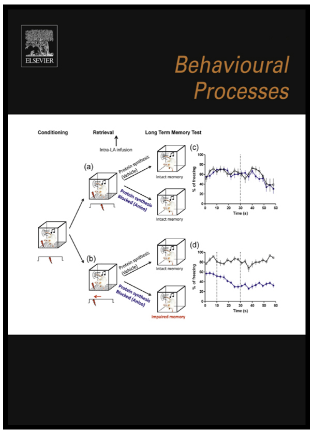

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Denise A. Passarelli, Micah Amd, Marlon A. de Oliveira, Julio Cesar de Rose

PII: S0376-6357(21)00225-4

DOI: https://doi.org/10.1016/j.beproc.2021.104541

Reference: BEPROC104541

To appear in: *Behavioural Processes*

Received date: 22 February 2021
Revised date: 22 October 2021
Accepted date: 8 November 2021

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Denise A. Passarelli, *MS*[1]

Micah Amd, *PhD*[2]

Marlon A. de Oliveira, *MS*[1]

Julio Cesar de Rose, *PhD*[1]

1 – Federal University of Sao Carlos, Brazil

2- University of the South Pacific, Fiji

Author's Note:

The work reported here is part of DP's Master's dissertation under the supervision of MA and JCR. The work reported here was funded in part by Grant 2019/01406-7 to DP from the Sao Paulo Research Foundation (FAPESP) and in part by Grant 465686/2014-1 from the National Research Council (CNPq) and Grant 2014/50909-8 to Instituto Nacional de Ciência e Tecnologia sobre Comportamento, Cognição e Ensino (INCT-ECCE). The reported work was designed by DP and MA. All data were collected by DP and MAO, under supervision of JCR and MA. All data were analyzed by MA and DP. The manuscript was prepared by MA, DP and JCR. DP and MAO assisted with final edits. We thank Táhcita Mizael, Mariana Brandao Zanelli and Julio Camargo for helpful comments across earlier drafts of the present work. All works reported here were approved by the local university ethics board and correspond with the guidelines in the Declaration of Helsinki. The authors have no conflict of interest to declare. All correspondence regarding the current work can be forwarded to DP at denise.ger012@gmail.com

Abstract

Correlating eating-related words (CS) with positively valenced words (US+) may augment eating-associated motivational responses (e.g., preingestive salivation) with minimal CS knowledge. We tested this claim using a subliminal conditioning procedure, where CS and US were presented under subliminal and supraliminal visual conditions. Three groups of Brazilian undergraduates (*N* = 69) viewed eating-related words (CS) or their scrambled counterparts (non-CS) followed by positive (US+) or neutral (US-) words. A free-selection visibility check confirmed that subliminally presented CS and non-CS had not been detected by any group. Participants exposed to CS/US+ pairings produced significantly more saliva relative to participants exposed to CS/US- and non-CS/US+ pairings. Reliable induction of salivation, coupled with null outcomes across evaluation measures, suggests that affective information related to *eating* can subliminally augment preingestive salivation with minimal deliberation.

*Key-words***:** subliminal conditioning; valence; appetite; motivation; deliberation.

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Behavioral responses to food-related information can be suppressed by deliberate processes, to the extent of endangering one's life (e.g., Başoğlu et al., 2006). Top-down suppression of appetite can be influenced by the conscious appraisal of eating-related information – for instance, receiving the message *eating is good for your health* may end up eliciting negative narratives, such as *eating will make me fat,* following appraisal of the term *eating*. In other words, the provision of EATING/POSITIVE information may counteractively generate EATING/NEGATIVE narratives across individuals with an aversive history towards 'eating' (Murray et al., 2016). If the detection of eating-related words elicits contraindicative narratives, then preventing the former's detection may facilitate acquisition. That is, the acquisition of EATING/POSITIVE information may be facilitated by inhibiting explicit appraisal of symbols/words associated with 'eating'.

A recent report by Amd and Baillet (2019) provided some evidence that EATING/POSITIVE relational information may be selectively acquired and behaviorally expressed without being consciously appraised. In that study, English-speaking participants associated eating-related words (CS) with positive (US+) or neutral (US-) words across a subliminal CS-US conditioning task (Veltkamp et al., 2011). CS appeared for 17 ms and was sandwiched between forward and backward masks, rendering them effectively subliminal. This was followed by a blank screen, then a US for 170 ms. The latter were presented under supraliminal visual conditions since US detection is necessary for registering valence information (Lähteenmäki et al., 2015). CS subliminality was assessed after each conditioning trial using 2-Alternative Forced-Choice (2AFC) tasks, which confirmed that CS had not been identified beyond chance levels.

The goal of Amd and Baillet's study was to investigate whether subliminal CS/US+ relations could reliably influence eating motivation. The latter was assessed using three measures hypothesized to differentially incorporate top-down deliberation. Specifically, that study recorded i) the total amount of saliva produced (presumed to require minimal deliberation), ii) response distributions across 2AFC tasks measuring current hunger (moderate deliberation), and iii) orally reported activity preferences (maximum deliberation) after each conditioning block. It was assumed that automatically salivating in a dark room involved less deliberation relative to selecting *Yes*/*No* following the question *Are you getting hungry?* or orally describing preferences into a microphone following onscreen prompts. Those authors reported a reliable increase in saliva after CS/US+, but not after CS/US-, trials. Parallel effects were observed across 2AFC response distributions - participants selected *Yes* (when asked whether they were 'getting hungry') at significantly higher frequencies after CS/US+ trials. Oral evaluations of hunger were not statistically different following CS/US+ and CS/US- trials (p. 7). Reliable increases in saliva weight following CS/US+ trials, coupled with null differences across oral evaluations, suggested that EATING/POSITIVE (CS/US+) information had augmented eating motivation, seemingly without detection of eating-related words (CS) and/or extensive deliberation.

We say *seemingly* because of two design limitations that seriously challenge Amd and Baillet's (2019) claims. First, those authors reported that CS had been undetected based on chance-level performances across visibility checks. The latter consisted of 2AFCs presented at the end of each conditioning trial, with the previous CS and an unrelated distractor presented as response options. Thus, there was a 50% chance of selecting a CS that had been presented in the previous trial. Since CS could be selected about half the time, it can be argued that participants had opportunities to infer causal links between the US and the visible CS - e.g., a participant may have generated the proposition *positive words and eating words co-occur together*, which would produce evaluative effects without assuming the operation of any subliminal processes (De Houwer, 2018). Indeed, there are some evidences that backward (US>CS) conditioning sequences can be as effective as forward (CS>US) sequences for generating evaluative effects across humans (Hoffman et al., 2010; Kim et al., 2016; also see Green et al., 2021). A second concern of that study was a lack of any independent control conditions – it is unknown whether repeated presentations of a visible US+ may augment saliva production through (say) perceptions of increased US intensity (Feather et al., 1967). Relatedly, because CS was presented for supraliminal durations after each US (during 2AFC tests), CS repetition may have facilitated CS acquisition. If either of the aforementioned limitations hold, the outcomes reported by Amd and Baillet (2019) can be explained without positing subliminally conditioned relations.

The present study corrected for Amd and Baillet's (2019) design limitations while extending on their work in three ways. We adapted those authors' conditioning procedure across three groups of participants. Participants viewed eating-related words (CS) or their scrambled counterparts (non-CS) for 17 milliseconds (ms), followed by positive (US+) or neutral (US-) words for 170 ms. US was presented under supraliminal visual conditions to facilitate valence acquisition (Lähteenmäki et al., 2015). The experimental group viewed CS/US+ trials; the two remaining control groups viewed CS/US- and non-CS/US+ trials respectively, similar to CS-alone and US-alone controls (Rescorla, 1967). We minimized the possibility of backward conditioning effects by presenting a free-selection visibility check after all conditioning trials were completed.

We collected saliva volume and activity evaluations before and after conditioning to respectively assess eating motivation and CS valence. Activities consisted of words related to eating (CS – eating, devouring, chewing, consuming) and distractors (DIS - running, reading, and sleeping). Distractor activities appeared exclusively during evaluation trials to check for familiarity effects (all activity-related words were evaluated before and after conditioning). As scrambled non-CS were semantically and structurally unrelated to distractors, we did not expect distractor evaluations to systematically vary after conditioning. By collecting evaluations before conditioning, we confirmed whether CS were affectively different between groups (which is not always the case, e.g., Silva, 2018).

A third feature of the present work was the inclusion of a performance-based measure of 'stimulus relatedness' called the *Function Acquisition Speed Test – FAST* (O'Reilly et al., 2012). The *FAST* assumes that stimulus relations established in a laboratory context (e.g., positive information about condoms) can predict subsequent attribute-target categorizations (increased fluency of positive-condom categorizations, see Cummins et al., 2018). Functionally, two stimuli are more likely to be categorized together when they are from the same (experimentally established) stimulus class relative to when they are members of different classes (Roche et al., 2012).

The *FAST* procedure includes three trial blocks (one practice, two testing) with minimal instructions (Cartwright et al., 2016). Across testing blocks, participants receive corrective feedback for categorizing stimulus items that are consistent/inconsistent with prior training histories. Response accuracy is regressed along reaction time, with the slope of the corresponding regression equation serving as a proxy of relatedness, with greater magnitude implying higher relatedness (Cummins et al., 2018). *FAST*s have been observed to reliably capture the 'relatedness' between stimulus relations established in a laboratory context (Cummins et al., 2020; O'Reilly et al., 2013), and between attributes associated with socially relevant categories (Cartwright et al., 2016; Gavin et al.,2012). By combining accuracy and latency data into a single metric (a 'slope-score'), the FAST provides an arguably clearer depiction of stimulus relatedness (Cummins & Roche, 2020) relative to the more well-known Implicit Association Test (Greenwald et al., 1998).

The present study tested the null hypotheses that three outcome measures (saliva weights, explicit evaluations, *FAST* slope scores) were not statistically different between our experimental (CS/US+) and control (CS/US-, non-CS/US+) groups, both before and after conditioning. We expected pre-conditioning outcomes would be not statistically different between groups before conditioning. Omnibus effects after conditioning would inform the effectiveness of our conditioning protocol. Null hypothesis significance tests can reliably inform whether mean parameter values vary ordinally between conditions (Lakens, 2021, p. 641). A reliable increase in saliva weight across the experimental group exclusively would replicate Amd and Baillet's (2019) main finding. Observing parallel effects (or not) across evaluation and *FAST* performances would respectively inform whether conditioning manipulations influenced evaluative CS knowledge and CS/US+ relatedness. Performances across free-selection visibility checks would highlight whether any subliminally presented terms had been consciously detected.

Method

Participants

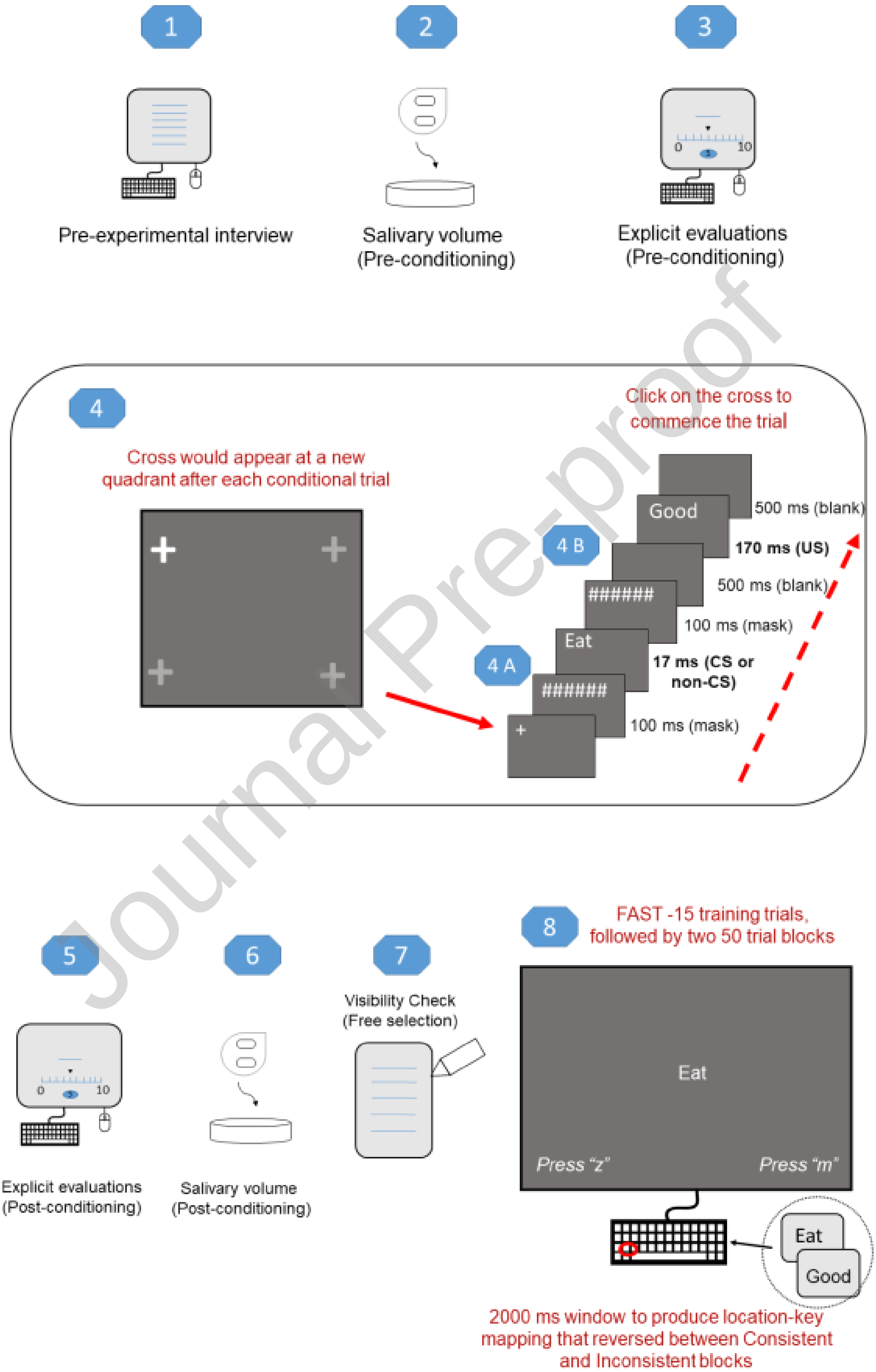
69 undergraduate students (22.5 ± 3.9 years; 42 females) were recruited from the Federal University of São Carlos (UFSCar) through online/personal invitation between January and April, 2019. All volunteers received vegan chocolates and freshly brewed coffee after participation, which took 30 minutes on average. Sensitivity analyses for one-way ANOVAs with alpha error rate set to 5% estimated moderate effects ($\eta_p^2 > .12$) could be detected across 69 participants with 80% power (Faul et al., 2007). Pre-experimental interviews confirmed the absence of any non-communicable chronic diseases, eating disorders, pre-existing psychiatric diagnoses and ongoing drug regimens, prescribed or otherwise. All reported procedures were approved by the regulatory ethics committee at UFSCar and followed the Declaration of Helsinki.

Materials

All procedures took place in a quiet room at the Human Behavior Studies Laboratory (LECH) at UFSCar. All computer tasks were presented on a 23.8” monitor with a 70 Hz refresh rate. Saliva weight was assessed through differences in weights of sterile dental-rolls before and after placement in participants’ mouths (see Procedure). Explicit evaluations of 10 activities were assessed using a 10-point visual analog scale with a slider. Participants were required to select a rating between 1 (*Not at all*) to 10 (*Very much*) in response to the question *How much would you like to* (activity) *right now*? Four activities were related to eating (*comer, devorar, consumir, mastigar*, translated as *eat, devour, consume, chew*) and were designated as CS. Eating-related words were scrambled (*merco, vorarde, mirconsu, tigarmas*) and classified as non-CS. Scrambled words were structurally similar to CS (e.g., presented the same character set) but were semantically meaningless for our Portuguese-speaking sample. Remaining activities (*correr, relaxer, ler, nadar, dormir, descansar*, translated as *run, relax, read, swim, sleep, rest*) never appeared during conditioning trials and have been classified as Distractors (DIS).

Across the *FAST*, four eating-related words and four sleeping-related words (*dormir, descansar, relaxar, cochilar,* translated as *sleep, rest, relax, nap*) were respectively classified as CS and DIS targets. Affective words (US) constituted of four positive (*prazeroso, agradável, bom, feliz,* translated as *pleasurable, agreeable, good, happy*) and four neutral (*elevador, cinza, lápis, janela*, translated as *elevator, gray, pencil, window*) words. US were adopted from the Brazilian affective norm database (Kristensen et al., 2011). Mean ± SD *valences* for positive and neutral US were respectively 9.1 ± .4 and 5.1 ± .4, with normative arousal levels remaining within a single standard deviation across terms. All tasks were designed and implemented on PsychoPy v3.0 (Peirce et al., 2019). Data were organized and analyzed on the open-source *R* platform RStudio (Wickham, 2019) using the packages *ggplot2* (Wickham, 2011), *tidyverse* and *forcats* (Wickham & Wickham, 2017), *rstatix* (Kassambara, 2020), *ggthemes* (Arnold & Arnold, 2015), and *ggpubr* (Kassambara & Kassambara, 2020). All data and scripts are available at https://osf.io/vmep7/

Figure 1. Phases of the present study



Procedure

Volunteers arrived at a pre-determined time and location to participate in the study. Participants were instructed not to eat anything for at least 2 hours before arriving on the day scheduled for the experiment (Karremans et al., 2006). All participants reported adhering to this instruction (Figure 1, Phase 1). Following the collection of informed consent, participants commenced the experimental task.

Pre-conditioning***:*** Saliva weight and Likert evaluations were recorded before and after conditioning. The former involved the experimenter first recording the weight of two sterile dental rolls inside a plastic bag. Next, the participant was asked to place one roll on each side of the mouth, positioned between the gum and the bottom lip (right and left sides). After one minute, participants were asked to remove the rolls and place them in the same plastic bag. This was weighed on a digital scale with .01g resolution within 20 seconds of removal (Figure 1, Phase 2). The difference in roll weights before and after being placed in the participant's mouth indicated saliva produced. New dental rolls and plastic bags were used for each participant. After dental rolls were collected, participants commenced with baseline evaluations (Phase 3). Across 10 trials, participants were asked ‘how much’ they would like to perform various activities. Participants had to move a slider along a 10-point visual analog scale. The slider appeared at the mid-point at the beginning of every trial. The slider had to be interacted with for the trial to progress. Across 4 trials, participants evaluated eating-related words (CS). Across 6 trials, participants evaluated eating-unrelated activities (DIS). Trial presentation sequences were randomized across participants. Completion of evaluation trials commenced the conditioning task.

Conditioning***:*** All participants viewed the following instructions on the screen (translated from Portuguese):

You will see a plus sign (+) *appear along one of four screen quadrants. Please use the mouse and select the* (+). *Next, some words/characters/symbols will appear in the location where the* (+) *sign had appeared. Please attend carefully to the items that appear at this location. If you have no further questions, you may press the spacebar to begin.*

Following a spacebar press, a fixation cross (+) appeared inside one of four screen quadrants randomly (Figure 1, Phase 4). Participants had to click on the quadrant with the cross to continue. Doing so produced a [mask→CS/non-CS→mask] sequence (Figure 1, Phase 4a) followed by a blank interval and a US in the corresponding screen quadrant (Figure 1, 4b). Stimulus presentation sequences were varied between quadrants to facilitate acquisition (Amd et al., 2017; Amd et al., 2018). For the experimental group, eating-related activities were paired with positive US (CS/US+). Across one control group, eating-related words were paired with neutral words (CS/US-). For the second control group, scrambled words were paired with positive words (non-CS/US+). Masks appeared for 100 ms and consisted of the characters '########' in the same white font/grey background as CS and US words. CS appeared between masks for 17 ms. After the second 100 ms mask, a blank screen appeared for 500 ms followed by a US (170 ms). The entire inter-stimulus interval (ISI) was 600 ms[1]. US offsets were followed by another blank screen for 500 ms, followed by the emergence of a fixation cross in a new screen quadrant. Participants were required to click on the fixation cross to commence a new trial. The period after US offset (500 ms) plus any additional time participants required to select the fixation cross (between 200 and 1000 ms on average) functioned as the inter-trial interval (ITI). ITIs varied between 700 ms and 1500 ms across trials and participants.

[1] The decision to incorporate a 600 ms ISI (100 ms mask + 500 ms blank screen) was motivated by investigations on semantic priming, which employ similar ISIs following brief presentations of textual stimuli (Daza et al., 2007; Megias et al., 2020). A 500 ms ISI can also be more effective for establishing conditioned (eye blink) responses relative to shorter (300 ms) ISIs (Kjell et al., 2018).

Post-conditioning***:*** Saliva weight and activity evaluations were recorded again after conditioning. Next, participants received a printed sheet of paper containing a list of 24 words, which contained all CS, non-CS, US+ and US- from previous trials. List item sequences were varied between participants. Participants were asked to freely mark any items they recalled from the previous conditioning task using a pen without any feedback from the experimenter. After returning the marked sheet to the experimenter, participants commenced the *FAST*.

During the *FAST*, eating-related words (CS) and sleeping-related distractors (DIS) were presented as attribution targets, with previously displayed neutral (US-) and positive (US+) functioning as attributes. Participants received instructions that they would view a target near the center of the screen and they should press the 'z' or 'm' key as fast as they can. The *FAST* initiated with 15 practicing trials with stimuli unrelated to the study. This was followed by two 50-trial test blocks. Across any given *FAST* trial, an attribution target appeared near the center of the screen (Figure 1, Phase 8). Participants had 2000 ms window press the keys 'z' or 'm'. Keypress responses were followed by feedback messages ‘correct’ or ‘wrong’ for 1000 ms. If no response was detected within 2000 ms, the trial was recorded as incorrect and the task progressed. Responses scored as correct/incorrect depended on the specific trial block. Across test trials categorized as Consistent, participants viewed the message 'correct' for producing location-congruent keypresses when CS/US+, or DIS/US-, appeared. This mapping was reversed for test trials categorized as Inconsistent, where participants viewed the message 'correct' for producing matching keypresses when CS/US-, or DIS/US+, appeared. Test block sequences were counterbalanced between participants. Completion of the test blocks marked the end of the *FAST* and the experiment.

Results

1. Saliva production

Mean saliva weights with 95% confidence intervals (CI) are illustrated in Figure 2, Panel A. Shapiro tests indicated saliva weights were not normally distributed (p's < .02). Levene's tests indicated variances were statistically homogenous between groups before (p = .455) and after (p = .154) conditioning. Kruskal-Wallis tests respectively estimated whether saliva weights statistically varied between groups before and after conditioning. Eta-squared estimates were based on the rank-sum H statistic generated by the Kruskal-Wallis tests, where $\eta_H^2 = H – k -1/N – k$, with N and k respectively indicating the number of observations and groups (Kassambra, 2020). All reported p-values were false-discovery-rate corrected to reduce false positives and minimize false negatives (Jafari & Ansari-Pour, 2019).

Saliva weights did not statistically vary between groups before conditioning, H (2, 69) = .243, p = .886, η_H^2 = .03. After conditioning, saliva weights varied ordinally, H (2, 69) = 9.68, p = .008, η_H^2 = .17, justifying post hoc tests. Effect sizes were estimated using Cohen's standardized differences (d), which is appropriate across balanced groups with samples larger than 20 (Cohen, 1992). Saliva weights were significantly greater for the experimental group relative to CS/US- (d = .39, p = .014) and non-CS/US+ (d = .40, p = .014) control groups after conditioning. Saliva weights were not statistically different (d = .06, p = .724) across control groups.

2. Explicit evaluations

Mean and CIs across evaluations of eating-related words (CS) and distractors (DIS) are illustrated in Figure 2, Panels B and C. Shapiro tests indicated valences were not normally distributed for CS or DIS (p's < .001). Levene's test confirmed variances were homogenous between groups for CS and DIS (p's > .5). Kruskal-Wallis tests confirmed no statistical difference in the DIS evaluations between groups before (p = .537) and after (p = .789) conditioning. Across CS evaluations, valences varied before conditioning, *H* (2, 276) = 7.78, $p = .021$, $\eta_H^2 = .02$, but not after ($p = .421$). Post hoc tests confirmed CS were evaluated more negatively by the experimental group relative to the CS/US- ($d = .39$, $p = .026$) and non-CS/US+ ($d = .29$, $p = .081$) control groups before any conditioning took place.

3. Implicit relatedness

Blocks of test trials that reinforced CS/US+ and DIS/US- categorizations were classified as Consistent. Blocks that reinforced CS/US- and DIS/US+ categorizations were classified as Inconsistent. For each group, we regressed response times with matching accuracy across each block. Slope coefficients of the regression equation ('slope scores') ranged between .06 to .44, with larger scores (steeper slopes) indicating greater relatedness. Normality was not violated for slope score distributions across any condition (all *p*'s > .09). Levene's tests indicated variances across slope scores were homogenous between groups across Consistent ($p = .605$) and Inconsistent ($p = .860$) blocks. A 2 x 3 Type-2 ANOVA with block (Consistent, Inconsistent) and groups entered as independent factors did not reveal any interaction term ($p = .99$) or main effects (*p*'s > .24). Slope scores did not statistically vary between blocks and groups (Figure 2, Panel D).

4. CS visibility

None of the participants reported any CS or non-CS items during visibility checks, so no one was excluded from analyses. 86% of all participants ($n = 59$) correctly identified all supraliminal stimuli that had appeared during conditioning. All participants correctly identified at least three-quarters of all US showed, confirming stimulus presentation sequences had been attended to (Mastropasqua & Turatto, 2015).

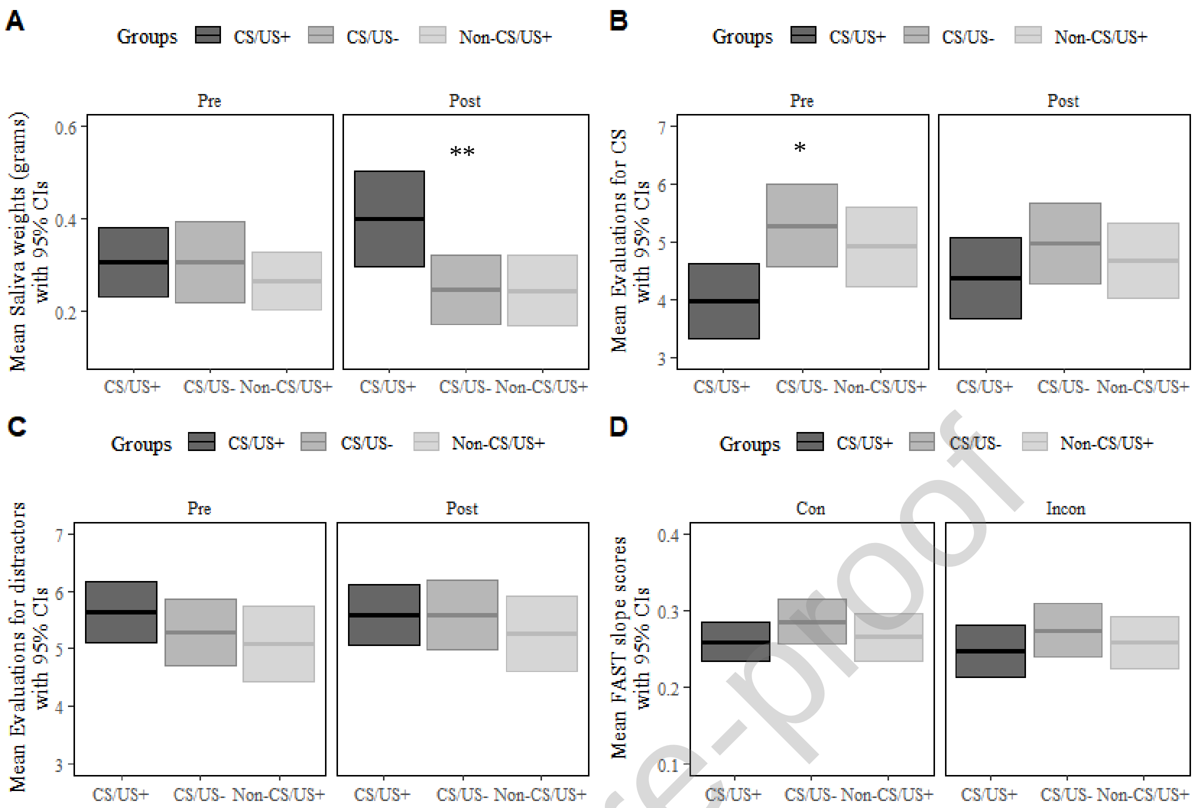


Figure 2. Crossbar plots of outcome means with 95% CIs (*y*-axes) across groups (*x*-axes). Saliva weights collected after (Post) and before (Pre) conditioning are summarized in Panel A. Evaluations for eating-related and distractor words are summarized in Panels B and C respectively. Slope coefficients from regression equations estimated from *FAST* performances across consistent (Con) and inconsistent (Incon) test blocks are summarized in Panel D. Single (p = .02) and double (p = .008) asterisks indicate significant omnibus effects.

Discussion

Subliminally presented eating-related words (CS) or their scrambled counterparts (non-CS) were paired with supraliminal positive (US+) or neutral words (US-) across three samples of Brazilian participants. Post-conditioning visibility checks showed none of the subliminally presented terms were detected during conditioning trials, suggesting that CS had been indeed subliminal. Explicit evaluations of eating-related CS (and eating-unrelated distractors), as well as *FAST* slope-scores indicating CS/US+ (and CS/US-) relatedness, were statistically unaffected by conditioning. Central to our main prediction, the experimental group (CS/US+) produced reliably more saliva relative to control groups after conditioning.

The induction of saliva production following subliminal CS/US+ associations replicates Amd and Baillet's (2019) main finding while controlling for those authors' limitations. Inclusion of non-CS/US+ and CS/US- control groups confirmed that repeated presentations of US+ or CS were insufficient by themselves to reliably influence saliva production. Our free-selection visibility check presented multiple response options and reduced the likelihood of detection rates being artificially inflated (Gendron et al., 2014). Positive (US+) and neutral (US-) words were selected at similar rates during visibility checks, implying that attentional processes were not statistically biased towards emotionally salient targets (Yiend, 2006). While the removal of a trial-by-trial visibility check minimized the possibility of valence generalization through backward conditioning, it should be noted that an end-of-task visibility check may have undermined the latter's sensitivity, since transitory term knowledge can extinguish (be 'forgotten') by the end of acquisition trials (Shanks & St. John, 1994).

The non-significant differences across CS evaluations reported here corroborates a recent report by Heycke and Stahl (2020), who found no evidence of subliminal conditioning on CS evaluations when CS were undetected. None of the CS presented here were detected during visibility checks, and CS evaluations were similarly unaffected by conditioning[2]. We also found no differences between groups across *FAST* performances, suggesting CS/US+ relatedness was statistically unaffected by conditioning. This suggests that the partial information provided by subliminal CS/US+ contingencies, while 'sufficiently' salient to become perceptually organized and selectively activate motivational systems, may have been ecologically insufficient to be consciously appraised (Kimchi et al., 2018). Indeed, the

[2] Within-subject contrasts indicated CS evaluations became significantly more positive for the experimental group. However, CS evaluations were significantly different between groups before conditioning (Silva, 2018). As a reviewer of the present work noted, because the experimental group produced the lowest CS evaluation scores pre-conditioning, they had more 'room' to vary (regress towards the population mean, see Barnett, et al., 2005). A significant within-group effect may have been due to random error generated from repeated measurements across a sub-sample, which can shift sample parameters towards population estimates by chance alone. We have consequently refrained from presenting any within-subject change scores.

minimum onscreen duration required for conscious appraisal of textual CS may be 60 ms (Greenwald & De Houwer, 2017), whereas the CS used here were presented for less than a third of that duration (17 ms). One may even argue that CS/US+ relations were acquired 'outside' conscious awareness (ie without explicit knowledge support), although our present design cannot confirm this assertion. Future work could incorporate trial-by-trial awareness checks, similar to the procedure reported by Jurchiș and colleagues (2020), to assess whether CS knowledge structures become updated following exposure to subliminal CS-US relations. This would illustrate the extent to which subliminally conditioned salivation is consciously regulated.

On an applied level, the effects reported here may have implications for treating *anorexia nervosa* (AN). Central to AN is a 'fear of weight gain' (American Psychiatric Association, 2013), which may be rooted in aversive CS/US- (EATING/NEGATIVE) associative histories (Murray et al., 2016). Murray et al suggested that aversive 'fear associations' between food-related information and 'catastrophic weight gain' are central to AN maintenance. On a similar note, Glashouwer and de Jong (2021) discussed how negative associations with the activity of eating (e.g., a fear of "becoming fat") contributes to aversive evaluations of food-associated stimuli. We propose that the subliminal protocol reported here be adapted for use with AN population to test whether negative affect associated with pre-established fear associations can be counter-conditioned subliminally (Kerkhof et al., 2011). It was demonstrated here (and elsewhere – Amd & Passarelli, 2020; Veltkamp et al., 2011) that symbols can become positively valenced and motivationally salient following subliminal CS/US+ conditioning. If the conscious appraisal of eating-related words (CS) can be bypassed through subliminal presentations, it could be valuable to note whether a similar protocol can augment preingestive salivation across an AN population. Increasing salivation may, in turn, influence food intake (Nederkoorn et al., 2000). A positive finding would provide clinicians with an additional instrument for countering pre-established 'fear associations' that goes beyond repeated exposure (extinction) therapies (Murray et al., 2016b).

One concern of our design that may be raised involves the lack of an unpaired control condition, which involves CS and US appearing in randomized sequences to convey minimal contingency information (Rescorla, 1967). A "truly random" presentation sequence that eliminates any possibility of CS predicting US (non-)occurrence can be an effective control, but only if one assumes the "temporal contingency between CS and US" (Rescorla, 1967, p.3) as a necessary operating condition during acquisition. The effectiveness of a "truly random" control can be questioned from contiguity-based learning theory however, which argues contiguous CS-US pairings suffice to produce conditioning effects irrespective of contingency information (Guthrie, 1933; Blask et al., 2020).

If a fully randomized presentation sequence was applied, there would be some trials where CS and US appear together by chance. If learning operates along 'all-or-nothing' rules rather than incrementally expanding associations (an issue that still remains unresolved – Roediger & Arnold, 2012), even a single CS-US pairing may yield evaluative effects (Blechert et al., 2016). Since the number of pairings required for acquisition may vary between individuals, an unpaired control condition would variably generate positive and/or null conditioning outcomes. On the other hand, an explicitly unpaired group (where CS and US appear in pseudo-randomized sequences but never together, even by chance) could induce inhibitory conditioning effects from a contingency-based learning perspective (because CS now predicts US non-occurrence - Rescorla, 1967). In other words, a 'truly' random unpaired control is not an effective control from a contiguity-based perspective (since CS and US can still appear together by chance), whereas an explicitly unpaired control can be criticized from a contingency-based perspective (since CS would predict US non-occurrence and thus become inhibitory). We avoided both issues here, as neither control group presented CS and US+ within the same block. The assumption of temporal contingency was not central to our predictions, nor necessary for explaining conditioning outcomes (Minster et al., 2011).

A second issue may be raised regarding our decision to include only sleeping-related words as distractors during *FAST* trials. If one assumes that (some) participants became fatigued by the task's end, one could expect SLEEPING/POSITIVE (Inconsistent) slope scores to be affected. This would minimize/eliminate any increases in EATING/POSITIVE (Consistent) categorization fluencies. Since our *FAST* was applied once post-conditioning, we can make no claims as to the augmentation/degradation effects on 'sleeping' and 'eating' evaluations. Future researchers are encouraged to replicate the present work but with pre-post measurements involving *FAST* and other assessment methods (e.g., Amd & Roche, 2016). Those investigations could include alternate distractor activities and note whether the present effects hold at an 'implicit' level (but recall Heycke & Stahl, 2018).

Conclusion

We demonstrate how preingestive salivation may be selectively activated by positively conditioned nutrition-signals, even if the latter are not consciously appraised. We hypothesize that across modern humans, primordial behavioral systems associated with nutrition remain sensitized to food-associated contingencies. The perceptual organization of positive affect with food-related stimuli may be sufficient to activate preingestive salivation with minimal conscious deliberation (Kimchi et al., 2018).

It is evolutionarily sensible to assume that affective information can selectively influence appetitive motivational systems with minimal engagement of higher-order processes (Boag, 2008; Berlyne, 1964). Even organisms without central nervous systems can behaviorally discriminate between cues signaling the presence (absence) of nutritive content (Staddon, 2016 pp.17-20; McNaughton, DeYoung, & Corr, 2016). The capacity to normatively distinguish between nutrition-associated tokens is likely affective, and must have been acquired early during evolution for more complex behavioral systems to develop (Boag, 2008; Glasgow, 2018; Hull, 1930; Killeen, 2019). We encourage future research to assess whether other 'primordial' motivational systems, such as those related to sexual reproduction, may also be amenable to subliminal information. For instance, it would be interesting to note whether textual representations of sexual activity, which are more likely to be affectively 'neutral' than pictures of erotica (Both et al., 2008) or guns (Hoffmann et al., 2004), could subliminally activate sexual arousal. Researchers are encouraged to investigate other motivational systems that may be susceptible to subliminally presented information (Amd & Passarelli, 2020).

Acknowledgments and Funding Included in the title page to preserve blind review.

Competing interests

The authors have no competing interests to declare.

Ethical Approval

All procedures reported were approved by the local IRB at the Federal University of Sao Carlos**.**

Inform Consent

Written consent was obtained from all participants involved in the study.

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CRediT authorshipcontribution statement

The work reported here is part of DP's Master's dissertation under the supervision of MA and JCR. The work reported here was funded in part by Grant 2019/01406-7 to DP from the Sao Paulo Research Foundation (FAPESP) and in part by Grant 465686/2014-1 from the National Research Council (CNPq) and Grant 2014/50909-8 to Instituto Nacional de Ciência e Tecnologia sobre Comportamento, Cognição e Ensino (INCT-ECCE). The reported work was designed by DP and MA. All data were collected by DP and MAO, under supervision of JCR and MA. All data were analyzed by MA and DP. The manuscript was prepared by MA, DP and JCR. DP and MAO assisted with final edits. We thank Táhcita Mizael, Mariana Brandao Zanelli and Julio Camargo for helpful comments across earlier drafts of the present work. All works reported here were approved by the local university ethics board and correspond with the guidelines in the Declaration of Helsinki. The authors have no conflict of interest to declare. All correspondence regarding the current work can be forwarded to DP at denise.ger012@gmail.com

Highlights

- Associating subliminal eating activities (CS) with positive attributes (US) reliably increased salivation
- Subliminal CS-US pairings did not reliably influence CS implicit and explicit evaluations
- The CS and non-CS were not explicitly identified during visibility checks after conditioning
- CS-US relations reliably influenced select motivational systems with minimal top-down deliberation