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EFFECTS OF CONSUMING VARIOUS FOODS AND NUTRIENTS ON OBJECTIVE AND SUBJECTIVE ASPECTS OF HUMAN PERFORMANCE AND BEHAVIOR

FINAL REPORT

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I. SUMMARY

The Massachusetts Institute of Technology wishes to transmit a final report on a research program, initiated with NASA support three years ago, on the performance-related and behavioral responses of normal humans to the consumption of particular foods and nutrients.

During the three years, we have set up a variety of behavioral tests described in our initial application and have completed studies on young healthy subjects receiving tryptophan, tyrosine or their placeboes and studies on young and old subjects receiving protein and carbohydrate meals. Our observations demonstrate that significant nutrient generated effects can, in fact, occur. We also have started to examine the behavioral effect of the hormone melatonin since it may modify human circadian rhythms.

Some of our studies have involved administering one of two dietary amino acids - tryptophan or tyrosine - to people, and examining consequent changes in objective and subjective variables. (Objective variables measured included pain sensitivity, somatosensory sensitivity, visual information processing, psychomotor speed, manual dexterity, manipulative dexterity, and eye-hand coordination; subjective aspects of mood assessed were autobiographical memory, visual analogue scales, and mood factors determined by then POMS questionnaire). The nutrients were chosen both because their brain levels are known to be changed by eating (e.g., carbohydrate consumption elevates brain tryptophan, while a high-protein meal elevates brain tyrosine) and because their levels in brain can influence neurotransmission mediated by their products, serotonin and the catecholamines. Since the initiation of work on this project, we developed an apparatus (i.e. people, instruments plus a standardized battery of tests) for doing these nutritional-behavioral studies, and have obtained data

affirming the existence of predictable relationships. Specifically, we have determined that tryptophan modifies subjective mood (inducing drowsiness and fatigue) but does not impair reaction time and other measures of performance. Tryptophan also reduces pain sensitivity. We have also demonstrated that reaction time is altered when tryptophan as opposed to tyrosine is ingested. Given these initial positive findings, we have studied the biochemical, behavioral and performance effects of regular foods and documented changes in mood and performance.

II. INTRODUCTION

It is now well established that the consumption of particular foods - or of food constituents, like certain amino acids or lecithin - can change the rates at which neurons synthesize and release their neurotransmitters, and can thereby modify brain functions and behavior. These neuronal responses to nutrients have already been used widely to treat human diseases resulting from inadequacies in the release of precursor-dependent neurotransmitters (e.g., lecithin for tardive dyskinesia or presenile dementia; tyrosine or tryptophan for depression); however little information was available concerning the possible effects on normal brain function, or on objective and subjective indices of performance and mood in normal people. If eating tryptophan (or a carbohydrate meal, which elevates brain tryptophan levels) enhances serotoninergic neurotransmission in people as in animals, and thereby, as we have shown, makes them drowsy, it is important for NASA to be aware of this, - in order to advise astronauts and pilots about what not to eat before critical points in flight and what to eat before sleep. Furthermore, there is good reason to believe that the "normal" neurons loss that occurs as people age makes their brains progressively more responsive to food-induced changes in neurotransmitter synthesis; hence, as NASA contemplates flying passengers over fifty years of age, acquisition of such information becomes all the more important.

Besides measuring the effects of common food constituents on human mood and performance, added a new and related line of investigation to our studies. We have conducted preliminary experiments on melatonin, a hormone released by the human pineal gland. Melatonin is synthesized by the pineal gland from tryptophan, one of the dietary precursors we have been studying.

In humans, melatonin is normally released during the night; however, bright light (luminance levels less than full sunlight) can suppress its nocturnal secretion.

The experiments we have conducted have characterized the pharmacokinetics of oral melatonin administration to humans and demonstrated that melatonin has powerful hypnotic properties. Based on these findings and on supporting animal research, it seems possible that melatonin is the natural substance responsible for synchronizing human circadian rhythms to the external environment. Melatonin could also be an endogenous sleep-inducing agent of the human brain.

The overall aim of this line of investigation was to examine the roles of melatonin in inducing and maintaining human sleep, otherwise affecting behavior and synchronizing circadian rhythms. Such information is of direct relevance to NASA since the artificial environment of space may lack important cues, such as the correct lighting conditions, for sychronizing circadian rhythms. Performance deteriorates when circadian desychronization occurs.

During the past three years, we have completed the experiments proposed in our previous applications. We have tested subjects, analysed data, and written up our results for publication. We have determined that the nutrient tryptophan has specific behavioral effects: it increases self-reported drowsiness and fatigue but does not impair sensorimotor performance and it decreases pain sensitivity. Both of these properties could prove to be of considerable practical value. For example, most hyponotics are known to impair performance. However, since the effects of tryptophan appear to be limited to mood, it may have considerable advantages in applications were a hypnotic may be needed, but performance must be unimpaired (e.g., space flight). Also, tryptophan may be uniquely valuable as an analgesic since, as a dietary substance, it may have less side effects than analgesic drugs.

We have also determined that carbohydrate foods have sedative-like effects on performance and mood.

III. ACCOMPLISHMENTS

- The data analysis was completed for the food and nutrient experiments we were conducting, i.e., the effects of tryptophan and tyrosine on human mood and performance, and the effect of these two dietary constituents on human pain sensitivity. Results from these studies demonstrate that food constituents can alter human mood, performance, and pain sensitivity. Of particular interest to NASA may be the statistically significant difference between tryptophan and tyrosine on a reaction time task. The effects of these substances on brain chemistry are similar to the effects of ingesting a carbohydrate versus a protein meal. That tryptophan and carbohydrate foods have substantial effects on subjective alertness is also of practical importance since under stressful conditions (such as space flight) subjective effects documented in the laboratory are likely to have objective consequences. In other words the tired, stressed astronaunt may be more sensitive to the effects of foods then the well rested, college-age experimental subjects that we tested. In fact it has been noted that pilot performance during flight is highly correlated with subjective mood.

The findings from these studies were presented at numerous conferences, published in various scientific journals.

In the past year we have also measured the effects of specific meals (protein versus 2 types of carbohydrates, simple sugars and complex starches) on neurotransmitter precursor plasma concentrations. The effects, as we predicted, demonstrated that these meals had very differnent effects on plasma amino acid levels and therefore, by inference, brain neurotransmission. We also examined the effects of these same meals on measures of mood and performance. We found that protein meals relative to carbohydrate meals speed performance and improve self-reported alertness.

We also developed a battery of performance tests that appear to be very sensitive to effects of foods and nutrients on human behavior. Some of these tests were developed for our melatonin experiment and were found to be quite sensitive to the effects of this hormone on human performance. For example, the 4-choice reaction time (RT) task that we developed detected a significant decrement in RT after melatonin ingestion. However, it also detected a concurrent reduction in the number of errors subjects made. The simple RT task that we administered during the experiment corroborated the improvement in accuracy induced by melatonin. Melatonin, as noted above had significant hypnotic properties as documented by the various self-report mood questionnaires that we administered.

Therefore melatonin, a naturally occuring hormone released at night, makes people feel drowsy and slows their reaction time, but it improves accuracy. Since melatonin levels are altered by environmental lighting conditions, these effects could have considerable practical significance to NASA and others. There are other practical implications. For example, melatonin has been reported to synchronize circadian rhythms when administered to animals at certain times. A similar effect could possibly be demonstrated in humans.

A new measure of human behavior that we have recently acquired and adapted for our purposes is an ambulatory activity monitor. This small solid-state device can be worn comfortably on the wrist or around the waist, and continuously records human motor activity on a minute-to-minute basis. We believe this device will provide a new objective method for assessing the effects of foods, nutrients, and hormones such as melatonin on human performance and sleep.

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