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## Standard preload-test meal study designs may underestimate satiety effects: sugar containing drinks as an example

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A widely used method for investigating the acute effects of food and drink ingredients on satiety is to feed a fixed portion of a food or drink vehicle with and without the ingredient (the preload) and follow this with measurement of energy intake in a test meal (food served in excess of likely intake at a fixed interval after the preload). Because of the large variation in test meal energy intake between individuals, it is common practice to use cross-over (within-subject) designs in preload-test meal studies, in which the different preloads are fed on separate days and preload order is counterbalanced across participants. It is also usual to match, in terms of taste and appearance, the preload containing the ingredient under investigation with the control (placebo) preload. In a study of the satiety effects conferred by sugar energy in a drink, the control drink might be sweetened to the same level of sweetness with an intense sweetener, and both drinks would contain the same flavours, colours etc. A potential problem here is that the experience of satiety occurring after the first preload is partly transferred through learning (learned satiation<sup>(1)</sup>) to affect how much satiety is experienced after the second preload<sup>(2)</sup>. Take for example participants consuming the sugar-containing (SCD) on the first occasion and the zero-energy drink on the second occasion. They would experience greater satiety after the zero-energy drink than would participants consuming the zero-energy drink first. And these latter participants (zero-energy drink first) would experience less satiety for the SCD (consumed second) than would the former participants (SCD first, zero-energy second). This will cause the 'true' satiety effect of sugar energy in a drink, as experienced by a regular consumer of such a drink, to be underestimated. With more treatments in a study (e.g. different levels of sugar energy) the potential impact of learning on estimation of satiety effects becomes more complex.

Study 1 here conformed to the standard design. The effect of a 300 ml sucrose *vs* 300 ml sucralose sweetened blackcurrant juice drink (670 and 10 kJ, respectively) on energy intake in a lunch-time test meal (bite size cheese and ham sandwiches, crisps, sweet biscuits, yogurt, grapes and water: 10MJ) served 20 minutes later was measured in 33 healthy men and women. In Study 2 each of these drinks were compared separately against 300 ml water in two further similar groups of participants ( $n = 32$  and  $33$ ). This second design avoids the interfering effect of learning, and it assesses the effects of sweetness and energy independently. Mean age and BMI of the participants was 25 years and 23.8, respectively.

Test meal energy intake was 372 kJ lower ( $P = 0.08$ ) after the SCD (*vs* sucralose drink) in Study 1. In Study 2 it was 521 kJ ( $P = 0.007$ ) lower after the SCD (*vs* water), and 88 kJ ( $P > 0.1$ ) higher after the sucralose drink (*vs* water). This represents 56% and 92% compensation for the difference in energy consumed as sugar in Studies 1 and 2, respectively. For Study 2 the calculation includes the sucralose *vs* water condition, which controls for the effect of sweetness, and is as follows:  $((521 + 88)/660) \times 100$ . The reduction in energy intake after the SCD tended to be greater in males than in females, significantly so in Study 2, where the mean difference (SCD – water) was  $-894$  kJ for men and  $-147$  kJ for women ( $P = 0.046$ ).

These studies show that sugar energy in a drink reduces subsequent energy intake, and suggest that this satiety effect, and by implication the satiety effects of other macronutrients and food ingredients, are underestimated by the standard study design. The gender differences in satiety, which have been observed previously<sup>(3)</sup>, are noteworthy. They may be related to the greater dietary restraint displayed by women, and/or their greater habitual consumption of reduced energy products, including drinks containing intense sweeteners.

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