歐洲心理學研討會是由 EFPA (The European Federation of Psychologists Association)贊助，由 Norwegian Psychological Association 主辦，於 7 月 7 日至 10 日在挪威 Oslo 舉辦。此研討會為每兩年舉辦一次，上次（2007）是在捷克舉辦，下次（2011）之舉辦地點為土耳其的 Istanbul。此研討會內容涵蓋心理學各個領域，從生理、社會、知覺，一直到諮商、臨床等。此研討會邀請多位演講者以及 symposia，除了以上，尚有多個口頭以及海報場次，讓人目不暇給。以監獄實驗著名的社會心理學家 Zimbardo 也蒞臨演講，甚為有趣。

由於研討會資訊繁多，我主要挑選與我近來研究主軸相關的研究，來進一步瞭解，我的研究主軸主要在選擇性注意力、情緒與注意力以及短期記憶與注意力。注意力與記憶之間的關係，長久以來一直是視知覺研究之重點，這次研討會也以此為主題探討了視覺的 repetition priming。演講很精彩，可惜知名以色列學者 Dominique Lamy 因故取消無法參加。Campana 以 TMS 發現 prime 之特徵（e.g., motion direction 和 spatial location）在大腦中相關的區域處理，例如 motion direction 就在 motor area 處理。除了這些以廣為人之的腦區外，其他與作業有關的腦區也會激發。此外，他們也發現 priming 可能夠發生在更高階的處理歷程，例如 size of attentional focus。Sneve 以 event-related fMRI 發現 V1 對 visual short-term memory 之重要性。受試者在做 spatial frequency discrimination task 的同時，需要記憶一個無關的 mask 的 spatial frequency。當 mask spatial frequency 與 discrimination task 中的 target spatial frequency 類似時，作業的正確率下降（memory mask effect）。而同時 V1 的血流量也下降。作者推論當 retrieve mask from visual STM，V1 會產生側抑制，去抑制競爭的 target spatial frequency。