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A Pavlovian Intervention to Condition Comforting Effects of Fruits

Laura E. Finch, PhD, Jenna R. Cummings, PhD, Sophie C. Lee, BS, and A. Janet Tomiyama, PhD

ABSTRACT

Objective: Perceived stress, lower fruit intake, and comfort eating are all risk factors for chronic disease. The present pilot study aimed to simultaneously mitigate all three risk factors by applying Pavlovian conditioning to change the nature of comfort eating. Specifically, stressed participants underwent a Pavlovian conditioning intervention designed to elicit comforting effects of fruit intake and thereby reduce negative mood while promoting fruit intake.

Methods: We developed a seven-dose Pavlovian conditioning intervention wherein participants temporally paired together Progressive Muscle Relaxation (unconditioned stimulus) with fruit intake (conditioned stimulus) daily for 1 week. Participants ($N = 100$, mean [standard deviation] age = 20.7 [4.6] years; 74% female) with moderate to high levels of baseline perceived stress were randomized to the intervention or an active explicitly unpaired control group, wherein the Progressive Muscle Relaxation and fruit intake also occurred but were *not* temporally paired together. After the intervention, participants' negative mood was assessed immediately before and after fruit intake to assess conditioning effects. Then, participants logged their regular food intake for 4 days using the MyFitnessPal smartphone app.

Results: After the intervention, fruit intake acutely improved negative mood to a greater extent among the intervention versus control group ($F(1,98) = 3.99$, $p = .048$, $\eta_p^2 = 0.039$). However, there was not a significant between-group difference in intake of fruit or traditional comfort foods at postintervention.

Conclusions: Repeated pairing of fruit intake with a reliable distress-reducing activity led to the conditioning of comforting effects of fruit intake. Further refinement of the intervention design is necessary to translate this conditioned association to actual intake of fruit and other foods.

Key words: comfort eating, distress, fruit intake, conditioning, Pavlovian conditioning, intervention.

INTRODUCTION

Perceived stress is pervasive across the globe. For example, in a 2018 Gallup survey conducted in 142 countries, 35% of adults reported that they experienced a lot of stress the day before the survey (1). This has critical consequences for public health. Frequent stressor-induced activation of physiological allostatic systems or failure to shut off allostatic activity after stressors can lead to greater morbidity (2) and mortality from a variety of diseases (3).

Poor diet represents another widespread threat to public health. Only 12% of adults in the United States consume the recommended daily intake of fruits (4), and low fruit intake is a modifiable risk factor for chronic diseases such as type 2 diabetes (5), cardiovascular disease (6), and certain cancers (7). Furthermore, many adults respond to stressors by "comfort eating" foods that are traditionally high in calories, fat, sugar, and/or salt (8), with approximately 39% of US adults overeating or eating unhealthy foods because of stress (9). Comfort eating is also a risk factor for chronic conditions such as type 2 diabetes (10).

Innovative methods targeting traditional comfort eating, fruit intake, and perceived stress are therefore sorely needed to reduce morbidity and mortality (3,6,7,10,11). The present pilot intervention thus simultaneously addressed all three risk factors, with the aim of promoting mood-improving effects of fruit intake. We hypothesized that promoting relaxing effects of fruit intake might improve mood while encouraging stressed individuals to shift their comfort eating to exclude traditional comfort foods (e.g., chips, ice cream) and include fruit. Fruits make plausible comfort foods because they naturally contain sugar, and sweet taste activates neurotransmitter systems at limbic system sites capable of increasing pleasure (12).

This intervention is the first of its kind to apply long-standing Pavlovian conditioning principles (13) to the context of comfort eating. Pavlovian conditioning—also known as classical conditioning—has been conceptualized as a process in which an organism learns an association between an initially neutral stimulus (i.e., a conditioned stimulus) and a stimulus that elicits a reflexive response before the learning (i.e., an unconditioned stimulus). After these two stimuli have been repeatedly paired together, presentation of the formerly neutral stimulus alone will elicit a reflexive response (i.e., a conditioned response). In the present intervention, we hypothesized that after repeatedly pairing together fruit intake (the conditioned stimulus) with a reliable distress-reducing activity (Progressive

CR = conditioned response, **CS** = conditioned stimulus, **PMR** = Progressive Muscle Relaxation, **PSS** = Perceived Stress Scale, **US** = unconditioned stimulus

From the Academic Research Centers (Finch), NORC at the University of Chicago, Chicago, Illinois; Social and Behavioral Sciences Branch, Division of Intramural Population Health Research (Cummings), Eunice Kennedy Shriver National Institute of Child Health and Human Development, Rockville, Maryland; and Department of Psychology (Lee, Tomiyama), University of California, Los Angeles, Los Angeles, California.

Address correspondence to Laura E. Finch, PhD, NORC at the University of Chicago, 1155 E 60th St, Chicago, IL 60637. E-mail: finch-laura@norc.org

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Muscle Relaxation [PMR]—the unconditioned stimulus), that fruit intake alone would elicit psychological distress relief (the conditioned response). Thus, we aimed to condition participants with moderate to high levels of baseline perceived stress to experience fruit intake as mood improving. As a result of these comforting effects of fruit intake, we hypothesized that participants would show greater intake of fruits and lower intake of their favorite traditional comfort foods at postintervention, compared with a stringent, criterion-standard control group.

METHODS

Design

We designed a 7-day intervention in which participants were randomly assigned to either a) the intervention group, wherein fruit intake (the conditioned stimulus) was repeatedly temporally paired with relaxation (the unconditioned stimulus) using PMR, a well-validated method for inducing relaxation, or b) the control group, wherein participants still ate fruit and engaged in PMR, but the two were explicitly *un*paired and never overlapped temporally.

The frequency of one trial per day was selected for several reasons. First, some of the fruits provided are typically kept chilled and sliced (e.g., pineapples, honeydew) and are thus not as easily transported as others (e.g., bananas). Whereas a frequency of once per day would easily allow participants to consume their fruit at a time when they are at home (e.g., at the start or end of their day), an increased frequency might require them to transport the fruit to their classrooms as a midday snack, potentially decreasing the fruit's palatability and freshness. Second, participants were asked to fast for the 3 hours before their fruit consumption to facilitate the conditioning process. Multiple daily trails would have increased the required daily fasting significantly, placing undue burden on the participants.

A total of 7 days of trials was selected because with an increasing number of trials, the strength of conditioned responding is known to steadily increase to an asymptotic value (14). Although single-trial learning is sometimes effective in fear-conditioning paradigms (15), it is rarely achieved in other forms of conditioning such as salivary conditioning (13).

Participants

Participants were 100 healthy undergraduate men and women. This sample size provides a power of 0.80 to detect a within-between interaction for two repeated measures of negative mood and two conditions, even if the interaction effect size is small ($\eta_p^2 = 0.02$) and there is a moderate correlation ($r = 0.5$) among repeated measures.

Procedures

Recruitment and Prescreening

The University of California, Los Angeles Office of the Human Research Protection Program Institutional Review Board approved all study activities. The period of data collection ranged from October 2016 to February 2018. Participants were recruited via the psychology department subject pool and fliers distributed throughout the University campus. In online prescreening, individuals provided their demographics, dieting status, perceived stress, and traditional comfort food preferences. Participants also completed a Food Dimensions Survey, adapted from a food evaluation survey used in a prior conditioning study (16). In this survey, participants rated up to 20 fruits available at nearby grocery stores. Participants rated each fruit that they had ever tasted before on several dimensions: familiarity, pleasantness, and the likelihood of buying the fruit in the future (16). The food selected for conditioning for each participant was one that was rated as relatively neutral on the dimension of pleasantness (i.e., score of 40–75 and closest to 50). If this applied to multiple fruits, the fruit also rated as the most novel (i.e., lower on familiarity) was chosen. This is because it is well established that conditioned responding develops faster when the conditioned stimulus is novel and/or neutral in valence (17,18). The selected fruits provided included the following: pomegranate ($n = 16$); apples and bananas ($n = 11$ each); blueberries, honeydew, pears, and pineapples ($n = 9$ each); oranges ($n = 7$); grapes ($n = 6$); clementines ($n = 4$); apricots ($n = 3$); strawberries ($n = 3$); mangos ($n = 2$); and kiwis ($n = 1$).

Lastly, the online prescreening included a run-in task (19) of one 6-minute PMR activity to be used in future conditioning trials. To assess attentional adherence, after the PMR, participants completed a multiple-choice question, "Which of these phrases was included in the recording that you just listened to?" with one correct and four incorrect responses. In addition, participants rated how much they liked the PMR activity (1 = *disliked a lot* to 6 = *liked a lot*). To increase acceptability, only those who reported some liking (i.e., a score of 4 or higher) were eligible (20).

Additional inclusion and exclusion criteria were based on ability to carry out study activities. Further inclusion criteria included the following: a) age 18 years or older, b) fluent in English, c) access to a smartphone with Internet access and a camera, d) rated a fruit in season as relatively neutral, and e) showed a moderate to high level of baseline perceived stress on the 10-item Perceived Stress Scale (PSS) (21): 13 or higher for women and 10 or higher for men. These cutoffs were determined using prior research in college students (22), which found that women and men of moderate stress exhibit mean PSS-10 scores of 18.17 (standard deviation [SD] = 6.13) and 15.83 (SD = 6.53), respectively. We established the lower threshold for moderate stress for each sex to be 1 SD below these mean scores, rounded up to the nearest whole number. Only individuals with moderate to high baseline stress levels were recruited, so that they would already have some level of stress to be reduced (23). Exclusion criteria included the following: a) responding incorrectly to the prescreening PMR attentional adherence item, b) current strict dieting, c) history of substance abuse or eating disorder, d) current diagnosis of a psychiatric condition (e.g., depression, anxiety disorder, bipolar disorder), and e) current major illness or injury.

Progressive Muscle Relaxation

To reliably induce distress reduction for the conditioning trails, we selected PMR as the unconditioned stimulus. Brief PMR activities are known to decrease perceived stress (24). Nonetheless, we collected preliminary data in an initial, separate group of 27 participants (7 men) to confirm that a 6-minute PMR recording would reduce psychophysiological stress in our target population. Participants had their heart rate monitored and reported the extent to which they felt four emotions both immediately pre- and post-PMR. Post-PMR, participants reported decreased tenseness and stress, as well as increased relaxation and calmness (all p values < .026). Their heart rates also decreased from pre-PMR (M [SD] = 76.15 [15.87]) to the fifth minute of the PMR (M [SD] = 74.67 [15.68]; $t(26) = 2.09$, $p = .047$). We then created a distinct PMR recording for each day of the intervention. Each 6-minute recording included tensing of the same four body parts (i.e., left and right fists and thighs), and the order of muscle tensing was counterbalanced. Furthermore, four different tones each occurred one time in two recordings, either as a cue to begin eating (intervention) or as a control tone.

Paired Trails

Once per day on 7 consecutive days, intervention participants completed a paired trial. As outlined in Figure 1, two trials were administered at least partially in the laboratory, whereas the remaining five field trials were administered entirely outside of the laboratory. To ensure freshness of study fruit, at the first laboratory visit, participants were given a fruit kit containing two servings of their assigned fruit for their next two field trials. At the second laboratory visit, they received another fruit kit containing three servings of their assigned fruit for their remaining field trials. Figure 2 outlines the order of events making up each paired trial.

Laboratory trials took place in a private room with dimmed lighting. A serving of each participant's assigned fruit was set aside within reach before starting the trial. Participants began by engaging in the PMR activity without eating. During minute 5 of the PMR, a tone cued participants to begin

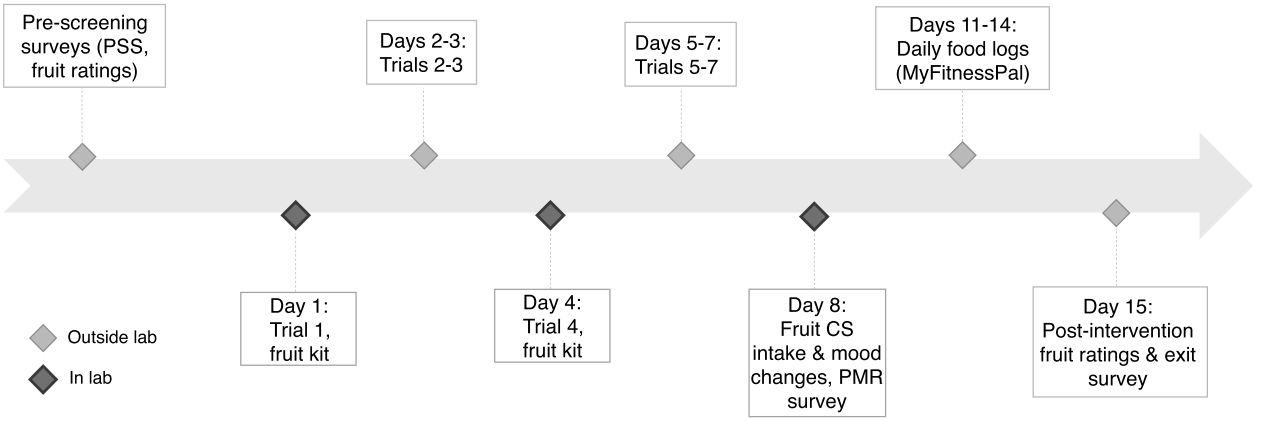

FIGURE 1. Location and outline of study activities by day. According to randomization, participant trials were either paired or unpaired. PSS = Perceived Stress Scale; CS = conditioned stimulus; PMR = Progressive Muscle Relaxation.

consuming their fruit. For the first minutes that participants were eating, they continued to listen to the PMR recording. During the last minute of the PMR, the audio content shifted to focus on guided imagery without any muscle tensing.

For paired trials in the field, the aforementioned protocol was altered in a few ways. Participants used Qualtrics to complete their trials online and were asked to vary the location (e.g., in a dorm room, at a dining hall) and time (e.g., morning, evening) of these trials. It is important to vary the context of the trials so that participants do not learn that the conditioned stimulus–unconditioned stimulus association only applies to a single context (25). Participants were asked to complete the activities any time from waking to bedtime, and to only eat the fruit while completing paired trials —not during their regular eating. Participants were also encouraged to complete trials when feeling stressed.

Unpaired Trials

To determine whether an observed conditioned response is uniquely due to temporal conditioned stimulus–unconditioned stimulus pairing, researchers must choose an appropriate control group. We opted for the criterion-standard *explicitly unpaired control*, wherein control participants receive the same number of conditioned stimulus and unconditioned stimulus presentations as the intervention group, except the two stimuli never occur in close temporal proximity (26). Therefore, for their 7 days of unpaired trails, control participants were assigned to consume their fruit earlier in the day (i.e., after waking and before 1:30 PM) and to engage in the PMR activity in the evening (i.e., after 5 PM and before going to bed). On trial days with a laboratory visit, participants consumed their conditioned stimulus fruit in the laboratory before 1:30 PM and engaged in the PMR (unconditioned stimulus) outside of the laboratory after 5 PM.

Adherence

PMR adherence was monitored via Qualtrics. Participants also submitted before and after photographs of the fruit (e.g., a whole fruit versus a fruit core), which were used to check adherence to fruit intake. Participants were told to take screenshots of their photographs to confirm the date and time of the photographs. Paired trials were considered on time if they were completed before 4:00 AM of the following day. For trials taking place entirely in the field, we considered a trial to have full adherence if the online PMR and photographs were fulfilled on time. For the other trials, we considered a trial to be fully adhered to if the laboratory visit was completed (and if the PMR was completed later that day for the control group). To ensure that a substantial dose of the treatment was received, participants who did not fully adhere to at least 5 of 7 (~71%) of their trials were dropped from the study and were not scheduled for the final visit.

Laboratory Visits

Participants were asked not to eat during the 3 hours before all laboratory visits and field trials to increase the salience of their fruit conditioned stimulus (18,27). Following an existing hunger adherence procedure (16), participants produced a saliva sample at the start of each laboratory visit or field trial and were told that this was to confirm fasting. However, these saliva samples were not analyzed and were solely used to encourage fasting adherence.

Visit 1 (Day 1)

All participants provided written informed consent. Intervention participants completed their first paired trial, whereas control participants completed fruit consumption. Participants received written and verbal instructions for conducting the field trials.

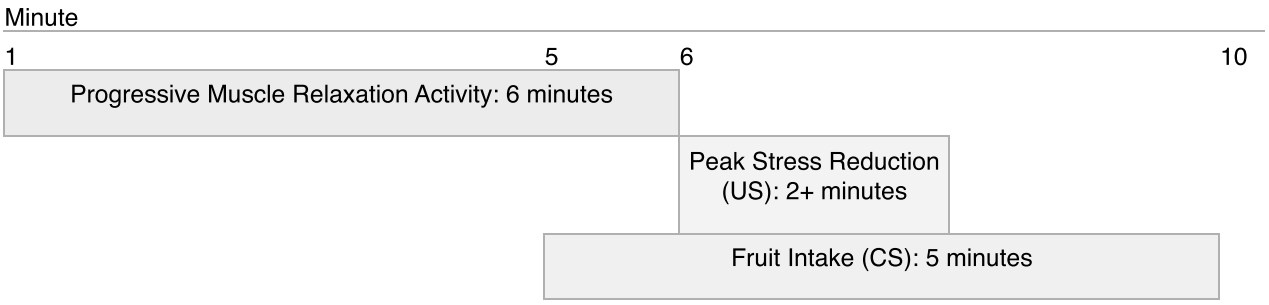

FIGURE 2. Order of events of each paired trial. US = unconditioned stimulus; CS = conditioned stimulus.

Visit 2 (Day 4)

The experimenter asked participants how they were doing with the activities outside of the laboratory and clarified trial information to assist with adherence. Intervention participants completed a paired trial and control participants completed fruit consumption.

Visit 3 (Day 8)

Participants completed a baseline mood questionnaire (28) and were then given two servings of their idiosyncratic fruit conditioned stimulus and asked to consume at least one serving. After 5 minutes, the fruit was removed and participants completed the mood questionnaire a second time, followed by a PMR acceptability questionnaire. Next, the experimenter explained how to estimate serving sizes and complete food logs outside of the laboratory via the free smartphone app MyFitnessPal. The experimenter answered any questions about the food logging and then measured participants' height and weight.

Food Logs

On 4 consecutive days (days 11–14: always a Friday-Monday to capture weekday/weekend variability), participants used MyFitnessPal to record their food and beverage intake. The experimenter removed default settings about weight loss and monitoring, as well as social media sharing/community features. Participants were instructed to not track exercise or weight. For each log day, participants received an email reminder.

Postintervention Questionnaires

On day 15, participants completed postintervention assessments for the Food Opinions Survey and Food Dimensions Survey. Debriefing information was provided online, and participants were compensated with either course research credit or $50.

Measures

Descriptive Information

Participants self-reported their age, sex, race/ethnicity, and family income while growing up. The PSS-10 was modified to measure perceived stress in the past 7 days (21). Weight and height were measured by study staff in the laboratory and used to compute body mass index.

Primary Outcomes

Negative Mood

The Positive and Negative Affect Schedule (28) captured acute change in negative mood. In addition to the original scale items, the survey also included the items "sad," "stressed," and "tense" in the negative affect subscale (29,30). Items were summed to create a total score, such that higher scores indicate greater negative mood.

Fruit Intake

All food logs were reviewed by two coders to quantify each dietary outcome. Three participants were excluded from food log analysis: one who consumed fewer than 600 average daily calories (31), one who missed one full log day, and one who added only calorie information for 1 day without identifying the items consumed.

To calculate consumption of fruits in the standardized unit of cups, the online dietary tool Super Tracker was used (www.supertracker.usda.gov). Provided by the US Department of Agriculture, this tool is informed by the federal government's national dietary guidelines (www.ChooseMyPlate.gov). In general, one cup of fruit was considered one serving of fruit. Total conditioned stimulus fruit intake was calculated by summing across the 4 days.

Traditional Comfort Food Intake

To capture traditional comfort food preferences at prescreening, an item from the modified Food Opinions Survey (30) asked, "What foods would make you feel better if you were stressed? Please list your top three choices." This item was embedded among distractor questions such as, "What foods would you want if you were on-the-go?" All items for this survey were in free-response format.

We calculated the number of times participants consumed one of their top three idiosyncratic traditional comfort foods from prescreening in their food log data. If multiple types of the same comfort food were consumed as a part of the same meal or snack (e.g., two different cookies in one snack), they were counted jointly as one instance. Instances of eating one's favorite traditional comfort foods were summed across the 4 days.

Exploratory Outcomes

Fruit Dimension Ratings

Participants rated 20 fruits on the dimensions of familiar and pleasant from 0 (*not at all*) to 100 (*extremely*) using a visual analog scale (16). A third dimension (32) assessed the likelihood of purchasing the fruit in the future. We examined pleasantness and the likelihood to buy ratings specific to each participant's conditioned stimulus fruit.

Acceptability

We created a seven-item survey to assess perceptions of PMR acceptability (day 8). Sample item: "This activity was easy to incorporate in my daily routine," from 1 (*not true at all*) to 6 (*extremely true*). In an exit survey

TABLE 1. Sample Demographics

Characteristic	*n*	M (SD) or %	Min-Max
Age, y	100	20.65 (4.63)	18–50
Race/ethnicity	100		
Asian, Asian American, Pacific Islander	43	43	
White/Anglo or European American	24	24	
Hispanic/Latino(a)	18	18	
Biracial	6	6	
Arabic/Middle Eastern	4	4	
Black/African American, Caribbean	4	4	
Other	1	1	
Family income	100		
<$10,999	2	2	
$10,000–$19,999	3	3	
$20,000–$29,999	7	7	
$30,000–$39,999	7	7	
$40,000–$49,999	7	7	
$50,000–$59,999	9	9	
$60,000–$69,999	6	6	
$70,000–$79,999	6	6	
$80,000–$89,999 (median)	6	6	
$90,000–$99,999	9	9	
$100,000–$124,999	15	15	
$125,000–$149,999	7	7	
>$150,000	16	16	
Perceived stress	100	20.32 (4.97)	11–34
Body mass index, kg/m^2	100	23.81 (3.66)	17.20–39.02
Average daily calorie intake (Days 11–14)	97	1782 (561)	709–3826

M (SD) = mean (standard deviation); Min-Max = minimum-maximum.

(day 15), participants were also asked via free response what they liked and disliked about the study and what they would change about it, if anything.

Statistical Analysis

Some primary outcomes were significantly skewed and were therefore transformed in the appropriate direction: negative mood was log transformed, and all food log/intake outcomes were square root transformed. Between-subject analysis of variance tested for effects of condition on each food log outcome. Repeated-measures analyses of variance tested for effects of condition on outcomes collected at two time points: negative mood and conditioned stimulus fruit pleasantness and likelihood to buy. Statistical significance for all analyses was set at $p < .05$.

RESULTS

Adherence and Acceptability

Table 1 presents descriptive statistics for the 100 analyzed participants (74 female). Figure 3 displays a CONSORT (Consolidated Standards of Reporting Trials) flow diagram (33) for the study, including details about participant enrollment, allocation, follow-up, and analysis. Adherence to the trials was high, with 100 of the 116 participants who started the study (86.21%) fully adhering to five or more of their trials. On average, the intervention group fully adhered to a greater number of trials (M [SD] = 6.54 [0.68]; median = 7; mode = 7) than the control group (M [SD] = 5.76 [0.77]; median = 6; mode = 5; $F(1,98) = 28.92$, $p < .001$). The voluntary participant dropout rate was extremely low in both conditions (3.4% of the 116 total enrolled participants).

Table 2 displays PMR acceptability data. Overall, participants reported that they completed the PMR activity the number of times that they were instructed to. On average, participants reported that they enjoyed engaging in the PMR activity and that it made them feel relaxed. In addition, participants did not feel that the PMR took too much time out of their day, and they found the PMR to be easy to incorporate into their daily routine. Participants also

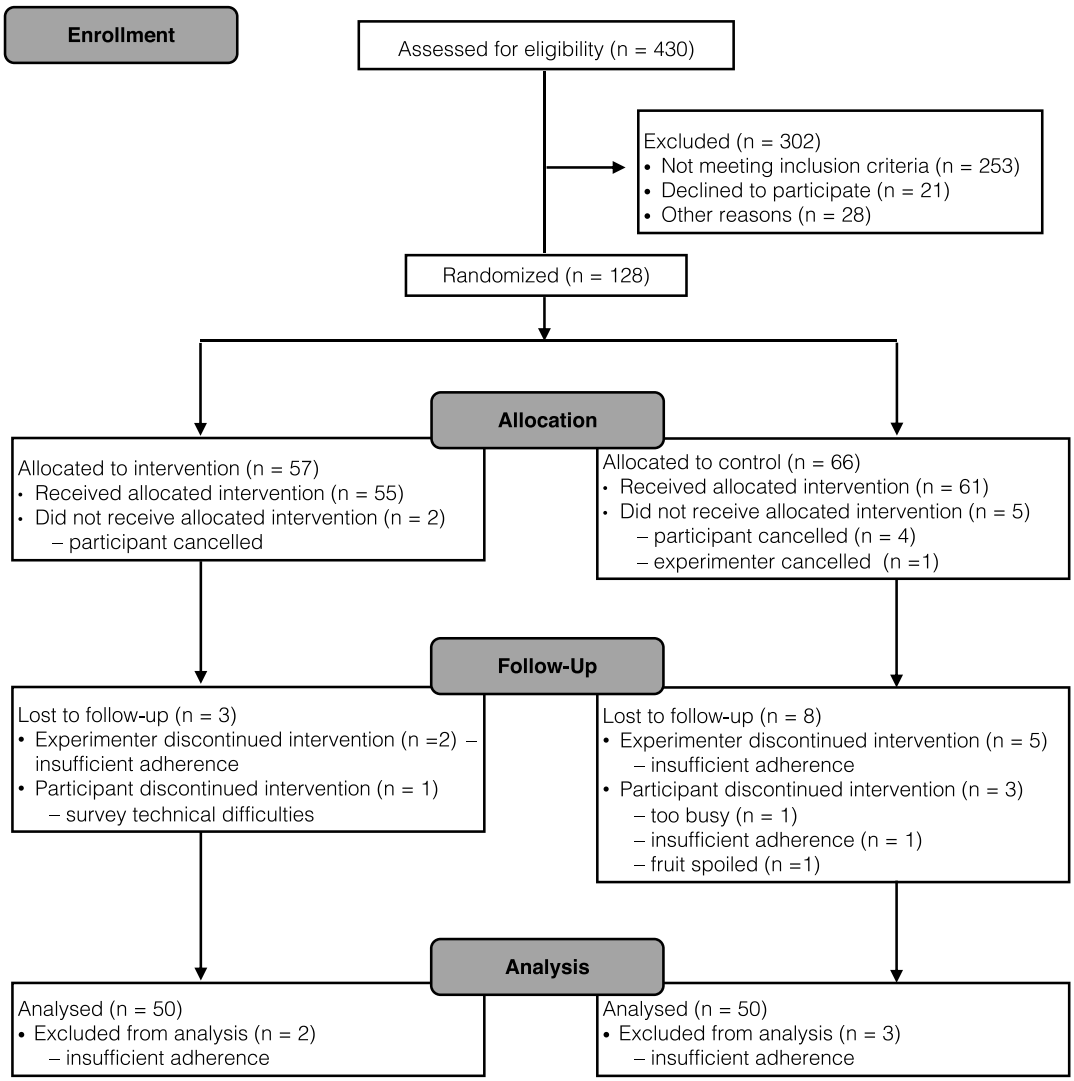

FIGURE 3. CONSORT flow diagram including details about enrollment, allocation, follow-up, and analysis. A total of five individuals were eligible for the study and scheduled for laboratory visits, but elected to cancel their participation before their first visit. Information is not available regarding which condition these five individuals had been initially randomized to, and therefore, they are excluded from the allocation boxes.

TABLE 2. Progressive Muscle Relaxation Acceptability

Item	Entire Sample, M (SD)	Intervention Group, M (SD)	Control Group, M (SD)	Test, *p*
"I enjoyed engaging in this activity"	4.11 (1.15)	3.92 (1.09)	4.30 (1.18)	.097
"I would recommend this activity to others"	4.11 (1.41)	3.84 (1.30)	4.38 (1.48)	.056
"This activity took too much time out of my day"	1.63 (0.81)	1.74 (0.85)	1.52 (0.76)	.160[a]
"This activity was easy to incorporate in my daily routine"	4.06 (1.36)	4.00 (1.25)	4.12 (1.48)	.662
"This activity made me feel relaxed"	4.42 (1.22)	4.04 (1.05)	4.80 (1.26)	.001
"I would use this activity as a stress reduction technique in the future"	4.00 (1.52)	3.62 (1.43)	4.38 (1.52)	.012
"I completed this activity the number of times that I was instructed to"	5.75 (0.74)	5.88 (0.52)	5.62 (0.91)	.056[b]

M (SD) = mean (standard deviation).

Items were rated on a scale from 1 (*not true at all*) to 6 (*extremely true*).

[a] To correct for significant positive skew, values were log transformed before testing.

[b] To correct for significant negative skew, values were squared before testing.

reported that they would use the activity as a stress reduction technique in the future and that they would recommend it to others. In some instances, the control group rated the PMR significantly more favorably than the intervention group.

Some participants did not report enjoying the PMR or their conditioned stimulus fruit. In the exit survey, 14 participants reported via free response that they either did not enjoy the PMR or felt that it was too repetitive. In addition, 22 participants reported that they did not like their assigned fruit, that it did not taste good or went bad over time, that they got tired of eating it repeatedly, or that they believed that the study could be improved by allowing participants to choose their own fruit because there may be another one that they may like better. Finally, 10 participants reported that they did not enjoy fasting for 3 hours before fruit intake.

Negative Mood

Figure 4 presents negative mood before and after fruit intake by condition. Overall, negative mood significantly decreased from pre– to post–fruit intake ($F(1,98) = 125.31$, $p < .001$, $\eta_p^2 = 0.561$). This effect differed by condition; fruit intake improved negative mood to a greater extent among the intervention (from M [SD] = 21.24 [6.56] to M [SD] = 17.22 [5.57]) versus control group (from M [SD] = 19.34 [4.72] to M [SD] = 16.64 [3.82]; $F(1,98) = 3.99$, $p = .048$, $\eta_p^2 = 0.039$. In addition, when the 41 participants who expressed dissatisfaction regarding the PMR ($n = 14$), fruit ($n = 22$), or fasting ($n = 10$) were removed in a post hoc analysis, fruit intake reduced negative mood to an even greater extent among the intervention group (from M [SD] = 20.63 [5.41] to M [SD] = 16.13 [3.19]) than the control group (from M [SD] = 18.51 [4.20] to M [SD] = 16.34 [3.74]; $F(1,57) = 7.80$, $p = .007$, $\eta_p^2 = 0.120$).

Fruit and Traditional Comfort Food Intake

Total conditioned stimulus fruit intake was similar between the intervention (M [SD] = 0.14 [0.33]) and control (M [SD] = 0.18 [0.48]) groups ($F(1,95) = 0.15$, $p = .70$). Instances of eating traditional comfort foods were also similar between the intervention (M [SD] = 2.23 [3.04]) and control (M [SD] = 2.45 [3.14]) groups ($F(1,95) = 0.22$, $p = .64$).

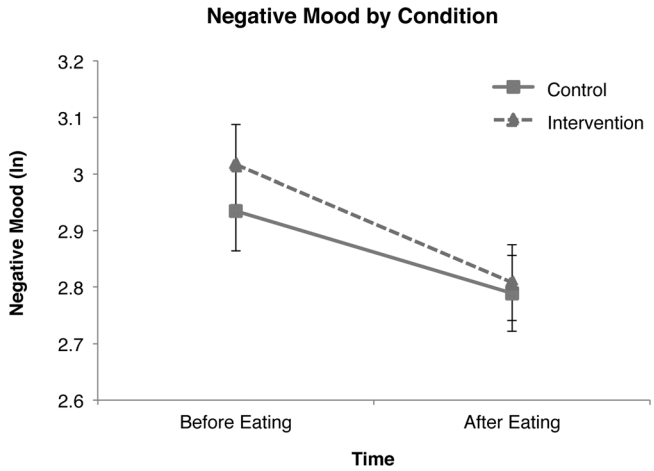

FIGURE 4. Log-transformed negative mood immediately before and after eating fruit by condition on day 8. Error bars represent 95% confidence intervals.

Fruit Dimension Ratings

Overall, participants rated their respective conditioned stimulus fruit as more pleasant at postintervention (M [SD] = 67.18 [22.35]) compared with baseline (M [SD] = 57.05 [10.82]; $F(1,98) = 19.33$, $p < .001$, $\eta_p^2 = 0.165$). This effect did not differ by condition ($F(1,98) = 0.05$, $p = .83$). Overall, participants reported a greater likelihood to buy their respective fruit at postintervention (M [SD] = 65.91 [29.49]) compared with baseline (M [SD] = 52.87 [29.99]; $F(1,98) = 19.36$, $p < .001$, $\eta_p^2 = 0.165$). This effect did not differ by condition ($F(1,98) = 1.33$, $p = .25$).

DISCUSSION

Three major risk factors for chronic disease are perceived stress, low fruit intake, and comfort eating (3,5,10). Existing interventions have addressed these risk factors separately (34,35). In the present pilot study, we developed and evaluated a novel intervention to instead address these risk factors simultaneously by conditioning participants to experience fruit intake as mood improving. Specifically, we developed a seven-dose Pavlovian conditioning intervention wherein participants temporally pair together PMR with fruit intake daily for 1 week. In our hypothesized pathway, we expected that the Pavlovian conditioning would cause participants to experience an acute reduction in negative mood when consuming fruit at postintervention. As a result of this newly formed fruit-mood conditioned response, we expected that participants would consume more fruit and less of their favorite traditional comfort foods high in calories, fat, sugar, and/or salt.

Indeed, results from this pilot intervention indicated that the Pavlovian conditioning trials increased the capacity of fruit intake to acutely repair negative mood, compared with a stringent control group that also ate fruit and engaged in relaxation at separate times. These results are similar to those of prior studies wherein Pavlovian conditioning has increased preference for neutral and novel foods, as well as for vegetables (36–39). Moreover, these results are promising because several naturalistic and laboratory studies document that negative mood shifts dietary choices away from fruits and toward traditional comfort foods that are high in calories, fat, sugar, and/or salt (for a review, see Ref. (23)). This may be because people believe that eating these types of comfort foods will acutely reduce negative mood, despite little evidence to support this belief (29,30). Experiencing acute reductions in negative mood after fruit intake may therefore encourage individuals to eat fruits in place of traditional comfort foods, and offer a novel and accessible strategy for individuals to mitigate negative mood states. In a global society where many people respond to stressors with behaviors that can be harmful for physical health (e.g., drinking alcohol, smoking, or eating foods high in processed carbohydrates (40,41), it is critical that alternative coping mechanisms such as fruit intake (11) and physical activity (42) that confer benefits for both mental well-being and physical health are available.

Although the present results support fruit intake as a mood-improving technique, findings did not reveal significant group differences in eating behavior at postintervention. The intervention and control groups were similar in intake of their favorite traditional comfort foods and of the specific fruit that they repeatedly consumed during the study. One possible explanation for this may be the rigor of the control group. This study incorporated a criterion-standard explicitly unpaired control group, with control participants receiving the same number of doses of PMR and fruit intake as the intervention group, but in a temporally unpaired fashion. Given that repeated exposure alone is sufficient to increase liking of foods such as vegetables (39), had the study instead incorporated a no-treatment control group, the intervention may have shown greater efficacy.

Further refinement of the intervention arm design may also be needed to impact food choice; for example, future work could test whether a greater number of doses/pairings may be effective in influencing food intake. Although participants paired fruit intake with relaxation seven times, in their lifetimes they may have eaten traditional comfort foods when psychologically distressed many more times. It may also be beneficial to have traditional comfort foods available (but not selected) during the trials to mimic the pervasive toxic food environment in the United States (43). Lastly, although the Pavlovian conditioning caused participants to associate fruit intake with acute improvement in mood, the conditioning trials did not necessitate that participants practice this mood-improving technique in response to an acute stressor. Participants were encouraged—but not required—to complete their trials outside of the laboratory at times when they were feeling particularly stressed that day. Thus, future intervention refinements might induce negative mood before each trial, ensuring that individuals grow accustomed to eating fruit in response to negative emotions.

In terms of dropouts and adherence, the intervention fared well. The voluntary participant dropout rate was extremely low (3.4% of all enrolled participants), and the intervention group had fewer dropouts than the control group. Furthermore, trial adherence was high; 86.21% of all enrolled participants fully adhered to five or more trials, and those in the intervention group most often completed all seven trials.

Nonetheless, results should be interpreted in light of study limitations. Fruit and traditional comfort food intake were measured through MyFitnessPal. Although MyFitnessPal food logs demonstrate moderate consistency with written self-reports of dietary intake, participants tend to report more difficulty with logging their food intake and estimating portion sizes when using MyFitnessPal versus paper-based methods (44). Future work might improve upon the measurement of food intake by using more objective measures that also eliminate the cognitive burden placed on participants to estimate portion sizes, such as the Remote Food Photography Method (45). The sample size for the study was also determined based on power analysis specific to assessing the repeated measures nature of negative mood; thus, the sample may have been underpowered to detect differences in food intake. Future work might consider using repeated measures of food intake before and after an intervention. Also, although the sample included those who showed a moderate to high level of baseline perceived stress, it comprised generally healthy young adults who did not self-report any current diagnosed psychiatric conditions (e.g., mood disorders) or major physical health conditions, limiting generalizability. Finally, the presentation of the fruit stimulus was timed specifically to coincide with the point of maximal relaxation (5 minutes into the PMR activity) that we identified in our pilot study. Thus, it is ambiguous whether this protocol followed forward conditioning procedures or the less common backward conditioning. In backward conditioning, the unconditioned stimulus is presented shortly before the conditioned stimulus; in forward conditioning, the reverse order occurs. Forward conditioning procedures

tend to produce stronger conditioned response effects; nonetheless, other variations of Pavlovian conditioning such as backward conditioning have indeed been found to produce conditioned responding (25). Future research could optimize this intervention by shifting the timing of the unconditioned stimulus to determine the exact timing of fruit presentation that maximizes efficacy.

In sum, we conducted a Pavlovian conditioning intervention with the aims of fostering mood-improving effects of fruit intake and thereby encouraging the comfort eating of fruits rather than traditional high-calorie/fat/sugar/salt comfort foods. The intervention improved the comforting effects of fruit intake relative to the rigorous control group and thus represents a promising strategy for negative mood improvement. However, refinements to the nature or quantity of the intervention components may be necessary to impact the food choices of those with baseline perceived stress and reduce their risk of related poor health outcomes.

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