RESEARCH
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Effects of Bite Count Feedback from a Wearable Device and Goal Setting on Consumption in Young Adults

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ABSTRACT

Background New technologies are emerging that may help individuals engage in healthier eating behaviors. One paradigm to test the efficacy of a technology is to determine its effect relative to environment cues that are known to cause individuals to overeat.

Objective The purpose of this work was to independently investigate two questions: How does the presence of a technology that provides bite count feedback alter eating behavior? and, How does the presence of a technology that provides bite count feedback paired with a goal alter eating behavior?

Design Two studies investigated these research questions. The first study tested the effects of a large and small plate crossed with the presence or absence of a device that provided bite count feedback on intake. The second study tested the effects of a bite count goal with bite count feedback, again crossed with plate size, on intake. Both studies used a 2×2 between-subjects design.

Participants/setting In the first study, 94 subjects (62 women aged 19.0±1.6 years with body mass index [BMI] 23.04±3.6) consumed lunch in a laboratory. The second study examined 99 subjects (56 women aged 18.5±1.5 years with BMI 22.73±2.70) under the same conditions.

Intervention In both studies subjects consumed a single-course meal, using either a small or large plate. In the first study participants either wore or did not wear an automated bite counting device. In the second study all participants wore the bite counting device and were given either a low bite count goal (12 bites) or a high bite count goal (22 bites).

Statistical analyses Effect of plate size, feedback, and goal on consumption (grams) and number of bites taken were assessed using 2×2 analyses of variance. As adjunct measures, the effects of serving size, bite size (grams per bite), postmeal satiety, and satiety change were also assessed.

Results In the first study there was a main effect of plate size on grams consumed and number of bites taken such that eating from a large plate led to greater consumption (P=0.001) and a greater number of bites (P=0.001). There was also a main effect of feedback on consumption and number of bites taken such that those who received feedback consumed less (P=0.011) and took fewer bites (P<0.001). In the second study there was a main effect of plate size on consumption such that those eating from a large plate consumed more (P=0.003) but did not take more bites. Further analysis revealed a main effect of goal on number of bites taken such that those who received the low goal took fewer bites (P<0.001) but did not consume less.

Conclusions Providing feedback on the number of bites taken from a wearable intake monitor can reduce overall intake during a single meal. Regarding the first research question, providing feedback significantly reduced intake in both plate size groups and reduced the overall number of bites taken. Regarding the second research question, participants were successful in eating to their goals. However, individuals in the low goal condition appeared to compensate for the restricted goal by taking larger bites, leading to comparable levels of consumption between the low and high goal groups. Hence, the interaction of technology with goals should be considered when introducing a health intervention.

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OVERWEIGHT AND OBESITY HAVE REACHED epidemic levels in the United States.[1] One of the driving forces behind this trend may be a "mindless margin" in which humans can overeat and not notice.[2] Wansink and colleagues[3] have shown that various environment cues (eg, portion size, serving dish size, plate size, and social interaction) can lead to an increase in eating within the mindless margin. For example, people will eat more from a larger popcorn container than from a smaller popcorn container without realizing it, even if the popcorn in the larger container is stale. Students still served themselves 55% more from a larger bowl without believing the size of the bowl played into their own serving sizes, demonstrating that the effect persisted despite the warning.[4] Further studies have shown that individuals using larger plates, even food and nutrition practitioners—individuals who were expected to show increased sensitivity to such an effect—consistently serve and consume greater amounts compared with using a smaller plate.[5] The experiments in our article were motivated by the idea that an objective intake monitoring technology might be able to help an individual avoid this mindless margin.

Technologies such as the HapiFork (HapiLabs), Mandometer (Mandometer), and Bite Counter (Bite Technologies) devices provide objective, real-time measurements during eating. The HapiFork is an eating tool that measures duration of eating, eating rate, and the number of bites an individual takes.[6] It is based on an electric circuit that is closed when the fork is inserted into the mouth. The Mandometer is a portable scale connected to a computer that generates a real-time graph of weight representing food removal from a plate.[7] It can help individuals control their eating rate by providing feedback relative to a goal rate, represented by a line on the computer monitor.

The Bite Counter is worn like a watch and tracks wrist motion to detect a pattern indicative of a hand-to-mouth gesture (ie, a bite). It counts the detections and, thus, provides feedback on the number of bites taken. One proposed mechanism behind why bite count feedback would reduce overeating is that it provides a more precise measure of behavior beyond that of basic visual input; that is, simply viewing the plate as one eats. Research has shown that the more complete and precise the monitoring and feedback is the greater ability one has to reach a goal.[8,9] In this case, the goal is to eat less. Thus, by providing an accurate measure of how much is eaten, individuals should be able to successfully eat less than they otherwise would.

The Bite Counter has been shown to count bites with 94% accuracy under controlled conditions and 86% in uncontrolled conditions.[10] A recent study of 273 free-eating people in a cafeteria found it correctly detected 82% of bites across a wide range of foods, utensils, and participants. Furthermore, bite count has been shown to correlate with calories. One study found an average per-meal correlation of 0.53 between bites and calories for 83 people using the Bite Counter for 2 weeks.[11] Automatically measured bite count was compared against a computerized food diary program with a resulting correlation of bites to calories in the range of 0.4 to 0.8 for 76% of those participants. Results from these studies provide support for the Bite Counter's ability to provide individuals with real-time portion feedback.

The overall purpose of this work was to separately investigate two research questions. The first research question was designed to explore how the presence of the Bite Counter with feedback presented in isolation alters eating behavior compared with not wearing it. The second research question was designed to explore how bite count feedback coupled with either a low or high goal alters eating behavior. Research has shown that self-monitoring alone is useful in helping individuals achieve success.[12] However, self-monitoring when paired with a goal has been shown to be more effective.[13]

The design, methods, results, and discussion for both research questions, which were investigated in two separate studies, are presented conjointly followed by a conclusion tying together the findings regarding both research questions.

STUDY DESIGN AND HYPOTHESES

Research Question 1: How Does the Presence of a Technology that Provides Bite Count Feedback Alter Eating Behavior?

The first research question was investigated using a 2 (plate size)×2 (device feedback) design. The first independent variable was plate size with two levels: "small plate" and "large plate." the second independent variable was feedback with two levels: "no feedback" and "feedback." Specifically, in the feedback condition participants wore the Bite Counter and saw their bite count or they did not. Participants were not given a reference or instruction regarding bite count or its use they were simply told that it was a device that would count their bites. The two main dependent variables were grams consumed and bites taken.

Plate size was manipulated as an environmental cue known to affect eating intake; that is, eating from a larger plate leads to increased intake. It was therefore hypothesized that there would be a main effect of plate size such that those eating from a larger plate would consume more and take more bites. The rationale for using the plate size manipulation was to see whether feedback from a Bite Counter intervention would reduce or eliminate this known environment cue/plate size effect on intake. It was further hypothesized that there would be a main effect of feedback such that those who received feedback on the number of bites taken would consume less and take fewer bites. Finally, it was hypothesized that there would be an interaction between plate size and feedback such that presence of the feedback would reduce the effect of plate size. This hypothesis is based on the notion that an external cue regarding how much one has eaten may be more influential than the perceptual cue offered by the plate in this case. This is similar to studies that examined the effect of leaving food scraps, candy wrappers, and bottle caps visible to individuals as a cue to how much they have consumed, which consequently leads to a reduction in consumption.

Research Question 2: How Does the Presence of a Technology that Provides Bite Count Feedback Paired with a Goal Alter Eating Behavior?

Based on the results from the first study, we sought to determine what effect providing bite count feedback along with a bite count goal would have on eating behavior. Specifically, would the implementation of a bite count goal reduce the effect of plate size?

To test the effects of feedback and the bite count goals, the authors provided participants with bite count feedback and gave them either a low goal or a high goal. Of particular interest was whether or not participants in the low goal condition would eat to their given goal without changing other behavior-related outcomes such bite size. It was reasoned that if participants would eat to the low goal without changing other behaviors, then bite count feedback along with a goal representing slightly less intake than normal would be a useful tool in getting people to stop eating earlier than they normally would without feeling less satisfied while eliminating the effect of plate size.

The study used a 2 (plate size)×2 (goal) design. As with the first study, plate size had two levels: "small plate" and "large plate." The second independent variable was goal with two levels: a 12 bite "low goal" and a 22 bite "high goal." Again, the two main dependent variables were grams consumed and bites taken.

It was hypothesized that there would be a main effect of plate size such that those eating from a larger plate would consume more and take more bites. It was further hypothesized that there would be a main effect of goal such that those who received the low bite count goal would consume less and take fewer bites. Finally, it was hypothesized that there would be an interaction such that the presence of the goal would eliminate the effect of plate size.

METHODS

Participants/Setting

Participants were recruited for the studies from the Clemson University undergraduate population using an online recruitment tool. All participants were healthy. Exclusion criteria included history of an eating disorder and food allergies to macaroni and cheese. Participants were asked to abstain from food for at least 3 hours before the study. The data were collected in the Applied Psychophysiology Laboratory in Brackett Hall at Clemson University. This study received approval from the Institutional Review Board at Clemson University before data collection. Informed consent was obtained from all participants at the beginning of the study, and the rights of all participants have been protected. Sample size was determined by using the Power and Sample Size program[14] using α=.05 and power=0.8 and effect size=0.4. This effect size was chosen due to the reported moderate effect of plate size as reported in studies such as those by Wansink and Kim.[3] A sample size of 12 per condition was calculated. However, due to the unknown effect of the wearable intake monitor the researchers oversampled to increase the chances of avoiding a type II error.

Materials

Food Item. Stouffer's Party Size Macaroni & Cheese (Nestle S.A.) (dimensions=33.02 cm×26.67 cm×3.81 cm) was chosen as a meal because it is easy to prepare in the laboratory, is acceptable for lunch, and is amorphous and, thus, can be eaten in different-sized bites without changing energy density. Participants did not state finding the meal item unusual as a lunch served by itself. Nutrition Facts per serving: serving size 225 g, 330 kcal, total fat 17 g, cholesterol 25 mg, sodium 920 mg, total carbohydrate 31 g, and protein 14 g. Serving temperature was 120°F.

Plates. Two different-sized plates were used. For the large plate condition, a white plate with a diameter of 26.4 cm was used. For the small plate condition, a white plate with a diameter of 17 cm was used. Participants did not report finding the size of the plate unusual.

Height and Weight Measurement. Height, weight, and body mass index (BMI) were obtained using the Tanita WB-3000 (Tanita) scale with built-in stadiometer and BMI calculator.

Bite Counter. The Bite Counter is worn on the wrist and uses a gyroscope to track wrist motion. It detects a pattern of motion distinctive of hand-to-mouth gestures used to ingest foods and beverages. The device has to be turned on at the start of eating and turned off at the end of eating. During eating it displays bite count for the current eating activity in real time.

Instrumented Eating Station. Participants ate at a four-person table customized for the purpose of monitoring bite count and food weight. The table included four scales hidden in recesses cut out at each place setting for weighing the food before and after the meal. All of the measuring equipment was connected to two laptops.

Questionnaires

Satiety Labeled Intensity Magnitude (SLIM) Scale. The SLIM scale allows for a quantitative index of hunger and fullness on a 0 to 100 scale, with higher numbers indicating greater levels of fullness. The SLIM scale is a sensitive, reliable, and easy-to-use scale for measuring perceived satiety.[15] Thirty-seven subjects rated the semantic meaning of 47 phrases describing different levels of hunger or fullness using magnitude estimation. The scale was developed by evaluating 11 phrases based on response consistency, symmetry, bipolarity, and inclusion of end point anchors. These phrases were placed along a vertical line scale at positions corresponding to their geometric mean magnitude estimates to create a labeled magnitude scale of satiety.

Relationship Questionnaire. This questionnaire indexed any potential relationships the participants might have had with one another and to help characterize the composition of the social structure of the group. In cases where any of the participants had a relationship with one or more of the other participants, they recorded the following: duration of relationship, source of relationship, and strength or quality of relationship. This information was collected to account for the known social effects on eating; for example, social facilitation and impression management.[16] This information was also collected as a reference when conducting outlier analysis. If a case was found to be an extreme outlier, we referenced the relationship questionnaire to see whether a long-standing relationship was held among the participants in that session.

Procedure

Participants entered the laboratory in groups of up to four people and completed an informed consent form as well as a demographic questionnaire. Height and weight were

measured and used to derive BMI. Next, each participant completed the first of three SLIM scales and filled out the relationship questionnaire. Upon completion of the measurements and questionnaires, the participants were moved to the eating station. At this time the macaroni and cheese was removed from the oven and placed at the center of the preset table. Before each data collection session the group of participants was randomly assigned to one of the four conditions via the use of a random number generator. All participants in a single session ate from the same sized plate and all either did or did not use a Bite Counter. Participants ate in groups to simulate a somewhat natural eating environment for college students; that is, eating with others in the cafeteria.

Participants were asked to listen to all instructions carefully before serving themselves and eating. As part of the experimental manipulation, during the feedback conditions the instruction included the purpose of the Bite Counter and how to wear and operate it. Those participants in the no-feedback condition did not wear a Bite Counter. All participants were told, "You are allowed to eat freely." Next, participants completed the second SLIM scale, which was introduced to determine whether the presence of food or relocation to the eating station had an effect on satiety. Participants were then instructed to put on the Bite Counter in the feedback condition, and they were allowed to serve themselves from the macaroni and cheese tray. The participants were provided a serving utensil and were allowed to serve themselves ad libitum. Stable weights of the served portions were recorded using the recessed scales for the purposes of obtaining serving size and grams consumed. Participants were then asked to turn on the Bite Counter in the feedback condition. In all conditions, participants were then allowed to commence eating.

Participants were further instructed to eat as naturally as possible, including engaging in conversation with the other participants. This instruction was used to help mitigate the effects of the artificial setting. If participants indicated that they were finished, plate waste weight was recorded. Participants were instructed to wait until the rest of the participants were done eating. In the feedback condition, they were also asked to turn off and remove the Bite Counter. After the eating session participants completed the third SLIM scale.

The same setting, materials, and procedures were used in the second study. Plate size was manipulated as in the first study and it was crossed with goal (low or high bite count). Immediately before serving themselves participants in the low goal condition were told: "Please eat 12 bites," whereas participants in the high goal condition were told: "Please eat 22 bites." Once the bite goals were given, participants were allowed to serve themselves and commence eating in the same manner as described in the first research question. The high bite count goal was based on a previous study that found an average bite number of 22.[11] The low bite count goal was obtained from the lowest average bite count between the conditions in the first study described here, which was 12 bites.

Statistical Approach

Analyses of variance were employed to investigate the effect of plate size and feedback on the dependent variables. Analysis was performed with IBM-SPSS version 20.[17] The significance level was set to 0.05 for all tests.

The dependent variable of grams consumed was measured by subtracting plate waste, or the amount of food in grams left over on the plate after the participant indicated that he or she was finished eating, from the amount of food in grams that the participants served themselves. The dependent variable of bites taken was measured and recorded using the Bite Counter.

Additional dependent variables of interest were serving size, bite size, and postmeal satiety. Serving size was calculated by subtracting the weight of the fixed plastic plate and disposable paper plate from the total combined weight of the plastic plate, paper plate, and macaroni as reported by the recessed scales. Note that serving size is different than grams consumed because grams consumed considered plate waste and calculated actual amount consumed. Bite size was calculated by dividing grams consumed by the number of bites taken. Postmeal satiety was obtained from the third (ie, postmeal) SLIM scale. Note: the Bite Counter was turned on after the participants served themselves the first course. For the purposes of this study, data from participants who consumed only one course were analyzed. Participants who consumed more than one course were excluded from all analyses. The rationale for this was because only a small subset of participants (<10%) requested a second serving, and given such a small number, we could not independently examine the effect of a second course in a statistically sound manner. Therefore, we excluded these participants from analysis because they potentially were different than the main body of participants as shown by their second course behavior.

RESULTS

No outliers were detected in the dataset for the first study. Outliers were predefined as individuals who consumed an unusually high or low amount. Specifically, these outliers were considered those individuals who consumed three times more than the interquartile range. Ninety-four participants (62 women aged 19.0±1.6 years with BMI 23.04±3.6) completed the first study and only consumed a single course and were included in the analyses (Table 1).

Using the same outlier criteria in the second study, no outliers were detected in the dataset. Ninety-nine participants (56 women aged 18.5±1.5 years with BMI 22.73±2.70) completed the second study at only consumed a single course (Table 2).

Grams Consumed and Number of Bites Taken

Research Question 1. Means and standard deviations of grams consumed and bites taken by condition can be found in Table 3. The analysis of grams consumed revealed a main effect of plate size ($F[1, 90]=11.375$; $P=0.001$) such that those eating from a larger plate consumed more than those eating from a smaller plate, on average 39.7 g more. Further analysis revealed a main effect of feedback ($F[1, 90]=6.809$; $P=0.011$) such that those who received bite count feedback consumed less than those who did not receive bite count feedback, on average 35.7 g less. No interaction of plate size and feedback on grams consumed was reported.

Table 1. Sample size and demographic characteristics for participants in a study examining the effect of plate size and use of a wearable intake monitor on overall intake[a]

	No Feedback		Feedback	
Characteristic	Large Plate	Small Plate	Large Plate	Small Plate
	←——————*n*——————→			
Sample size	20	25	22	27
Female sex	14	15	16	17
White ethnicity	15	18	15	23
	←————*mean±standard deviation*————→			
Age (y)	18.9±1.2	19.1±2.2	18.8±1.2	19.2±1.5
Body mass index	22.6±2.9	23.2±4.3	22.8±2.9	23.4±4.4

[a]Feedback refers to the presence of visible real-time bite count provided by Bite Counter (Bite Technologies).

Furthermore, it was shown that there was an effect of plate size on bites taken ($F[1, 90]=11.644$; $P=0.001$) such that those eating from a larger plate took more bites than those eating from a smaller plate, on average 4.5 bites more. In addition, it was shown that there was an effect of feedback ($F[1, 90]=15.051$; $P<0.001$) such that those who received bite count feedback took fewer bites than those who did not receive feedback, on average 5.0±5.3 bites fewer. No interaction of plate size and feedback on bites taken was reported.

Research Question 2. Means and standard deviations of grams consumed and bites taken can be found in Table 4. Analysis of grams consumed indicated a main effect of plate size ($F[1, 95]=9.029$; $P=0.003$) such that those eating from a larger plate consumed more than those eating from a smaller plate, on average 36.2 g more. Further analysis revealed no main effect of goal, indicating that there was no difference in intake between those who received the low bite count goal and those who received the high bite count goal. No interaction of plate size and goal on grams consumed was found, indicating that neither the low goal nor high goal altered how much people ate.

Analysis of bites taken indicated a main effect of goal ($F[1, 95]=27.691$; $P<0.001$) such that those who received the low bite count goal took fewer bites than those who received the high bite count goal, on average 5 bites fewer. No effect of plate size or an interaction between plate size and goal on bites taken was found.

Table 2. Sample size and demographic characteristics by condition for participants in a study examining the effect of plate size and use of a wearable intake monitor coupled with an eating goal on overall intake[a]

	Low Goal		High Goal	
	Large Plate	Small Plate	Large Plate	Small Plate
	←——————*n*——————→			
Sample size	28	32	22	17
Female sex	16	17	11	12
White ethnicity	27	26	20	14
	←————*mean±standard deviation*————→			
Age (y)	18.3±.98	18.6±1.2	18.4±2.4	18.8±1.3
Body mass index	22.7±2.9	22.8±3.2	22.1±1.8	23.3±2.2

[a]Goal is defined by a target bite count. The low and high goals are 12 and 22 bites, respectively.

Bite Size, Serving Size, Postmeal Satiety, and Satiety Change

Research Question 1. Further analyses were conducted on bite size, serving size, postmeal satiety, and satiety change. No effect of plate size or feedback was found on bite size. Analyses revealed a main effect of plate size on serving size ($P<0.001$), postmeal satiety ($P=0.031$), and satiety change ($P=0.025$) such that those who ate from a larger plate served themselves more, reported greater satiety after the meal, and reported greater satiety change from premeal levels. Furthermore, analysis revealed a main effect of feedback on satiety change ($P=0.004$) such that those who received feedback reported less satiety change than those who did not receive feedback. Finally, no interaction ($P=0.489$) was found indicating that average satiety change for those who received feedback was less than for those who did not receive feedback regardless of plate size. No effect of feedback on serving size or postmeal satiety was found. Finally, no interaction between plate size and feedback was reported for bite size, serving size, or postmeal satiety.

Research Question 2. Analyses revealed a main effect of plate size on serving size ($P=0.032$) such that those eating from a larger plate served themselves more than those eating from a smaller plate, on average 34.9 g more. No effect of plate size on bite size, postmeal satiety, or satiety change was found. Analyses further revealed a main effect of goal on bite size ($P=0.003$), serving size ($P=0.023$), postmeal satiety ($P<0.001$), and satiety change ($P<0.001$) such that those who received the low goal served themselves more, took larger bites, reported lower levels of satiety after the meal (ie, lesser fullness), and reported less satiety change from premeal levels. Finally, an interaction between plate size and goal was found on satiety change ($P=0.014$) such that those who ate from the small plate reported significant changes in satiety change between goal levels compared with those who ate from the large plate who did not report significant differences between goal levels. No interaction of plate size and goal on bite size, serving size, or postmeal satiety was found.

DISCUSSION

Research Question 1: How Does the Presence of a Technology that Provides Bite Count Feedback Alter Eating Behavior?

The hypothesis stated that participants would consume more and take more bites when eating from a large plate than

Table 3. Descriptive statistics of grams consumed and bites taken by 94 participants who completed a study examining the effect of plate size and the use of a wearable intake monitor on overall intake[a]

	No Feedback		Feedback[b]	
Variable	Large Plate	Small Plate	Large Plate	Small Plate
	←——— *mean±standard deviation* ———→			
Grams consumed	166.95±63.31	144.06±34.03	151.64±57.24	107.53±27.31
Bites taken	20.5±6.8	18.5±6.2	17.9±5.2	12.0±3.8

[a]On grams consumed, plate size (P=0.001) and feedback (P=.011) had significant effects. On bites taken, plate size (P=0.001) and feedback (P<0.001) had significant effects.
[b]Feedback refers to the presence of visible real-time bite count provided by Bite Counter (Bite Technologies).

participants who ate from a small plate. The findings support this hypothesis. It was further hypothesized that participants who received bite count feedback would consume less and take fewer bites. Likewise, the findings support this hypothesis.

It has been shown in some previous work that grams consumed and bite count do correlate.[11] The concept behind this research is that a reduction in bite count should result in a reduction in grams consumed. Furthermore, research has shown that when provided with an external cue regarding how much has been consumed (eg, allowing bottle caps or candy wrappers to accumulate, not bussing tables at a restaurant), individuals will consume less than they otherwise would.[18] It is along this line that by providing bite count as an external cue regarding how much has been consumed, individuals will consume less than they otherwise would.

The plate size cue was considered a suitable manipulation to test the effect of continuous bite count feedback on eating behavior. It was found that the presence of the feedback did reduce overall consumption; however, it did not eliminate the plate size effect because people receiving feedback still consumed more when eating from a larger plate than those eating from a smaller plate. It was found that individuals decreased the number of bites they took when receiving feedback without changing their bite size. This finding shows that people will change their behavior, in this case how many bites they take, without engaging in compensatory behavior such as increasing bite size. Taken together, these results suggest that it may be possible to help people to stop eating earlier than they otherwise would, without feeling any less full immediately following the meal. In other words, it may be possible that by providing bite count feedback, people may stop eating when they are in the low end of the mindless margin.

The results of this research question show that the presence of bite count feedback reduced intake but did not eliminate the effect of plate size. It may be that to eliminate this effect, individuals need to be provided with a bite count goal. It has been suggested that individuals will eat to a goal regardless of the size of their plates, without changing other influential behaviors, thus eliminating the effect.

Research Question 2: How Does the Presence of a Technology that Provides Bite Count Feedback Paired with a Goal Alter Eating Behavior?

Similar to the first research question, it was hypothesized that participants would consume more and take more bites when eating from a larger plate than participants who ate from a smaller plate. The findings of the second research question support the hypothesis. It was further hypothesized that participants who received the low bite count goal would consume less and take fewer bites. The findings did not support this hypothesis. Although participants in the low bite count goal condition took significantly fewer bites, they did not consume less than those in the high bite count goal. Our study issued participants a goal of eating a certain number of bites. Our results indicate that people were successful in eating to their bite goals. This finding is consistent with current literature that shows if you give people a goal relating to their eating behavior, they will be successful in achieving their goal.[19] However, as highlighted in our study, efforts to meet target goal behaviors may have unintended consequences on secondary behaviors if these behaviors are also

Table 4. Descriptive statistics of grams consumed and bites taken by 99 participants who completed a study examining the effect of plate size and the use of a wearable intake monitor coupled with an eating goal on overall intake[a]

	Low Goal		High Goal	
Variable	Large Plate	Small Plate	Large Plate	Small Plate
	←——— *mean±standard deviation* ———→			
Grams consumed	172.59±59.49	132.51±49.71	174.56±58.40	146.26±52.20
Bites taken	12.2±1.6	11.7±3.2	17.5±4.8	16.2±5.8

[a]On grams consumed, plate size (P=0.003) had a significant effect. On bites taken, bite count goal (P<0.001) had a significant effect. Goal is defined by a target bite count. The low and high goals are 12 and 22 bites, respectively.

not considered as part of the goal. For example, in our study, some participants were given a low bite goal but were not instructed to decrease consumption. Although participants were successful in eating to their bite goal, a change in other behaviors was observed (ie, changing bite size) led to no change in consumption compared with those given a high bite goal.

It was found that those in the low goal condition significantly increased their bite size over those in the high goal condition, taking on average 3.5 g more per bite. It is possible that individuals believed 12 bites to be an inappropriately low number of bites to take during a lunchtime meal. The finding from this research question of increased serving sizes in the low goal condition lends support to the notion that before serving, individuals may have changed their behavior in anticipation of only being able to take 12 bites, in this case making sure they had enough food supply to maximize each allowed bite. Once eating commenced, it is plausible that participants took much larger bites in an effort to feel satisfied in the presence of a restricting goal from the experimenter.

In cases where bite-by-bite analysis revealed that participants took larger bites starting with the first bite, then there would be support for the above hypothesis. Alternatively, if the analysis revealed that participants only increased their bite size as they approached the bite goal, then there would be support for the hypothesis that participants became conscious of the fact that 12 bites is less than they would typically take while eating. However, a microanalysis of the bite-by-bite eating behavior is beyond the scope of our work because bite-to-bite grams consumed data were not monitored.

CONCLUSIONS

The purposes of the two studies described above were to determine whether the availability of continuous feedback on the number of bites taken would have an effect on overall intake and have an effect on the eating behavior of individuals influenced by the cue of plate size. Furthermore, the purpose was to determine whether feedback would have an effect on overall intake when paired with an eating goal and have an effect on the eating behavior of individuals affected by the cue of plate size when paired with an eating goal.

It was found that the presence of bite count feedback led to a reduction in overall consumption. This finding is consistent with current literature that shows feedback on consumption leads people to consume less.[18] It was found that this type of feedback does not eliminate the effect of environment cues such as plate size. Individuals may eat less when they receive bite count feedback, but feedback alone may not be sufficient in terms of helping them to take an "appropriate" or "normal" number of bites, particularly in the presence of large plates. One possible explanation for this is that individuals may not know what exactly constitutes an "appropriate" or "normal" number of bites; even in cases where bite count feedback is present, they do not know when to stop eating; thus, environment cues are still influential. The notion that individuals do not know what is an "appropriate" or "normal" number of bites is in line with current literature that has shown that humans have a poor ability to control intake and to estimate calories.[20] To test this hypothesis and in an attempt to mitigate the plate size effect, we further investigated the effect of a bite count goal.

As described above, the findings were partially unexpected. Of particular note is that individuals who received the low bite count goal did not consume any less than those who received the high bite count goal. Although participants who were given the low goal were successful in eating to and stopping at their bite count goal, a concurrent increase in bite size resulted in comparable consumption regardless of goal assignment. It is possible that this compensatory behavior is intentional, a reaction to a perceived limitation such that participants believed 12 bites to be too restricting of a goal. In other words, in an effort to reach satiety while not surpassing the given goal, participants believed they needed to take larger bites perhaps than they typically would.

The question then becomes not, "Will individuals use bite count feedback to eat to a given goal?", but rather, "How can individuals or practitioners set appropriate goals, such that individuals working toward the goal are not compelled to compensate by changing other behaviors?" The answer to that question is not immediately clear. One possible approach is a bite count goal titration method such that a goal is based on an individual's average bite count, and formulated by subtracting only a small number of bites at a time (eg, two or three). This method could be implemented multiple times until a change in bite size is observed.

Limitations

Generalizability of this research is limited due to a homogenous sample: Participants were all college undergraduates, most of whom fell within healthy BMI ranges. Furthermore, the authors did not block on BMI to determine whether that measure would affect the outcome. In addition, this research question could have implemented more measures to ensure for greater comparability between the groups. Although the groups were balanced by sex composition, other influential factors such as restrained eaters were not considered. In future experiments, a more diverse sample should be examined and other characteristics controlled for and balanced, such as those above.

Another limitation is that the exact cause of the change in bite size among those in the low bite goal condition is unknown. Such hypotheses as those proposed in the discussion of the second research question and accompanying analyses were outside the scope of our study; however, future studies could implement such approaches, as well as the inclusion of additional controls, manipulation checks, and subjective inquiries in an attempt to isolate the cause of the effects observed.

Future research should also consider implementing a manipulation in all groups. The authors acknowledge that all groups should receive some form of manipulation because it may be unclear whether the specific feedback itself in the first research question was the catalyst for the change in behavior or whether the fact that one group had a manipulation and the other did not was the cause of the behavior change.

Additional future research should examine the microstructural pattern of intake; that is, eating rate. The influence of the Bite Counter on behavior outcomes such as interbite interval (ie, time between bites) and cumulative food intake

curves is of great interest because it has been shown that these behaviors influence intake.[21]

Finally, it may be beneficial to obtain participant baselines before subjecting them to a goal condition as reported in Research Question 2. As seen in the results, individuals were successful at eating to their given bite goals. However, they changed other behaviors leading to no difference in intake between conditions. A consideration of baseline behaviors before goal creation and implementation may be useful in achieving a reduction in intake.

Applications

Although the results from these studies highlight the broader-reaching influence of bite count goals without providing a foolproof method of controlling influential behaviors, the utility of bite count feedback as a mechanism to help people monitor intake has been shown to be valuable because its mere presence leads people to eat less than they typically would.

Wearable technologies, particularly wrist-worn devices such as the iWatch (Apple Computers), and devices from Pebble and Fitbit are becoming increasingly popular.[22] These are some examples of the devices discussed above that aim at augmenting human performance and health outcomes.[22]

Our results show that it is important for scientists to study how interventions that employ these devices may affect primary (the behavior intended to be changed) and secondary (behaviors not intended to be changed) behaviors. In the case of Bite Counter, it is clear that feedback from the device alone can reduce intake and bite count in a single eating session. However, when the feedback is coupled with a goal, if the bite count goal is somehow considered unreasonable by the individual targeted, he or she may compensate by altering other behaviors; for example, increasing bite size. Therefore, specific device feedback and intervention goals should be simultaneously considered in future research.

References

1. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and trends in obesity among US adults, 1999-2008. *JAMA*. 2010;303(3):235-241.
2. Wansink B. From mindless eating to mindlessly eating better. *Physiol Behav*. 2005;100(5):454-463.
3. Wansink B, Kim J. Bad popcorn in big buckets: Portion size can influence intake as much as taste. *J Nutr Educ Behav*. 2005;37(5):242-245.
4. Wansink B, Cheney MM. Super bowls: Serving bowl size and food consumption. *JAMA*. 2005;293(14):1723-1728.
5. Wansink B, Van Ittersum K, Painter JE. Ice cream illusions: Bowls, spoons, and self-served portion sizes. *Am J Prev Med*. 2006;31(3):240-243.
6. Hapifork [package insert]. HapiLabs, Hong Kong, China.
7. Mandometer [package insert]. Mandometer. Brighton, Victoria, Australia.
8. Burke LE, Wang J, Sevick MA. Self-monitoring in weight loss: A systematic review of the literature. *J Am Diet Assoc*. 2011;111(1):92-102.
9. Bravata DM, Smith-Spangler C, Sundaram V, Gienger AL, Lin N, Lewis R, Sirard JR. Using pedometers to increase physical activity and improve health. *JAMA*. 2007;298(19):2296-2304.
10. Dong Y, Hoover A, Scisco J, Muth E. A new method for measuring meal intake in humans via automated wrist motion tracking. *Appl Psychophyisol Biofeedback*. 2012;37(3):205-215.
11. Scisco JL. *Source of Variance in Bite Count*. PhD dissertation. Clemson, SC: Clemson University Psychology Department; 2012.
12. Baker RC, Kirschenbaum DS. Self-monitoring may be necessary for successful weight control. *Behav Ther*. 1993;24(3):377-394.
13. Bandura A, Cervone D. Self-evaluative and self-efficacy mechanisms governing the motivational effects of goal systems. *J Pers Soc Psychol*. 1983;45(5):1017.
14. Dupont WD, Plummer WD. PS: Power and sample size calculation. *Control Clin Trials*. 1990;11:116-128.
15. Cardello AV, Schutz H, Snow C, Lesher L. Predictors of food acceptance, consumption and satisfaction in specific eating situations. *Food Qual Pref*. 2000;11(3):201-216.
16. Salvy S, Kieffer E, Epstein L. Effects of social context on overweight and normal-weight children's food selection. *Eat Behav*. 2008;9(2):190-196.
17. IBM-SPSS Statistics for Windows, version 20.0. Released 2011. Armonk, NY: IBM Corp.
18. Wansink B, Payne CR. Counting bones: Environmental cues that decrease food intake. *Percept Motor Skills*. 2007;104:273-276.
19. Bandura A, Simon KM. The role of proximal intentions in self-regulation of refractory behavior. *Cognit Ther Res*. 1977;1(3):177-193.
20. Chandon P, Wansink B. The biasing health halos of fast-food restaurant health claims: Lower calorie estimates and higher side-dish consumption intentions. *J Consum Res*. 2007;34(3):301-314.
21. Guss JL, Kissileff HR. Microstructural analyses of human ingestive patterns: From description to mechanistic hypotheses. *Neurosci Biobehav Rev*. 2000;24(99):261-268.
22. Guo F, Li Y, Kankanhalli M, Brown M. An evaluation of wearable activity monitoring devices. In: *Proceedings of the 1st ACM International Workshop on Personal Data Meets Distributed Multimedia*. New York, NY: Association for Computing Machinery; 2013.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

E. R. Muth and A. W. Hoover have formed a company, Bite Technologies, to market and sell a bite counting device. Clemson University owns a US patent for intellectual property known as The Weight Watch (Patent No. 8310368). Bite Technologies has licensed the method from Clemson University and has received funding from South Carolina Launch, a state organization that incubates startup companies associated with university intellectual property, and has received funding from the National Institutes of Health to validate the device. E. R. Muth and A. W. Hoover receive royalty payments from bite counting device sales. No potential conflict of interest was reported by the other authors.

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