Leaving a Flat Taste in Your Mouth: Task Load Reduces Taste Perception

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What is This?
One of the very nicest things about life is the way we must regularly stop whatever it is we are doing and devote our attention to eating.

—Luciano Pavarotti and William Wright, 1981

Contrary to Pavarotti’s assertion, research suggests that people in contemporary Western society are devoting less and less attention to their meals. For instance, almost half of all weekly meals are reportedly consumed in a room with a television switched on (Gore, Foster, DiLillo, Kirk, & Smith West, 2003). Moreover, people have become increasingly dependent on fast-food chains (Nielsen, Siega-Riz, & Popkin, 2002), with almost half of U.S. food spending going toward such establishments (Clauson & Leibtag, 2011). Foods consumed away from home are typically higher in fat, sugar, and salt than foods prepared and consumed at home (Drewnowski, 2003). Further, the average U.S. citizen now consumes about 355 calories of sugar and 3,436 mg of sodium per day (Hobson, 2009). The decreased attention directed to meals, on the one hand, and increases in fat, salt, and sugar consumed, on the other hand, may not be independent phenomena. We propose that when attention is limited, the concentration of tastants in food has to be augmented to maintain similar levels of taste experience as when attention is unrestrained.

Several findings suggest that the environment in which food is consumed influences people’s taste perception (e.g., Marks & Wheeler, 1998; Wansink, 2010) and, most important, that attention may play a key role in how these signals are interpreted (Elder & Krishna, 2010). Although a physiological response (the stimulation of the taste buds) underlies taste perception, taste perception is ultimately ambiguous. It is the complex integration of data from all the senses through which food is identified (e.g., Wansink, Park, Sonka, & Morganosky, 2000). For example, people experience tastants as less intense when there is loud background noise (Spence & Shankar, 2010), and blue and green room lights make wine appear spicier (Oberfeld, Hecht, Allendorf, & Wickelmaier, 2009).

Abstract
In recent years, people have tended to pay less attention to their meals, often consuming them while engaging in other activities. At the same time, foods have become increasingly sweet and salty. We therefore investigated how performing concurrent activities affects taste perception and how this relates to actual consumption. Participants tasted sour, sweet, and salty substances in various concentrations under differing task loads. Our results demonstrated that under high task load (relative to low task load), participants rated the substances as less intense, consumed more of the substances, and preferred stronger tastants. Our findings suggest that increased task load reduces people’s taste perception by limiting attentional capacity to assess taste intensity and that people adjust their consumption accordingly.

Keywords
taste perception, task load, eating behavior, attention, self-control, food
Environmental factors not only influence taste perception, but they also may play a role in actual eating behavior. For example, people tend to eat more while watching TV and listening to music (e.g., Blass et al., 2006; Hetherington, Foster, Newman, Anderson, & Norton, 2006). It seems that if people cannot devote their full attention to the food they are consuming, they are less responsive to sensory cues that, for example, signal satiation (Wallis & Hetherington, 2004). Similarly, an attention-absorbing activity may dishabituate taste perception, which then provides a mechanism for increased energy intake (Temple, Giacomelli, Kent, Roemmich, & Epstein, 2007).

In the current research, we proposed that people’s activities, on the one hand, and sensory input, on the other hand, arouse continuous competition over limited attentional resources (Yantis, 2000). Research has shown, for example, that task load attenuates the intensity of negative and positive feelings (Kron, Schul, Cohen, & Hassin, 2010; van Dillen & Koole, 2007), such that the more resources are taxed, the less intense people’s affective experiences are. Similar effects of task load have been reported on subjective ratings of and brain responses to painful stimuli (Bantick et al., 2002; Frankenstein, Richter, McIntyre, & Remy, 2001). We therefore reasoned that task load may likewise attenuate people’s taste perception and that this consequently increases consumption.

To examine the generalizability of our effects, we tested our hypotheses in four studies on both aversive tastants (i.e., sourness; Rosenstein & Oster, 1988; Steiner, 1977) and pleasant tastants (i.e., sweetness and saltiness; Desor, Maller, & Turner, 1977). We used the same basic design in the first three studies. Participants tasted various concentrations of sour (Study 1), sweet (Study 2), and salty (Study 3) substances while we varied their task load in a memory-span manipulation (Sternberg, 1966). In a final study (Study 4), participants created their own preferred concentration of a sweet drink under high or low task load.

We expected participants to rate the tastants as less intense while under high task load than while under low task load. In addition, we predicted that, to obtain similar levels of taste intensities under both types of load, participants would consume more of a substance (Study 3) under high load than under low load. Even though participants were instructed explicitly to rate the tastes of the sour solution (Study 4) while under high than under low task load.

### Study 1: Sourness

**Method**

**Participants and design.** Twenty students (15 women, 5 men; mean age = 21 years, SD = 1.88) participated in the study in exchange for €3. The study had a 2 (concentration: strong vs. weak) × 2 (task load: high vs. low) within-participants design. The main dependent variable was participants’ sourness ratings.

**Procedure.** Participants were instructed to rate the sourness of a strong and a weak lemon juice solution. The pretested solutions consisted of water mixed with 30% lemon juice (strong solution) and 10% lemon juice (weak solution). Before each tasting, participants were instructed to memorize either a seven-digit number (high load) or a one-digit number (low load), a well-validated manipulation to tax people’s attentional resources (Sternberg, 1966). Next, participants received 20 ml of one of the solutions in a cup and were asked to consume it all at once. Participants then wrote down the number they had memorized. Finally, participants rated how sour they thought the drink was on a scale from 1 (not at all) to 7 (very much). This procedure was repeated four times so that all participants tasted the strong and weak lemon juice solution under high and low task load, in random order. To neutralize their taste, participants took a sip of water between each tasting.

### Results

A repeated measures analysis of variance (ANOVA) with concentration and task load as within-participants variables and taste ratings as the dependent variable yielded a significant main effect of concentration, $F(1, 19) = 21.41, p < .001, \eta_p^2 = .53$, and a marginally significant main effect of task load, $F(1, 19) = 3.95, p = .062, \eta_p^2 = .17$. Participants perceived the strong lemon juice solution as sourer than the weak lemon juice solution, and they perceived the lemon juice solutions as less sour under high load than under low load (Fig. 1). The analysis also revealed a significant interaction between concentration and task load for sourness ratings, $F(1, 19) = 4.93, p = .039, \eta_p^2 = .21$. Simple contrasts revealed that participants perceived the strong lemon juice solutions as less sour under high load than under low load, $F(1, 19) = 8.40, p = .009, \eta_p^2 = .31$. Task load did not affect sourness ratings of the weak lemon juice solutions, $F < 1$.

### Discussion

Participants tasted varying concentrations of a lemon juice solution while holding seven digits (high task load) or one digit (low task load) in working memory. We found that participants rated the sourness of strong lemon juice solutions as less intense while under high than under low task load. Even though participants were instructed explicitly to rate the tastes of the sour solutions, it thus seems that the digit-span task distracted attention away from the taste sensations. Accordingly, participants were not able to fully perceive the tastes of the sour solution.
The fact that the task-load manipulation affected the taste ratings of only strong concentrations may suggest a linear effect of task load on taste perception. More specifically, similar to the finding that strongly negative information captures more attention than mildly negative information (Schimmack & Derryberry, 2005), strong tastants may occupy more attention than weak tastants. Accordingly, the stronger the concentration of a certain tastant, the more competition there will be over attentional resources between task load and taste perception (for a similar explanation of the effects of task load on the intensity of negative feelings, see van Dillen & Koole, 2007).

Study 2: Sweetness

In Study 2, participants tasted sweet solutions of varying concentrations and memorized letters rather than digits. In this study, we controlled for several factors that may have affected the results of Study 1. For example, in Study 1, task load did not attenuate participants’ taste ratings of the weak lemon juice solution. Perhaps participants did not perceive the weak solution as particularly sour (i.e., a floor effect). We therefore added water as a baseline control condition in Study 2. Additionally, we controlled for task duration, as memorizing a multiple-digit number takes more time than memorizing a single-digit number, and thirst levels, because deprivation may influence taste perception (Zverev, 2004). We again reasoned that the more attentional capacity is used to perform a task, the less attention is devoted to taste perception.

Method

Participants and design. Eighteen students (16 women, 2 men; mean age = 22 years, $SD = 2.85$) participated in the study in exchange for €3. The study had a 3 (concentration: strong vs. weak vs. control) × 2 (task load: high vs. low) within-participants design. The main dependent variable was participants’ sweetness ratings.

Procedure. The procedure was the same as in Study 1, with the following exceptions. The pretested drinks consisted of water mixed with a specific amount of grenadine syrup (strong, weak, or none). The strong solution consisted of 30% grenadine syrup; the weak solution contained 10% grenadine syrup. We used red cups to ensure that participants could not visually determine any differences in concentrations. The task-load manipulation this time consisted of consonant series instead of digits (high load: seven consonants vs. low load: one consonant). Furthermore, the experimenter unobtrusively measured, by means of a stopwatch, the time interval between the moment participants started memorizing the consonants and the moment participants provided the
first taste rating. Finally, participants indicated how thirsty they were on a scale from 1 (not at all) to 7 (very much).

Results

A repeated measures ANOVA with concentration and task load as within-participants variables revealed a main effect of concentration, \( F(1, 17) = 420.51, p < .001, \eta^2_p = .96 \), and a main effect of load, \( F(1, 17) = 8.61, p = .009, \eta^2_p = .34 \), on sweetness ratings. Participants perceived strong solutions as sweeter than weak solutions, and they perceived the solutions as less sweet under high than under low task load (Fig. 1). We again observed an interaction of concentration and task load on sweetness ratings, \( F(1, 17) = 7.59, p = .014, \eta^2_p = .31 \). Simple contrasts further revealed that participants perceived the strong grenadine solutions as significantly less sweet under high than under low task load, \( F(1, 17) = 11.33, p = .004, \eta^2_p = .40 \), whereas the effects of task load were much weaker for ratings of the weak grenadine solution, \( F(1, 17) = 2.69, p = .119, \eta^2_p = .14 \), and nonsignificant for water, \( p = .331 \). Including task duration or thirstiness as covariates in the analysis did not affect the pattern of results.

Discussion

The results of our second study further supported the hypothesis that task load attenuates taste perception. Participants perceived sweet solutions as less intense under high than under low task load. It thus seems that the effects of task load on taste perception not only apply to aversive tastants, such as sourness (Rosenstein & Oster, 1988), but also to more pleasant tastants, such as sweetness (Desor et al., 1977). In addition, differences in task duration and thirst levels were ruled out as alternative explanations for the reported findings.

Note that the task-load manipulation again had a larger influence on taste ratings of weak than of strong concentrations, whereas the effect was absent in the control condition (water). This is in line with our reasoning that the sensory processing of strong tastants should be more affected by task load than the sensory processing of weak tastants, as a result of greater competition between the two activities.

Study 3: Saltiness and Consumption

In our third study, we wished to further extend our limited-resources account of taste perception by examining taste ratings of various salt concentrations. In addition, we measured the effects of task load on actual consumption. We aimed to demonstrate that taxing the mind with a demanding task not only influences participants’ capacity to assess taste intensity of a substance, but also affects how much of that substance the participant consumes. That is, we reasoned that under high task load, participants need to consume more of a substance to obtain the same preferred taste levels as when under low task load. To test this hypothesis, we varied task load while participants ate crackers with salty or salt-free butter. We examined both participants’ saltiness ratings of the crackers and the amount of crackers they consumed.

Method

Participants and design. Seventeen students took part in the experiment (11 women, 6 men; mean age = 21 years, \( SD = 2.44 \)) in exchange for €3. The study had a 2 (concentration: strong vs. control) × 2 (task load: high vs. low) within-participants design. The main dependent variables were saltiness ratings and the amount of cracker consumed.

Procedure. The procedure of Study 3 was identical to that of Study 2, with two modifications. Instead of consuming drinks, participants this time ate crackers with either salty or salt-free butter. The salty butter contained 0.43 grams of salt (per 100 grams of butter); the salt-free butter contained 0.01 grams of salt (per 100 grams of butter). Participants were instructed to eat as much of the cracker as they thought was necessary to perceive a reliable taste. After each tasting, the experimenter measured the amount of cracker that was left over. The percentage of cracker consumed was then computed using the following formula: percentage of cracker consumed = (total − leftover)/total × 100. Because we examined actual food consumption, we assessed individual differences in general saltiness preference and hunger state (Zverev, 2004). Again, we also assessed task duration.

Results

Saltiness. A repeated measures ANOVA with concentration and task load as within-participants variables revealed a main effect of concentration, \( F(1, 16) = 95.50, p < .001, \eta^2_p = .86 \), and a main effect of task load, \( F(1, 16) = 4.56, p = .049, \eta^2_p = .22 \), on saltiness ratings. Participants perceived the salty cracker as saltier than the salt-free cracker, and they perceived the crackers as less salty under high load than under low task load (Fig. 1). Moreover, there was again an interaction between concentration and task load on saltiness ratings, \( F(1, 16) = 10.91, p = .004, \eta^2_p = .41 \). We observed that participants perceived the salty buttered cracker as saltier than the salt-free cracker, and they perceived the crackers as less salty under high load than under low task load (Fig. 1). Moreover, there was again an interaction between concentration and task load on saltiness ratings, \( F(1, 16) = 19.46, p < .001, \eta^2_p = .55 \). There was no effect of task load on the taste ratings of the salt-free crackers, \( F(1, 16) = 2.48, p = .135, \eta^2_p = .13 \). The same analysis with task duration or
self-reported hunger as covariates did not change the pattern of results.

Consumption. The amount of cracker that participants consumed was analyzed in a repeated measures ANOVA with concentration and task load as within-participants variables. We observed a main effect of concentration, $F(1, 16) = 11.52, p = .004, \eta^2_p = .42$. Participants ate more of the salty buttered crackers than of the salt-free buttered crackers (Fig. 2). Moreover, we found a marginally significant interaction of concentration and task load on consumption, $F(1, 16) = 4.36, p = .053, \eta^2_p = .21$. As predicted, simple contrasts showed that participants consumed more of the salty buttered crackers than of the salt-free buttered crackers (Fig. 2). Moreover, we found a marginally significant interaction of concentration and task load on consumption, $F(1, 16) = 4.36, p = .053, \eta^2_p = .21$. As predicted, simple contrasts showed that participants consumed more of the salty buttered crackers than of the salt-free buttered crackers (Fig. 2). Moreover, we found a marginally significant interaction of concentration and task load on consumption, $F(1, 16) = 4.36, p = .053, \eta^2_p = .21$. As predicted, simple contrasts showed that participants consumed more of the salty buttered crackers than of the salt-free buttered crackers (Fig. 2).

Discussion

Study 3 replicated and extended the findings of Studies 1 and 2. We again found that task load attenuated taste perception, such that participants perceived salty buttered crackers as less salty while memorizing seven consonants rather than one consonant. Participants consumed more of the salty cracker under high than under low task load. These findings suggest that task load not only affects taste perception, but also actual consumption. To have an optimal taste experience, people may need to increase their intake of a substance when engaged in demanding activities.

Study 4: Creating the Preferred Lemonade

The goal of Study 4 was to extend the findings of Study 3. We instructed participants to create their preferred lemonade by adding as much grenadine syrup as they liked. We again varied concurrent task load, this time between participants. After creating their optimal lemonade, participants rated how sweet and pleasant they thought their drink was. We aimed to demonstrate that participants would create sweeter drinks when under high than under low task load. Note, though, that we did not expect task load to affect participants’ taste ratings. To obtain a similar taste experience, participants under high task load were expected to add greater amounts of the sweet grenadine syrup than participants under low task load.

Method

Participants and design. Forty-two students took part in the experiment (32 women, 10 men; mean age = 19 years, $SD = 2.12$) in exchange for course credit. Task load (high vs. low) was a between-participants factor, and the grenadine syrup concentration of participants’ self-created lemonade and participants’ taste ratings were our dependent variables.

Procedure. Participants were instructed to create their own lemonade by pouring water (maximum of 150 ml) and grenadine syrup (maximum of 50 ml) into an empty cup. We applied the same task-load manipulation as in Study 1. Participants created lemonade while memorizing either a seven-digit number (high load) or a one-digit number (low load). Participants tasted their lemonade to make sure it contained the preferred mixture of water and grenadine syrup. If it did not, participants could start over a maximum of two times (participants memorized a new number each time). After creating their lemonade, participants reported the digits they had memorized and then rated the sweetness and pleasantness of their drink. Finally, participants indicated their general sweetness preference and thirst level. The experimenter then measured the amount of grenadine syrup that was left over. We also measured the amount of lemonade participants consumed and the number of times participants took to create their lemonade to ensure that any differences in

![Fig. 2. Mean percentage of crackers consumed as a function of type of butter and task load (Study 3) and mean percentage of grenadine syrup added to a drink to reach preferred sweetness as a function of task load (Study 4). Error bars indicate ±1 SE.](image-url)
added grenadine concentration could be attributed to our task-load manipulation. For our analyses, we computed the percentage of grenadine syrup that participants added using the following formula: (total amount of grenadine syrup – leftover amount)/(total amount of grenadine syrup plus water that was used) × 100. We thus assessed the relative concentration of grenadine syrup.

**Results**

A generalized linear model with task load (high vs. low) as a between-participants variable and grenadine syrup concentration as the dependent variable yielded a main effect of task load, $F(1, 40) = 8.89, p = .005, \eta^2_p = .19$. Participants added more grenadine syrup under high than under low task load (Fig. 2). We found no effects of task load on participants’ taste ratings, $F$s < 1. That is, whereas participants created sweeter lemonade when under high than under low task load, they did not perceive their drink as sweeter or more pleasant. When entered as covariates, the amount of lemonade participants consumed, the number of times participants took pants consumed, the number of times participants took

3) substances. Participants rated strong tastants and, to a lesser extent, weak tastants as less intense while performing a high-load task than when performing a low-load task. Moreover, to experience the same taste intensities under both types of task load, participants consumed more of a salty substance (Study 3) and created higher concentrations of sweet lemonade (Study 4) under high than under low task load. It thus seems that task load attenuates taste perception and, accordingly, increases consumption.

In Study 3, we demonstrated that participants consumed more of a salty buttered cracker while performing a high-load task than while performing a low-load task. These findings are consistent with previous research on task load and food consumption (e.g., Boon, Stroebe, Schut, & Ljintema, 2002; Friese, Hofmann, & Wänke, 2008; Ward & Mann, 2000), which demonstrated that situational reductions in cognitive resources elicit less self-controlled behavior (such as overeating; e.g., Andrade, Greene, & Melanson, 2008). The current findings provide an additional but novel confirmation of the assumption that limited self-regulation capacity leads to impulsive, uncontrolled eating. Specifically, our results suggest that limited attentional resources reduce sensory experience, which may be an important cause of overeating. When people's attention is burdens by a demanding activity, they will need to consume more of a certain food to obtain an optimal taste experience.

The present findings also fit well with research on the neural pathways underlying taste perception. For example, it has been demonstrated that reward systems in the brain (i.e., ventral striatal opioids) respond specifically to sweet and salty foods and promote associated behaviors such as increased food intake, most likely because sugar and salt are crucial building blocks for the body and brain (Berridge, 1996; Kelley et al., 2002). Our findings seem to underline this mechanism, in that participants consumed more of salty but not of salt-free buttered crackers (Study 3) and added more sweet grenadine syrup (Study 4) when concurrent task load attenuated their taste perception. Given that we did not directly assess the relationship between taste perception and consumption, future research using more direct measures of reward processing, such as neuroimaging, may provide better insight into the causal pathways.

To conclude, the current work highlighted the cognitive limitations of taste perception. When attention is allocated to a concurrent task, the ability to perceive tastants is significantly impaired. These results are highly relevant in today’s society, in which multitasking is common. When cognitively engaged, such as while watching TV or driving a car, people’s taste perception is likely attenuated, which may contribute to unhealthy eating behaviors, such as increasing the intake of certain foods or adding more of certain flavorings. Conversely, the current findings also suggest that abstaining from any activities during one’s meals should enhance taste perception. Recent work on mindfulness meditation indeed suggests that paying more attention to food cues can be a helpful tool in obtaining healthier eating patterns (Alberts, Mulkins, Smeets, & Thewissen, 2010; Papes, Barsalou, & Custers, 2012). Thus, in keeping with Luciano Pavarotti: Devote your full attention to your meal, or the food will only leave a flat taste in your mouth.

**Author Contributions**

L. F. van Dillen developed the study concept. L. F. van Dillen and R. C. van der Wal both contributed to the study design.
Testing and data collection were performed by R. C. van der Wal. The authors performed the data analysis together. R. C. van der Wal drafted the article, and L. F. van Dillen provided critical revisions. Both authors approved the final version of the article for submission.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Notes

1. If participants reported cold symptoms or food allergies in any of the studies, they could not participate.
2. To rule out the possibility that the observed effects of task load were due to contrast effects, we replicated the findings of Study 1 using a between-participants design. Fifty-four participants rated the sour lemon juice solution while holding either a seven-digit number (high-load condition: n = 28) or a one-digit number (low-load condition, n = 26) in memory. Results were in line with the findings of Study 1, demonstrating a main effect of concentration, F(1, 51) = 16.91, p < .001, ηp2 = .25, and an interaction between concentration and task load, F(1, 51) = 4.47, p = .039, ηp2 = .08. Simple contrast analyses again revealed that participants rated the sour lemon juice solution as relatively less sour under high task load than under low task load. F(1, 51) = 2.38, p = .043, ηp2 = .08. Task load did not affect sourness ratings of the weak lemon juice solution, F < 1. Hence, task load affected participants’ taste ratings regardless of whether it was manipulated between or within participants.

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