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Decelerated and linear eaters: Effect of eating rate on food intake and satiety

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ABSTRACT

Women were divided into those eating at a decelerated or linear rate. Eating rate was then experimentally increased or decreased by asking the women to adapt their rate of eating to curves presented on a computer screen and the effect on food intake and satiety was studied. Decelerated eaters were unable to eat at an increased rate, but ate the same amount of food when eating at a decreased rate as during the control condition. Linear eaters ate more food when eating at an increased rate, but less food when eating at a decreased rate. Decelerated eaters estimated their level of satiety lower when eating at an increased rate but similar to the control condition when eating at a decreased rate. Linear eaters estimated their level of satiety similar to the control level despite eating more food at an increased rate and higher despite eating less food at a decreased rate. The cumulative satiety curve was fitted to a sigmoid curve both in decelerated and linear eater under all conditions. Linear eaters rated their desire to eat and estimated their prospective intake lower than decelerated eaters and scored higher on a scale for restrained eating. It is suggested that linear eaters have difficulty maintaining their intake when eating rate is dissociated from its baseline level and that this puts them at risk of developing disordered eating. It is also suggested that feedback on eating rate can be used as an intervention to treat eating disorders.
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1. Introduction

Kissileff described a method for continuous recording of food intake in man, the Universal Eating Monitor [1]. The subject places a plate on a scale and puts food on the plate and a computer records the weight loss of the plate during the meal. Using this procedure and careful mathematical modeling, the cumulative food intake of normal volunteers was fitted to a quadratic equation and the curve had a decelerated shape in most subjects [2,3]. A review of the research performed with this method [4] showed that restrained eating, which is thought of as a self-imposed cognitive strategy to restrict food intake in order to control body weight [5,6] is an important factor that affects eating behavior. Restrained eaters eat at a constant rate compared to unrestrained eaters, who eat at a decelerated rate [7]. A visual analogue scale for rating of satiety was subsequently added to this procedure and it was suggested that satiety is relatively constant in the beginning of the meal and then increases in a linear fashion in restrained eaters and that satiety displays a similar curve that levels off by the end of the meal in unrestrained eaters [4,8,9].

We have further developed these methods for different purposes by adding a touch screen. Curves for eating rate are displayed on the touch screen to provide visual feedback during meals and the participants are asked to follow these curves when they eat. This is possible because the subject can see her/his eating rate appearing on the screen during the meal. Thus, this method, Mandometer®, makes it possible to increase or decrease eating rate experimentally. We also display a scale on the touch screen and ask participants to rate how full they feel. Thus, Mandometer® also yields an estimate of the development of satiety.

In the present study, we examined the effect of experimental manipulation of eating rate on food intake and the development of satiety in women who were first divided into those eating at a decelerated or linear rate. Specifically, we wanted to know if women with a decelerated pattern of eating respond differently to changes in the rate of eating than women with a linear pattern of eating. In other words, the aim of this study was to evaluate the role of individual eating patterns on food intake and satiety when the rate of eating diverts from the subject's habituated rate. Previous research has suggested that changes in eating rate affect food intake [reviewed in Ref. [10]].

2. Methods

2.1. Subjects

Forty-seven normal-weight (body mass index, BMI = 22.2 (20.2–24.3) kg/m^2) (median; range) women (aged 21.2 (19.5–23.1) years) were recruited by advertisement on a nearby college campus. They completed a health questionnaire to ensure that they met the criteria for inclusion in the study. They should be 18–25 years old and have a normal BMI = 19–25 kg/m^2. They should be healthy, non-smokers, free from food allergies and they should not have a history of eating

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disorders or use medication known to affect food intake. Athletes and pregnant and lactating women were excluded. Four women who did not meet these criteria were excluded. We study women, because we want to understand eating disorders and these afflict mainly women. Eating disorders, however, are not specifically addressed here.

A group of 30 healthy men and women of the same age and body weight was tested to examine the reliability of the method. They were recruited as the women described above.

2.2. Apparatus

Mandometer® consists of a scale (IDEMA 750, IDEMA, Gävle, Sweden) built into a table and connected to an IBM compatible PC. The Mandometer® software reads the scale every 2 s with an accuracy of 1 g. Thus, the amount of food consumed and the duration of the meal are recorded.

Mandometer® has a 15″ TFT touch screen and subjects rate their feeling of fullness on a rating scale, which appears on the screen. The rating scale, a revised Borg CR10 Scale [11], is a vertical bar with labeled categories and an associated numerical value ranging from "nothing at all" = 0 to "extremely strong" = 100 and "maximal" > 100.

2.3. Procedure

2.3.1. Meals

Subjects ate their meals at 11:30, 12:00 or 12:30 h with one week between meals. They were asked to refrain from snacking and drinking (except water) after breakfast. Subjects were tested individually, with food presented on an adjacent table. The food (Nasigoreng, i.e., rice, sliced chicken and vegetables, Findus, Bjuv, Sweden; 400 kJ, 4.5 g protein, 18 g fat and 15 g carbohydrate/100 g) was prepared fresh before each meal; its temperature was 65 °C when served from an oven. In order not to reveal the precise intention of the experiment, participants were told that the goal of the study was to assess mood under different conditions of eating; they got detailed information about the study after completion of the last test.

2.3.2. The cumulative food intake curve

The women were first tested for food intake with no rating scales presented during the meal to determine the cumulative intake with no constraints. A bowl with 1200 g food was presented before the meal and the women could eat as much as they wanted. The purpose of this test was to examine the baseline eating pattern of the women; the test is therefore referred to as the baseline test.

2.3.3. Effect of increasing and decreasing eating rate and interrupting the meal

The women ate and rated their satiety at 1 min intervals under the following conditions: 1. Control: the women ate as much as they wanted without constraints. 2. Short meal (Short): the women were asked to eat as much as they wanted in 40% of the time they spent eating in the control condition. An alarm clock next to the subject signaled when the time was over. 3. Increased eating rate (ER+): while eating, the women followed the cumulative curve of food intake that they had generated in the baseline test which was presented on the touch screen but they were required to eat faster during the meal. This was achieved by placing 40% more food on their plate compared to the amount they consumed in the baseline test. 4. Decreased eating rate (ER−): as in 3 except that the women were required to eat 30% less food during the meal. If their eating rate deviated by more than 15% from the requested rate, the women were notified by a red oval and the text: "You are eating too slow" or "You are eating too fast" that appeared on the touch screen. 5. Interrupted meal (Interrupt): the women were asked to take a 1 min break each time they had consumed 60 g of their meal. The meals were interrupted by the appearance of the message: "Please take a break" on the touch screen. The testing conditions were presented in random order.

Thus, the aim of the Short and ER+ condition was to examine the effect of an increase in eating rate and the aim of the ER− condition was to examine the effect of a decrease in eating rate. The aim of the Interrupt condition was to examine the effect of taking a break while eating. Interrupting the meal has been thought to reduce the rate of eating and therefore reduce intake; however, the opposite effect has been reported [12]. The women in this study were able to comply with these procedures, except women eating at a decelerated rate, who had difficulty eating at an increased rate.

2.3.4. Ratings of satiety, hunger and mood

The first satiety rating was done immediately before the women started eating, i.e., time point 0 and satiety was then rated every minute. By use of 100 mm Visual Analogue Scales (VAS) presented on a PDA (iPAQ 3660, Hewlett-Packard, Palo Alto, CA), the women also rated their hunger and desire to eat before and after the meal and in addition, they estimated how much they would eat before the meal. Furthermore, the women rated the following aspects of their mood: happy, relaxed, restless and nauseous before and after eating. The vertical line on the VAS was anchored with the words "Not at all" and "Extremely" at each end.

2.3.5. Restrained eating

By the end of the study, the women filled in the Dutch Eating Behaviour Questionnaire (DEBQ) [13], as a measure of restrained, emotional, and external eating. The DEBQ was administered last to ensure that it did not affect the outcome of the experimental manipulations.

2.3.6. Reproducibility

To assess the reliability of Mandometer®, 30 men and women were tested three times at weekly intervals as in the baseline test. The intra-class correlation (ICC) [14] was calculated to estimate the reproducibility of the results.

The study was approved by the Ethics Committee of the Karolinska Institute and the subjects gave written consent to participate.

2.4. Statistical analysis

The cumulative food intake was fitted to a quadratic equation: $y = ax^2 + bx + c$, where a = change in the slope of the curve over time i.e., rate of deceleration, b = constant slope of the curve over time, i.e., initial rate of eating, and c = food intake at the start of the meal, i.e., 0. The cumulative satiety curve was fitted to a two-parameter sigmoid curve: $y = \alpha/(1 + e^{-(x - x_0)/\beta})$, where $\alpha = 100$, i.e., the maximum of the satiety rating scale, x_0 = time at which satiety has reached the half maximal value, which corresponds to the inflection point of the curve and β = steepness of the curve. Inspection of residuals showed that these models fitted the experimental data satisfactorily; all square correlations were $r^2 \geq 0.99$. Observed values are presented as box plots in the figures and median (range) in the text. K-means cluster analysis [15] showed that the women could be divided into those eating either at a decelerated or linear rate in the baseline test and these two eating patterns were analyzed separately. ANOVA for repeated measures was used for analyzing effects of testing condition and eating pattern and interactions between these two factors. SigmaPlot 10 (Systat Software, Inc. Point Richmond, CA) was used for curve fitting and STATISTICA 6 (StatSoft Inc, Tulsa, TX) was used for the statistical analyses.

3. Results

3.1. Decelerated and linear eaters

Two different patterns of eating were identified in the baseline test (Fig. 1). Thus, in 17 women the cumulative curve of food intake was decelerated ($a < -1$) and in the 30 other women the curve was linear ($a \approx 0$). There was no overlap in the a-values between the two groups

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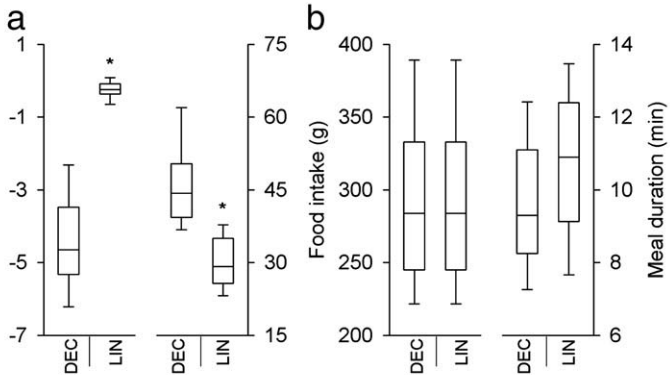

Fig. 1. Rate of deceleration (a), initial eating rate (b), food intake and meal duration in women who ate with a decelerated (DEC, $n=17$) or linear (LIN, $n=30$) pattern. *Significantly different from DEC, $p<0.001$, t-test after ANOVA.

[$t(45)=-14.42$, $p<0.001$]. The women are, therefore, referred to as decelerated and linear eaters in the following.

Decelerated eaters ate at an initially higher rate than linear eaters [$t(45)=8.60$, $p<0.001$], (Fig. 1), but the amount of food ingested did not differ significantly between the two groups [$t(45)=0.24$, *ns*] and although the duration of the meal was somewhat longer among the linear eaters (Fig. 1), the difference was not statistically significant [$t(45)=1.82$, *ns*].

Once the women were divided into decelerated and linear eaters, we examined if these two groups differ with regard to food intake and satiety in response to experimental manipulation of eating rate.

3.2. Effect of increasing or decreasing eating rate and interrupting the meal

3.2.1. Food intake

There was a significant effect of testing condition [$F(4,180)=20.97$, $p<0.001$)] and eating pattern [$F(1,45)=13.2$, $p<0.001$] on food intake and a significant interaction between these two factors [$F(4,180)=45.77$, $p<0.001$].

Within group comparison (Fig. 2) showed that in comparison with the control condition, decelerated eaters ate significantly less food when the meal was short [$t(16)=-7.30$, $p<0.001$] and when the eating rate was increased [$t(16)=-5.69$, $p<0.001$]. There was no effect on food intake when the eating rate was decreased [$t(16)=1.56$, *ns*] or when the meal was interrupted [$t(16)=2.02$, *ns*]. By contrast, linear eaters ate significantly more food when the meal was short [$t(29)=3.97$, $p<0.001$], when the eating rate was increased [$t(29)=6.74$, $p<0.001$] and when the meal was interrupted [$t(29)=6.19$, $p<0.001$], but less food when eating rate was decreased [$t(28)=-6.57$, $p<0.001$].

Between group comparisons (Fig. 2) showed that there was no significant difference in food intake in the control condition [$t(45)=0.24$, *ns*] or when the eating rate was decreased [$t(45)=-1{,}49.44$, *ns*]. However, the decelerated eaters ate less food than the linear eaters when the meal was short [$t(45)=-7.44$, $p<0.001$], when the eating rate was increased [$t(45)=-6.39$, $p<0.001$] and when the meal was interrupted [$t(45)=-2.38$, $p<0.05$].

It is noteworthy that while the linear eaters ate less food when the eating rate was decreased compared to when the meal was interrupted [$t(29)=-9.76$, $p<0.001$], the duration of the meal was similar in these two conditions (10.7 (7.5–14.3) vs. 11.1 (8.3–17.1) min) [$t(29)=1.6$, *ns*] if the pauses were excluded from the meal. Thus, when they were eating, the linear eaters ate at a significantly higher rate when the meal was interrupted (30.2 (22.1–43.8) g/min) than when the eating rate was experimentally reduced (20.3 (16.2–32) g/min) [$t(29)=6.21$, $p<0.001$] or during the control condition (26.6 (19.3–38) g/min) [$t(29)=5.63$, $p<0.01$].

The differences in meal duration were not further analyzed because these differences emerged from the experimentally imposed differences in eating rate and hence are not outcome variables. Note, however, that when the meal was interrupted, the duration of the meal was almost twice as long as during the control condition among the linear eaters (see Fig. 4 below).

Thus, decelerated eaters had difficulty adapting to a higher than normal rate of eating and so ate less food in this condition. On the other hand, when eating at a reduced rate or when the meal was interrupted, decelerated eaters did not change the amount of food they ingested. By contrast, linear eaters were able to eat both at a higher and at a lower rate and consumed more and less food, respectively, when they did.

The group difference in the capacity to eat at an increased rate was also reflected in that the decelerated eaters were notified "you are eating too slow" significantly more often than the linear eaters (7 (4–12) vs. 3 (0–7) times) [$t(45)=6.57$, $p<0.001$]. There were no significant differences in the notification measure of compliance in the other experimental conditions and the women were notified less often that they deviated from the requested rate of eating (data not shown).

3.2.2. Satiety

There was a significant effect of testing condition [$F(4,180)=36.28$, $p<0.001$] and eating pattern [$F(1,45)=17.8$, $p<0.001$] on satiety by the end of the meal and a significant interaction between these two factors [$F(4,180)=7.39$, $p<0.001$].

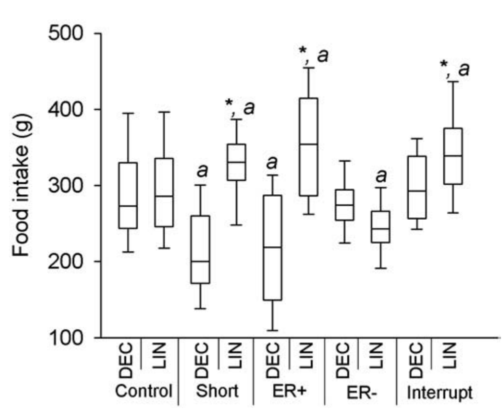

Fig. 2. Food intake in women who ate with a decelerated (DEC, $n=17$) or linear (LIN, $n=30$) pattern. The women were tested without constraints (Control), when trying to finish a meal in a 40% shorter period of time (Short), when eating at an increased (ER+), or decreased rate (ER−) and when taking 1 min pauses after consuming 60 g during the meal (Interrupt). *Significantly different from DEC, $p<0.001$, t-test after ANOVA. [a]Significantly different from Control value, $p<0.001$, t-test after ANOVA.

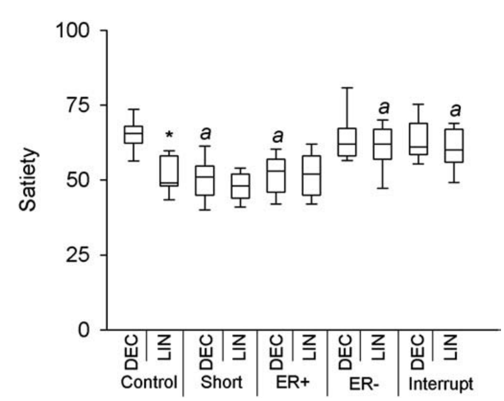

Fig. 3. Satiety after a meal in women who ate with a decelerated (DEC, $n=17$) or linear (LIN, $n=30$) pattern. The women were tested without constraints (Control), when trying to finish a meal in a 40% shorter period of time (Short), when eating at an increased (ER+), or decreased rate (ER−) and when taking 1 min pauses after consuming 60 g during the meal (Interrupt). *Significantly different from DEC, $p<0.001$, t-test after ANOVA. [a]Significantly different from Control value, $p<0.001$, t-test after ANOVA.

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Within group comparison (Fig. 3) showed that in comparison with the control condition, decelerated eaters reached a lower level of satiety when the meal was short [$t(16)=8.74$, $p<0.001$] and when the eating rate was increased [$t(16)=7.63$, $p<0.001$]. However, there was no effect on satiety when the eating rate was decreased [$t(16)=0.49$, *ns*] or when the meal was interrupted [$t(16)=1.06$, *ns*]. By contrast, there was no effect on satiety in linear eaters when the meal was short [$t(29)=2.1$, *ns*] or when the eating rate was increased [$t(29)=-0.54$, *ns*]. Linear eaters reached a higher level of satiety when eating rate was decreased [$t(28)=5.94$, $p<0.001$] and when the meal was interrupted [$t(29)=5.37$, $p<0.001$].

Between group comparison (Fig. 3) showed that the decelerated eaters reached a higher level of satiety than the linear eaters under the control condition [$t(45)=7.48$, $p<0.001$]. There were no other significant group differences (t-values not shown).

It is noteworthy that the linear eaters ate more food when the meal was short and when eating rate was increased and that their rating of satiety did not increase. Equally interesting, the linear eaters ate less food when eating rate was decreased yet their rating of satiety increased (Figs. 2 and 3).

3.2.3. The cumulative satiety curve

Fig. 4 shows the development of satiety among decelerated and linear eaters as a function of eating rate. The satiety levels by the end of the meal in Fig. 3 correspond to the maximal values of the uninterrupted lines in Fig. 4. The dashed and dotted lines in Fig. 4 correspond to the further development of satiety as predicted by the model.

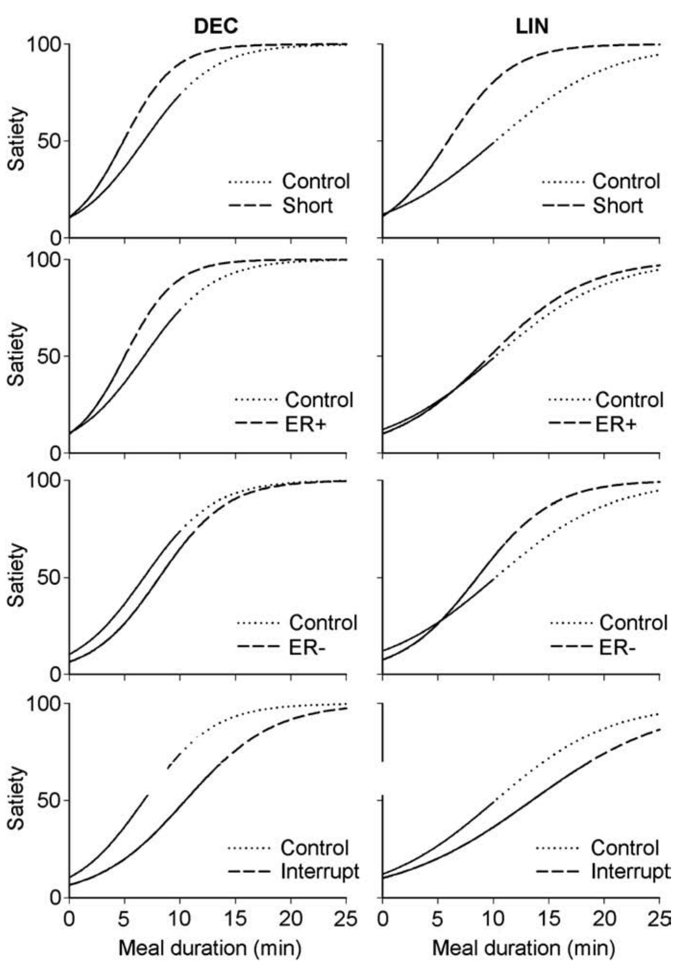

Fig. 4. The cumulative satiety curve in women who ate with a decelerated (DEC, $n=17$) or linear (LIN, $n=30$) pattern. The women were tested without constraints (Control), when trying to finish a meal in a 40% shorter period of time (Short), when eating at an increased (ER+), or decreased rate (ER−) and when taking 1 min pauses after consuming 60 g during the meal (Interrupt).

The sigmoid model fitted the cumulative satiety estimations under all conditions of testing. Decelerated eaters eat more rapidly in the beginning of the meal than by the end and the inflection point of the sigmoid satiety curve appeared when they ate at a normal or below normal rate and when the meal was interrupted but not when they ate a short meal or at an increased rate (Fig. 4). Linear eaters eat at the same rate throughout the meal and the inflection point of the sigmoid satiety curve appeared only when their eating rate was decreased or when the meal was interrupted (Fig. 4). The statistical analysis of the differences in the two measures x_0 = the inflection point of the curve and β = steepness of the curve, is given in Table 1 in the Appendix.

3.3. Hunger and mood

There was no effect of testing condition or eating pattern on the rating of hunger either before or after the meal. Also, there was no effect of testing condition on the desire to eat or on the estimation of prospective intake before the meal. However, the decelerated eaters rated their desire to eat and their prospective intake higher than the linear eaters in all conditions. For a statistical analysis of these results, see Table 2 in the Appendix.

Both decelerated and linear eaters rated their nausea as low before the meals. However, the decelerated eaters estimated their nausea much higher after eating a short meal (5.6 (3.2–8.2)) and after eating at an increased rate (4.2 (1.9–6.5)) compared to the control condition (1.1 (0.5–2.4)) [$t(16)=11.6$, $p<0.01$ and $t(16)=8.6$, $p<0.01$, respectively], but there were no significant differences in the rating of nausea after the meal in the other conditions. There were no effects on the ratings of other aspects of mood such as happy, relaxed and restless (Table 2 in the Appendix).

3.4. Restrained eating

Decelerated eaters scored significantly lower on restrained eating than the linear eaters (1.5 (0.9–3.1) vs. 3.0 (2.2–4.1)) [$t(45)=-7.55$, $p<0.001$], but had about the same score on the external (3.2 (1.5–4.0) vs. 3.5 (2.1–4.3)) [$t(45)=-1.63$, *ns*] and emotional (2.9 (2.2–3.6) vs. 3.1 (1.8.4.2)) [$t(45)=-0.52$, *ns*] scale as the linear eaters.

The rate of deceleration in the control test, not outcome on the DEBQ scales, correlated with food intake in the experimental conditions (Table 3 in the Appendix).

3.5. Reproducibility

Eating behavior and satiety showed relatively little intra-subject variability in repeated tests (Table 4 in the Appendix).

4. Discussion

The data on cumulative food intake in the women in this study fitted a quadratic curve as described before [2,3]. This pattern is very stable from test to test [present data, 3,4,16,17]. However, while a "quadratic curve adequately describes the cumulative food intake in man" [2,3], it obviously does not predict intake beyond the duration of the meal; a positive quadratic term indicates that intake escalates over time and a negative term indicates that intake declines over time. The model has a time constraint; it describes intake within, but not beyond meals.

Based on their pattern of eating, the women in this study were divided into decelerated and linear eaters, as has been described before [3,4]. There was no overlap between the two groups; the change in the slope of the quadratic curve over time was virtually = 0 in 30 women and it was <−1 in 17. The cumulative food intake, however, did not differ between decelerated and linear eaters and although the

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duration of the meal was somewhat longer among the linear eaters, the difference was not statistically significant. These results suggest that food intake cannot be related to e.g., the rate of deceleration of the quadratic curve of food intake in women tested under the present conditions.

Thus, linear eaters eat at an initially lower rate than decelerated eaters. However, we found that they are able to eat more food at a higher rate. By contrast, decelerated eaters have difficulty in increasing their rate of eating, most likely because they eat at an initially high rate. Thus, they were often notified "you are eating too slow" when eating at an increased rate and their rating of nausea increased markedly after that meal. Interestingly, reducing the rate of eating caused a decrease in intake in the linear eaters but did not affect intake among the decelerated eaters. Taking pauses during the meal increased eating rate among linear eaters if the pauses were excluded in the calculation of eating rate and this experimental procedure also made them eat more food confirming a previous report [12]. However, this manipulation had no effect on intake in the decelerated eaters. These results suggest therefore, that as the rate of eating is dissociated from its baseline pattern, linear eaters are less able than decelerated eaters to monitor their intake.

Previous research has tested the hypothesis that a reduction of eating rate decreases food intake and it has been suggested that this intervention therefore can be used to treat obesity [10]. However, this research has yielded inconsistent results [10]. The results presented here suggest that manipulation of eating rate affects intake mainly in normal weight women who eat at a constant rate, i.e., linear eaters. If the rate of food intake is a risk factor for e.g., obesity [10], it follows that a linear rate of eating may be the important factor. However, the distinction between decelerated and linear eaters has not been made in previous studies and it remains to be determined if it is useful in other groups of people, such as men and, indeed, the obese.

The estimated level of satiety by the end of the meal did not differ markedly between the decelerated and linear eaters with the exception that the linear eaters experienced a lower level of satiety when the meal was not manipulated despite the similarity in the amount of food eaten and the duration of the meal. Although linear eaters ate more food when they ate a short meal or at an increased rate, their estimation of satiety did not increase. Interestingly, when the linear eaters ate at a reduced rate, they ate less food yet their estimation of satiety increased. Thus, the synchrony between intake and satiety is disrupted when linear eaters eat at a rate that differs from their baseline eating rate. Interrupting the meal caused a parallel increase in food intake and the estimation of satiety in the linear eaters. Eating rate was somewhat increased in this experimental condition and the increase in intake is therefore in line with the finding that intake increased when the eating rate was experimentally increased.

Relatively little information is available on the cumulative satiety curve in humans [4,8,9,18,19]. The rating scale [11] used in the present study yielded results similar to those previously reported using a VAS [4,8,9]. In the absence of direct information on the "data-generating mechanism" of satiety, we used a simple model to represent that "mechanism" [20; for a discussion of some of the factors known to influence ratings during the meal see Ref. [21]]. Thus, a two-parameter sigmoid curve described the cumulative satiety data well in all experimental conditions and yielded only little random variability as evidenced by the high square correlations. Also, repeated testing of 30 subjects showed that the rating of satiety is stable from test to test confirming the reliability of the present method. These results suggest that the methods described here can be used for the simultaneous measurement of food intake and the development of satiety.

The cumulative satiety curve differed between the decelerated and linear eaters mainly in that the estimation of satiety leveled off by the end of the meal in the decelerated eaters but not in the linear eaters. It has previously been reported that the shape of the cumulative satiety curve and the shape of the cumulative intake curve are maintained in decelerated eaters when intake is changed as a consequence of ingestion of an appetizer before the meal [9]. The results reported here extend these data by showing that the sigmoid model described the cumulative satiety curve well under a variety of conditions in both decelerated and linear eaters; the main difference is that the curve levels off by the end of the meal in decelerated eaters because their rate of eating decreases continuously during the meal. When the rate of eating was experimentally decreased, the inflection point of the sigmoid satiety curve emerged also among the linear eaters and their estimation of satiety reached the level that the decelerated eaters displayed when eating with no constraints. However, it is as yet not possible to relate the sigmoid cumulative satiety curve to a physiological variable, and this may be particularly important among the linear eaters. They eat at the same rate throughout the meal and while they rate their level of satiety as increasing only slowly in the beginning, their rating of satiety increases throughout the rest of the meal without leveling off by the end [4,8,9, present data]. These observations raise the question of what causes the linear eaters to stop eating.

The shape of the cumulative intake curve is only little affected by the physiological manipulations so far tested and it has therefore been suggested that cognitive factors play a more important role than physiological factors in determining eating rate [reviewed in Ref. [6]]. This hypothesis should perhaps be modified because cognitive factors, of course, are not emancipated from physiological context, although that context has not yet been determined. However, instead of exploring the physiology of cognitive factors, a considerable amount of research has been devoted to studying the influence of one of these factors, restrained eating, on food intake and many questionnaires have been developed to measure this factor [13,22,23].

The postulated cognitive control over eating in restrained eaters can be disrupted by e.g., dysphoric emotions, caloric preload, alcohol or the availability of appetizing foods, which results in overeating; a phenomenon referred to as "disinhibition" [5]. We suggest that the increase and decrease in food intake among linear eaters observed in the present study when the rate of eating was experimentally increased and decreased are also measures of disinhibition. Linear eaters showed additional signs of restrained eating. Thus, they estimated their desire to eat before meals as lower than the decelerated eaters, they estimated that they would eat less food during the meal and they scored higher on the scale of restrained eating in the DEBQ. However, while the rate of deceleration correlated with the cumulative food intake, the DEBQ scores did not and because we selected subjects according to their pattern of eating rather than on their score on the DEBQ scale, our results raise the question of cause and effect between the pattern of eating and restrained eating. It has been suggested that restrained eaters are also linear eaters [4], but we suggest that the causal relationship may very well be in the other direction, i.e., eating at a constant rate may cause cognitive change. We address this question further in the accompanying paper [24].

Disinhibition, and by inference restrained eating is thought to be a cause for obesity, binge eating and bulimia nervosa [25,26]; restrained eating has also been associated with anorexia nervosa [27,28]. Our observations that linear eaters ate more food but did not increase their rating of satiety when eating at a higher than normal rate and less food yet rated the satiety as higher when eating at a decreased rate are in line with these suggestions. However, further research has yielded inconsistent results of the relationships between restrained eating as measured by the available questionnaires and the different eating disorders, including the effect of disinhibition [6,28–37]. We hypothesize that replacing the cognitive construct of restrained eating with the behavioral measure of linear eating may resolve this issue.

The ratio between linear and decelerated eaters found in the present study (30/17) was unexpectedly high if compared to what would be expected to occur by chance (23.5/23.5, $Chi^2=3.6$, $p=0.058$). We suggest that this reflects the possibility that many women are at risk of

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developing disordered eating, including overeating yet showing no increase in satiety when eating at a high rate and undereating yet showing an increase in satiety when eating at a low rate, i.e., patterns possibly associated with obesity and anorexia nervosa, respectively. We have presented evidence that the pattern of eating, rather than body weight, is an important determinant of cognitive state [38]. Here we add the hypothesis that the decelerated rate of eating is a default setting that protects the individual from the effects of disinhibition.

Our results generate the hypothesis that teaching women to eat at a decelerated rate might induce resistance to disinhibition, thereby reducing the risk of eating e.g., too much food when challenged to eat at a higher than normal rate. We have tested this hypothesis in the accompanying paper [24]. Also, we are already teaching patients with anorexia and bulimia nervosa [39] and obesity [40] to resume normal eating behavior using the methods presented in this paper. However, previous studies have produced conflicting data on the relationship between eating pattern and e.g., obesity [41] and so the details of the best way of eating among clinical populations need to be further researched. In addition, the clinical importance of the effects of eating pattern on the rating of satiety associated with an increase or decrease in the rate of eating remains to be examined.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.physbeh.2008.10.011.

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