Research report

Relationships between tea and other beverage consumption to work performance and mood ☆

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ARTICLE INFO

ABSTRACT

The aim of this research was to examine relationships between tea, coffee and other beverage consumption and associates of work performance and mood among individuals in relatively stressful and cognitively demanding work-place settings. Using a naturalistic, cross-sectional study design, 95 professional and academic staff logged their beverage intake and completed self-reports of associates of work performance (fatigue/exhaustion, mindfulness, work engagement), subjective work performance, mood, work-related strain and recovery four times daily during ten working days. Data were analysed using multilevel modelling in keeping with the hierarchical structure of the data. Tea consumption was associated with increased perceived work performance and reduced tiredness, especially when consumed without milk or sugar. Consumption of non-caffeinated beverages was associated with increased relaxation and recovery from work. In contrast, tea and other caffeinated beverages were found to enhance the negative effects of evening recovery and morning mood on mindfulness during the day. The findings suggest that beverage intake may have a role in optimising work-related psychological states and performance.

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Introduction

As tea is one of the most frequently consumed beverages in the world, there is a growing interest in its beneficial effects, including improved cognitive performance and mood. So far, most research has focused on the effects of some dietary components of tea, in particular caffeine, both at higher doses, but also at lower doses such as 37.5–150 mg, which is comparable to what is found in 1–4 cups of tea (Durlach, 1998; Leathwood & Pollet, 1983; Smit & Rogers, 2000); and, more recently, the amino acid theanine, but only at doses above those afforded by typical tea consumption (Haskell, Kennedy, Milne, Wesnes, & Scholey, 2005, 2008). Tea is also a rich source of flavonoids, but it has been mainly the physical, rather than psychological, health benefits of tea flavonoids that have been studied.

Consistently, findings show that tea has a positive effect on mood such as on increased wakefulness, vigour, energy, clarity of thought, efficiency, hedonic tone and decreased perceptions of sedation (Hindmarch, Quinlan, Moore, & Parkin, 1998; Quinlan et al., 2000). Tea has also been found to have sustained effects when taken at regular intervals across the course of a day, being associated with lower perceived sedation or fatigue than coffee (Hindmarch et al., 2000; Scott, Rycroft, Aspen, Chapman, & Brown, 2004), and less disruption on sleep quality at night than coffee (Hindmarch et al., 2000). These findings suggest that tea's effects appear to be somewhat different from the effects of coffee indicating that other tea components, such as theanine of flavonoids, may play a role.

Theanine has been found to affect neurotransmitters serotonin and *gamma*-aminobutyric acid (GABA), and may modulate and "tone down" central nervous system (CNS) responses and regulate anxiety (Kimura & Murata, 1986a,b; Nathan, Lu, Gray, & Oliver, 2006). Furthermore, theanine has been found to increase alpha brain wave activity during rest, which is indicative of a state of wakeful relaxation, especially among those reporting higher levels of anxiety (Ito et al., 1998; Nobre, Rao, & Owen, 2008; Song, Jung, Oh, & Kim, 2003). Reduced subjective ratings of anxiety and other

measures of psychological stress support these findings (Kimura, Ozeki, Juneja, & Ohira, 2006; Lu et al., 2004).

Tea has also been found to positively influence cognitive performance. Very low doses of caffeine (37.5 mg), found in a single cup of tea, taken at regular intervals throughout the day, significantly benefited speed of perception (Hindmarch et al., 2000). Two to three 200 ml servings of black tea enhanced both objective and self-reported attention and alertness (De Bruin, Rowson, Van Buren, Rycroft, & Owen, 2011). Furthermore, when the level of caffeine in tea was increased such that it was equivalent to coffee (i.e. 75 mg and 100 mg per serving), caffeinated tea provided an advantage over coffee in the increase and maintenance of speed of perception (Hindmarch, Quinlan, Moore, & Parkin, 1998; Hindmarch et al., 2000). This result suggests that regular tea intake across the day may result in more consistent levels of simple task performance. Effects of tea on more complex cognitive tasks are yet to be investigated.

Findings to date suggest complex associations between theanine and cognitive performance. Recent EEG studies found that theanine improved selective attention (Gomez-Ramirez, Kelly, Montesi, & Foxe, 2009; Gomez-Ramirez et al., 2007), evidenced by increased task-related alpha activity and decreased background alpha activity. At the behavioural level, there appear to be no effects (Haskell et al., 2008), or negative effects (Haskell et al., 2005; Rogers et al., 2005) of theanine alone. However, both EEG (Kelly, Gomez-Ramirez, Montesi, & Foxe, 2008) and behavioural studies (Haskell et al., 2008; Owen, Parnell, De Bruin, & Rycroft, 2008) have shown that theanine appears to potentiate the cognitive effects of caffeine, when consumed in combination. These findings support the hypothesised interactive neurochemical effects of caffeine and theanine (Kimura & Murata, 1986a,b), however these studies have used doses of theanine (200–250 mg) that are higher than those typically consumed (30–50 mg theanine per 200 ml cup of tea).

Tea is also rich in two of the main classes of flavonoids: flavonols and flavanols. When typically prepared, black tea contains about 150–200 mg flavonoids per cup, and is a major source of dietary flavonoids, contributing up to 82% of the total dietary intake (Somerset & Johannot, 2008). Current evidence suggests that tea and tea-derived flavonoids can reduce the risk of cardiovascular disease (Hooper et al., 2008) and stroke at doses of ⩾3 cups of tea per day (Arab, Liu, & Elashoff, 2009). Findings from cross-sectional studies in humans ascribe neuroprotective effects of tea to its flavonoid content (e.g. Ng, Feng, Niti, Kua, & Yap, 2008). These effects of tea flavonoids suggest that they may influence physical and psychological health over the longer-term, in contrast to the acute effects of caffeine.

Most of the research on the association between tea consumption and psychological outcomes has used short-term laboratory-based intervention studies. Although these findings have good internal reliability, their generalisability to the more complex cognitive demands of everyday life is unclear. To date, there is only one cross-sectional naturalistic study assessing associations between beverage consumption and mood (Steptoe & Wardle, 1999). The study employed 49 participants from two high stress occupation groups who completed daily reports of beverage consumption and mood for 8 weeks. Tea and coffee consumption was not related to mood. Steptoe et al. (2007) investigated the effects of longer-term consumption of tea on subjective, cardiovascular, cortisol and platelet responses to acute stress. Healthy males, who had withdrawn from caffeine-containing products for 4 weeks, consumed tea containing 72 mg caffeine and 6.4% flavonols (equivalent to four cups of black tea), or a caffeine-matched placebo, daily for 6 weeks. Compared with the placebo, tea consumption did not affect blood pressure or heart rate. Tea reduced platelet activation before and after stress, reduced cortisol levels

and increased subjective relaxation at the end of the recovery period, reflecting a positive effect of tea on recovery from stress.

The current study is the first to examine the relationship between daily habitual consumption of tea, and other beverages, and variables associated with work performance, work-related strain, mood and recovery in a naturalistic setting. These outcomes reflect the everyday cognitive and emotional challenges faced by individuals in relatively stressful and cognitively demanding work-place settings. Studies in Australian academics have found increasing levels of reported stress in this occupational group, most likely due to on-going changes in the University sector (Gillespie, Walsh, Winefield, Dua, & Stough, 2001; Winefield et al., 2003), so South Australian university employees were chosen as our sample. Diaries were used to log daily experiences over 10 working days among academic and administrative staff in South Australian universities. Based on previous research findings, and the mechanism by which tea and its ingredients influence the CNS, it was expected that the amount of tea consumed would have a greater positive relationship with outcomes than consumption of other beverages. We also examined whether beverage additives, milk and sugar, would moderate these relationships. Furthermore, we examined whether tea consumption would moderate the effects of morning mood and previous evening recovery on indicators of daily work-related mood, performance, and strain later in the day.

Method

Participants

Participants were academic and professional staff members from three universities. One hundred and forty-two participants expressed interest in the study and of these, 118 participants filled in a baseline assessment, and 95 completed all diaries. There was no difference on baseline data between those who completed the study and those who did not. Volunteers were excluded from participating if they reported being victims of workplace bullying over the last 6 months (Einarsen, Hoel, Zapf, & Cooper, 2003; Leymann, 1996 – 7 excluded) or burnout using the *Utrecht Burnout Inventory* (Brenninkmeijer & van Yperen, 2003; Schaufeli & Van Dierendonck, 2000 – 0 excluded). The final sample is described in Table 1. Participation was voluntary and participants provided written informed consent prior to their inclusion. They were provided with an honorarium of $50 to compensate for their time. The protocol was approved by the University of South Australia Human Research Ethics Committee.

Materials and measures

Participants completed a diary four times per day for 10 working days in order to report beverage consumption, subjective work

Table 1
Descriptive statistics for participants who completed diaries.

Variable	Frequencies		
Gender	Female	Male	
	75 (78.9%)	20 (21.1%)	
Employment Position	Academic	Professional	
	31 (32.6%)	64 (67.4%)	
Employment status	Permanent	Casual	Contract
	58 (61.1%)	7 (7.4%)	30 (31.6%)
	Mean (SD)		
Age	36.96 (11.17)		
Years employed at University	5.28 (6.47)		
Self-rated health[a]	4.08 (0.69)		

[a] Rated on a scale of 1 = poor, 2 = fair, 3 = moderate, 4 = good, 5 = excellent.

performance, cognitive-affective associates of work performance (fatigue/exhaustion, mindfulness, work engagement), mood, work-related strain and recovery. The four daily reporting epochs were: before work, at the middle of the work day, at the end of the work day and at bedtime. In addition, baseline assessments of beverage consumption, the selected outcomes, background and demographic variables, bullying and burnout were gathered prior to the distribution of the diary. Beverage consumption was reported four times daily, and work-related outcomes were assessed three times daily (before work, in the middle of the work day and at the end of the work day) with the exception of subjective performance, work engagement and recovery.

Beverage consumption

Beverage consumption was the type of beverage consumed, the amount consumed, and details of preparation methods and additives (e.g. milk, sugar). From this, consumption in cups was calculated for four drink types: tea, coffee, other caffeinated beverages and non-caffeinated beverages.

Subjective work performance

Subjective work performance was assessed twice daily (in the middle and at the end of the work day) using a one-item, global self-rating ("Overall, how would you rate your performance in the last four hours?") to which participants responded on a scale from 1 = "Poor" to 5 = "Excellent".

Fatigue/exhaustion

Fatigue/exhaustion was measured using an 8-item scale constructed by adapting relevant items from the *Oldenburg Burnout Inventory*, *Copenhagen Burnout Inventory*, and the *Checklist Individual Strength* (adapted by van Gelderen, Heuven, van Veldhoven, Zeelenberg, & Croon, 2007). Participants reported the extent to which items (e.g. "I felt rested") were true for them on a scale of 1 = "Yes, that is true" to 7 = "No, that is not true". Possible scores ranged from 8–56, with high scores reflecting higher fatigue.

Mindfulness

Mindfulness is a state of being attentive to and aware of what is taking place in the present (Brown & Ryan, 2003) and was used here to indicate the level of conscious attention and awareness given to work. Mindfulness was assessed using a shortened 7-item version of the Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003; test–retest reliability $r = 0.81$). Participants reported the frequency of experiences (e.g. "I rushed through activities without really being aware of them") on a scale of 0 = "Never" to 3 = "Very often". Possible scores ranged from 0–21, with high scores reflecting lower mindfulness.

Work engagement

Work engagement is an affective-cognitive state comprising vigour, dedication, and absorption in work. It was assessed twice daily (in the middle and at the end of the work day) using items modified from the short version of the *Utrecht Work Engagement Scale* (Schaufeli, Bakker, & Salanova, 2006) Rank order reliability has been reported as $r = 0.82$–0.86 (Seppälä et al., 2009). Participants reported the frequency of experiences (e.g. "I am immersed in my work" or "my job inspired me") on a scale of 0 = "Never" to 6 = "Always". Scores were summed and averaged and possible scores ranged from 0–6, with high scores reflecting higher levels of engagement.

Mood

Mood was assessed using the *Positive and Negative Affect Scale* (PANAS; Watson, Clark, & Tellegen, 1988) and an adaptation of the *Visual Analogue Mood Scales* (VAS; Bond & Lader, 1974). The 20-item PANAS comprises two sub-scales, positive affect and negative affect, and participants reported the extent to which they experienced these on a scale of 1 = "Not at all" to 5 = "Extremely". Possible scores ranged from 10–50 for each sub-scale, with high scores reflecting higher positive or negative affect. The 7-item VAS (Cronbach's alpha = 0.85–0.90; Watson & Clark, 1994) contained 6 adjectives (relaxed, jittery, tired, tense, headache, mental fatigue) for which participants rated their status on a 100 mm line anchored by the labels "Not at all" to "All of the time" and overall mood, which was anchored with the labels "Excellent" and "Very bad". All items were analysed individually with lower scores reflecting a better mood.

Work-related strain

Work-related strain was measured using the 14-item stress sub-scale from the *Depression Anxiety Stress Scale* (DASS; Lovibond & Lovibond, 1995; test–retest reliability $r = 0.81$; Crawford & Henry, 2003). Participants reported the extent to which items applied to them on a scale of 0 = "Did not apply at all" to 3 = "Applied much of the time". Possible scores ranged from 0–42, with high scores reflecting higher work-related strain.

Recovery

Recovery combines psychological detachment from work, relaxation, and mastery of experiences that provide opportunities for learning. It was assessed at bedtime using 12 items from the *Recovery Experience Questionnaire* (Sonnentag & Fritz, 2007; Cronbach's alpha = 0.85; adapted for use in diary studies; Sonnentag, Binnewies, & Mojza, 2008). Participants reported the extent to which they agreed with items (e.g. "Tonight, I distanced myself from my work") on a scale of 1 = "Not at all agree" to 5 = "Fully agree". Possible scores ranged from 12–60, with high scores reflecting higher recovery.

Data analysis

As the diary data in this project were organised hierarchically, with each participant providing measures at various time-points across a number of work days, data were analysed using multilevel modelling (MLM; Hofman, 1997; Hofman & Gavin, 1998; Hox, 1995) and the statistical program MLWiN 2.10 (Rasbash, Steele, Browne, & Goldstein, 2008). MLM analyses variables from different hierarchical levels simultaneously using regression models that take into account the dependencies in the data and explicitly models variance in the outcome arising from different hierarchical levels. Thus relationships both within and across a hierarchical levels can be modelled (Hofman, 1997; Hox, 1995). For the current study, up to four data collection time-points were nested within each work day, and 10 work days were nested within each individual participant to give a three-level hierarchical structure: Level 3 = Participant; Level 2 = Day; and Level 1 = Time-point. In MLM, power is determined by the number of data points available for analysis, rather than number of participants *per se*. Most of the analyses utilised the full three-level data set, comprised of (up to) 3800 data points, which provides statistical power equivalent to 3800 participants in a (single-level) cross-sectional study. Some analyses utilised a two-level data file (e.g., for the recovery outcome variable), for which (up to) 950 observations were available. The number of Level 3 units and observations per unit exceed the recommended minimum levels for multilevel regression (Hox, 1995) therefore the study was more than adequately powered to detect effects.

Daily trends in the data

Concurrent daily trends may produce spurious relationships between independent (e.g. beverage consumption) and dependent

(e.g. work performance) variables and therefore inflate or reduce associations. Of particular concern was that intra-individual daily patterns of beverage consumption might align with consistent daily variations in mood. We thus chose to detrend the data (all variables) to remove daily fluctuations within individuals. Detrending involved (1) calculating standardised variables for each time point by subtracting the daily mean and dividing by the daily standard deviation, (2) computing the daily pattern for each variable by averaging the standardised scores for each time point across the ten days, (3) computing the expected pattern for each variable by multiplying the averaged standard scores for all time points by the daily standard deviation, and (4) calculating detrended scores by subtracting the expected pattern from the original scores. Therefore effects of beverage consumption on outcomes were over and above any co-incidental daily trends in the data.

Preparation for MLM

Data were examined for accuracy of entry, missing data and outliers. There were few missing data which were imputed using mean substitution for individual, randomly spread missing values (Tabachnick & Fidell, 2001), or retained as missing as MLM deals with missing data well. We examined whether there was sufficient variation at all levels in the multilevel model for relevant outcome variables by calculating the intra-class correlation (Hox, 1995) based on the highest level intercept only model. Analyses were conducted only if at least 12% (i.e. intra-class correlation >0.12) of the variance could be attributed to each level of the model (James, 1982). Although the basic structure of the study data corresponded to a three-level data file, some analyses necessitated the use of a two-level data structure (i.e. when measures were collected only once per day), or a lagged data file that represented relationships over time. The Null model was the intercept only model at the highest level. For nested models, the $\Delta-2 \times$ log statistic is presented as an indication of improvement in model fit, with the significance of these values as referred to the chi-square distribution. Only results that were significant at the $p \leqslant 0.01$ level are reported in order to minimise chances of a Type 1 error. Where

relevant, baseline/trait scores were included as control variables in the first model prior to adding the variables of substantive interest. Following the recommendations of Hofman and Gavin (1998), grand mean centering was used for all analyses except for those in which previous day variables were examined as predictors and moderators of following day variables, in which person mean centering was used.

Results

Beverage consumption

Average daily beverage consumption appears in Table 2 below. Tea consumption ranged from 0 to 7.5 cups per day with a median consumption of 1 cup per day. Coffee consumption was similar, ranging from 0–6.5 cups per day and a median intake of around 1 cup per day. Very few other caffeinated beverages were consumed. The greatest intake was of non-caffeinated beverages, which included water.

Table 2 also shows that 64 participants consumed tea, 62 participants consumed coffee, 41 participants consumed other caffeinated beverages and 81 participants consumed non-caffeinated beverages *at some stage during the 10 days*. For all beverages the most common addition was milk, followed by milk with sugar and the least common additive was sugar alone. Additives were less likely to be added to other caffeinated beverages than to other beverages.

Effects of beverage consumption on work-related outcomes

We examined whether the amount of tea consumed would have a greater positive relationship with the selected work-related outcomes than consumption of other beverages. In addition, we examined whether these relationships were moderated by the use of beverage additives. For these analyses, the full three-level data set was used for all outcomes except for recovery (which was measured once per day) for which a two-level data file was created. For

Table 2
Average daily beverage consumption in cups and frequencies of beverage additives.

Beverage	Number of participants	Number of occurrences over 10 days	Range Mean (SD) Median
Tea	64	1297	0–7.50 1.58 (1.75) 0.95
Tea + milk	39	448	
Tea + sugar	8	47	
Tea + milk + sugar	17	190	
Coffee	62	1081	0–6.50 1.38 (1.42) 1.05
Coffee + milk	53	567	
Coffee + sugar	13	35	
Coffee + milk + sugar	39	380	
Other caffeinated beverages	41	261	0–2.70 0.32 (0.54) 0.05
Other caffeinated beverages + milk	20	81	
Other caffeinated beverages + sugar	4	4	
Other caffeinated beverages + milk + sugar	5	5	
Non-caffeinated beverages	81	4601	0.10–15.50 5.64 (2.85) 5.25
Non-caffeinated beverages + milk	31	78	
Non-caffeinated beverages + sugar	10	16	
Non-caffeinated beverages + milk + sugar	13	64	

Table 3
Statistically significant effects for effects of beverage and additives on work-related outcomes.

Variable	Intra-class correlation	Significant model	$\Delta-2 \times \log (\Delta df)$	Relation	γ (SE)
VAS[a] 1 (relaxed)	Level 1 = 0.44 Level 2 = 0.16 Level 3 = 0.40	2	14.46 (4)[**]	Positive with non-caffeinated	1.06 (0.47)
VAS[a] 3 (tired)	Level 1 = 0.45 Level 2 = 0.17 Level 3 = 0.38	4	26.54 (12)[**]	Tea + sugar	3.34 (1.08)
Subjective work performance	Level 1 = 0.48 Level 2 = 0.20 Level 3 = 0.32	4	31.46 (12)[**]	Tea + milk Tea + sugar Tea + milk + sugar	−0.30 (0.08) −0.12 (0.05) −0.24 (0.09)
Recovery	Level 2 = 0.50	2	16.996 (4)[**]	Positive with evening non-caffeinated	1.66 (0.60)

[**] $p < 0.01$.
[a] Visual Analogue Scale.

all outcomes except recovery, the following models were tested in sequence: (Model 1) the relevant baseline/trait scores (to control for these as covariates); (Model 2) direct associations between outcomes and beverage consumption; (Model 3) the direct associations between outcomes and beverage additives (to control for all direct effects prior to examining interaction effects); and (Model 4) the interaction of beverage consumption and additives. Interactions were interpreted following the recommendations of Aiken and West (1991). Where a significant interaction term was indicated, values on the dependent variable for high (1 SD above the mean) and low (1 SD below the mean) values of the independent variable and moderator variable were plotted and the nature of the interaction was interpreted from the plots. Table 3 provides an overview of the significant effects found.

There was a significant positive main effect of non-caffeinated beverage consumption on VAS ratings of relaxation. Furthermore, there was a significant interaction effect between tea consumption and the addition of sugar on VAS ratings of tiredness. When tea was consumed with sugar, there was no relationship between tea consumption and tiredness, but when consumed without sugar, there was a negative relationship between tea consumption and tiredness, with those drinking more tea reporting less tiredness (Fig. 1).

For subjective work performance, there were significant interaction effects between beverage intake and additives (Figs. 2–4). Tea consumption had a positive relationship with work performance, such that higher consumption was related to higher levels of performance, but only when consumed without any additives (i.e. milk, sugar or both). As observed for tiredness, the performance benefits of increasing tea consumption were lost when sugar was consumed (Fig. 3), whereas the addition of milk was not a factor in tiredness ratings.
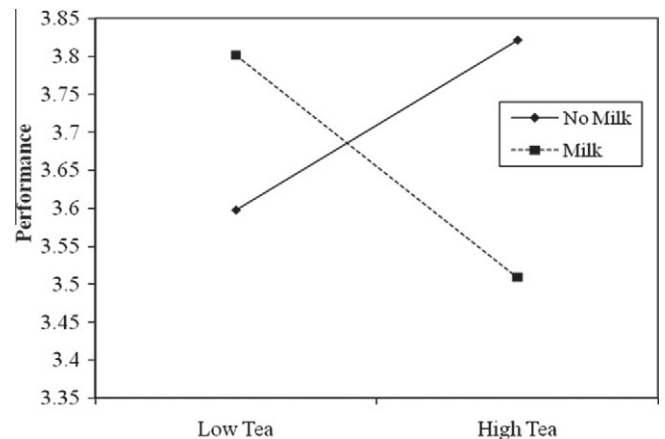
There were no effects of beverage consumption or interactions between beverage consumption and additives for reports of jitteriness, tense, headache, mental fatigue, overall mood, fatigue, engagement, mindfulness, strain, positive or negative affect.

For evening recovery, there were no main effects of day-time beverage consumption or interactions between beverage consumption and additives. However, there was an effect of evening beverage consumption on recovery, with higher intakes of non-caffeinated beverages related to higher levels of recovery.

We also examined whether consumption of tea, rather than other beverages, would moderate the relationship between prior mood and work related outcomes. To test this we created a two level data file that represented previous evening recovery and morning mood as predictors at Level 2, and beverage consumption and work-related outcomes across the day at Level 1. The following models were tested: (Model 1) the significance of baseline/trait variables; (Model 2) the direct effects of morning mood and previous evening recovery on the outcomes, (Model 3) the direct
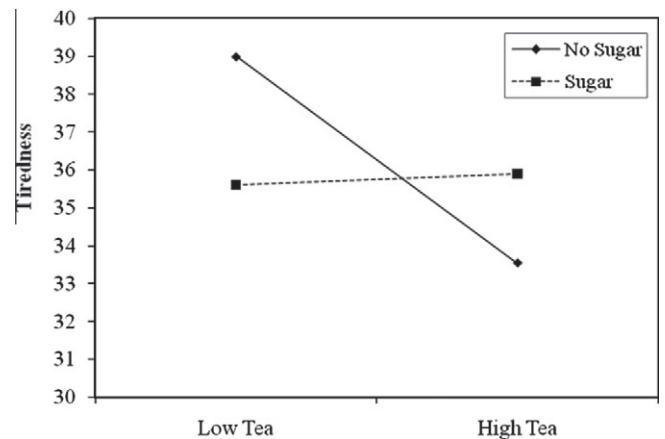
Fig. 1. Interaction between effects of tea consumption and the addition of sugar on tiredness.

Fig. 2. Interaction between effects of tea consumption and the addition of milk, sugar, and both milk and sugar, on work performance.

effects of beverage consumption on the outcomes (to control for all direct effects prior to examining interaction effects); (Model 4) the effects of the interactions between morning mood and beverage consumption, and between previous evening recovery and beverage consumption on the outcomes. Table 4 provides an overview of the significant effects.

Tea consumption moderated the negative effects of evening recovery on mindfulness. Among those consuming higher levels of tea, there was a negative relationship between previous evening
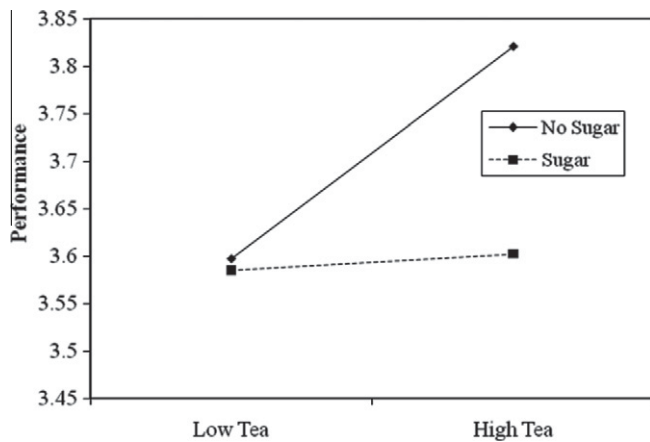
Fig. 3. Interaction between effects of tea consumption and the addition of sugar on work performance.
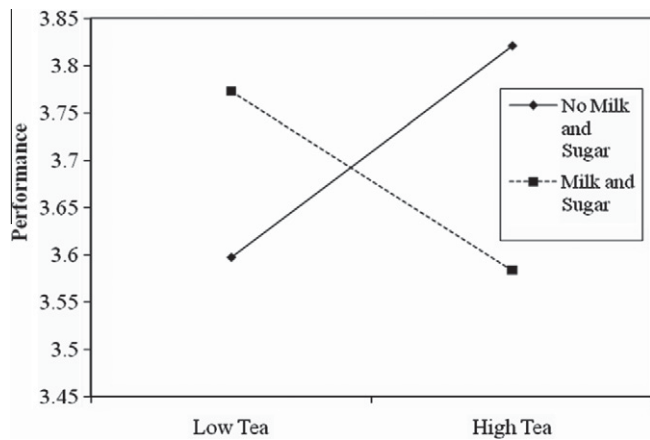

Fig. 4. Interaction between effects of tea consumption and the addition of milk and sugar on work performance.

recovery and mindfulness the following day. The same was found for other caffeinated beverages. Among those consuming higher levels of other caffeinated beverages, there was a negative relationship between previous evening recovery and mindfulness the following day, and a negative relationship between morning mood and mindfulness later in the day.

Discussion

The current study is the first to examine the relationship between daily habitual consumption of tea, and other beverages, and work-related outcomes in a naturalistic, work-place setting, over 10 days. Among this sample we found that participants consumed more non-caffeinated beverages than caffeinated beverages other than tea and coffee. Non-caffeinated beverages included

water, herbal teas and other non-caffeinated hot beverages, juices, non-caffeinated soft drinks and alcohol. The median intakes of tea and coffee were one cup per day, however there was a large range of intakes with participants consuming between 0–7.5 of tea and 0–6.5 cups of coffee per day. This intake compares with previous research in a community Australian sample (Bryan, Crichton, & Murphy, 2009). Very few other caffeinated beverages were consumed.

Also of note was the variability with which participants consumed additives (milk, sugar or both) with their beverages. It appears that rather than consuming the beverages in a consistent way (e.g. always drinking tea without milk or sugar) participants varied the additives they consumed. This could be because tea and coffee are commonly consumed outside the home and in many forms. For example, it could be the case that even though individuals commonly drink their tea black, they may order sweetened milk teas, such as chai latte, when in a café.

Our first research question examined whether tea consumption would have a greater positive relationship with work-related outcomes than consumption of other beverages. This was supported only for ratings of tiredness and subjective work performance. Tea, when taken without sugar was related to lower ratings of tiredness; and, when taken without milk, sugar or both, was related to better perceived work performance. The positive effect of tea consumption on tiredness supports previous findings (Hindmarch et al., 2000; Scott et al., 2004) in which tea, when consumed across the day, was associated with lower perceived sedation and fatigue than was coffee. This is the first study to show positive effects of tea consumption on subjective work performance. As reported beverage consumption in this study is likely to reflect participants' longer-term consumption habits, these positive effects of tea are more likely to be due to the effect of tea flavonoids, rather than effects of caffeine, and perhaps theanine, which have been shown to have acute effects.

The moderating effect of tea additives on tiredness and perceived work performance is a unique finding. There are no scientific studies demonstrating that effects of tea on mood and performance are reduced by the addition of milk or sugar. Indeed Quinlan, Lane, and Aspinall (1997) found that the addition of milk to (de)caffeinated tea and coffee had a positive effect on mood and anxiety. It is not clear how milk could modulate effects of tea on mood and performance. Bioavailability research in human subjects indicated no effect of milk up to 25% on the polyphenol or tea catechins concentration in blood or on the antioxidant activity of flavonoids (Dufresne & Farnworth, 2001; Joshi & Ganguli, 2008; Reddy, Vidaya Sagar, Sreeramulu, Venu, & Raghunath, 2005). There are no studies to date which investigate the effect of milk on the bioavailability of other tea flavonoids, caffeine or theanine, but due to a lack of interaction between milk and these ingredients an altered bioavailability is unlikely to be the mechanism behind the effects. However, Lorenz et al. (2007) found that improvements in flow-mediated dilation following black tea consumption were negated by the addition of milk to black tea. Given that there is evidence linking potential vasoactive nutrients, such as tea flavonoids, with improved psychological health by enhancing cerebral blood flow (Sinn & Howe, 2008; Spencer, 2010), this may be the mechanism by which milk moderates the relationship between tea

Table 4
Statistically significant effects for the effects of evening recovery, morning mood and beverage consumption on work-related outcomes.

Variable	Intra-class correlation	$\Delta-2 \times \log (\Delta df)$	Relation	γ (SE)
Mindfulness (higher values are negative)	Level 1 = 0.22	19.63 (8)[*]	Tea + evening recovery	0.03 (0.01)
	Level 2 = 0.16		Other caffeinated + morning mood	0.03 (0.01)
	Level 3 = 0.62		Other caffeinated + evening recovery	0.09 (0.03)

[*] $p = 0.01$.

consumption and work performance. Moreover, the amount of sugar added to tea is much smaller than doses that have been shown to influence performance in previous studies (25–75 g; Messier, 2004). As between-subject differences cannot be ruled out at the moment, it would be interesting to find out whether this effect can be replicated in an experimental study manipulating milk and sugar using a within-subjects design.

In addition to tea, non-caffeinated beverages consumed during the day were positively associated with relaxation and, when consumed during the evening, with greater recovery. The absence of caffeine appears to enhance relaxation during the day. The associations between non-caffeinated beverages and greater evening recovery may in part be due to the consumption of alcohol and its associated social context which may aid recovery.

We also examined whether tea consumption would moderate the effects of morning mood and previous evening recovery on indicators of daily work-related mood, performance, and strain later in the day. Mindfulness was the only variable for which beverage consumption influenced the effects of prior mood and recovery. Tea consumption moderated the negative effects of evening recovery on mindfulness. Contrary to what might be expected, those who reported higher levels of recovery during the previous evening reported lower levels of mindfulness the following day, but only among those who had higher levels of tea consumption.

In addition, the consumption of other caffeinated beverages also moderated the negative effects of morning mood and evening recovery on mindfulness. For those who consumed lower levels of other caffeinated beverages there was no relationship between evening recovery and morning mood and mindfulness. However among those consuming higher levels of other caffeinated beverages, there was a negative relationship between previous evening recovery and morning mood and mindfulness the following day or later in the day. One possible explanation for this finding could be that caffeine tolerance might be higher among higher tea consumers. Evening recovery might be higher and subsequent mindfulness lower among higher, compared with lower, tolerant consumers. These findings suggest that while beverage consumption has the ability to moderate effects of prior mood on subsequent associates of work performance, these effects appear to be detrimental. Longer-term intervention studies that assess indices of work performance after manipulating beverage types would extend these findings.

The strengths of the current study were the richness of the data, utilising multiple reporting points over 10 working days, and the high internal and external validity. The internal validity of the findings was enhanced by detrending the data, while assessing relationships between beverage consumption and outcomes over 10 working days allowed reflection of everyday cognitive and emotional experiences, thus providing ecologically valid data. A limitation is that causality remains untested. It is a possibility that those who drank tea without additives also had different health and lifestyle behaviours or even personality traits than those who drank tea with additives, thereby confounding the results. Although we controlled for baseline measures of associates of work performance, we did not control for other characteristics of the sample, such as food consumption, nutritional knowledge, personality factors and expectations.

In conclusion, tea consumption is associated with increased perceived work performance and reduced tiredness, especially when consumed without milk or sugar. Furthermore, non-caffeinated beverages are associated with increased relaxation and recovery from work, while tea and other caffeinated beverages may enhance the negative effects of evening recovery and morning mood on mindfulness during the day. Overall, the findings raise the possibility that beverage intake may have a role in optimising work-related psychological states and performance.

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