Acute effects of tea consumption on attention and mood[1–4]

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ABSTRACT

Tea has historically been associated with mood and performance benefits, such as relaxation and concentration. This review summarizes the research on the acute effects of tea, and its ingredients theanine and caffeine, on attention and mood. Consistent with abundant research on the benefits of caffeine, the performance benefits of tea were identified in a number of studies, with particularly consistent evidence for improved attention. Tea consumption also consistently improved self-reported alertness and arousal, whereas effects on pleasure or relaxation were less consistent. In addition to the research on caffeine in real-life performance, 2 recent studies have provided a broader perspective on tea's effects on psychological function in that they showed beneficial effects in related areas such as work performance and creativity. These studies showed the validity of laboratory findings by supporting the idea that tea consumption has acute benefits on both mood and performance in real-life situations. *Am J Clin Nutr* 2013;98(suppl):1700S–8S.

INTRODUCTION

Whereas consumers have historically associated tea with mental benefits, these alleged benefits were largely anecdotal until relatively recently. In the past 15 y, the effects of tea consumption on mental performance, especially attention, and mood have been investigated in a number of studies. Notably, the studies reviewed here mainly pertain to relatively acute effects of tea and tea ingredients, which occur immediately after consumption or during the course of a day, in healthy adult populations. The timing of the occurrence of these benefits contrasts with the research on neuroprotective effects of tea that used longitudinal designs, which have suggested long-term benefits of tea consumption in elderly or impaired populations (1). Whereas the literature on tea's acute psychological benefits focuses on outcome measures such as attention and mood, the primary focus of the literature on tea's chronic health benefits lies in prevention of cardiovascular disease (2–4), diabetes (5, 6), depression (7, 8), and neurodegenerative diseases such as dementia (1, 9). The underlying mechanisms for acute and chronic benefits are likely to be different; the acute effects have been ascribed to caffeine and theanine, whereas the chronic effects have been linked to other components in tea, such as flavonoids. Based on the knowledge currently available, the different outcome measures and different underlying mechanisms appear to hinder linking tea's acute benefits to tea's chronic benefits. In this article, we mainly focus on the acute benefits of tea on attention and mood.

In September 2012, relevant studies were identified through searches of the PubMed (http://www.ncbi.nlm.nih.gov/pubmed) and Scopus (http://www.scopus.com/) electronic databases by using the entry terms "tea," "caffeine," or "theanine" in combination with "attention," "concentration," "alertness," "cognition," "cognitive function," or "mood." We limited our search to journal articles written in English. To be included, studies were required to investigate the effects of tea, caffeine, and/or theanine; report data on at least one acute behavioral measure of attention or mood; include at least one (sub)sample of healthy adults; include a control condition; and have been published in a peer-reviewed journal. Relevance was assessed on the basis of the titles and abstracts. Finally, relevant articles that appeared until April 2013 in the electronic databases of PubMed and Scopus were included.

TEA AND ATTENTION

According to the American Psychological Association, attention is "a state of focused awareness on a subset of the available perceptual information." Attention allows the brain to effectively deal with the vast amount of input that is continuously received through its sensory (eg, vision, hearing) and cognitive (eg, memory) processes and to focus on what is relevant. As such, attention is an important prerequisite for many cognitive processes, including memory and reasoning. Attention can be measured objectively as performance on attention tests, usually in terms of speed of response and number of correct responses, or subjectively as self-reported alertness, usually by means of a visual analog rating scale (VAS)[5] (10).

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[5] Abbreviations used: CFFT, Critical Flicker Fusion Threshold; EGCG, epigallocatechin-3-gallate; VAS, visual analog scale.

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Acute effects of tea ingredients on attention

Tea contains a large number of bioactive compounds, yet its attention benefits have generally been attributed to 2 of its components: caffeine and theanine (11). Typically, a cup of tea contains 35–61 mg caffeine and 4.5–22.5 mg theanine. Other ingredients in tea, such as the green tea polyphenol epigallocatechin-3-gallate (EGCG), have been ascribed certain neuroprotective effects (12), but acute effects on performance measures have not been found (13).

There is a large body of evidence that caffeine is highly bioavailable because it is rapidly and almost completely absorbed (14) and readily distributed throughout all tissues of the body (15) including the brain (16). Peak plasma concentrations are reached at ~30 min postconsumption, and half-lives for elimination range between 2.5 and 10 h, dependent on the food matrix, genetic factors, and smoking status (14, 17). Caffeine is extensively metabolized in the liver into >25 derivatives, whereas considerably less than 5% of the ingested dose is excreted unchanged in the urine (14).

Caffeine is known to affect neurotransmission in general by antagonizing (ie, competing with) adenosine receptors. When adenosine binds to its receptors in the brain, primarily A1 and A2a receptors, neural activity slows down. However, when caffeine binds instead to these receptors it causes a general increase in neurotransmission (18–20). As such, caffeine attenuates the inhibitory effects of adenosine in the brain. As an adenosine antagonist, caffeine also affects the dopaminergic system (21), which is involved in arousal and higher-order attentional processes (22). In addition, caffeine has secondary effects on the release of specific neurotransmitters, including noradrenaline, acetylcholine, serotonin, glutamate, and γ-aminobutyric acid, which have been hypothesized to be involved in caffeine's effect on arousal (23).

Caffeine is present in a range of beverages (eg, tea, coffee, soft drinks, energy drinks) and in some foods (eg, chocolate) and is the most consumed psychoactive ingredient worldwide (24). Its attention effects have been studied extensively (25, 26). Across a large variety of tests and doses, these studies indicate that even in low doses such as 50 mg (ie, approximately the equivalent of a cup of tea) caffeine improves performance on attention tasks and subjective alertness. Whereas effects on simple attention tasks have been well established, recent studies have also indicated beneficial effects of caffeine on more complex, multifaceted attention tasks (27–29).

Theanine is an amino acid that is virtually unique to tea (apart from the fungus *Bay bolete*). Theanine has been shown to be highly bioavailable, reaching its maximum concentration in plasma at ~45 min postadministration (30). It is metabolized into glutamic acid and ethylamine, and a minor fraction is excreted into urine (30–33). On administration of theanine, concentrations of some other amino acids (eg, tryptophan, tyrosine) were reduced in the brain in rats (34). Some of these amino acids are precursors of neurotransmitters that are important for cognitive performance (eg, tryptophan is converted into serotonin, and tyrosine is converted into dopamine), which are both involved in higher-order complex attention processes in humans (serotonin: references 35 and 36; dopamine: reference 37). Hence, it has been suggested that theanine may attenuate neurotransmitter levels by interfering with the availability of their precursors and thus affect cognition. In addition, theanine can bind to receptors and transporters involved in glutamate and γ-aminobutyric acid neurotransmission (37, 38), neurotransmitters that are also involved in attention performance (39, 40).

For theanine, the psychoactive properties appear to be more complex than caffeine. During rest, theanine increases α wave brain activity, which has been associated with relaxation (41, 42). During attention task performance, theanine increased background (resting) α activity, yet decreased α activity when preparing to attend to the task stimuli (43, 44), which has been related to better performance (45). Behavioral effects of theanine were largely absent. However, these studies were designed to measure brain activity rather than behavioral effects.

Because caffeine and theanine are always consumed together when consuming tea, studying the effects of these ingredients in combination is more relevant than studying either ingredient in isolation. Few studies have investigated this combination, and most of them used an increased amount of theanine, compared with the amount typically present in tea. This combination improved speed and accuracy on a range of tasks from the Cognitive Drug Research test battery (46), improved accuracy on an attention-switching test (47–49), improved accuracy on a cued attention test (50), and improved accuracy on a sustained attention test (51).

Acute effects of tea on attention

The evidence on tea ingredients indicates that tea can provide cognitive benefits, in particular in the domain of attention. Four studies to date have specifically assessed the effects of black tea on attention performance. Details of these studies are shown in **Table 1**. Hindmarch et al (52) compared the effects of coffee, water, and tea with and without 100 mg caffeine on 2 tasks that are frequently used to measure attention effects in pharmaceutical trials, the Critical Flicker Fusion Threshold (CFFT) and Choice Reaction Time tasks, and self-reported alertness. Overall, caffeinated beverages improved performance and self-reported alertness compared with decaffeinated beverages. Interestingly, performance on the CFFT improved more after caffeinated tea than after caffeinated water, suggesting that the attention benefit cannot be wholly attributed to caffeine, and that other tea components also contributed to the benefit. Furthermore, whereas performance naturally declined over time, this decline was attenuated by beverage type, in that tea was associated with a smaller decrease (ie, better performance) than water. Thus, this study provided tentative evidence for a beneficial effect of tea on a performance measure related to attention. In a follow-up study, main effects of caffeine (37.5 and 75 mg, respectively) on both tasks were replicated (53). Moreover, CFFT performance improved after consumption of tea with 75 mg caffeine, compared with coffee with the same amount of caffeine. In sum, these findings suggest that tea effects—at least on simple attention tasks—are not merely a result of caffeine and that on some outcomes tea might "outperform" coffee. Notably, both studies were of an open-label design and thus did not control for expectations and taste differences between the beverages.

Two recent studies used a double-blind, placebo-controlled crossover design and more complex attention tasks to further investigate these effects (54). In the first study, 26 healthy

TABLE 1
Acute effects of tea consumption on attention[1]

First author, year (reference)	Sample	Design	Results
Hindmarch, 1998 (52)	19 Healthy volunteers; 10 F, 9 M; mean age = 29.2 y	Randomized CO design, 5 conditions: –black tea, 100 mg caffeine –black tea, decaffeinated –coffee, 100 mg caffeine –water, 100 mg caffeine –water, noncaffeinated	CFFT: overall, tea improved performance vs water (P = 0.034); acutely caffeinated beverage improved CFFT level vs noncaffeinated beverages (P = 0.024) CRT: no significant effects
Hindmarch, 2000 (53)	30 Healthy volunteers; 15 F, 15 M; mean age = 27.3 y	Randomized CO design, 5 conditions: –black tea, 37.5 mg caffeine –black tea, 75 mg caffeine –coffee, 75 mg caffeine –coffee, 150 mg caffeine –hot water, noncaffeinated	CFFT: caffeinated beverages resulted in superior performance overall (P = 0.0376) and immediately after drink 1 (P = 0.0425) vs water; also, tea improved performance 30–90 min postconsumption ($P < 0.01$) after drink 1 vs coffee CRT: caffeinated beverages resulted in improved recognition reaction times after drink 2 vs water (P = 0.0486); also, coffee improved recognition reaction time (P = 0.0484) after drink 2 vs tea
De Bruin, 2011 (54)			
Study 1	26 Healthy volunteers; 20 F, 16 M; mean ± SD age = 30.7 ± 11.2 y	Randomized PC CO design, 2 conditions: –black tea –placebo tea	Attention-switching task: improved accuracy after tea ($P < 0.002$) Intersensory attention task: improved accuracy on multisensory auditory and visual tasks after tea ($P <$ 0.001 and $P < 0.030$, respectively) and faster responses to the visual task (P = 0.043)
Study 2	32 Healthy volunteers; 15 F, 17 M; mean ± SD age = 30.3 ± 10.1 y	Randomized PC CO design, 2 conditions: –black tea –placebo tea	Attention-switching task: improved accuracy after tea (P = 0.007) Intersensory attention task: no significant effects

[1] Line analog rating scale and Bond-Lader self-reported alertness scores are reported in Table 2. CFFT, Critical Flicker Fusion Threshold (task); CO, crossover; CRT, Choice Reaction Time (task); PC, placebo-controlled.

participants consumed 2 cups of black tea and a placebo tea (colored and flavored water) on separate test sessions. After each cup, participants completed 2 complex tasks of attention (attention-switching task and intersensory attention task) and a self-rating of alertness, calmness, and contentment. Results indicated that accuracy on the attention-switching task was better after tea than after placebo. Moreover, participants also provided more accurate responses on 2 of the 4 subtasks of the intersensory attention task and also responded faster on 1 of these 2 tasks. Finally, participants felt more alert and less calm after tea consumption. In a replication of this study, participants consumed 3 cups of tea that consisted of a slightly weaker tea blend (54), followed by the same tasks as the previous study after each cup. Again, accuracy on the attention-switching task improved after black tea compared with placebo, and participants also reported feeling more alert. Tea did not significantly affect performance on the intersensory attention task. The authors speculated that this difference between the studies could be a result of the difference in the strength of the tea blend and of the potentially dose-dependent build-up of the active ingredients in plasma.

From the totality of research on tea summarized above and in Table 1, it can be concluded that consumption of black tea may improve attention and self-reported alertness. These conclusions are further supported by studies on caffeine and on theanine and caffeine in combination.

TEA AND MOOD

The influence of food and beverage consumption on mood has been (and still is) widely researched. Mood refers to a state of mind ranging from increased happiness, contentment, relaxation, alertness and energy, and relief of depression and anxiety to

feelings of guilt and failure (55). The consumption of tea, both black and green, has been associated with relaxation and refreshment (56, 57) and feelings of satisfaction (58). These putative benefits may be the result of the interaction of a number of elements, including the hot temperature at which tea is consumed, its sensory properties (eg, smell, color, mouth-feel), and its active ingredients, which exert effects at different times during and after tea consumption. In the studies summarized below, the effects of tea or tea ingredients on mood have been investigated by using various validated scales with self-reports (eg, Bond-Lader VAS, Profile of Mood States, University of Wales Institute of Technology Mood Adjective Checklist). These include facets of mood related to arousal and relaxation, as well as aspects related to the pleasantness of mood. In addition, particular changes in mood related to arousal and alertness can also be determined with physiologic measures, for example, blood pressure and skin conductance (59).

Acute effects of tea ingredients on mood

Caffeine is well known for its effects on feelings of arousal, energy, and alertness (60, 61), even at doses as low as 50 mg, which is comparable to the amount of caffeine in a cup of tea. In addition, a number of studies also found improved hedonic tone (62, 63), happiness and calmness (64), and contentment (65) after caffeine consumption. The number of studies on the effects of theanine in relation to mood is limited. Three studies found benefits in relation to stress: 200 mg theanine reduced self-reported anxiety in anticipation of a stressful event (66) or after a mental task (67) and reduced physiologic indexes of stress such as heart rate and salivary immunoglobulin during engagement in a stressful task (68). Another study found that 250 mg caffeine increased self-rated alertness, jitteriness, and blood pressure, with 200 mg theanine antagonizing caffeine's effect on blood pressure but not its effects on alertness or jitteriness (69). Although psychological health benefits (including lower risk of cognitive decline) have been ascribed to tea flavonoids in cross-sectional studies (67), there is limited evidence for acute effects of these ingredients in healthy adults. Notably, the catechin EGCG has recently been associated with increased calmness and reduced stress in one study that used a 300-mg dose (12) but not in another study in which a lower dose of 135 mg was used (13).

Acute effects of tea on mood

A range of studies have assessed the effect of tea on mood (for an overview *see* **Table 2**). However, most of these studies focused on alertness or arousal, which is closely related to attention. Findings consistently show an increase in self-reported alertness or arousal after consuming black tea (and other caffeinated beverages) compared with consumption of noncaffeinated beverages. Five studies found reduced ratings of sedation on a line analog rating scale, reflecting higher alertness, immediately after tea consumption (70) or 30 and 60 min after consumption of caffeinated beverages including tea (52, 53, 71) compared with noncaffeinated beverages. In addition, 3 studies found increased ratings of energetic arousal after consumption of caffeinated beverages, including tea, compared with noncaffeinated beverages (71, 72). Two studies reported increased alertness ratings after black tea consumption compared with placebo on the Bond-Lader VAS (54). In one recent study (SJL Einöther, M Baas, M Rowson, T Giesbrecht, unpublished data, 2012), no effect of tea on arousal (using an affect grid) when compared with water was found; in contrast to most of the previously mentioned studies, mood was assessed immediately after consumption. Findings from physiologic measures, such as skin conductance and blood pressure, which are collected under controlled laboratory settings, further support that black tea can stimulate the autonomous nervous system in a manner associated with increased arousal (70, 71).

With regard to valence of mood or pleasure, findings with tea are less consistent. Quinlan et al (72) found improved hedonic tone after drinking any beverage (ie, black tea, coffee, hot water) at 30 and 60 min after consumption compared with a condition with no drink at all. In a follow-up study, the researchers again found improved hedonic tone but after all caffeinated beverages, including black tea, compared with noncaffeinated beverages (71). However, these findings were not replicated in a second study in the same report (54, 71), which found no significant effects of black tea consumption on contentment. All of these studies focused on the effects of the active ingredients, which are expected to be absorbed and distributed to the brain relatively soon after consumption. An alternative hypothesis not driven by active ingredients, however, might be that subjective mood is affected around and/or immediately after consumption because of the sensory "tea experience" itself, including (the combination of) the activity of preparing the tea and its smell, taste, mouth-feel, and visual appearance, which is a hypothesis that was not tested in any of the studies described above. Finally, in a recent study (SJL Einöther, M Baas, M Rowson, T Giesbrecht, unpublished data, 2012), tea consumption (as well as a positive control) positively affected pleasantness of mood immediately after consumption compared with water.

To date, no studies have assessed the acute effects of tea on self-reported relaxation. However, 2 studies have attempted to relate tea consumption to stress relief. Steptoe et al (73) investigated the effects of daily tea consumption during 6 wk in healthy men. Whereas tea consumption did not affect blood pressure or heart rate, it did reduce platelet activation before and after stress, reduced cortisol concentrations, and increased subjective relaxation at the end of the recovery period, reflecting a positive effect of tea on recovery from stress. In addition, cross-sectional data on healthy Japanese adults showed that a high consumption of green tea (>5 cups daily) was related to lower psychological distress, even after adjustment for possible confounders (74).

Although caffeine is known to affect various aspects of mood, in particular alertness, effects of other ingredients such as theanine or EGCG on mood are largely unknown. The effects of tea on self-reported alertness and arousal have been well researched and have consistently shown a positive effect, which is consistent with the findings for caffeine. In contrast, only a few studies addressed the effect of tea on pleasure/hedonic tone and/or relaxation, and their results were variable.

EFFECTS OF TEA IN REAL LIFE: BEYOND ATTENTION AND MOOD

Laboratory interventions using validated measures indicate that tea consumption exerts acute positive effects on attention

TABLE 2
Acute effects of tea consumption on self-reported mood[1]

First author, year (reference)	Sample	Design	Results
Aspen, 1998 (70)	16 Healthy volunteers; 8 F, 8 M; age >18 y	Randomized CO design, 7 conditions: –black tea, swallowed or rinsed –caffeinated water, swallowed or rinsed –water, swallowed or rinsed (no caffeine) –no drink, control	LARS: <10 min; more alert, energetic, attentive, clearheaded, refreshed, and less tired ($P < 0.05$) after tea vs caffeinated water, regardless of rinse or swallow; relaxed, calm, tense, sad, happy unaffected 30 min; more alert, energetic, attentive, clearheaded, refreshed, and less tired ($P < 0.01$) after caffeinated beverages if swallowed; more calm, relaxed, and less tense after tea vs caffeinated water and after caffeinated beverages vs water ($P < 0.05$); more happy, less sad after caffeinated beverages ($P < 0.01$)
Quinlan, 1997 (72)	16 Healthy volunteers; 8 F (mean ± SD age = 34.4 ± 11.8 y); 8 M (mean ± SD age = 36.9 ± 6.3 y)	Randomized CO design, 10 conditions: –black tea, decaffeinated or 100 mg caffeine –black tea with milk, decaffeinated or 100 mg caffeine –coffee, black tea, decaffeinated or 100 mg caffeine –coffee with milk, decaffeinated or 100 mg caffeine –hot water, decaffeinated or 100 mg caffeine –no drink	UMACL: Hedonic tone improved by hot beverages vs no drink at 30 min ($P = 0.0024$) and 60 min ($P = 0.02$) postconsumption; tense or energetic arousal rating unaffected Energetic arousal, hedonic tone improved by caffeinated vs noncaffeinated beverages at 30 min (energetic arousal: $P = 0.0001$; hedonic tone: $P = 0.0025$) and 60 min (energetic arousal: $P = 0.000$; hedonic tone: $P = 0.015$) postconsumption; tense arousal ratings unaffected STAI: anxiety improved by caffeinated vs noncaffeinated beverages at 60 min postconsumption ($P = 0.05$)
Hindmarch, 1998 (52)	19 Healthy volunteers; 10 F, 9 M; mean age = 29.2 y	Randomized CO design, 6 conditions: –black tea, decaffeinated or 100 mg caffeine –coffee, decaffeinated or 100 mg caffeine –hot water, noncaffeinated or 100 mg caffeine	LARS: Daylong effects: reduced sedation after caffeinated vs noncaffeinated beverages ($P = 0.033$) Acute effects: interactions between caffeine amount and time ($P = 0.025$); reduced sedation by caffeinated vs noncaffeinated beverages, most prominent for coffee STAI: no significant effects
Hindmarch, 2000 (53)	30 Healthy volunteers; 15 F, 15 M; mean age = 27.3 y	Randomized CO design, 5 conditions: –black tea, 37.5 mg or 75 mg caffeine –coffee, 75 mg or 150 mg caffeine –hot water, noncaffeinated	LARS: No daylong effects but acute effects at drink 1 ($P = 0.0110$): reduced sedation after caffeinated beverages vs water ($P = 0.0049$)
Quinlan, 2000 (71) Study 1	17 Healthy volunteers; 9 F, 8 M; mean age = 35 y	Randomized CO design, 6 conditions: –black tea 37.5 mg or 75 mg caffeine –coffee, 75 mg or 150 mg caffeine –hot water, noncaffeinated –no drink	UMACL: energetic arousal ($P = 0.05$), hedonic tone ($P = 0.007$) increased by caffeinated vs noncaffeinated beverages; tense arousal rating unaffected LARS: sedation reduced by caffeinated vs noncaffeinated beverages ($P = 0.03$) and by coffee vs tea ($P = 0.04$); dose-dependent: 150 mg resulted in greater increase than 75 mg ($P = 0.03$)

(Continued)

TABLE 2 (*Continued*)

First author, year (reference)	Sample	Design	Results
Study 2	15 Healthy volunteers; 8 F, 7 M; mean age = 33.9 y	Randomized CO design, 6 conditions: –black tea, decaffeinated or 25, 50, 100, or 200 mg caffeine –hot water, noncaffeinated	UMACL: caffeine increased energetic arousal ($P = 0.006$); dose-dependent ($P = 0.046$): lowest and highest dose produced largest increase; tense arousal, hedonic tone unaffected LARS: caffeine ($P = 0.0003$) reduced sedation; dose-dependent ($P = 0.0003$): all doses except for 50 mg produced an effect
De Bruin, 2011 (54)			
Study 1	26 Healthy volunteers; 20 F, 16 M; mean ± SD age = 30.7 ± 11.2 y	Randomized PC CO design, 2 conditions: –black tea –placebo tea	Bond-Lader VAS: more alert ($P < 0.001$) and less calm ($P = 0.008$) after tea vs placebo; contentment rating unaffected
Study 2	32 Healthy volunteers; 15 F, 17 M; mean ± SD age = 30.3 ± 10.1 y	Randomized PC CO design, 2 conditions: –black tea –placebo tea	Bond-Lader VAS: more alert after tea ($P = 0.021$) and tendency toward greater feelings of contentment ($P = 0.085$) after tea vs placebo; calmness rating unaffected

[1] CO, crossover; LARS, line analog rating scale; PC, placebo-controlled; STAI, State Trait Anxiety Inventory; UMACL, University of Wales Institute of Technology Mood Adjectives Checklist; VAS, visual analog scale.

and aspects of mood. Although such findings have good internal reliability, the generalizability to the complex cognitive demands of everyday life has been questioned. Few studies investigated whether benefits could be extended to everyday settings.

Effects of tea ingredients in real life

The performance benefits of caffeine have been identified in real-life tasks. For example, caffeine is recognized by the US military as an "alertness-enhancing compound" (75) and has been shown to improve vigilance during military combat (76–78). Beneficial effects of caffeine consumption on simulated and/or actual driving are commonly found under extreme circumstances, such as after sleep deprivation (79–82) or during nighttime driving (83). Moreover, 2 studies have shown benefits in nonfatigued subjects during daytime on outcomes corresponding to safer and more stable driving. The consumption of caffeine (3 mg/kg) improved steering accuracy during a 1-h simulated drive (84). Furthermore, 80 mg caffeine consumed after 2 h of monotonous simulated driving improved lane keeping and speed maintenance during a 2-h follow-up drive (85). In contrast, Heatherley et al (86) found no significant effects of caffeine (1.2 mg/kg) on steering variability, but this study may have been underpowered. Furthermore, a review of 13 studies of shift work performance showed that caffeine can reduce errors and improve cognitive performance in shift workers, compared with no intervention (87). Finally, other studies have indicated that caffeine (100 mg) improved self-reported concentration while attending a university lecture when compared with placebo (88) and improved passing accuracy during a simulated soccer game (6 mg/kg) (89). No studies to date have assessed the effects of theanine or other tea ingredients on real-life tasks.

Effects of tea in real life

Recent meta-analyses have confirmed that positive mood states lead to improved creative problem solving compared with neutral mood states (90, 91). Because tea has been shown to affect mood, it was hypothesized that consumption of tea and tea-based beverages would enhance creativity via positive affect. Isen et al (92) reported that tasting a cup of commercially available or branded iced tea led to more creative problem solving on an adapted Remote Associate Test when compared with tasting bottled water and compared with no intervention. This finding was confirmed recently (SJL Einöther, M Baas, M Rowson, T Giesbrecht, unpublished data, 2012) through a study in which hot black tea was found to positively affect pleasantness of mood immediately after consumption, as well as creative problem solving. Specifically, both tea and a validated positive affect induction (a procedure for recalling happy personal memories) were found to increase feelings of pleasantness compared with water immediately after consumption. Furthermore, there was an indication that both positive affect–inducing conditions improved creative problem solving compared with water, in that both tended to yield faster insights on difficult problems.

In addition, 2 cross-sectional studies have assessed associations between consumption of tea (and other beverages) and performance and mood by using a naturalistic design. Steptoe et al (93) tested participants from 2 high-stress-occupation groups who completed daily reports of beverage consumption and mood for 8 wk and found a relation between tea consumption and mood. In contrast, Bryan et al (94) asked professional and academic staff to complete reports of beverage consumption and mood and work performance during 10 working days. Their results indicated that participants who consumed more tea felt less tired and reported that they performed well at work more often than participants who drank less tea—but only if it was consumed without milk and/or sugar. In addition, higher

consumption of noncaffeinated beverages was associated with feeling more relaxed. Coffee did not have a stronger relation than other beverages with any of the variables assessed.

CONCLUSIONS AND FUTURE DIRECTIONS

Tea is one of the most consumed beverages in the world, and its many putative benefits appear to be well known and appreciated by consumers. We have summarized the acute psychological benefits of tea on attention and mood in an effort to link some of these anecdotal beliefs to the existing science. The tea ingredients caffeine and theanine, alone or in combination, have been linked to attention, with the available research showing that consumption of black tea improves attention on validated complex tasks as well as self-reported alertness. Mood benefits of tea and tea ingredients, other than improved alertness, have been less extensively researched until now, and these findings are less consistent. The psychological benefits of tea and tea ingredients have been extended to some real-life areas including driving, creativity, and work performance.

Research on the benefits of tea is promising for attention and alertness, although questions remain regarding the scope and magnitude of impact as well as the sensitivity of different individuals. Whereas the bioavailability of both caffeine and theanine has been established (14–17, 30–33), as well as the (suggested) mechanisms of action in the brain (18–23, 34–40), the extent to which they actually cross the blood-brain barrier in humans and how much this is associated with (individual) changes in subsequent performance and mood measures are as yet unknown. It would be interesting to conduct a study in humans measuring cerebrospinal fluid concentrations of caffeine and theanine after acute ingestion of tea and to correlate the concentrations with the acute effects on attention, mood, and real-life performance. Other cognitive processes, such as memory or specific aspects of memory (eg, working memory), that encompass a large component of the attention domain, have not yet been investigated in relation to the acute effects of tea consumption. Indeed, very few studies have been conducted outside of the laboratory, and it would be highly relevant to better understand the effects of tea consumption on other daily activities that require attention—for example, driving and cooking. Similarly, few studies have objectively assessed the acute effects of tea on pleasant feelings and relaxation, attributes that are often associated with each other by tea consumers. Investigating mood states during and after consumption of tea with validated measures will further build our understanding of the potential benefit of tea in this aspect of health and well-being.

Research on the benefits of caffeine on driving and other types of real-life performance is consistent with results from laboratory studies with regard to improved alertness, reduced fatigue, and sustained performance benefits. Recent research provides tentative support for the hypothesis that benefits from tea can be found in related areas such as creative problem solving. Similarly, a cross-sectional study has shown that tea consumption improves self-reported work performance and fatigue. These results also warrant replication and further research. Nevertheless, the available evidence on the benefits of tea and tea ingredients on mood and performance in real-life settings does support the validity of findings from earlier laboratory-controlled studies on attention and mood.

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