Self-monitoring of eating rhythm with smartphone application reduces the number of daily consumed meals in adults

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Introduction

Eating rhythm is an integral part of healthy eating. A regular eating pattern including breakfast, lunch, dinner and 1-2 snacks has been found to be associated with good diet quality [1] while skipping breakfast has been consistently found to associate with poor overall diet quality and exposure to weight gain [2,3]. Irregular eating has been recently associated with various adverse health effects [4] as it may complicate weight regulation via hindered circadian system [5]. In addition, eating less than three times a day influences negatively appetite control, and unplanned snacking and consumption of the major part of the energy at the end of the day seems unfavourable for weight balance [6,7]. A recent review has also found irregular eating habits to be associated with increased risk of metabolic syndrome and cardiometabolic risk factors [8].

Alarmingly, reports from different parts of the world suggest that irregular eating is becoming more common. Irregular eating patterns that manifest as a tendency to skip conventional meals (‘unsynchronized eating patterns’) have increased in Nordic countries; approximately one fifth of Danish, Finnish, Norwegian and Swedish people have been found to possess unsynchronized eating pattern during weekdays and about one third during weekends [9]. The prevalence is specifically high among young and singles. Similarly, a meal pattern with obscured meal times has been found to be more common in young German adults than in older adults [10]. Irregular eating patterns and vast differences between weekdays and weekends have been observed also in US adults; breakfast-lunch-dinner pattern has been found to be largely absent and fasting period (night fast) relatively short [11]. In addition, snacking has increased [12]. Moreover, approximately one fourth of Australian adults have been found to follow a “grazing” pattern where there are no clear meal times but frequent peaks of eating occasions during the day [13]. Therefore, actions are needed to change the course towards more regular, health-supporting eating rhythm.

Changing habits requires well-developed self-regulation, which in turn is enabled by self-monitoring and self-evaluation of progress [14]. Self-monitoring, which assists individuals to
become aware of their current behaviour, has been successfully applied in weight loss interventions using both traditional methods as well as self-monitoring with mobile applications [15]. Moreover, adherence to weight management intervention has been found to be better with smartphone based intervention compared to website or paper food diary based interventions [16]. An array of mobile applications related to nutrition are launched yearly and installed by millions of people [17]. Majority of the apps are food diaries that provide detailed dietary information when they are consistently filled in. However, food diaries are laborious for the user and might suffer from problems with memory and interpretation of the data. Therefore, ecological momentary assessment (EMA) where events are recorded real-time in natural environment, has been suggested as a tool also for nutrition research to collect more accurate information about dietary behaviour and underlying reasons for the behaviours [18]. EMA builds picture of an individual’s habits by recording multiple days. For example, EMA was recently used to evaluate how fasting influences disordered eating behaviours [19]. These approaches could be applied also in the context of self-monitoring of eating rhythm, offering a possibility to direct users’ attention to own eating behaviour and push them towards positive behavioural changes with low burden to the user.

The aim of the study was to explore the influence of self-monitoring of daily eating pattern with EMA mobile application on eating rhythm, awareness of one’s eating behaviour, and underlying motives and attitudes related to eating. A further aim was to study whether one of the two application versions (healthy-unhealthy dichotomy or content-discontent dichotomy) is more influential.

Methods

EMA mobile application development

A mobile application “Button” was developed for this study to monitor eating rhythm. The Button consists of two components: the desktop widget and the actual application. The user presses one of the two buttons reflecting different types of eating occasions (healthy or unhealthy / content or...
discontent) in the Button widget after each eating occasion to record the timestamp and type of the eating occasion. The Button application visualizes the user’s eating pattern with three summary screens (Figure 1). The data on the user’s eating occasions is automatically transferred to a research database, where user data is protected using identification codes and encryption. The application frontend was implemented for Android mobile devices using Java, while the server backend utilizes Spring framework.

Figure 1 The Button widget with green and yellow buttons (circled) on mobile phone desktop (a) and visual summaries shown in the Button application (b-d). The user presses either green (content with eating occasion) or yellow (discontent with eating occasion) button of the widget after every eating occasion. The first visualization (b) in the application shows the eating occasions during the past seven days (weekdays on x-axis, time on y-axis), the second screen (c) shows the average interval between eating occasions per day during the past 14 days and, the third screen (d) shows the average number of eating occasions per day during the past 14 days. Green horizontal lines in c and d indicate the shortest (2 h) and longest (4 h) recommended interval between eating occasions and the smallest (3) and the highest (6) recommended number of eating occasions per day.

The application development was an iterative process including two real-life user trials in January 2017 and April 2017. The aim of the user trials was to find a feasible way to record the eating
to guarantee the technical functionality of the Button application and easiness to use.
Volunteers (trial 1: n=9 and trial 2: n=8) used the application for a two-week period which was followed by a focus group discussion about the usability aspects. The application was developed further after each trial based on the feedback obtained in focus group discussions. The participants of the first trial found it nebulous to interpret the graphs related to the optimal interval between meals and number of eating occasions per day. Therefore, green horizontal lines depicting the recommendations (2-4 h intervals between meals, 3-6 meals per day) were included in the application after the first trial. This change increased the easiness of the data interpretation in the second trial.

Two application versions

The user trial participants found colour coding in Button widget as the most feasible option to differentiate eating occasions. They also preferred the healthy (green) - unhealthy (red) dichotomy for the buttons. Considering that healthiness is not the only viewpoint when evaluating eating and food choices, also a version with content (green) - discontent (yellow) dichotomy was developed. It was considered that the possibility to make a subjective judgement about whether the eating episode is subjectively good or bad versus normative healthy-unhealthy logic, might provide the user with stronger feeling of autonomy and thus motivate the user towards healthier eating behaviour. Thus, two application versions (Healthiness version and Contentment version) were developed. “Healthiness” version had green and red buttons, the green button meaning an eating occasion that the user perceived as healthy and the red button meaning an occasion that was perceived as unhealthy. “Contentment” version had green and yellow buttons. The green button reflected an eating occasion that the user was content with and the yellow button reflected an eating occasion with what the user was not fully content. Only the meanings for the two buttons of the widget varied, but the functionalities of the two application versions were the same.
Self-monitoring study

Participants

Participants (n=74) were recruited through public advertisements, email advertisements and institutions’ intranets in two university campus areas in Finland. The participants had to be over 18 years of age and interested in well-being. In addition, an updated Android phone (Version 4.3 or newer) was a prerequisite for attendance. The volunteers with red–green colour blindness (self-reported) were excluded from the study.

The eligible volunteers were invited to the study location where the details of the study were explained and they had a chance to ask questions. After receiving both written and verbal information about the study (voluntariness, purpose, content, and confidentiality), the volunteers signed an informed consent form. The Button application was installed in the participants’ personal smartphones and they were instructed how to use the application. The participants were given four movie tickets worth of 52 euros to compensate their time and effort. Data collection was conducted in May-June 2017. The study protocol was approved by the Coordinating Research Ethics Committee of the Helsinki and Uusimaa Hospital District. The study was conducted according to the ethical principles of good research and clinical practice described in the declaration of Helsinki.

The participants were randomly distributed to Healthiness group or Contentment group. Background information about the participants is given in Table 1. The members of the Healthiness and Contentment groups were alike regarding gender distribution, age, BMI and perceived importance of new technologies. The share of participants currently working was higher in Healthiness group than in Contentment group (P=.05). There were 20 normal weight, 13 overweight and 4 obese in Healthiness group and 14 normal weight, 15 overweight and 8 obese in Contentment group.
Table 1 Background information about the participants.

<table>
<thead>
<tr>
<th></th>
<th>All participants</th>
<th>Healthiness group</th>
<th>Contentment group</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (female)</td>
<td>45 (60.8 %)</td>
<td>24 (64.9 %)</td>
<td>21 (56.8 %)</td>
<td>.48</td>
</tr>
<tr>
<td>Age (mean ± SD)</td>
<td>36.2 ± 12.5</td>
<td>35.4 ± 11.2</td>
<td>36.9 ± 13.8</td>
<td>.14</td>
</tr>
<tr>
<td>BMI, kg/m² (mean ± SD)</td>
<td>26.1 ± 4.9</td>
<td>25.5 ± 4.9</td>
<td>26.7 ± 4.8</td>
<td>.99</td>
</tr>
<tr>
<td>Working currently</td>
<td>67 (90.5 %)</td>
<td>36 (97.3 %)</td>
<td>31 (83.8 %)</td>
<td>.05</td>
</tr>
<tr>
<td>Personal importance of new technologies¹ (mean ± SD)</td>
<td>5.2 ± 1.4</td>
<td>5.1 ± 1.4</td>
<td>5.2 ± 1.3</td>
<td>.70</td>
</tr>
</tbody>
</table>

¹measured on 7-point scale in which 1=not important at all and 7=extremely important

Study design and experimental procedure

The study adopted within and between-subject design with two independent study groups using one of the two application versions (Healthiness group and Contentment group) (Figure 2).

![Study design](image)

The participants were instructed to maintain their normal eating habits and to record the eating occasions (excluding eating occasions with calorie-free drinks only) by pressing either green or red/yellow buttons after eating according to their own evaluation about the eating occasion. They were also instructed that they could freely open the Button application and observe the visual summaries of their eating rhythm and add comments. The intervention lasted for 30 days. Surveys
measuring participants’ self-reported daily meals, attitudinal constructs, food choice motives and awareness of own eating behaviour were administered prior and after the intervention period to detect potential changes caused by the Button usage.

Independent variables

Table 2 presents the independent variables that were used in the surveys and their sources. The main interest was in the changes of eating rhythm during the intervention period. Therefore the main independent variables were derived from Button data that was sent from mobile phone applications to the research database. The surveys prior (pre-survey) and after the intervention (post-survey) consisted of variables related to the eating rhythm (daily consumed meals), attitudes towards health (general health interest) and food choice related motives (health, mood, weight control). Daily consumed meals were measured by asking the respondent to mark down the meals that he/she consumes daily. The meal options included breakfast, lunch, afternoon snack, dinner or such, evening snack and five unspecified options. The number of daily consumed meals was calculated as a sum of the marked meals. The scale to measure general health interest was adopted from Roininen et al. (2001). Cronbach’s alphas for general health interest scale were acceptable (pre-survey: 0.812, post-survey: 0.804). Values higher than 0.70 have been considered sufficient (Nunnally & Bernstein, 1994). Scales to measure the three food choice motives (Health, Mood, Weight control) were adopted from Konttinen et al. (2013). All scales performed well in reliability analysis. Scale for health motive received alpha score of 0.751 in pre-survey and 0.744 in post-survey. Alphas for mood scale were acceptable as well (pre-survey: 0.800, post-survey: 0.881). Weight control scale received alpha score of 0.763 in pre-survey and 0.785 in post-survey.

Three factor eating questionnaire was administered as an indicative instrument about awareness of one’s own eating behaviour [20]. A recently modified version (TFEQ-R15) of the questionnaire was used [21]. It was considered that participants should, due to the increased attention, be able to elaborate their eating behaviour better due to the Button usage and this should be pronounced in
169TFEQ-R15 responses. All items were measured with 4-point scales. The raw scale scores were transformed to a 0–100 scale \[\text{[(raw score - lowest possible raw score)/possible raw score range] * 100} \] (De Lauzon et al., 2004). The higher raw scale scores mean greater tendency towards the measured subscale. Discontent with eating at different meal times was measured by asking the respondents to rate the frequency of discontent at different meal times (breakfast, lunch time, afternoon, dinner time, late evening or in the night, some other time) on a scale 1=never to 5=very often. Mean value for discontent in each meal time was calculated.

Post-survey included also an open-ended question about gained insights related to one’s personal eating rhythm, eating behaviour and factors affecting those. First, participants were asked if they gained insights during the intervention period. In positive case, the participant was asked to describe those insights in written.

### Table 2 Independent variables used in the study

<table>
<thead>
<tr>
<th>Category</th>
<th>Content</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Button data</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Button press data</td>
<td>Interval between eating occasions per day</td>
<td>Button application</td>
</tr>
<tr>
<td>Button press data</td>
<td>Number of eating occasions per day</td>
<td>Button application</td>
</tr>
<tr>
<td>Adherence</td>
<td>Application opening per day to observe visual summaries about eating rhythm</td>
<td>Button application</td>
</tr>
<tr>
<td><strong>Survey data</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eating rhythm</td>
<td>Daily consumed meals</td>
<td>List of meals types</td>
</tr>
<tr>
<td></td>
<td>General Health interest (scale: 1=completely disagree, 7=completely agree)</td>
<td>[22]</td>
</tr>
<tr>
<td>Attitudes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food related motives</td>
<td>Food Choice motives regarding Health, Mood, Weight control (sub scales of Food Choice Questionnaire (scale: 1=not important at all, 4=very important)</td>
<td>[23]</td>
</tr>
<tr>
<td>Awareness about eating behaviour</td>
<td>Three Factor Eating Questionnaire (R-15) (scale: 1 to 4)</td>
<td>[20,21]</td>
</tr>
<tr>
<td></td>
<td>Discontent with eating in different meal times (scale: 1=never, 5=very</td>
<td>(modified from [21])</td>
</tr>
</tbody>
</table>
**Data analysis**

The collected Button data was pre-processed to screen out faulty data and to prepare it for the actual analysis. Records deemed as duplicate values (more than one timestamp within five minutes) were removed, and timestamp values were converted from server time to actual local time. To determine the actual number of eating occasions per day, it was decided that the day begins and ends at 4 AM instead of midnight, and the data was handled accordingly. Before the analysis, data was treated in the following manner: 1) For the evaluation of the changes in eating rhythm, the 30 day intervention period was divided into three 10 day periods, 2) Those participants (n=15) were removed from the data who had more than four days per one of the three 10 day periods without any stamps, 3) All days with less than average of 1000 seconds (<17 minutes) interval between the meals were removed (197/1770 days, 11%) as this was considered as an indication of multiple miss-presses or technical flaw, also evident outlier days with only one or two stamps per day were removed, 4) After suspicious data was removed, an average was calculated for each participant for each 10 days period and the average was applied for the days with missing data.

IBM SPSS Statistics 24 was used for the statistical analysis. Repeated measures ANOVA was used to analyse the within-group changes in eating rhythm (interval between meals, number of eating occasions) and in opening the application of the participants having valid Button application data (n=59). Independent samples t-test was carried out to study between-group differences in data derived from Button application (eating rhythm, adherence and Button presses). The survey data analyses were conducted for all the participants (n=74) and separately for the sub groups. Also the participants with no acceptable Button data were included in these analyses since they all had exposed to Button usage at least to some extent during the entire 30 days period. Therefore the survey data from the participants with valid Button data and those with no valid Button data were deemed comparable. Paired samples t-tests were conducted to analyse within-group changes in
206 these variables after the intervention from the situation prior the intervention among all the
207 participants and among subgroups. Independent samples t-tests were conducted to analyse
208 between-group differences in self-reported number of daily meals, awareness of eating behaviour
209 (TFEQ-R15), discontent with eating habits and general health interest.

Responses to the open-ended question about insights gained during the intervention period were
analysed following the standard content analysis procedures. Reported individual insights were
categorized based on their content in appropriate higher-order sub-categories and finally in main
categories.

Results

Eating rhythm

The average interval between eating occasions (based on data derived from Button application
recordings) was 96 ± 24 min in all participants during the first ten days of intervention and it
increased to 109.1 ± 36.4 min (P=.003) during the last 10 days of the intervention (Figure 3). This
was mainly due to the increased interval between eating occasions in Healthiness group (99.0 ± 24
min in the first 10 days, 115.4 ± 42.6 min in the last 10 days (P=.01)). The average interval between
eating occasions did not vary in Contentment group. Between-group analyses revealed no
significant differences in any of the periods (Period 1: P=.46; Period 2: P=0.54; Period 3: P=.19).
Figure 3 Average intervals between eating occasions (mean ± SD) in the three periods (Period 1 = days 1-10, Period 2 = days 11-20, Period 3 = days 21-30) in a) all participants (n=59) and members of b) Healthiness group (n=29) and c) Contentment group (n=30). Different superscript letters indicate a statistically significant difference between study periods.

In the pre-survey, participants reported to consume approximately 4.5 ± 0.9 meals a day (Figure 4). There were no differences between the groups (Healthiness group 4.6 ± 0.8; Contentment group 4.4 ± 1.0, \( P=.51 \)). The number of the reported daily meals was significantly lower after the intervention in all participants (4.2 ± 1.0 meals, \( P=.01 \)) and again mainly caused by the change in Healthiness group (4.2 ± 1.1 meals, \( P=.04 \)). The number of daily meals after the intervention was 4.2 ± 0.9
234(P=0.17) in Contentment group. There were no statistical differences in the number of daily meals between the groups after the intervention (P=0.35).

Figure 4 Number of reported meals (breakfast, lunch, afternoon snack, dinner, evening snack, and other snacks) per day (mean ± SD) prior and after the intervention in a) all participants (n=74) and members of b) Healthiness group (n=37) and c) Contentment group (n=37).

The number of reported eating occasions (Button recordings) reduced during the four week intervention from 4.9 ± 0.9 (Period 1) to 4.4 ± 0.9 (Period 3) (Figure 5). The trend was similar in both Healthiness group and Contentment group, and they did not differ from each other (Period 1: P=.57; Period 2: P=.59; Period 3: P=.93). On average 77 % of the eating occasions of the
Healthiness group were classified as “healthy” and 86 % of the eating occasions of the Contentment group were classified as “content”.

Figure 5 Average number of reported eating occasions per day (mean ± SD) in the three periods (Period 1 = days 1-10, Period 2 = days 11-20, Period 3 = days 21-30) in a) all participants (n=59) and members of b) Healthiness group (n=29) and c) Contentment group (n=30). Different superscript letters indicate a statistically significant difference between study periods.

Adherence to use the application and awareness of eating behaviour

The participants opened the application to observe the visual summaries about their eating rhythm during the test periods on average 2.6 ± 1.2 (period 1); 2.2 ± 1.4 (period 2) and 1.8 ± 1.3 (period 3) times per day (Figure 6). The number of openings decreased from period 1 to 2 and from period 2 to 3 (P<.001). Between-group analysis showed no significant differences between the groups (Period 1: P=.16; Period 2: P=.29; Period 3: P=.28).
Figure 6 Adherence to usage of the Button application. The average number of times the application was opened per day during the three periods in a) all participants (n=59) and members of b) Healthiness (n=29) group and c) Contentment group (n=30).

The members of Healthiness group had higher tendency for cognitive restraint than members of Contentment group prior the intervention ($P = .001$). There were no differences between groups regarding uncontrolled eating or emotional eating prior the intervention ($P = .46$ and $P = .23$, respectively). The reported tendencies of emotional eating, uncontrolled eating and cognitive restraint were higher after the intervention than prior the intervention in the both intervention groups (Table 3). The changes were statistically significant except that of uncontrolled eating among the members of Healthiness group. The members of Healthiness group had higher tendency for cognitive restraint than members of Contentment group also after the intervention ($P = .04$) while there were no differences between the groups regarding uncontrolled eating or emotional eating ($P = .25$ and $P = .69$, respectively).
Table 3 Participants’ (all participants and subgroups) responses to Three Factor Eating Questionnaire (R15) (mean ± SD) prior the intervention and after the intervention.

<table>
<thead>
<tr>
<th></th>
<th>All participants mean ± SD (n=74)</th>
<th>Healthiness group mean ± SD (n=37)</th>
<th>Contentment group mean ± SD (n=37)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prior</td>
<td>After</td>
<td>Prior</td>
</tr>
<tr>
<td>Cognitive restraint</td>
<td>29.1 ± 37.4 ± .001</td>
<td>29.7 ± 37.2 ± 24.2 .03</td>
<td>28.6 ± 37.5 ± 17.3 .01</td>
</tr>
<tr>
<td>Uncontrolled eating</td>
<td>24.5 ± 28.7 ± .002</td>
<td>25.2 ± 27.9 ± 12.3 .08</td>
<td>23.9 ± 29.5 ± 14.9 .001</td>
</tr>
<tr>
<td>Emotional eating</td>
<td>13.2 ± 29.7 ± &lt;.001</td>
<td>18.3 ± 27.6 ± 26.8 .001</td>
<td>23.5 ± 31.8 ± 24.7 .01</td>
</tr>
</tbody>
</table>

The participants were asked to evaluate how often they were discontent with their eating habits (1=never to 5=very often) and the average value for discontent was calculated for each meal time. In general, the participants were content with their eating habits (1.6–2.8) (Table 4). The two groups did not differ regarding the frequency of discontent prior the intervention ($P=.34$; $P=.77$; $P=.61$; $P=.49$; $P=.82$; and $P=0.78$ during breakfast time, lunch time, afternoon, dinner time, late evening or in the night, or some other time, respectively. More frequent discontent with eating habits during lunch time was reported after the intervention than prior the intervention among all participants and among the members of Healthiness group. Healthiness group reported more frequent discontent during dinner time after the intervention compared to Contentment group ($P=.04$). There were no other differences between the groups after the intervention ($P=.19$; $P=.07$; $P=.72$; $P=.51$; $P=.48$ during breakfast time, lunch time, afternoon, late evening / night and some other time, respectively).

Table 4 Participants’ (all participants and subgroups) evaluated discontent with their eating habits (scale 1–5) (mean ± SD) in different meal times prior and after the intervention.

<table>
<thead>
<tr>
<th></th>
<th>All participants mean ± SD (n=74)</th>
<th>Healthiness group mean ± SD (n=37)</th>
<th>Contentment group mean ± SD (n=37)</th>
</tr>
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<tbody>
<tr>
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<td>18.3 ± 27.6 ± 26.8 .001</td>
<td>23.5 ± 31.8 ± 24.7 .01</td>
</tr>
</tbody>
</table>
The participants reported that they had obtained insights about their eating behaviour during the intervention period. These were related to eating rhythm, variation in eating rhythm and healthiness of eating habits (Table 5).
Table 5 Examples of comments (in italics) of the participants after Button usage in three main categories: Eating rhythm, Variation in eating rhythm and Healthiness of eating habits, and their sub categories.

<table>
<thead>
<tr>
<th>Main category</th>
<th>Sub categories and examples of comments (in italics)</th>
</tr>
</thead>
</table>
| Eating rhythm                 | • Observations on eating rhythm in relation to own preconceptions  
  “My eating rhythm was surprisingly regular even though I felt that I eat very irregularly”  
  • Attention paid and observations made on one’s own eating rhythm  
  “Irregularity of my eating rhythm was shaped”  
  • Observation of a relationship between eating rhythm, food choices and wellbeing  
  ”Regular eating maintains blood glucose levels (which I already knew) and I was more alert during the day (which I finally experienced concretely)”  
  • Recognition of a need to change eating rhythm  
  “I am planning to reduce snacking”                                                                                                                                           |
| Variation in eating rhythm    | • Observation of variation in eating rhythm due to day of the week  
  “Eating rhythm is more irregular in weekends”  
  • Observation of variation in eating rhythm due to time of the day  
  “I noticed that often during forenoon my eating rhythm is regular. Often, towards evening I either forget to eat or increase eating, depending on the day”  
  • Observation of variation due to external factors  
  ”There are workdays and travels during which I cannot ensure short enough gaps between meals without planning.”                                                                 |
| Healthiness of eating habits  | • Observation of healthiness of one’s own eating habits  
  ”In many days I eat some unhealthy snack”  
  • Recognition of a need to improve eating habits  
  ”I decided not to buy some ice cream and candy when I still saw the last red mark on the screen”                                                                 |

300Attitudes and motives
301The measured attitudes towards health (General Health Interest) did not differ between the groups prior the intervention (Healthiness group 4.9 ± 1.0; Contentment group 5.1 ± 1.0, P=.35) and they did not change during the intervention. Among all participants, General Health Interest was 5.0 ± 0.41.0 prior the intervention and 4.9 ± 1.0 after the intervention (P=0.31). The groups did not differ regarding attitudes towards health after the intervention either (Healthiness group 4.9 ± 0.8; Contentment group 5.0 ± 1.1, P=0.15).
The groups were similar regarding motives related to food choices prior the intervention (Health: Healthiness group 3.3 ± 0.5, Contentment group 3.3 ± 0.5, \( P=.94 \); Mood: Healthiness group 3.1 ± 0.5, Contentment group 3.1 ± 0.5, \( P=.64 \); Weight Control: Healthiness group 2.4 ± 0.7, Contentment group 5.5 ± 0.5, \( P=.12 \)). Motives related to food choices remained unchanged. Means prior and after the intervention were 3.3 ± 0.4 and 3.3 ± 0.4 for Health (\( P=.83 \)), 3.1 ± 0.5 and 3.1 ± 0.6 for Mood (\( P=.21 \)) and 2.5 ± 0.6 and 2.6 ± 0.7 for Weight Control (\( P=.10 \)), respectively. No variation in food choice motives was observed in sub-groups either.

**Discussion**

Thirty days self-monitoring of eating occasions with an EMA smartphone application changed eating patterns: the average interval between meal occasions lengthened and the number of daily-consumed meals decreased. These changes were statistically significant among all the participants and among the members of Healthiness group. We construe that the awareness of eating behaviour increased since the participants reported higher tendencies of emotional eating, uncontrolled eating and cognitive restraint after the intervention than prior the intervention, and the discontent on eating slightly increased regarding eating in lunch time. Participants also reported having gained insights about eating rhythm or eating habits during the intervention period, which also supports the conception of increased awareness. The measured attitudes and motives remained unchanged.

Two versions of the Button application were developed and studied. The only difference between the versions was the logic of the two buttons (healthy-unhealthy, content-discontent), indicated by different button colours. The volunteers were randomized to these two groups and there were no differences between the groups regarding gender distribution, age or BMI. The trends for the changes in eating pattern (average interval between meals increased, number of meals per day decreased during intervention) were the same in both of these groups, but the changes were statistically significant only in Healthiness group. However, the groups did not differ after the intervention regarding eating rhythm, adherence, attitudes, motives or eating behaviour tendencies.
Healthiness group experienced slightly more frequently discontent with their eating during dinner time than Contentment group. There were no other differences in the frequency of discontent between the groups. Both of the groups classified majority of the eating occasions as “green” (healthy in Healthiness group, content in Contentment group). However, the proportion of red button presses (unhealthy) was larger than that of yellow button presses (discontent). We assume that this could have been due to that healthy-unhealthy dichotomy was likely more familiar and easier approach to evaluate eating. Therefore it might have been more effective to catch the participants’ interest to evaluate their eating habits and to motivate them to change the habits.

In both study groups, the three measured eating behaviour tendencies (emotional eating, uncontrolled eating, and cognitive restraint) were higher after the intervention compared to the situation prior the intervention. Earlier, cognitive restraint has been found to increase due to weight loss interventions [24,25] while uncontrolled eating has been found to decrease among successful dieters [25,26]. Also in a web-based weight loss program cognitive restraint increased and uncontrolled eating decreased among the participants that completed (620 out of 22800 enrolled participants) the 6 months intervention [27]. The different results of our study might be explained by the fact that our study population was not aiming to lose their weight or make other significant changes in their eating behaviour. Thus, the increase in all TFEQ-R15 measures might reflect our participants’ increased attention and awareness of their eating behaviour and thus better capabilities to evaluate their eating tendencies after the intervention period. This interpretation is supported by the open-ended responses related to insights about eating behaviour during the intervention period. Majority of the participants reported that they had paid attention to their eating habits and many of those insights were related to contrast between own prior beliefs and actual behaviour illustrated by the application. These insights might have made participants more susceptible and precise to evaluate their eating tendencies in the post-survey.
No changes were observed in the attitudes and food choice motives during the intervention period. This is not surprising as especially attitudes are difficult to be altered [28,29]. However, as attitudes are seen as predictors of behaviour [30,31], then alteration of sometimes misrepresented beliefs behind the attitudes might be a worthwhile effort. In the case of this study, the responses to the open-ended questions suggested that the use of application was able to reveal to the participants some of their misrepresented beliefs related to their eating behaviour. Although this effect was not visible in attitude and motive measurements, it could be suggested that an application with more features focusing on revealing incorrect beliefs might be powerful enough to alter even attitudes and thus result in long-lasting changes in eating behaviour.

The current study reports the results of a 30 days intervention of self-monitoring the eating rhythm. However, the lack of a control group without Button application limits the interpretation of the results. We cannot rule out the possibility of some external factors (such as season of the year) could also contribute to the observed changes in the eating rhythm. Furthermore, the charm of novelty of the application might have diminished towards the end of the intervention and therefore the ease of remembering to mark every eating occasion might have weakened. However, importantly, the reduction in the number of daily consumed meals was observed both in the survey data as well as in the data derived from the Button.

Self-monitoring of daily behaviour is one way to become more aware of behaviour, which in turn facilitates changes in behaviour [14]. There are plenty of technological solutions available for automatic real-time self-monitoring of sedentary behaviour and physical activity [32]. There is also a wide array of mobile applications available for monitoring eating (Franco et al., 2016). However, unlike many of the systems designed to monitor physical activity, majority of the applications for monitoring eating have been laborious to use and adherence does not last long (e.g. Reed et al., 2017). Often the data is filled in afterwards which causes problems in recalling. Therefore, we aimed to develop a simple ecological momentary assessment tool for monitoring real-time eating
rhythm, which would be easy to use and interpret. The system builds picture of an individual’s eating pattern. In the current study, the participants did not only record the eating occasions but also opened the Button application to observe the summaries almost twice a day even during the last 10 days of intervention. This indicates that adherence was good and the approach to monitor eating rhythm is a promising for self-monitoring of eating behaviour.

The participants of this study represented volunteers that were interested in their health. They were on average 36.2 years old. Approximately 47.3 % of the participants were normal weight, 16.5 % overweight and 16.2 % obese. The reported number of daily meals of the participants (4.5) was as recommended in the Finnish nutrition recommendations (4-5 meals per day, [33]) already prior the intervention. The participants were instructed to maintain their normal eating habits during the intervention. For these reasons, no dramatic changes were expected or aimed at. The application was easy to use and adherence was good. The current study indicated self-monitoring of eating with a simple mobile application to be a promising approach to promote regular eating patterns. The self-monitoring tool with healthy-unhealthy dichotomy was more effective to influence eating rhythm than the one with content-discontent dichotomy. In future studies, it would be interesting to test the application among consumer groups facing irregularities in their eating.

Declaration of interest: none

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