**A Habit-Based Randomised Controlled Trial to Reduce Sugar-Sweetened Beverage Consumption: the Impact of the Substituted Beverage on Behaviour and Habit Strength**

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**Abstract**

**Background:** Excess sugar consumption has been linked to numerous negative health outcomes, such as obesity and type II diabetes. Reducing sugar-sweetened beverage (SSB) consumption may reduce sugar intake and thus improve health. The aim of the study was to test the impact of the potentially different rewarding nature of water or diet drinks as replacements for SSB, using a habit and implementation intention based intervention.

**Methods:** An online randomised, single blind (participants), two-arm parallel design was used. One hundred and fifty-eight participants, (mainly from the UK and USA) who regularly consumed SSBs (Mage=31.5, 51% female) were advised to create implementation intentions to substitute their SSB with either water or a diet drink. Measures of SSB consumption, habit strength and hedonic liking were taken at baseline and at two-months. Water or diet drink consumption was only measured at two-months.

**Results:** There was a large and significant reduction in SSB consumption and self-reported SSB habits for both the water and diet drink groups, but no difference between groups. There were no differences in hedonic liking for the alternative drink, alternative drink consumption and alternative drink habit between the two groups. Reduction in SSB hedonic liking were associated with reduced SSB consumption and habit.

**Conclusions:** This study demonstrates that an implementation intention-based intervention achieved substantial reductions in SSB consumption and habits. It also indicates that hedonic liking for SSBs and alternative drinks are associated with changes in consumption behaviour. Substituting SSBs with water or diet drinks was equally as effective in reducing SSB consumption.

*Keywords:* sugar-sweetened beverages, intervention,habit, hedonism, behaviour change

The overconsumption of sugar is associated with numerous health issues such as obesity, type II diabetes and tooth decay 1 2. In highly developed countries, Obesity and related treatments cost approximately £5.1 billion each year for the UK National Health Service (NHS)2, and approximately US $2 trillion in the United States (US) 3. The US National Center for Health Statistics 4 estimates that obesity prevalence is 35% amongst adults aged 20 years and over. Free-sugars are any sugars (monosaccharides and/or disaccharides) that are artificially added to foods and beverages or sugars that are naturally present in products such as honey, syrups, fruit juices and fruit juice concentrates5 and it is recommend that free sugar intake be reduced to 10% of the total energy intake, and below 5% for processed sugar (approximately 20-25g per day) 5. The current estimated proportion of sugar intake across all age groups in England is between 12-15% of total energy intake 2, therefore the development of effective sugar reduction strategies is required. Sugar-sweetened beverages (SSBs) make up approximately 25% of the total sugar intake in UK adults 2. There is some variation in how researchers define SSBs, but they are generally considered to encompass soft drinks, fruit juices, sports drinks, iced teas, energy drinks and flavoured milk drinks 2 6. Just one 330mL can of soft drink may contain more than 25g sugar 7, which exceeds the WHO recommended daily sugar allowance. Therefore, a reduction in SSB consumption may be a relatively simple way to improve health and reduce obesity rates in high income countries such as the UK and US. One way to potentially do this is through weakening SSB consumption habits through interventions and replacing these unhealthy habits with healthier ones such as consuming diet drinks or water.

Habit has been shown to be important in many health behaviours including dental flossing 8, sunscreen use 9, physical activity 10 11 and healthy eating 12-14, such that increased habit strength has shown to predict increased behavioural frequency and execution 15. Habit has also been shown to be important in unhealthy behaviours such as binge drinking 16 and SSB consumption 17. It is generally accepted that a behaviour becomes habitual when it is performed in a stable context, so that the context comes to automatically prompt the behaviour 18. This automatic prompting, referred to as automaticity*,* separates a habitual behaviour from a repeated conscious decision to perform a behaviour in similar context 18 19. Even when behaviour change is initiated, it has been found that people tend to return to old behaviours over time 20 21. Therefore, the maintenance of new behaviours is an increasingly important goal. Given habits are difficult to change, forming good habits can increase the likelihood of maintenance of behaviour 22. It has been shown that those with healthy eating habits find it easier to make healthy choices in times of temptation compared to those who do not have healthy habits because they need to rely less on effortful self-control to inhibit unwanted existing behaviours 23.

One potential way to promote new behaviour and the formation of new habits is through the use of implementation intentions to suppress unwanted old habits 24-27. Implementation intentions are characterised as the formation of detailed “if-then” plans*,* where individuals commit to carrying out a specific action in response to a relevant and salient context or cue (typically defined by ‘when’ and ‘where’) 28. The effectiveness of implementation intentions to modify a wide range of health behaviours has been shown in studies exploring physical activity 29, dietary behaviours 30, smoking 31, sleep behaviours 32, and dental health behaviours 33. Implementation intentions have traditionally been used as a way to increase individuals acting on their goals and intentions, and have proven moderately successful in changing behaviour by creating new habits 34. The use of implementation intentions promotes behaviour repetition in a specific context to achieve habit formation – i.e. they aim to mimic the mechanisms of habit formation 35. Implementation intentions have been successful in overcoming unwanted habits in onestep hedonic behaviours where the reward for the new behaviour is not immediate, such as when trying to stop unhealthy snacking 36. Further research has identified the use of implementation intentions as a successful technique in reducing the influence of unwanted habits by replacing it with an alternative response, such as going for a run instead of smoking a cigarette 37 38. Implementation intentions were successful in reducing smoking behaviour amongst those with weak to moderate habits, but not those with strong habits 38. In the context of SSB behaviour, only one study has explored this mechanism of change and found that the creation of implementation intentions with an alternative response significantly reduced SSB consumption 39.

More recently, implementation intentions have been used as a mechanism to change existing unwanted habits with healthier alternative habits 26. Adriannse 37 suggested that substitution implementation intentions are able to facilitate habit formation for alternative behaviours by weakening habit strength of existing behaviours, thereby providing a window of opportunity for individuals’ alternative behavioural intentions to override existing habits. This was found in a study where non-recycling habits were broken and formed into new recycling habits 24. A systematic review of health eating interventions using implementation intentions found that they can increase healthy eating habits, and reduce unhealthy eating habits (though the effect size for these was smaller) 40. Substitution implementation intentions have yet to be explored as a way of reducing the habit of SSB consumption and forming healthier alternative habits, such as drinking water.

Substitution implementation intentions have shown to be most effective in changing behaviour when it is specified that the alternative behaviour will be carried out in the critical context that previously triggered the existing behaviour 24 30. It is therefore important for substitution implementation intentions to specify a context or cue in which they will enact the behaviour. There is currently uncertainty in the literature regarding the number of implementation intentions or plans that are required for successful behaviour change 41 42. Some research in the physical activity domain has shown that making two implementation intentions is more effective than making a single or three plans 41. In contrast, Verhoeven 42 found that making a single implementation intention was more effective for creating healthier snacking habits. It is still unclear how many implementation intentions are optimal for behaviour change and therefore it should be up to the individual how many plans they would like to make to have the best opportunity to achieve their goal.

Despite the potential for implementation intentions to successfully change existing behaviours and habits, it has generally been found that their effectiveness is limited in the presence of strong existing habits 38 43. Therefore, additional factors, such as reward, may be important in promoting longer-term performance of new behaviours. Reward is thought to moderate the habit-behaviour relationship by promoting repetition during the habit formation process and strengthening the association between the performance context and the target behaviour 19 44 45. In the case of dietary habits, greater pleasure in the form of hedonic liking for sugary foods is associated with increased sugar intake 46 47 and past behaviour is a stronger predictor of immediate hedonic behaviours than intention 48. As such, the effectiveness of SSB behaviour change interventions is likely to be influenced by hedonic liking for the SSB and alternative drinks. Intrinsic rewards, such as feeling pleasure or happiness from taste, may be more effective at sustaining habitual behaviour change compared to extrinsic rewards 49 50. For example, Wiedemann 50 found that intrinsic motivation was associated with future fruit consumption habit strength, and likely strengthened the relationship between fruit consumption behaviour and subsequent habit formation. Similarly, hedonic liking can be said to drive behaviour 44 such that if an individual has a hedonic preference for a particular food or drink (e.g. chocolate), they may be more likely to consume this food or drink rather than an alternative (e.g. fruit). As such, it is possible that if an individual has high hedonic liking for SSBs they will be more willing to substitute the SSB for a similar hedonic drink (e.g. diet drink), rather than a completely different drink (e.g. water). If the new behaviour (e.g. drinking diet drinks) has a high level of liking compared to the original behaviour (e.g. drinking SSBs), it is likely that the individual will continue the alternative behaviour and therefore reduce their SSB consumption habits.

**Aims and hypotheses**

There is sufficient evidence showing that replacing SSBs with water or low-calorie beverages can improve health by reducing overall sugar intake51-53. However, it is likely that existing SSB habits may hinder efforts to achieve long-term reduction in SSB consumption 54. The aim of the study was to reduce SSB habits and form habits for the replacement drink, using an online intervention based on habit formation principles. To assess the impact of the potentially different rewarding nature of water versus diet drinks, participants were randomised to either substitute their SSB with water or diet drinks.

A number of hypotheses were proposed. SSB consumption and habit strength will decrease over time in both the water and diet drink groups (Hypothesis 1). It is expected that diet drinks group will have higher scores for hedonism than the water group for the alternative drink at T2. Consequently: reduction in SSB consumption would be larger in the diet drinks group than the water group; and alternative drink consumption would be higher at T2 for the diet drinks group than the water group (Hypothesis 2). People who like their alternative drink more will reduce their SSB consumption and habits more at follow up (Hypothesis 3). It is also expected that those who form one implementation intention will have a larger decrease in SSB consumption over time, compared to those who form two or three implementation intentions (Hypothesis 4).

**Methods**

**Participants**

Participants were primarily recruited through the crowdsourcing website callforparticipants.com, as well as on social media and through word of mouth. Participants had to be at least 18 years of age and to consider themselves frequent consumers of SSBs. We did not provide any minimum or maximum consumption frequency cut-offs for participation in the study. Participants were excluded if they had a current BMI <18.5 (underweight), had a previous or current eating disorder, had a clinically diagnosed psychological disorder or condition and did not possess a high degree of English comprehension. SSBs were defined as soft drinks/soda, energy or sports drinks, fruit juice, hot chocolate, iced chocolate, iced tea and iced coffee 6. Successfully recruited participants were reimbursed with Amazon vouchers to the total of £10 GBP or $10 USD.

**Measures**

**Demographics** assessed were age, gender, ethnic group, Body Mass Index (BMI) by asking for height and weight, current employment status, highest education level attained, country of residence, and their most frequent/favourite SSB type consumed.

**Drinking behaviour** was measured as frequency of weekly self-reported consumption (total number of portions per week). SSB consumption behaviour was measured at T1 and T2. Alternative drink (water and diet drink) consumption behaviour was only measured at T2. A timeline follow-back method was applied at both time points to increase recall accuracy 55 56. Participants were asked to summarise each day’s activities, then to record the number of portions of SSB, water or diet drink that they consumed each day[[1]](#footnote-1), as well as portion size for each (e.g. can, bottle, glass). Portion size was asked as a way of ensuring participants understood what a single portion of an SSB/alternative drink looked like and aided in accurate recall of portions consumed. The wording of the measures can be found in Supplementary material 1. Consumption was primarily measured using the number of portions consumed, but when quantifiable measurements were given for portion size, volume consumed in the past week (litres) was also calculated.

**Habit (automaticity)** for most frequently consumed SSB and preferred alternative drink (water or diet drink) consumption was measured using the Self-Reported Behavioural Automaticity Index (SRBAI)57 at T1 and T2. The SRBAI is a 4-item subset of the automaticity items from larger Self-Report Habit Index (SRHI) 15 and has been shown to have good reliability and validity in measuring automaticity 57. It also has lower participant burden than the 12-item SRHI, particularly in this study as two behaviours were assessed. For this study the question stem, “Drinking [SSB/water/diet drink] is something…” preceded each of the SRBAI items (e.g. “…I do automatically”). Responses were measured on a 7-point Likert scale (1 = Strongly disagree, 7 = Strongly agree). Habit strength was calculated as the mean of the scores from the four items. At T1, reliability of the measure for SSB consumption habit (*a* = .89) and alternative drink consumption habit (*a* = .89) was good in this sample. At T2, reliability was also good with Cronbach’s *a* = .75 for SSB consumption habit and *a* = .79 for alternative drink consumption habit.

**Hedonic liking** for most frequently consumed SSBs and the preferred alternative drink (water or diet drinks) was assessed at T1 and T2 using 5 items. Responses were measured on a 7-point Likert scale (1=Strongly disagree, 7=Strongly agree). Hedonism was calculated as the mean of the scores from the 5 items. Four hedonism items were adapted from the Personally Expressive Activities Questionnaire (PEAQ) [e.g. “When I drink [SSBs/water/diet drinks] I am satisfied”] 58, as well as an additional question from the literature (“I like the taste of [SSBs/water/diet drinks]”) 59. Internal consistency in this sample was good for both drink options, SSB (*a* = .79) and alternative drink (*a* = .83) at T1 and similar at T2, SSB (*a* = .85) and alternative drink (*a* = .78).

**Procedure**

Ethical approval was obtained from the College’s Research Ethics Committee. Eligible and consenting participants completed the demographic questions and were then blindly randomised to the water or diet drink groups using the inbuilt algorithm on the survey creation website Qualtrics. In both groups, participants were asked to substitute their most frequently consumed SSB for water or a diet drink (according to the condition to which they were randomised). A questionnaire was then administered to assess baseline (T1) behavioural measures (SSB drinking behaviour, SSB consumption habit, alternative drink consumption habit, SSB hedonism and alternative drink hedonism). See Supplementary Material 1. Behavioural measures were reassessed at two months (T2) (SSB drinking behaviour, SSB consumption habit, alternative drink consumption habit and both SSB, alternative drink hedonism, as well as alternative drink drinking behaviour which was not measured at T1). See Figure 1 for an overview of the study design. After the completion of the measures at both time points (T1 and T2), participants were reimbursed with an Amazon voucher to the value of £5 GBP or $5 USD each time, totalling £10 GBP or $10 USD for full participation. Based on a similar study by McGowan14 who also utilised a habit-based intervention to improve healthy eating, for sufficient power to detect an effect size equivalent to the smallest reported by this study (range *d* = 0.29 – 0.61) using a mixed between-within participants ANOVA (alpha = .05, power = 80%), and accounting for 20% attrition, 58 participants per group (116 in total) were required. This power estimation is related to the measurement of the reduction in SSB consumption frequency, one of our primary outcomes.

**Intervention**

After consenting, participants completed the demographic questions and were then randomised to the diet drinks group or water group and were unaware of the instructions given to the other group. Both the diet drinks group and water group consisted of 1) basic information regarding diet drinks or water and 2) an implementation intention planning exercise. Both groups received the same intervention except for the suggested drink. First the types of drinks considered appropriate for the study were outlined e.g. water should be unflavoured and unsweetened by conventional (e.g. sucrose), or non-caloric (e.g. stevia) artificial sweeteners. Carbonated water was allowed. Diet drinks should contain no sugar but could contain non-caloric artificial sweeteners and could be flavoured and carbonated. Unflavoured milk was allowed. Both groups were advised to check that bottled products contained 0g sugars and were given examples of appropriate substitutes including brands. Next participants were guided to create personalised implementation intentions (up to three intentions) regarding substituting their SSB with a diet drink or water of their choice. First, they were asked to identify the time and location in which they usually purchased and/or consumed their favourite SSB, which they identified in the demographic questions (e.g. “I usually purchase orange juice on Saturdays, while online shopping”). This information was used to form context specific implementation intentions (e.g. “If I am shopping online on Saturday, I will buy bottled water instead”). Participants were asked to copy their implementation intentions onto a card or device that was in a highly visible or accessible place. Participant responses were checked by the researchers to ensure valid implementation intentions were created. The intervention materials can be found in Supplementary Material 2. Participants were sent short weekly reminders by email to encourage reading of the written study commitments to remind them of their intentions 60, and provide some information relevant to SSBs. An example weekly reminder is shown in Supplementary Material 3. The intervention used a combination of behaviour change techniques (BCTs), such as action planning (i.e. implementation intentions), repetition and substitution (i.e. behaviour substitution), prompts/cues (i.e. weekly reminders) and health consequences (i.e. information in weekly reminder), according to the behaviour change technique taxonomy (BCTTv1)61.

**Analysis**

All analyses were conducted on SPSS software. To evaluate whether randomisation was successful, the balance of categorical demographic variables between the two intervention groups was assessed using Pearson’s chi-square tests. A series of independent samples t- tests was used to compare groups according to age, BMI, and all variables of interest at T1 and T2. This procedure was repeated comparing completers and non-completers (see Supplementary Material 4).

The analyses were primarily conducted using the number of portions as the measure of consumption. However, they was repeated using volume data for those participants who gave quantifiable portion sizes, and any differences in findings using the two versions of the consumption variable were highlighted. A 2x2 mixed model ANOVA (time\*intervention) was used to investigate changes in SSB consumption between T1 and T2, and differences in change between the diet drink and water groups (Hypotheses 1 and 2). Independent samples t-tests were conducted to determine differences between groups in hedonic liking and consumption of alternative drinks at T2 (Hypothesis 2). and (iii) alternative drink habits between groups at T2. Hypothesis 2a was analysed in the ANOVA used for hypothesis one.

To assess relationships between changes in key variables, a correlation matrix was presented with: change in SSB consumption, change in SSB habit strength, alternative drink consumption frequency at T2, change in alternative drink habit strength, change in hedonic liking for alternative drink, change in hedonic liking for SSB’s and the preference for the alternative drink over SSB at T2. In order to address Hypothesis 3 about what may predict later SSB consumption and habit, two regression models were constructed. The first predicted SSB consumption at T2 from liking for SSB and alternative drinks at T1, controlling for group, SSB consumption and habit at T1. The second model predicted SSB habit at T1 from liking for SSB and alternative drinks at T1, controlling for group, SSB consumption and habit at T1. The predictors were all added in a single step. A t test was used to examine the differences in change in SSB consumption over time according to whether one or more than one implementation intentions were formed (Hypothesis 4).

**Results**

**Participants**

At baseline (T1) 184 participants provided valid and complete responses. Of those, 158 (86%) provided valid and complete responses to the follow-up (T2) questionnaire at two months (*N* = 86 (54%) complete responses from the water intervention and *N* = 72 (46%) complete responses from the diet drink intervention). The age of participants ranged from 18-74 years with mean age being 31.5 ± 10.1 and 51% were female. Most participants were White (60%), employed (75%), were educated to degree level (48%), and were living in the U.K. (59%) or the U.S. (38%). Participants had a mean BMI of 25.6 ± 4.8, with most participants being in the normal or overweight BMI range (18.5 to <30), however BMI ranged from 17.6 – 67.9. Participants consumed an average of 12.06 ± 6.05 portions of SSBs per week, with consumption frequency ranging from 2 to 40 portions per week. For the 112 participants who had quantifiable portion data, this corresponded to an average of 11.25 ± 4.46 litres of SSB a week, with a range of 0.6-11.25 litres. Soft drink (36.0%) and fruit juice (27.2%) were most frequently consumed. The most common brands and flavours of SSBs were Coca-Cola (15.4%), orange juice (14.7%) and Red Bull (8.8%). Portion size was generally reported as cups/cans (approx. 200 – 330mls), glasses (approx. 300 – 400mls), or large cans/bottles (approx. 450 – 550mls). See Table 1 for participant demographics at T1. All participants created implementation intentions in the correct format.

**Randomisation Check and Drop-out Analysis**

The scores for the key variables at baseline (T1), split by group and overall are shown in Supplementary Table 5. No significant differences were found between the diet drinks group and water group on any of the demographics or tested variables. Pearson’s chi-square test indicated a significant difference between completers and non-completers for the country of residence, χ2 (2, *N* = 184) = 6.96, *p* = .031. Independent samples t-test results also indicated a significant difference between completers and non-completers in BMI, *t*(177) = 2.07, *p* = .040, *d* = 0.52, and in SSB consumption frequency at T1, *t*(182), *p* = .031, *d* = 0.48. Compared to completers, non-completers were more likely to come from the U.K., have significantly lower BMI, and have lower baseline SSB consumption (see Supplementary Table 4). Similarly, Pearson’s correlations were assessed between the demographic variables and outcome variables of interest. No variables were strongly correlated (> .60) and therefore no demographic variables were included as confounders in analyses.

**Outliers**

Primary analyses were run with and without the inclusion of extreme outliers; inclusion resulted in significant findings in the SSB habit – SSB consumption correlation analysis in the diet drink group, which were not present when outliers were excluded. Therefore, in line with common practice 62, all extreme outliers were excluded from analyses. A total of 24 extreme outliers (data points) were excluded which led to the exclusion of 22 participants (two participants each had extreme outliers on two variables). Exclusions disproportionately affected the diet drink group where 21% participants were excluded, compared to 8% in the water group. For the means and standard deviations of each variable by group and overall (excluding outliers), see Supplementary Table 5.

**Change in SSB consumption and habit over time**

A 2 (time) x 2 (intervention group) mixed model ANOVA (see Table 2) revealed the main effect for time was significant *F*(1, 134) = 294.55, *p* <.001, partial η2 = .69, with SSB consumption (number of portions) at T2 (*M* =3.57) being significantly lower than SSB consumption at T1 (*M* = 11.50). A significant main effect for intervention group was obtained, *F*(1, 134) = 5.27, *p* = .023, partial η2 = .04. SSB consumption for the diet drinks group (*M* = 6.69) was significantly lower than the water group (*M* = 8.14). There was no significant interaction between time and intervention group, *F*(1, 134) = 0.02, *p* = .887, partial η2 = .00. Examination of the means indicated that SSB consumption decreased over time for both groups and that consumption was significantly lower in the diet drinks group, however, there was no group differences in the reduction in SSB consumption (number of portions). The findings were the same when using volume SSB consumed per week (N=107); no group differences in reduction in consumption was observed (see Supplementary material 6). The volume SSB consumed reduced from 4.71 litres to 1.11 litres in the diet drink group, and from 4.50 litres to 1.38 litres in the water group.

To determine the effect of intervention group on reduction in SSB habit strength over time, a 2 (time) x 2 (intervention group) mixed model ANOVA was conducted (see Table 2). There was a significant main effect of time, *F*(1, 134) = 102.08, *p* <.001, partial η2 = .43 with SSB habit at T1 (*M* = 5.25) being significantly higher than at T2 (*M* = 4.43). There was no significant main effect of intervention group found *F*(1, 134) = 1.07, *p* = .302, partial η2 = .01, meaning there was no significant difference in habit strength between the diet drinks group (*M* = 4.94) and the water group (*M* = 4.77). No significant interaction between time and intervention group was found, *F*(1, 134) = 2.06, *p* = .153, partial η2 = .02. From examination of the SSB habit scores, this indicates that SSB habits got weaker over time in both groups, however there was no difference between groups in SSB habit strength scores, or group differences in reduction in habit strength (change) over time.

**Group differences in alternative drink hedonic liking and consumption**

An independent samples t-test was used to determine the difference in hedonism scores for the alternative drink (diet drink or water) at T2. There was no evidence to support this first hypothesis, as hedonism scores did not significantly differ between groups, *t*(134) = 1.81, *p* = .073. The results from the 2x2 ANOVA showed there were no significant difference in the reduction of SSB consumption over time between groups, *F*(1, 134) = 2.06, *p* = .153, partial η2 = .02.

Anindependent samples t-test was conducted to determine the difference in the mean consumption of the alternative drink at T2 for both the diet drinks group (*M* = 9.59, *SD* = 8.26) and the water group (*M* = 10.86, *SD* = 9.83). The diet drinks group consumed on average 1.27 fewer portions of the alternative drink than the water group, however the difference between groups was not significant, *t*(125) = -0.78, *p* = .440. Likewise, using the volume consumed of the alternative drink at T2, while the diet drink group (M = 3.57 litres, SD = 8.25) consumed less than the water group (M = 4.06 litres, SD = 9.83), this difference was not significant t(105) = -0.88, p=.383.

**Associations between changes in consumption, habit and liking**

Associations between changes in key variables, and the preference for alternative drinks over SSB at T2 are shown in Table 3. The main outcome of the decrease in SSB consumption (number of portions) between T1 and T2 was positively and significantly associated with increase in alternative drink habit, increase in alternative drink hedonic liking, decrease in SSB hedonic liking, and preference for alternative drink over SSB at T2. While not suggestive of a causal relationship, or the direction of any relationship, these associations show that consumption changes and changes in liking for the SSB and alternative drink are related. Decrease in SSB habit between T1 and T2 was strongly associated with decrease in hedonic liking for SSBs (b=.458, p<.001), and significantly associated with preference for alternative drink over SSB at T2 (b=.206, p=.016). Likewise, increase in alternative drink habit was significantly associated with increase in alternative drink hedonic liking ((b=.236, p=.005), and preference for alternative drink over SSB at T2 (b=.208, p=.015).

As anticipated, increase in alternative drink hedonic liking, and decrease in SSB hedonic liking are both strongly and significantly associated with preference for alternative drink over SSB at T2. However, the increase in alternative drink hedonic liking was not associated with the decrease in alternative drink, indicating that the change in liking scores for the two types of drinks are independent. (The same associations were observed for the volume alternative drink consumed at T2, and change in volume of SSB consumed.)

**Regression predicting SSB consumption and habit**

Given the lack of group effects as described above, and as group was not significant, it was removed from both regression models. The multiple regression predicting SSB consumption (number of portions) at T2 is shown in Table 4. T1 SSB consumption strongly predicted consumption at T2 (b=0.206, p<.001). However, SSB habit at T1 was not a significant predictor, suggesting that habit did not affect later behaviour (which may be expected to be due to the effect of the intervention). Hedonic liking for the SSB at T1 did not significantly predict consumption at T2. Alternative drink hedonic liking at T1 significantly predicted SSB consumption at T2, however this was in the opposite direction to expected, whereby higher liking for the alternative drink at T1 was found to predict higher SSB consumption at T2 (b=1.292, p<.001). The model accounted for 23.9% of the variance in T2 SSB consumption, R2 = .239, F(4, 135) = 10.30, p <.001. The model was repeated using consumption data in volume, which predicted 29.6% of the variance, however, the findings were not consistent. SSB consumption (volume) at T1 was no longer a significant predictor (b=0.063, p=0.187), however SSB habit at T1 now significantly predicted T2 consumption (volume) (b=0.267, p=.027). Alternative drink hedonic liking again predicted T2 SSB consumption (volume) (b=0.499, p<.001) in the opposite direction to anticipated. SSB T1 hedonic liking was now a significant predictor of later SSB consumption (volume) (b=0.551, p=.001).

The multiple regression predicting SSB habit at T2 is shown in Table 5. SSB habit at T2 was significantly predicted by SSB habit at T1 (b=0.476, p<.001), however, SSB consumption at T1 did not reach significance at the 0.05 level (b=0.025, p=.073). Hedonic liking for the alternative drink at T1 significantly predicted SSB habit at T2, however the relationship was in the opposite direction to expected, whereby the higher the liking for the alternative drink, the higher the T2 SSB consumption (b=0.192, p=.015). SSB hedonic liking at T1 did not predict SSB habit at T2. The model accounted for 42.4% of the variance in T2 SSB habit, R2 = .424, F(4, 135) = 24.09, p <.001. The model was repeated using the consumption data in volume, which predicted 38.6% of the variance. The findings were only partially consistent with the regression model using consumption based on number of portions. Habit at T1 was still a significant predictor of habit at T2 (b=0.487, p<.001), and SSB consumption (volume) at T1 was still not a significant predictor of T2 habit (b=0.076, p=.206). Hedonic liking for the alternative drink was no longer a significant predictor (b=0.159, p=.070), but liking for SSB was now significant (b=0.224, p=.050).

**Effect of number of implementation intentions formed**

Four participants formed three implementation intentions, twenty formed two, and 112 formed one. The decrease in SSB consumption was compared in participants who formed one implementation intention against those who formed more than one. There was not homogeneity of variances (Levene’s test F=3.92, p=.050) so a Welch’s t-test was conducted. This indicated that those who formed one implementation intention had a larger decrease in SSB consumption (M = 8.30 portions) than those who formed more than one (M = 6.13 portions), t=2.32 (p=.025).

**Discussion**

There was a significant reduction in SSB consumption frequency for both groups at T2. The volume of SSBs consumed reduced from 4.46 litres to 1.23 litres. Portions of SSBs consumed reduced by approximately 68% (11.5 portions/week reduced to 3.7 portions/week, see Supplementary table 5) in both groups and is comparable with other studies that have reported reductions in consumption 51 63. As the current intervention was considerably less intensive than these interventions, the results are very promising. More specifically, our results represent a reduction in sugar intake from SSBs as a result of the reduced consumption. Therefore, the current intervention may be an effective tool in reducing SSB and sugar consumption to the levels currently recommended for optimal health.

The regression analysis did not give consistent findings, as the results were different using the consumption measurement as portions or as volume. In both versions, higher liking of the alternative drink at baseline predicted higher consumption of SSBs at the end of the study. This is in the opposite direction to the hypothesised effect, whereby stronger liking for the alternative drink should predict lower later SSB consumption. In the model predicting SSB habit, liking for SSB at baseline predicted later SSB habits when using the measure of SSB consumption in volume. However this was not the case using volume as portions per week, when instead higher liking for the alternative drink at baseline predicted higher SSB habits at the end of the study. These conflicting findings using slightly different calculations for drink consumption mean that it is not possible to draw conclusions about predictive relationships between the key variables measured in the study. However, it is important to note that only around three quarters of participants had quantifiable consumption data which could be used to calculate volume consumed. One limitation of the regression analysis is that it is only possible to use baseline measurements as predictors in order to determine causal relationships. Due to exposure to the alternative drinks following the intervention, the liking score for these are likely to change from the baseline scores, and these new, more informed liking ratings may subsequently affect behaviour and habit. Had there been additional measurement points, we could have developed a model to examine how changes in certain variables predict later outcome measures (e.g. using a path analysis).

We calculated associations between the changes over time in different variables. While these cannot reflect causal relationships, they give insights into correlated variables which could be investigated further in future studies. This analysis showed consistent results across the measurements of consumption using number or portions or estimated volume consumed. Increase in liking for the alternative drink over time, decrease in liking for the SSB and preference for the alternative drink over SSB at follow up were all associated with reductions in consumption of SSBs. Decrease in SSB habit over the study was strongly associated with decrease in liking for the SSB and preference for the alternative drink at follow up. Likewise, the increase in habit for the alternative drink was significantly associated with the increase in alternative drink habit, and the preference for the alternative drink over SSBs at follow up. These findings cannot be assumed to be causal, as rather than increased liking predicting later consumption and habit, it is plausible that following increased consumption, the liking of a drink may increase. However, the observed relationships are suggestive that ratings of liking may influence success when substituting an unhealthy behaviour for a healthier alternative. This is something that warrants further investigation, potentially using multiple measurement points to investigate the impact of different predictors over time.

While the regression findings are inconclusive, the associations are consistent with the literature that hedonic liking drives behaviour8 44, but if the behaviour is not pleasurable (no or small hedonic liking) the behaviour is not executed as often. Similarly, as habits form due to the repetition of behaviour in a stable context 18, it is not surprising that increased alternative drink habits were associated with reduced SSB consumption.

It was hypothesised that the diet drink group would have higher hedonic liking for the alternative drink than the water group, due to the similarities in taste 44 45 48 64. This in turn was hypothesised to result in the diet drinks group (compared to the water group) having a greater change in SSB consumption over time, increased consumption of the alternative drink at T2 and stronger alternative drink habits at T2. There was no difference in alternative drink hedonism between groups, suggesting water to be equally as rewarding as diet drinks. The lack of differences in hedonic liking between water and diet drinks means it is not surprising that the intervention effects did not differ between groups, as the proposed mechanism of the hypothesised difference was not observed. The lack of group differences in hedonic liking also explains why no significant differences were detected between the diet drinks group and the water group in alternative drink consumption at T2 and alternative drink habit strength at T2. It is also possible that no significant difference was found because the interventions received by the two groups were very much the same (except for the suggested drink). Adriaanse 37 found that higher quality control conditions (i.e. those very similar to the water condition) are associated with smaller intervention effect sizes.

Both the diet drink and water group experienced decreases in SSB habit strength however there were no significant differences between groups. This suggests that any substitute of an SSB is likely to yield a decrease in the strength of SSB habits, even if these habits are not completely broken. Both the lack of differences between groups in SSB consumption over time and SSB habit strength over time add to the evidence that both diet drinks and water are viable alternatives in SSB substitution interventions. Flexibility in alternative drink choice may be beneficial in future studies as interventions could be tailored to personal preferences, which have shown to positively affect behaviour change 65. Allowing participants to choose their alternative drink may increase their sense of autonomy and intrinsic motivation which has been identified as important for successful long-term behaviour change 8 66. Furthermore, it also allows for flexibility outside of SSB interventions, and into the real-world. Despite the lack of group differences in alternative drink hedonism, the results partially support the view of the importance of hedonic liking in behaviour, given that a decrease in SSB hedonic liking was associated with reduced SSB consumption and that decreased hedonic liking for SSB decreases is related to decreased SSB habit strength.

Finally, sub-analysis of implementation intentions showed that those who formed one implementation intention had greater decreases in portions consumed compared to those who formed two or three. This is in line with previous research that suggests having one plan is more effective than having multiple plans 42.

**Strengths**

One of the many strengths of this intervention study was the representative sample. Participant characteristics across several demographic variables demonstrate good generalisability to the wider population. For example, the balance of female and male participants was approximately 50/50, the average age (32yrs) is representative of findings that 20 – 39 year olds are the highest consumers of SSBs globally 67, and the proportion of employed people (75%) is similar to employment rates in the U.K. (77%) 68 and the U.S. (62%) 69. Secondly, a strength of this study is that it shows that water is just as effective as diet drinks when substituting SSBs and trying to reduce consumption frequency and in turn reduce sugar intake. Public health departments should consider implementing this finding in future campaigns.

**Limitations**

However, the study also had limitations. One potential limitation is the use of the water group which acted as an active control group, rather than using a ‘no substitute’ control group condition. This presents difficulties with teasing apart the individual effects of each BCT in the intervention, such that we do not know whether the found effects are the result of the implementation intentions or the reminders. Reminders may serve as an additional habit breaking facilitator by preventing forgetfulness and increasing recall of implementation intentions45 70, however it is unknown whether participants read the reminders or payed attention to them. Future research could investigate the effects of implementation intentions with and without the use of reminders.

Reliance on self-report measures may also limit accuracy. Firstly, habit is a difficult construct to measure and this presents challenges in what can be self-reported 71. We also do not know whether participants believe that doing a behaviour less often means it is less of a habit or no longer habitual. Similarly, the context/cue that participants initially identified as triggering their SSB consumption was not included in the habit measure, which would have given a clearer indication of the specific habit changing. Secondly, the measure of behaviour used (timeline follow-back) asked participants to report all portions consumed during the day, rather than just for the time the implementation intention was planned for. This limits the ability to identify if replacing one behaviour with another was successful. With regard to participants, completers were more likely to be from the USA, have a higher BMI and higher baseline SSB consumption. As such, with more opportunities for SSB substitution due to higher consumption at baseline the findings may not be replicable for samples who consume fewer SSBs or have lower BMIs. However, the completion data does suggest that the intervention may be most acceptable to those who may benefit most from it due to higher BMI and baseline SSB consumption.

Larger effects have been observed in behaviour change outcomes when using stringent outcome measurement methods (e.g. 7 day food diary) rather than methods relying heavily on memory recall 40. This suggests that our measurement method may have lacked the sensitivity or accuracy to detect differences in SSB behaviour between groups. Nonetheless, as this study only targeted one specific SSB item, a food diary or food-frequency questionnaire would be inappropriate, and objective measures would not be feasible through an online medium (and would increase participant burden). The fact that using number of portions consumed or volume consumed resulted in very different findings in the regression analyses is concerning. Reports of consumption could not be quantified into volume consumed for around a quarter of participants. However, approximately half of the participants reported differently sized portions (either in volume, or in reference to glasses/bottles/can etc). This is a limitation of the measure of consumption used. However, in the t-tests, ANOVAs and correlation analysis the two versions of self-reported consumption did not lead to any differences in results.

**Conclusion**

The current research provides promising evidence that a significant reduction in SSB consumption behaviour can be achieved through a relatively simple intervention, and both water and diet drinks are just as effective in reducing consumption. Considering there is limited evidence on the mechanisms of implementation intentions in changing behaviour, this study supports existing literature that implementation intentions may weaken existing habits 24 37, as both groups experienced a significant decrease in SSB habit over time. The intervention is also partially supported in that it aided the formation of a new healthier habit for the consumption of diet drinks or water. Furthermore, results provide tentative support for the role of hedonism in behaviour such that decreased hedonic liking for SSBs are associated with decreased SSB consumption. It can be said that allowing people to choose their preferred alternative drinks may lead to greater and more sustained changes in behaviour.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee.

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Table 1: Participant Demographics for the Water Group and Diet Drinks Group at T1 (baseline)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Water Group  (N = 79) | Diet Drink Group (N = 57) | Total (N = 136) |
|  | Statistic/  n (% group) | Statistic/  n (%group) | Statistic/ n (% total) |
| Age  Mean ± SD  95% CIs of Mean | 32.0 ± 11.2 29.5 – 34.5 | 31.0 ± 8.7 28.7 – 33.4 | 31.5 ± 10.1 29.8 – 33.3 |
| BMI  Mean ± SD  95% CIs of Mean | 25.6 ± 3.8 24.7 – 26.5 | 25.3 ± 3.2 24.5 – 26.2 | 25.5 ± 3.5 24.9 – 26.1 |
| Gender  Male  Female | 39 (49.4) 40 (50.6) | 28 (49.1) 29 (50.9) | 67 (49.3) 69 (50.7) |
| Ethnic Group  White  Asian   Black  South Asian  Hispanic or Latino   Middle Eastern   Mixed   Black-Asian  Prefer not to say | 49 (62.0) 7 (8.9) 7 (8.9) 8 (10.1) 4 (5.1) 1 (1.3)  1 (1.3) 2 (2.5) | 33 (57.9) 6 (10.5) 8 (14.0) 1 (1.8) 7 (12.3) 1 (1.8)  0 (0.0) 1 (1.8) | 82 (60.3) 13 (9.6) 15 (11.0) 9 (6.6) 11 (8.1) 2 (1.5)  1 (0.7) 3 (2.2) |
| Employment  Student  Employed  Unemployed  None apply | 16 (20.3) 58 (73.4) 4 (5.1) 1 (1.3) | 8 (14.0) 47 (82.5) 2 (3.5) 0 (0.0) | 24 (17.6) 105 (77.2) 6 (4.4) 1 (0.7) |
| Education  Partial secondary school  Secondary school  Partial university  Trade, technical, or vocational training  Professional qualification  Bachelors Degree  Masters Degree  Doctorate Degree | 1 (1.3)  14 (17.7)  5 (6.3)  10 (12.7)  7 (8.9)  24 (30.4)  15 (19.0)  3 (3.8) | 0 (0.0)  9 (15.8)  6 (10.5)  6 (10.5)  13 (22.8)  16 (28.1)  6 (10.5)  1 (1.8) | 1 (0.7)  23 (16.9)  11 (8.1)  16 (11.8)  20 (14.7)  40 (29.4)  21 (15.4)  4 (2.9) |
| Country of Residence  U.K.  U.S.A.  New Zealand  Serbia  Bangladesh | 51 (64.6) 25 (31.6) 2 (2.5) 0 (0.0) 1 (1.3) | 29 (50.9) 26 (45.6) 1 (1.8) 1 (1.8) 0 (0.0) | 80 (58.8) 51 (37.5) 3 (2.2) 1 (0.7) 1 (0.7) |

*Table 2:* Mixed-Model ANOVA Results for Hypothesis 1(time x intervention) (*N* = 136)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | SSB Consumption | | | |  | SSB Habit | | | |
|  |  | *df* | Mean square | *F* | *p* |  | *df* | Mean square | *F* | *p* |
| Main Effects: |  |  |  |  |  |  |  |  |  |  |
|  | Time | 1 | 4180.55 | 294.55 | <.001\*\* |  | 1 | 46.84 | 102.08 | <.001\*\* |
|  | Intervention | 1 | 138.51 | 5.27 | .023\* |  | 1 | 2.03 | 1.07 | .302 |
|  | Error (Within) | 134 | 14.19 |  |  |  | 134 | 0.46 |  |  |
|  | Error (Between) | 134 | 26.30 |  |  |  | 134 | 1.89 |  |  |
| Interaction: |  |  |  |  |  |  |  |  |  |  |
|  | Time x Intervention | 1 | .34 | .02 | .877 |  | 1 | .95 | 2.06 | .153 |

*Note:* SSB = Sugar-sweetened beverage

\**p*<.05, \*\* *p*<.001

Table 3: Pearson correlations between the key variables at T2

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 Decrease in SSB  Consumption | - | .033  (.715) | .160  (.063) | .218\*  (.011) | .263\*\*  (.002) | .317\*\*  (<.001) | .430\*\* (<.001) |
| 2 Alternative drink T2  Consumption |  | - | -.026  (.770) | -.146  (.103) | -.103  (.247) | -.153  (.086) | -.080  (.368) |
| 3 Decrease in SSB habit |  |  | - | -.076  (.376) | .061  (.484) | .458\*  (<.001) | .206\*  (.016) |
| 4 Increase in alternative drink  Habit |  |  |  | - | .236\*\*  (.006) | .103  (.233) | .208\*  (.015) |
| 5 Increase in alternative drink  hedonic liking |  |  |  |  | - | .081  (.346) | .517\*  <.001) |
| 6 Decrease in SSB hedonic  Liking |  |  |  |  |  | - | .567\*\*  (<.001) |
| 7 Preference for alternative  drink (over SSB) at T2 |  |  |  |  |  |  |  |

Note: \* *p* <.05 \*\* *p* <.001, SSB = sugar-sweetened beverage, T2 = Time-two

Table 4: *Regression predicting SSB consumption at T2*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Unstandardized Coefficients | | Standardized Coefficients | Sig. | 95.0% Confidence Interval for B | |
|  | B | SE | Beta | Lower | Upper |
| Constant | -9.355 | 2.673 |  | 0.001 | -14.644 | -4.067 |
| SSB Consumption T1 | 0.206 | 0.057 | 0.291 | <0.001 | 0.093 | 0.319 |
| Alternative drink hedonic liking T1 | 1.292 | 0.324 | 0.305 | <0.001 | 0.651 | 1.933 |
| SSB hedonic liking T1 | 0.500 | 0.433 | 0.098 | 0.251 | -0.357 | 1.356 |
| SSB habit T1 | 0.394 | 0.287 | 0.122 | 0.173 | -0.174 | 0.962 |

Table 5: *Regression predicting SSB habit at T2*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Unstandardized Coefficients | | Standardized Coefficients | p | 95.0% Confidence Interval for B | |
|  | B | SE | Beta | Lower | Upper |
| Constant | -0.048 | 0.642 |  | 0.941 | -1.317 | 1.221 |
| SSB consumption T1 | 0.025 | 0.014 | 0.127 | 0.073 | -0.002 | 0.052 |
| Alternative drink hedonic liking T1 | 0.192 | 0.078 | 0.164 | 0.015 | 0.038 | 0.345 |
| SSB hedonic liking T1 | 0.150 | 0.104 | 0.106 | 0.151 | -0.055 | 0.356 |
| SSB habit T1 | 0.476 | 0.069 | 0.532 | <0.001 | 0.339 | 0.612 |

1. The frequency, hedonic liking and habit questions for the SSBs were automatically populated with the type of drink they reported drinking most frequently. For the alternative drinks, the question text specified “water”/”artificially sweetened drinks” but the sections were preceded by a statement saying that: "Artificially-sweetened Drinks" refers to your preferred artificially-sweetened drink / “Water” refers to your preferred type of water. [↑](#footnote-ref-1)