THE RELATIONSHIP BETWEEN DIETARY FACTORS AND MENTAL ENERGY

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ILSI North America
Washington, DC

Life Sciences Research Office, Inc.
9650 Rockville Pike
Bethesda, Maryland 20814
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Prepared for:
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INTRODUCTION
This report summarizes the findings of a comprehensive literature review on the relationship between dietary factors and mental energy. It was developed under a contract between the International Life Sciences Institute (ILSI) North America Technical Committee on Energy and Life Sciences Research Office (LSRO). Mental energy is the ability to perform mental tasks, the intensity of feelings of energy and fatigue, and the motivation to accomplish mental and physical tasks. Mental energy is a three-dimensional construct consisting of mood (transient feelings about the presence of fatigue or energy), motivation (determination and enthusiasm), and cognition (attention and speed of information processing) of energy (O'Connor, 2006b). The techniques used to measure these three components were based on reviews that identified valid cognitive (Lieberman, 2006), mood (O'Connor, 2006a), and motivation (Barbuto, Jr., 2006) measures of mental energy. These three dimensions collectively exemplify effort, performance, and attitude (Barbuto, Jr., 2006). Marketing claims for herbal supplements and food, beverage, and drug products designed to increase mental energy have widely risen, increasing the need for scientific specificity.

Objectives and Approach
The objectives were to:

- Describe the scope of published scientific literature about human studies on food, diet, and food components and mental energy
- Identify and evaluate measures of mental energy

METHODS
LSRO conducted a literature search using the Pubmed and PsychInfo databases for articles cited up to December 15, 2008. This includes articles e-published and listed in Pubmed by December 15, whose actual publication dates occurred in winter 2009. Searches were conducted using Medical Subject Headings (MeSH) combined with key words to define the topic, see able 1 for the detailed search strategy.

Studies were restricted to human only and included both prospective and observational studies. Study subjects were limited to adults 18 years of age and older; including seniors with managed disease (e.g., diabetes). We excluded studies of seniors with
Alzheimer’s disease or other dementia. Both oral ingestion and gastric infusions were included in the review. Other exclusion criteria included review articles and studies evaluating the effects of caffeine, genetics, pain, sleep, and/or disease on mental energy. The initial search strategy retrieved 2488 articles, excluding reviews. The abstracts were read and approximately 250 articles were included that used measures of mood, cognition, and/or motivation to evaluate food or food component intake. The remaining articles were screened for exclusion/inclusion criteria and those meeting inclusion criteria were manually cross-referenced. Two-hundred forty articles met the inclusion criteria.

Data were extracted and entered into a Microsoft Access (Microsoft Corp, Redmond, WA) database. Extracted information included population description, number of subjects, type and duration of the study, dosage and timing of treatment, and outcome measures for mental energy measures of mood, cognition, and motivation. Timing and duration of ingestion of dietary components were categorized into five groups: short-term acute (less than 2 hours), long-term acute (2–24 hours), short-term chronic (2–7 days), moderate-term chronic (1–26 weeks), and long-term chronic (greater than 26 weeks).

METHODS AND RESULTS

Individual Tests of Mental Energy

Mood

O’Connor (2006a) recommended three widely used methods for measuring the mood of mental energy: VAS, vitality scale of the SF-36 Health Survey, and the vigor or fatigue scale of the POMS. In the current review, numerous studies employed these surveys to determine mood. However, usually they employed the full version of the POMS and VAS, in addition to the specific scales mentioned by O’Connor. There were 49 studies that reported using the VAS, 42 that used the POMS, and five that used the SF-36. As mentioned previously there were several other mood tests administered, but they were used with much less frequency. Results for the current review were not restricted to suggested ‘mental energy’ factors for the POMS and VAS and all relationships between mood and dietary components were included.

Cognition
Lieberman (2006) recommended four tests of vigilance and reaction time that can be effectively used to detect changes in mental energy. These tests include the psychomotor vigilance test, the Wilkinson four-choice visual reaction time test, the Wilkinson auditory vigilance test, and the scanning visual vigilance test. However, in the current review there were no studies identified that used these particular tasks. Lieberman (2006) was interested mainly in dietary components and outcomes that were outside the scope of the current review, such as caffeine and sleep. However, several included studies reported on the effects of dietary components and reaction time and vigilance using other methods. There were 43 articles that used a combination of one or more reaction time tests, or analyzed the reaction time component of another cognitive task, these included: simple reaction time, choice reaction time, auditory or visual reaction time, continuous performance task, digit symbol substitution, five-choice serial reaction time, letter-digit pairs. The most commonly used reaction time tests were simple and choice reaction time. There were 27 articles that used a vigilance task, these included: continuous performance task, visual vigilance, digit vigilance, rapid information processing task, a portable vigilance monitor, and dot-probe task. The most commonly used vigilance task was digit vigilance. Here, we included all tasks of attention, memory, and speed of information processing.

**Motivation**

Barbuto (2006) recommended four approaches for studying the motivation domain of mental energy. Out of the 240 studies included in the review, only two measured motivation. The measures they used were ‘time spent trying to remember words’ and pupil size, a measure of mental effort (Benton *et al.*, 2001; Deijen *et al.*, 1992). Given the paucity of data at this time, there are no conclusions that can be drawn about the association between dietary components and motivation nor the tests used to measure motivation. This mental energy component will not be discussed further because of the lack of data.

**Nutrients, Food Constituents, and Dietary Supplements That May Enhance or Lower Mental Energy Levels**

*Ginkgo biloba*

*Mood*

**Cognition**

Four studies report that *Ginkgo biloba* improved speed of processing (Mix & Crews Jr., 2000; Polich & Gloria, 2001; Santos *et al.*, 2003; Stough *et al.*, 2001). Two studies report that Ginkgo improved long-term memory in older subjects (55–79 years); however there was no effect in younger subjects (Burns *et al.*, 2006; Mix & Crews Jr., 2000). Two studies report that *Ginkgo biloba* increased reaction time (Cieza *et al.*, 2003; Subhan & Hindmarch, 1984), but two other studies report no effect (Moulton *et al.*, 2001; Polich & Gloria, 2001). While two studies reported improved memory after *Ginkgo biloba* (Cieza *et al.*, 2003; Stough *et al.*, 2001), five studies reported no detectable effects of Ginkgo on memory (Carlson *et al.*, 2007; Dodge *et al.*, 2008; Moulton *et al.*, 2001; Nathan *et al.*, 2002; Solomon *et al.*, 2002). Two studies reported that *Ginkgo biloba* improved attention (Elsabagh *et al.*, 2005a; Santos *et al.*, 2003), but four studies report no effect (Carlson *et al.*, 2007; Elsabagh *et al.*, 2005b; Hartley *et al.*, 2003; Mix & Crews Jr., 2002). *Ginkgo biloba* consistently improved speed of processing (Mix & Crews Jr., 2000; Polich & Gloria, 2001; Santos *et al.*, 2003; Stough *et al.*, 2001). However, there seems to be a lack of evidence for an association between *Ginkgo biloba* and attention (four studies) and memory (five studies).

*Ginkgo biloba* may have time and dose-dependent effect on memory and attention (Kennedy *et al.*, 2000; Kennedy *et al.*, 2001a; Kennedy *et al.*, 2002; Kennedy *et al.*, 2007; Rigney *et al.*, 1999; Scholey & Kennedy, 2002). However, despite the large number of studies performed by one group of authors, the results are inconsistent on which doses and time-points reliably produce the same results. The literature regarding *Ginkgo biloba* and mental energy, except for speed of processing, contains no consistent evidence that *Ginkgo biloba* improves cognitive function. Many of the acute studies used multiple outcomes and report positive effects on one or more of these
tasks at particular time points and doses, but are not replicated or are contradicted by other studies using similar extracts and procedures.

**Ginseng**

**Mood**

One study reported that ginseng improved vigor (POMS) (Ussher *et al.*, 1995). Ginseng decreased fatigue (2 studies) and alertness (1 study) (VAS) (Kennedy *et al.*, 2001b; Reay *et al.*, 2006). However, three studies report no effect of ginseng on mood (Cardinal & Engels, 2001; Kennedy *et al.*, 2004; Scholey & Kennedy, 2004). There is no consistent evidence that ginseng has any effects on mood, more research is needed.

**Cognition**

Ginseng improves mental processing, but had no effect on attention, recognition memory, or reaction time (D'Angelo *et al.*, 1986). Ginseng improved abstract thinking and increased auditory reaction times, but had no effect on learning and memory or speed of processing (Sørenson & Sonne, 1996). Ginseng improved attention and reaction time and enhanced memory (Kennedy *et al.*, 2004). The same group also reported that ginseng (400mg) improved accuracy and slowed speed of processing (200mg) on serial sevens, but had no effect on serial threes (Scholey & Kennedy, 2002). Ginseng (200mg) improved accuracy on a task of concentration (serial sevens), but had no effect on another (serial threes) nor speed of processing (Reay *et al.*, 2005). However in a later study from the same authors the opposite effect was reported, that the same dose of ginseng improved concentration (serial threes) and improved speed of processing, but did not effect a different test of concentration (serial sevens) (Reay *et al.*, 2006). Reay *et al.* (2006) postulates that possible differences in performance might stem from inconsistencies in ginsenosides in the extract. Ginsenosides are highly variable and are dependent on the species, age and part of plant, preservation method, season of harvest, and extraction method (McDaniel *et al.*, 2003). The literature is inconsistent on the effects of ginseng on cognition. Some studies report that it improves mental arithmetic, but the same study also reports null findings at different doses and time points and the effect seems to vary between reports from the same authors [see (Reay *et al.*, 2005) and (Reay *et al.*, 2006)].

**Glucose**
**Mood**

Glucose decreased fatigue (VAS) (Reay et al., 2006). Glucose enhanced vigilance (VAS), but only when subjects knew they were given glucose (Green et al., 2001). Five studies report no effect of glucose on mood (Benton & Donohoe, 2004; Scholey & Fowles, 2002; Scholey & Kennedy, 2004; Winder & Borrill, 1998). Overall, there seems to be no effect of glucose on mood. All of the included studies are similar in dosing and timing and used similar ‘mood’ tests such as POMS or VAS.

**Cognition**

The effect of glucose on cognitive performance, particularly memory, is well established in the literature (Hoyland et al., 2008). Eight studies report that glucose improved some aspect of memory (recognition, logical, word list recall, non-verbal, and short and long-term) (Benton & Donohoe, 2004; Foster et al., 1998; Green et al., 2001; Hall et al., 1989; Manning et al., 1990; Parsons & Gold, 1992; Sünram-Lea et al., 2001; Sünram-Lea et al., 2002a). However, 10 studies report that glucose does not enhance memory (visual, short and long-term) (Azari, 1991; Benton & Owens, 1993; Ford et al., 2002; Foster et al., 1998; Green et al., 2001; Hall et al., 1989; Manning et al., 1990; Scholey & Kennedy, 2004; Sünram-Lea et al., 2001; Winder & Borrill, 1998). Glucose increased performance on some aspects of memory recall and logical memory) in older subjects (Craft et al., 1994; Manning et al., 1997; Meikle et al., 2004). Glucose resulted in greater improvements in memory when given before task acquisition than when given before memory retrieval task (Manning et al., 1992; Manning et al., 1998; Sünram-Lea et al., 2002b). Glucose improved memory in fasted subjects, but not in subjects who had eaten breakfast (Martin & Benton, 1999).

Glucose improved performance on one task of concentration (serial sevens), but not another (serial threes) and had no effect on verbal fluency (Kennedy & Scholey, 2000). Another study from the same group of authors reported the opposite effect that glucose improved performance on one task of attention (serial threes), but not another (serial sevens) and also improved speed of processing (Reay et al., 2005). Glucose enhances memory in young healthy adults, when tasks of appropriate difficulty are used such as verbal declarative memory with fewer effects in tasks such as short-term or working memory and procedural memory (Gold, 2005). There is a wealth of data regarding
glucose and cognition, but the results are inconsistent. Timing, dosing, and study population contribute to the inconsistent findings. Certain populations, such as the elderly or those with poor gluco-regulation, are more likely to show improvements after glucose administration.

**Isoflavones**

*Mood*

One study reported that fatigue decreased and global mood score (POMS) improved after long-term treatment with isoflavones (60mg/day) (Casini et al., 2006). However, three studies report no effect of isoflavones and mood (Duffy et al., 2003; File et al., 2005; Ho et al., 2007).

*Cognition*

One study reported that isoflavones improved incidental learning, mental flexibility, and attention (Casini et al., 2006). Another study reported that isoflavones improved memory, frontal lobe function, and sustained attention, but not verbal fluency and planning ability (Duffy et al., 2003). Isoflavones improved verbal memory (Kritz-Silverstein et al., 2003). However, another study reported that isoflavones increased errors on a verbal working memory task, but had no effect on attention, visual long-term memory or visuospatial working memory (Fournier et al., 2007). Both ten and six weeks of soy supplementation improved immediate recall, short-term working memory, mental flexibility, and planning ability, but had no effect on attention or long-term memory (File et al., 2001; File et al., 2005). Six studies report that isoflavones had no effect on cognition (learning, memory, attention, and global cognitive function) (Fournier et al., 2007; Franco et al., 2005; Ho et al., 2007; Howes et al., 2004; Kreijkamp-Kaspers et al., 2004; Kreijkamp-Kaspers et al., 2007).

**Meal Composition-Carbohydrate**

*Mood*

Three studies report that a carbohydrate meal increased fatigue (flicker fusion frequency, VAS, POMS) (Cunliffe et al., 1997; Maridakis et al., 2009; Spring et al.,
Low fat/high carbohydrate meal decreased fatigue and increased vigor (VAS, POMS) (Lieberman et al., 2002; Lloyd et al., 1996). However, a carbohydrate drink produced the opposite effect and increased vigor and decreased fatigue during a laboratory stressor (POMS) (Markus, 2007). Five studies report that neither carbohydrate drinks nor meals had effects on mood (POMS) (Cline et al., 2000; Fischer et al., 2001; Greenwood et al., 2003; Reid et al., 2007; Reid & Hammersley, 1995).

Cognition
Carbohydrate drink improved vigilance (Lieberman et al., 2002). Four studies report that a high carbohydrate meal improved reaction time (Maridakis et al., 2009; Markus et al., 1999; Markus et al., 1998; Smith et al., 1988). However, two studies reported that a carbohydrate meal had no effect or slowed reaction time (Cunliffe et al., 1997; Spring et al., 1982). Two studies report that a carbohydrate meal had no effect on cognition (working verbal declarative memory, long-term memory, attention, alertness, executive function) (Kaplan et al., 2000; Paz & Berry, 1997).

Omega-3 polyunsaturated fatty acids
Mood
Two studies report that omega-3 polyunsaturated fatty acid (PUFA) supplementation increased vigor and decreased fatigue (POMS) (Fontani et al., 2005a; Fontani et al., 2005b). One study reported that omega-3 PUFA supplementation had no effect on mood (Rogers et al., 2008).

Cognition
High dietary intake of omega-3 PUFAs improved scores on global cognitive function (MMSE) and prevented decline in older adults (Kalmijn et al., 2004; Velho et al., 2008). An observational study reported that fish-oil supplement use was associated with better speed of processing, but had no effect on verbal memory or executive function (Whalley et al., 2004). Omega-3 PUFA supplementation improved reaction time (Fontani et al., 2005b). One study reported omega-3 PUFA supplementation had no effect on cognitive function (Rogers et al., 2008). There is some evidence that omega-3 supplements might benefit global cognitive functioning in the elderly, but more research is needed.

Vitamin Supplements
Mood
The following section describes studies for multi-vitamins; the exact formulation of these vitamins was poorly described. A dietary supplement increased vigor after 2 months of treatment (POMS) (Ussher et al., 1995). However, another study reported no effect on mood (POMS) after vitamin supplementation (Arwert et al., 2003).

Cognition
An enriched vitamin drink in the elderly improved immediate recall and category fluency (Wouters-Wesseling et al., 2005). Long-term vitamin supplementation improved abstract thinking and working memory, but had no effect on long-term memory (Chandra, 2001). Long-term vitamin supplementation improved reaction time in females, but had not effect on attention (Benton et al., 1995). Vitamin supplementation decreased speed of processing, but had no effect on global cognition or learning and memory (McMahon et al., 2006). Three studies report that a dietary supplement had no effect on cognition (Arwert et al., 2003; McNeill et al., 2007; Whalley et al., 2003).

B vitamins
One study reported no effect of vitamins B-6 or B-12 on mood (POMS) (Bryan et al., 2002). Vitamin B-6 improved recall in middle-aged subjects (Bryan et al., 2002). Vitamin B-6 improved long-term verbal memory, but had no effect on working verbal memory, long-term memory storage, long-term visual memory, and attention (Deijen et al., 1992). Vitamin B-6 decreased performance on the visual retention test, but had no effect on memorization (Molimard et al., 1980). Vitamin B-6 improved visual recognition and motor production (Tolonen et al., 1988). One study reported no reported effect of vitamins B-6 or B-12 on cognitive function (MMSE) (Tucker et al., 2005).

Folate
One study reported no effect of folate on mood (POMS) (Bryan et al., 2002). Younger subjects taking folate had improved recall (Bryan et al., 2002). Folate improved memory and global cognitive function, but had no effect on speed of processing (Durga et al., 2007). Dietary folate slowed cognitive decline and low dietary folate intake in the elderly was associated with decreased performance on both a memory and abstract thinking task (Goodwin et al., 1983; Tucker et al., 2005). However, high dietary folate intake was associated with cognitive decline, compared to the lowest quintile of intake (Morris et al., 2005).
Other dietary components
In our review of the data regarding dietary components and mental energy, several dietary components were found that had insufficient evidence to determine whether there were any effects on mental energy. These include: a-lactalbumin, antioxidants, beta-carotene, bonito broth (dried), *bacopa monnieri* (brahmi), calcium, chocolate, choline, creatine, curry, low calorie diet, low carbohydrate diet, low fat diet, high fat diet, fish, flavonoid, gotu kola, L-theanine, lecithin, lipid, protein, meal timing (breakfast, snack, lunch, evening meal), high fat meal composition, *melissa officinalis* (lemon balm), lignans, probiotic, *salvia lavandulaefolia* (sage), selenium, soybean, tea, tryptophan, vitamins A, C, D, and E, wine, and zinc

DISCUSSION
Consistency within the Data
There is very little consistent data concerning dietary components and mental energy. Variation in study design and task selection is the biggest contributing factor to this problem. Insufficient duration and inadequate sample sizes also contribute to the lack of findings. Studies are usually small, inconsistent, and investigate a limited number of tasks that can assess mental energy. The composition of herbal products may vary greatly between products and between batches of the same product. These variations often stem from variation in raw plant material (varietal factors), climate, growing season, soil, rainfall, and other growing condition, method of preparation and types of solvents used in the extraction process. Additionally, observational studies cannot control for the wide variation of dietary sources of a particular nutrient.

Currently, there are no standardized cognitive tests to objectively assess cognitive effects associated with dietary supplements or pharmacological treatments (Gevins *et al.*, 2002). A dietary component may only alter a small element of performance on a particular task, and overall performance analysis may not necessarily reveal subtle changes in performance. Behavior is a complex product of many neural systems. Testing healthy subjects usually results in smaller effects (Manders *et al.*, 2004).
Cognitive test selection is extremely important and may strongly influence outcome. A systematic review reported that general tests of cognitive function generally do not report positive effects between nutrition and cognitive function (Manders et al., 2004). However, when specific domains of cognitive function were tested (e.g., memory, attention), positive effects were often reported. Tests of cognitive function typically consider only a single component of cognitive function. Most studies also were done at breakfast time, it is unknown if there are any effects later in the day.

**Research Needs**

The relationship between dietary components and behavior is complex. Studies need to conform to the highest quality standards and good experimental design (Lieberman, 2007). Examples are double blind and placebo-controlled experimental procedures, with adequate numbers of subjects to provide sufficient statistical power and that control for circadian variation in performance and practice effects. Multiple doses of a treatment should be tested, when feasible. Meal composition studies should include baseline tests, and control for nutritional history (i.e. use a within-subjects design).

Given that the cognition tests recommended by Lieberman (2006) were not used in the studies retrieved by our search, it seems that more research focusing on specific processes versus specific tasks is needed (Lieberman, 2006). Tasks that are more sensitive to relatively subtle changes due to short-term nutritional intervention are needed to identify any effects of dietary components on mental energy.

Motivation is an important aspect of any neuropsychological testing. A subject's willingness to engage in a task and complete all trials with the same level of engagement depends on many factors, including motivation. Given the paucity of research on this topic, more attention should be paid to this factor by researchers in the future. Differences in motivation can result in wide variations in task performance between subjects (Schmitt et al., 2005). Future research also needs to control for population effects. Demographic characteristics such as age, gender, socio-economic status, and educational level are known to effect cognitive functions (Schmitt et al., 2005).
SUMMARY

The lack of consistent results regarding the effects of dietary components on mental energy is likely due to multiple factors, such as inconsistent dosing and duration, small sample sizes, and varied populations. The findings of this review suggest that at this time there is not enough quality peer-reviewed data to discern any strong influences of dietary components on the three facets of mental energy: mood, cognition, and motivation.
References


