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The effect of real-time vibrotactile feedback delivered through an augmented fork on eating rate, satiation, and food intake

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ABSTRACT

Eating rate is a basic determinant of appetite regulation, as people who eat more slowly feel sated earlier and eat less. Without assistance, eating rate is difficult to modify due to its automatic nature. In the current study, participants used an augmented fork that aimed to decelerate their rate of eating. A total of 114 participants were randomly assigned to the Feedback Condition (FC), in which they received vibrotactile feedback from their fork when eating too fast (i.e., taking more than one bite per 10 s), or a Non-Feedback Condition (NFC). Participants in the FC took fewer bites per minute than did those in the NFC. Participants in the FC also had a higher success ratio, indicating that they had significantly more bites outside the designated time interval of 10 s than did participants in the NFC. A slower eating rate, however, did not lead to a significant reduction in the amount of food consumed or level of satiation. These findings indicate that real-time vibrotactile feedback delivered through an augmented fork is capable of reducing eating rate, but there is no evidence from this study that this reduction in eating rate is translated into an increase in satiation or reduction in food consumption. Overall, this study shows that real-time vibrotactile feedback may be a viable tool in interventions that aim to reduce eating rate. The long-term effectiveness of this form of feedback on satiation and food consumption, however, awaits further investigation.

1. Introduction

The worldwide prevalence of overweight and obesity are cause for concern (Finucane et al., 2011). A promising means to combat overweight may lie in reducing eating rate (Martin et al., 2007; Robinson et al., 2014). People who eat quickly tend to consume more than slower eaters (De Graaf & Kok, 2010; Robinson et al., 2014; Viskaal-Van Dongen, Kok, & De Graaf, 2011) and feel less sated after a meal (Rolls, 2007; Zijlstra, De Wijk, Mars, Stafleu, & De Graaf, 2009). Moreover, there is a cross-sectional association between eating rate and obesity; people who eat at a faster rate are more likely to be overweight or obese (Ohkuma et al., 2015; Otsuka et al., 2006; Tanihara et al., 2011).

Eating rate may influence satiation levels and energy intake through a number of mechanisms. When people eat slowly, this influences the secretion of satiety hormones such as insulin and glucagon-like peptide 1 (Cassady, Hollis, Fulford, Considine, & Mattes, 2009; Kokkinos et al., 2010). Slower eating also increases food oral exposure (Weijzen, Smeets, & De Graaf, 2009; Bolhuis, Lakemond, De Wijk, Luning, & De Graaf, 2011) and the number of chews per unit of food (Bolhuis, Lakemond, De Wijk, Luning, & De Graaf, 2013; 2014), which have both been shown to lower energy intake (Bolhuis et al., 2013; 2014; Weijzen et al., 2009).

Finally, slower eating may decrease feelings of deprivation by enhancing and prolonging pleasurable aspects of eating (Brownell, 2000).

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One barrier to changing eating rate is that it may be a highly automatic behavior, making eating rate difficult to change (Wilson, 2002). However, recent research suggests that real-time feedback can interrupt the execution of deeply engrained habitual behaviors and make them available for conscious scrutiny and behavior change (Hermsen, Frost, Renes, & Kerkhof, 2016). Furthermore, feedback is known to have motivational consequences, giving higher priority to the behavior that is the target of the feedback (Northcraft, Schmidt, & Ashford, 2011).

In the case of eating rate, visual and auditory mealtime feedback has been used to give eaters feedback on how much and at what rate to eat during a meal (Zandian, Ioakimidis, Bergh, Brodin, & Sodersten, 2009). This method has been found to be effective in reducing food intake and promoting weight loss, both in clinical as well as non-clinical contexts (Ford et al., 2010; Ioakimidis, Zandian, Bergh, & Södersten, 2009; Zandian et al., 2009). A potential limitation of this type of feedback, however, could be that it can be too cumbersome or artificial to use in real-life eating contexts. Real-time vibrotactile feedback, the presentation of simple vibrations as a means of conveying alerts or information (Hoggan, Crossan, Brewster, & Kaaresoja, 2009; Qian, Kuber, & Sears, 2013) may present a viable alternative to visual and auditory mealtime feedback on eating rate. Vibrotactile feedback can provide straightforward real-time signals with little disruption to the visual and auditory channels (Hale & Stanney, 2004; Sigrist, Rauter, Riener, & Wolf, 2013). This form of feedback has been shown to improve motor skill acquisition (Spelzeman, Jacobs, Hilgers, & Borchers, 2009; Van Erp, Saturday, & Jansen, 2006), rehabilitation and posture control (Alahakone, Senanayake, & Arosha, 2009; 2010), and navigation and way finding (Heuten, Henze, Boll, & Pielot, 2008; Van Erp & Van Veen, 2004). Real-time feedback may also raise awareness about one's speed of eating without interrupting conversations or other pleasurable aspects of a meal. By doing so, this method may be more easily applied to reduce people's eating rate within real-world eating environments. However, little is known about the utility of real-time vibrotactile feedback to modify eating rate.

This study therefore set out to assess the effect of real-time vibrotactile feedback on eating rate, satiation, and ad-libitum food intake. In the present study, we used an augmented fork that contains sensors and actuators that provides people with vibrotactile feedback when they are eating too fast. Specifically, the fork delivers real-time feedback at 10 s intervals between bites. If users take a bite too quickly (i.e., before the end of the 10 s interval), they feel a gentle vibration in the handle of the fork. Although previous research indicates that the fork is perceived as a comfortable, accurate, and effective method to decelerate eating rate (Hermsen et al., 2016), it is still unclear whether vibrotactile feedback affects users' subsequent eating behavior. To examine this question, we conducted an experiment in which the real-time vibrotactile feedback of the fork was manipulated (i.e., vibrotactile feedback versus no feedback). First, we hypothesized that participants who received real-time vibrotactile feedback would decelerate their eating rate, conceptualized as eating fewer bites per minute and eating more bites outside the designated 10s time interval, compared to those who did not receive feedback. Second, we hypothesized that changes in eating rate would lead to increased satiation and decreased ad-libitum food consumption.

2. Materials and methods

2.1. Experimental design and stimulus materials

An experimental design with a single between-subjects factor (vibrotactile feedback versus no-vibrotactile feedback) was used. To provide participants with real-time feedback while eating, we used the 10sFork (SlowControl, Paris, France). This fork contains sensors to measure eating rate and actuators to deliver vibrotactile feedback when the user eats too quickly. In the Feedback Condition (FC), participants ate a lunch meal with the augmented fork. If participants took a bite too quickly (i.e., before the end of a pre-set 10 s time interval between bites), they felt a gentle vibration in the handle of the fork and saw a red indicator light. Pre-tests showed that this 10s bite speed slows down fast eaters, without making it too difficult for them to finish their meal (Hermsen et al., 2016). In the No-Vibrotactile Feedback Condition (NFC), participants ate the same lunch meal with the same augmented fork, but did not receive any feedback regarding their eating rate. Participants were randomly assigned to either the FC or NFC condition. The size, weight and design of the augmented fork resembled a normal fork. The present study and its primary and secondary outcome measures were pre-registered in the Dutch Trial Register (NTR5237).

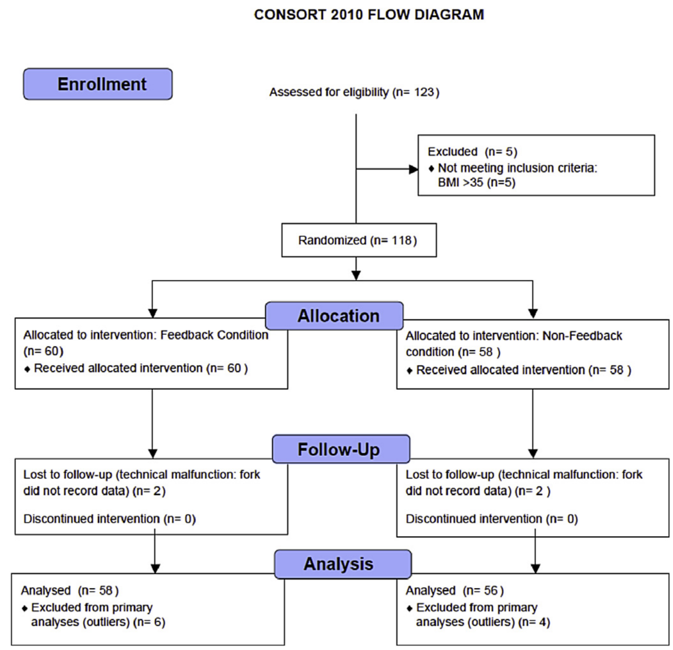

Fig. 1. Consort flow diagram of this study.

2.2. Participants

To be able to detect a medium effect size, with a power of 0.80 and a significance level of 0.05, 64 participants in each experimental condition were required. Therefore, we aimed to recruit 128 participants. Due to practical constraints, the total sample that was recruited consisted of 123 participants, of which 63% were female ($n = 77$). Participants were mainly undergraduate or graduate students at Radboud University (63%), or non-students, e.g. employees of the university or other institutions and companies (37%). Five participants were excluded before testing because of BMI scores (BMI: $kg/m^2 = >35$) that did not comply with our inclusion criteria. Four participants were excluded after testing because their fork data showed severe inconsistencies (e.g., one participant appeared to have consumed 296 g in only 30 s).[2] Therefore, the final sample consisted of 114 participants (70 female, 44 male) (see Fig. 1

[2] NB: Exclusion of these nine participants did not impact the significance and direction of the effects found in the present study.