

## Sugar & Human Behaviour

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**INTRODUCTION**The assertion that foods containing sugar might have an adverse effect on behaviour was first raised in 1922. This concept was further elaborated in 1947 by Randolph in his description of the tension fatigue syndrome. Sugar later appear in the 1970's as a major offending agent when the lay literature provided considerable coverage to the condition called functional reactive hypoglycemia. In establishing sugar as a major dietary component, it is important to review if a relationship does exist between sugar and behaviour. The first and most prominently believed relationship is that between sucrose and hyperactivity and/or aggressive behaviour. A second less well-known relationship has been suggested between glucose and enhanced memory, particularly in elderly individuals. A third reported relationship has been sugar's effect on the opposite of hyperactivity, namely sedation.

**SUGAR AND HYPERACTIVITY**The belief in the relationship between sugar and hyperactivity is based on two theories. The first, that hyperactivity is a possible allergic response to refined sugar, was conceived of in the first half of this century as the tension-fatigue syndrome, a behavioural correlate to the vomiting reaction to milk proteins. The second suggested etiology is that some children may experience functional reactive hypoglycemia similar to that seen in adults. Individuals with functional reactive hypoglycemia experience glucose levels in the hypoglycemic range while on diets high in carbohydrates. Consuming diets high in proteins seems to prevent this condition. It was theorized that children would display increased motor activity at low blood glucose levels. Most intervention research has entailed controlled double-blinded challenge studies. Children receive challenges with foods or drinks containing sucrose or an artificial sweetener where the children, their parents and the researchers are not aware of the composition of the foods or drink and their behaviour and cognitive performance is closely assessed within the few hours after ingestion. In reviewing these studies, there are some important considerations. The first consideration in any rigorous study is the characteristics of the subject. In examining the effects of sugar, the subjects have been children with a wide array of characteristics. Studies have involved normal children, children historically identified as behaving poorly after sugar ingestion, children diagnosed with hyperactivity or attention deficit disorders, and aggressive or delinquent children. The studies have used subjects ranging in age from preschoolers to adolescents. The second consideration is the type or quantity of sugar likely to affect behaviour. For this there are few, if any, guidelines. Sucrose has been the most prominent sweetening agent used although many foods are now sweetened with corn sweeteners, i.e. fructose. Fructose and glucose have been included in a few of the studies. Most challenge studies have employed the quantity used in glucose tolerance tests (1.75gm/kg) although doses as high as 5.6gm/kg have been studied. The diet condition prior to challenge is a third consideration. This issue, has been a concern, particularly regarding the specific manipulation of the carbohydrate to protein or fat ratio. There has, however, been a great deal of variation among studies, ranging from no diet control to restricted diets. It is expected, however, that with the degree of variation present in the studies, it would be possible to detect responses if pre-existing diets were a factor. The final important issue is the measurement of the proposed effects of refined sugar. Most measures have focused on the behaviour of children with attention deficit hyperactivity increased more activity compared to other children. The studies have utilized parent and/or teacher report to assess behaviour. Numerous behaviour rating scales with reasonable psychometric properties were used depending on age and range of behaviours. Other neuropsychological measures have also been employed to assess vigilance, impulsivity, memory and motor skills. Some studies have employed electronic motion detector devices to record activity level. There have also been direct observations and recordings of behaviours for short segments of time by independent observers and rating scales completed by independent observers. These have been important because, while parents are good reporters of their children's behaviours and have been blinded to conditions, they are not independent and do affect their children's behaviours. A meta-analysis of 23 studies which had been conducted over a period of 12 years from 1982 to 1994 has been completed, to test the hypothesis that sugar (mainly sucrose) affects the behaviour or cognitive performance of children. This analysis did not find support for the hypothesis. In conclusion, there is little objective evidence to suggest that sugar significantly alters the behaviour or cognitive performance of children. It is not appropriate to recommend restricting a child's sugar intake for the purpose of trying to control their behaviour. If behaviour problems exist, it is important to identify the underlying reasons and to seek the existing and more rigorously established interventions for their treatment.

**GLUCOSE AND MEMORY**There is increasing evidence that sugar, glucose specifically, can influence central nervous system activity. Although memory enhancement was not demonstrated in any of the challenge studies which measured memory in children, there is evidence that glucose levels influence memory functioning in rats and humans, locomotor activity and sleep patterns in rats, and the distress associated with painful procedures in human infants. The focus of research in this area has been to establish how glucose acts to mediate these effects. Since the retention of memory is an important central nervous system function in the process of cognition, central nervous system mechanisms salient to this function such as noradrenergic and cholinergic systems have been investigated. To investigate the positive effects of epinephrine on memory processing, one study systematically examined the effects of glucose on both animal and human subjects. The study employed a foot shock avoidance task on rats, and observed, similar to the epinephrine effects, significantly improved retention in animals who received 10 to 100 mg/kg injection of glucose immediately after training. No effect was observed if the injection was delayed by one hour or if higher or lower doses were used. In a subsequent study, glucose was shown to have similar effects to other memory modulators in that its administration with low foot shock training enhanced the rats' memory storage while its administration with high foot shock training impaired retention possibly due to endogenous levels of epinephrine

produced by the foot shock. Extending the postulate that glucose improves memory functioning to a human population, one study demonstrated significantly improved memory processing via a standardized measure in nine of eleven elderly human subjects after administration of oral glucose versus placebo. Further, a study found that enhancement of memory in elderly humans twenty-four hours after learning was significantly improved by glucose administration before or after the learning task. This may be similar to the finding in rats where memory potentiation in elderly rats was more marked than that demonstrated in a young adult rat population. None of the studies of sugar in children showed any effect on memory while those completed with elderly subjects did. However, it is important to note that most of the child studies used sucrose and only a few of them specifically tested memory. In summary, there is evidence that glucose is discretely involved in neuroendocrine modulation of memory storage in both rats and humans. This influence is best demonstrated in elderly subjects. Further, one site of action of glucose is the medial septum which is rich with communications to the hippocampus. Although, the precise mechanism of the effects of glucose on memory are not yet established. These findings may have far reaching implications for pharmacologic treatment of memory impairments resulting from old age or head trauma. As of now the clinical implications of these findings have yet to be defined. Much more extensive research is required before any conclusions about clinically relevant implications can be drawn. SUMMARY It appears clear that there is little evidence to support the claim that refined sugar intake has a significant influence on the behaviour or cognitive performance in children as popularly supposed. There may be a few children with idiosyncratic reactions or rate allergic syndromes who may respond adversely, but this has yet to be substantiated by carefully controlled research. The relationship of glucose to the improvement of memory processing appears clear. Further research is required to define its clinical relevance and to elucidate the mechanisms involved.