NUTRITION AND MENTAL PERFORMANCE AND MOOD

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1. INTRODUCTION

Public attention can be easily attracted by claims that behaviour is influenced by the diet. However, scientific evidence for such claims has been usually weak and existing data have often been over-interpreted. The investigation of the effects of food and food constituents on mental performance and mood of humans is extraordinarily complex. Firstly, sensitive tests and measures are required to identify, operationalize and measure behaviours associated with food intake, because such effects may be subtle. Secondly, direct effects of the diet may be mediated or modified by the expectancies of the subjects exposed to nutritive stimuli or by their past experiences with these stimuli. The present paper summarises well established scientific evidence for the effects of diet on mental performance and mood and points out were more research and information is needed for firm conclusions.

2. EFFECT OF MEALS AND ENERGY INTAKE

From everyday experience it is obvious that eating per se has effects on mood and mental performance. In a variety of social and personal contexts people eat to profit from the satisfying and rewarding effects of food. In addition, eating plays a major role in social interaction and communication among humans. Thus it is not surprising that eating and food is one of the most important sources of pleasure in life for humans (Westenhoefer & Pudel, 1993). The adverse consequences of prolonged and severe caloric restriction on mood and cognitive functions has been documented for a long time (Keys et al., 1950).

There is a substantial body of evidence on the effect of meals or energy intake on mental performance (For review see Bellisle et al., 1998). In summary, some research show that mental performance on a number of task (e.g. reaction time, memory, problem solving, logical reasoning, arithmetic tests) would be enhanced after the consumption of a breakfast when compared with no breakfast. In addition, some studies found better performance after a high energy breakfast compared to a low energy breakfast. These effects are consistently seen in adults and children as well. Improved performance may be related to a sustained blood glucose levels, and high carbohydrate meals seem to have the best effects.

While eating improves performance in the morning, it has opposite effects at midday. After lunch performance on attention and reaction time tasks is usually impaired, with larger lunch meals producing a more profound impairment. Impaired performance after lunch during the early afternoon has been called "post-lunch dip". There is considerable less research regarding the effects of evening meals, the few studies yielding inconsistent results.

Little is also known about the effects of between-meal snacks on mental performance. There is however one paper which reports two experiments (Kanarek & Swinney, 1990). In both experiments cognitive performance in a number of different tasks was improved after the consumption of an energy containing snack compared to a low-energy diet drink.

3. SEROTONIN AND CARBOHYDRATES, MOOD AND PERFORMANCE

Background

Serotonin (5-hydroxytryptamine, 5-HT) is an important neurotransmitter which is known to be involved in the regulation of mood (i.e. depression) (Young, 1993; Heninger et al., 1996) and food intake (Leibowitz & Shor-Posner, 1986). The idea that serotoninergic neurotransmission in the brain may be influenced by the diet has attracted much attention during the last decades.

The basic logic of this idea may be summarised as follows : Tryptophan is an essential amino acid which is the precursor of the neurotransmitter serotonin. Since tryptophan and other large neutral amino acids (LNAA), e.g. tyrosine, phenylalanin, leucine, isoleucine and valine, use the same transport mechanism for crossing the blood-brain barrier, tryptophan competes with the other LNAA for entry into the brain. If the ratio of tryptophan to other LNAA is large, relatively more tryptophan will enter the brain. Because the availability of tryptophan is the rate-limiting step for serotonin synthesis an increase of tryptophan will result in an increased central serotonin synthesis.

Based on the results of studies originally carried out on rats Wurtman and his colleagues have proposed that the ratio of carbohydrate versus protein in a meal may alter the ratio of plasma amino acids, especially the ratio of tryptophan to LNAA, which has been discussed above (Wurtman et al., 1981). The mechanism is that a carbohydrate rich meal leads to an insulin release, which in turn facilitates the uptake of most amino acids but not tryptophan into peripheral tissues such as the muscle. This will result in an increase of the tryptophan to LNAA ratio thereby enhancing transport of tryptophan into the brain and increasing serotonin synthesis. A protein rich meal has the opposite effect, primarily because most dietary proteins contain relatively little tryptophan as compared to other LNAA.

Despite its broad popularity the practical relevance of the hypothesis that high carbohydrate meals may increase brain serotonin synthesis must be seriously questioned. Teff et al. (1989) showed that adding as little as 40g protein per kg of a meal can abolish the tryptophan effect. Most usual meals will have a higher protein content than 4 percent.

Experimental evidence

The behavioural and psychological effects of tryptophan are well-documented (e.g. Hill & Blundell, 1988). In general, sleep and feelings of fatigue are affected by tryptophan intake. In both, adults and children, tryptophan reduces sleep latency, i.e. time to fall asleep and promotes feelings of drowsiness and fatigue (Steinberg et al., 1992).
Direct effects on mental performance are less clear. In one study, tryptophan had no significant effect on either of four performance tasks (Lieberman et al., 1983). However, again tryptophan increased subjective ratings of fatigue and decreased ratings of a vigour-activity rating scales. In clinical context, tryptophan has been successfully used in the treatment of depression (Young, 1996) and late luteal phase dysphoric disorder (Steinberg et al., 1994).

Far less clear than the effects of tryptophan are the effects of the carbohydrate-protein ratio on behaviour. A number of studies showed that carbohydrate vs. protein has significant effects on the plasma tryptophan-LNAA ratio. However, only one study found a correlation between carbohydrate ratio, amino acid ratio and mood (Goodwin et al., 1987), while others found no effects on mood despite significant effects on tryptophan-LNAA ratio (Deijen et al., 1989; Christensen & Redig, 1993). Most probably, the effect of dietary manipulations on plasma tryptophan-LNAA ratio is too small to induce changes in brain serotoninergic neurotransmission (Young, 1991). As mentioned above only 4 percent of protein in a meal may block the tryptophan effect (Teff et al., 1989). However, carbohydrates seem to have a reproducible effect on activation and to some degree on mental performance. Several studies have found greater drowsiness, sleepiness and calmness after carbohydrate-rich meals compared with protein-rich meals (Spring et al., 1983; Spring et al., 1987; Rosenthal et al., 1989) and after lunch poorer performance in e.g. reaction time and sustained attention (Lloyd et al., 1994; Spring et al., 1983; Lieberman et al., 1986).

4. GLUCOSE, CAFFEINE AND OTHER SINGLE NUTRIENTS

Glucose and caffeine are the best studied single nutrients with well documented effects on behaviour. There is a substantial number of studies with children, young adults and elderly subjects as well, demonstrating that glucose has generally beneficial effects on performance (For review see Bellisle et al., 1998). The effects of glucose are obviously mediated by blood glucose levels. They are observed across a wide range of blood glucose levels and, hence, are not only a result of an improvement of hypoglycaemia. The rising or higher levels of blood glucose following a glucose drink have been associated with faster information processing, better word recall, improvement on the Stroop test, and less errors during driving tasks.

Caffeine has psychoactive effects on the central nervous system (for review see James, 1991; Nehlig et al., 1992). In general, it is regarded as psychostimulant and thus increases mental performance in several contexts. It also leads to increased anxiety at higher doses in some susceptible individuals. All the effects of caffeine are only short-term (a few hours).

Cessation of caffeine consumption may yield adverse effects like headache, drowsiness and fatigue in some regular consumer of caffeine. Since many experiments with caffeine are conducted after an overnight or 24 hour deprivation from caffeine, this makes it often difficult to decide whether experimental results are due to beneficial effects of caffeine or to the amelioration of the negative consequences of short-term caffeine deprivation.

Other nutrients like dietary choline or vitamins and minerals have been discussed to impact cognitive performance in humans. The present experimental evidence does not support these ideas. For example only one study out of seventeen found an improvement of memory in elderly subjects using choline or lecitin which is a major source of choline in the diet (Bellisle et al., 1998). Effects of vitamins and/or minerals on intelligence scores have been reported in one study (Benton, 1992), but were not reproduced in other studies (Crombie et al., 1990; Nelson et al., 1990). In young adults vitamin supplements did not improve cognitive performance when vitamin supply in the diet was sufficient (Heseker et al., 1995).

5. Hyperactivity

Sugar as well as food additives have been blamed for promoting hyperactivity (attention deficit disorder) in children. However, most of the scientifically sound placebo controlled studies did not find support for these ideas (Bellisle et al., 1998; Logue, 1991; Wolraich et al., 1985).

6. Carbohydrate craving, sweets and chocolate

During the last decade the notion of "carbohydrate craving" has gained much attention. Although there is no generally agreed definition of the term "craving", Rozin et al., (1991) propose to consider craving as "a special case of liking, which is particularly intense, motivates behavior aimed at gaining the craved substance, and is periodic" (Rozin et al., 1991, p.200). Other researchers have described craving as a "strong desire to eat a specific food" (Weingarten & Elston, 1991) or " a strong desire for something, such that you would go far out of your way to get it" (Michener & Rozin, 1994). Carbohydrate craving refers to the phenomenon that states of dysphoria i.e. feeling unwell or unhappy are often associated with a strong preference for food high in starch and even more often high in sugar content (Wurtman, 1984). In a recent review Christensen concluded that is apparent that individuals who experience emotional distress or who show depressive symptoms show a preference for sweet simple carbohydrates (Christensen, 1997). This phenomenon is seen in normal individuals, obese individuals, depressed individuals, individuals with seasonal affective disorder and in individuals suffering from pre-menstrual syndrome. Typically, such individuals are described as anxious or tense before having eaten carbohydrates and relaxed afterwards (Wurtman, 1984).

The carbohydrate craving has been linked to the carbohydrate-serotonin connection which is described above in more detail. The phenomenon of carbohydrate craving has lost some attention during the last years, as some researchers failed to find an increased consumption of high carbohydrate foods in self-identified carbohydrate-cravers (Schlundt et al., 1993) or pointed out that carbohydrate cravers typically prefer foods like chocolate, ice-cream or other desserts, which are deriving the highest portion of calories from fat, not from carbohydrates (Drewnowski, 1990).

In fact, chocolate has been identified as the most frequently craved food in several studies, especially in women (Weingarten & Elston, 1991; Pelchat, 1997; Rozin et al., 1991). However, chocolate does not have the desired effect in individuals who identify themselves as "chocolate addicts". These chocolate addicts described themselves as more depressed and feeling guilty and feeling less content and relaxed before eating chocolate compared to controls. After having eaten chocolate their feelings of guilt increase while their feeling of depression or relaxation do not improve (Macdiarmid & Hetherington, 1995). At the present it seems most probable that chocolate can satisfy the craving for chocolate because of its sensory properties. There is no evidence for a role of pharmacological effects (Rozin et al., 1991; Michener & Rozin, 1994).

7. SUMMARY

- Breakfast usually improves mental performance compared to no breakfast.
- Lunch usually impairs mental performance (post-lunch dip).
- There is little research on the effects of evening meals and snacks. Existing studies found an improvement of mental performance following snacks.
- Tryptophan has profound effects on mood and activation which are mediated by the brain serotonin neurotransmitter system.
- At the present it is not clear whether the serotonin mediated effects may be elicited by high carbohydrate meals. Carbohydrates seem to have a reproducible effect on activation and to some degree on mental performance.
- Glucose and caffeine have clear effects in improving mental performance
- There is little evidence that other single nutrient have specific effects on mental performance or mood.
- There is no sound scientific evidence that either sugar or food additives promote hyperactivity in children.
- The satisfaction of chocolate craving is due to its sensory properties not to pharmacological mechanisms.

8. IOCCC POSITION

IOCCC believes that eating and food is one of the most important sources of pleasure in life for humans and that eating per se has effects on mood and mental performance. Moreover there are single nutrients in foodstuffs that may have clear effects on mental performance and mood.

IOCCC considers that significant scientific evidence exists to show that, for example, glucose and caffeine have clear effects in improving mental performance and that tryptophan has profound effects on mood and activation which are mediated by the brain serotonin neurotransmitter system.

IOCCC products are often characterised by their relatively high carbohydrate~~/glucose~~ contents and for this reason may have a positive effect on mental performance and mood.

IOCCC notes that the desire to consume chocolate is not due to any pharmacological mechanisms, rather it is due to chocolate's sensory properties.

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