Chapter 8
A smartphone intervention targeting fruit and vegetable consumption: The efficacy of textual and auditory tailored health information tested in a randomized controlled trial
Abstract

Smartphone applications are increasingly used to deliver health interventions, which provide the opportunity to present health information via different communication modes. In a randomized controlled trial we tested the efficacy of a six-month intervention delivered via a smartphone application aimed at stimulating fruit and vegetable intake. Respondents were monthly exposed to either text-based or audio-based tailored health information and feedback. In addition, respondents in the control condition only completed the baseline and post-test measures. Perceived own health and health literacy were included as moderators to assess for which groups (one of the) interventions can possibly lead to health behavior change. It was hypothesized that the intervention would be more effective compared to the control condition, irrespective of the mode of communication. Within a community sample (N = 146; online recruitment with a response rate of 45%), a significantly higher fruit intake (self-report questionnaire after six months) was found after exposure to the auditory information, especially in recipients with a poor perceived health. In addition, a significantly higher vegetable intake was found for recipients with high health literacy after exposure to the textual or auditory intervention compared to the control condition. In case of relatively low health literacy, vegetable intake was the highest in the control condition. The current smartphone application has the potential to change fruit and vegetable intake up to six months later, at least for specific groups. Different effects for fruit and vegetable intake were reported, which suggests that different underlying psychological mechanisms are associated with these specific behaviors. In addition, it seems worthwhile to investigate additional ways to increase fruit and vegetable intake in recipients with low health literacy.

Chapter 8 is based on Elbert, S.P., Dijkstra, A., & Oenema, A. (revised resubmitted). A smartphone intervention targeting fruit and vegetable consumption: The efficacy of textual and auditory tailored health information tested in a randomized controlled trial.
A smartphone intervention targeting fruit and vegetable consumption: The efficacy of textual and auditory tailored health information tested in a randomized controlled trial

An impressive number of smartphone applications or apps related to achieving a healthy lifestyle are currently available (Dennison, Morrison, Conway, & Yardley, 2013; Kratzke & Cox, 2012). In line with this, smartphone applications have been introduced as interventions within the field of health education and promotion, for example as telemedicine technologies, providing tools for health behavior change with the use of self-monitoring or feedback (e.g., Brindal et al., 2013; Hebden, Cook, van der Ploeg, & Allman-Farinelli, 2012). To the best of our knowledge, only few apps exist that actually tested an evidence-based health intervention (i.e., Brindal et al., 2013; Glynn et al., 2014; Lee, Chae, Kim, Ho, & Choi, 2010), for example with the use of behavior change techniques (Cowan et al., 2013; Dennison et al., 2013). This means there is limited knowledge on the efficacy of smartphone applications in the process of health behavior change.

Using smartphone apps to deliver an intervention can have a variety of advantages. Besides the increased availability and accessibility of smartphones and the potential of reaching many people, it provides the opportunity to use interactive technological possibilities for persuasion that may support behavior change (Brug, Oenema, Kroeze, & Raat, 2005; Kratzke & Cox, 2012). In particular, it enables the use of different communication modes (such as text, video and audio) and the use of computer-tailoring to convey health information (Middelweerd, Mollee, van der Wal, Brug, & te Velde, 2014). That is, smartphones are in general already partly used for their MP3-function, and smartphone applications can be easily used to include and deliver auditory information, for example as integrated within a health intervention. In addition, there is some evidence that at least audio-visual tailored messages can have advantages compared to text-based tailored messages (Soetens, Vandelanotte, de Vries, & Mummery, 2014; Stanczyk et al., 2014) and at least one study suggests that audio-based information may be of added value in the stimulation of fruit and vegetable consumption (Connell, Goldberg, & Folta, 2001). Furthermore, tailoring can have beneficial effects in health interventions over providing non-tailored information, for example by increasing the relevance of the information (Dijkstra, 2005; Hawkins, Kreuter, Resnicow, Fishbein, & Dijkstra, 2008; Lustria et al., 2013; Oenema, Brug, Dijkstra, de Weerdt, & de Vries, 2008). The goal of the current study is to investigate the efficacy of
a smartphone intervention that delivers tailored persuasive information as communicated via two different communication modes: text versus audio.

The mode of communication via which the persuasive health information is delivered might affect how the information is processed. For instance, compared to textually tailored information, interactive tailored information (either video- or audio-delivered) has been found to lead to greater attention (Alley et al., 2014; Lee, 2011) and is perceived as being more salient (Chaiken & Eagly, 1983) and engaging (Lee, 2011). In addition, in processing video- and audio-delivered communication, source considerations and peripheral cues or heuristics may play a more important role (Pfau, Holbert, Zubric, Paska, & Lin, 2000). Furthermore, one study showed no significant differences between auditory and textual feedback on the recall of health-related information (Corston & Colman, 1997). Other studies found mixed results between audio-visual and textual feedback (Alley et al., 2014; Corston & Colman, 1997); audio (visual) information was not always more effective than textual feedback. Thus, concerning the communication of health-related information, no explicit conclusion can be formulated with regard to the efficacy of a specific communication mode.

The current intervention will apply and compare auditory and textual persuasive communication aimed at stimulating fruit and vegetable intake. A sufficient daily intake of fruit and vegetables contributes to the prevention of cardiovascular diseases and certain types of cancer (WHO, 2002). However, over 70% of the Dutch adult population does not meet the recommended minimum intake of fruit and this percentage is even higher for vegetable consumption (van Rossum, Fransen, Verkaik-Kloosterman, Buurma-Rethans, & Ocké, 2011). These recommendations refer to a daily consumption of two pieces of fruit and two-hundred grams of vegetables for an adult population (Netherlands Nutrition Centre, 2011). In addition, the average intake levels of fruit and vegetables seems to be decreasing over the years (van Rossum et al., 2011). Moreover, similar intake patterns and trends are identified all over the world (Murphy, Barraj, Spungen, Herman, & Randolph, 2014). Thus, the stimulation of fruit and vegetable consumption remains to be a highly important health promotion topic.

To determine which communication mode can be used to deliver the tailored health information most effectively, it is important to test this in a randomized controlled trial. In the current study, two research questions will be central. First, we aim to answer the question whether a tailored health intervention delivered via a smartphone application is able to change fruit and vegetable intake in the advocated direction. Second, the study provides a test of the possible difference in efficacy between the more classic textual mode of communication (reading) and the auditory mode of communication (listening).

With regard to the first research question, it is expected that a tailored health intervention will be more effective compared to a control condition in which no health information is given. However, this difference may not be displayed in everyone, but only
in a specific group of people. It is hypothesized that this will be especially the case in people who perceive a need to change their fruit and vegetable intake. It is reasoned that people who perceive the own health as relatively good do have a lower need to change, whereas this need is higher for people who perceive the own health as relatively poor. The intervention might fit within the need for this latter group, and therefore might be more beneficial for people who perceive the own health as relatively poor. Within the unimodel of persuasion (Kruglanski & Thompson, 1999) this could be described as a match between the persuasive information and a premise held by a person (e.g., 'I might need this information because my health is not that good), whereas this match might be lacking for people who perceive the own health as good in advance. Therefore, we will test the hypothesis that the intervention (either textual or auditory) will be more effective, especially for people who perceive the own health as relatively poor.

With regard to the second research question, it will be investigated whether the efficacy of the auditory intervention differs from the textual intervention. Again, this might not be the case for everyone. A relevant individual difference in this context is health literacy, defined as “the degree to which individuals can obtain, process, and understand the basic health information and services they need to make appropriate health decisions” (Institute of Medicine, 2004). Furthermore, health literacy is found to be related to level of education, cognitive and social skills, language and cultural barriers, and motivation (Institute of Medicine, 2004; Santo, Laizner, & Shohet, 2005) and low health literacy is associated with poorer health outcomes as well (Mõttus et al., 2014; Norman & Skinner, 2006). It seems worthwhile to consider the communication modality in combination with the construct of health literacy (Norman & Skinner, 2006). For instance, it is recommended to explore the use of auditory information as this might be especially beneficial for people with low health literacy (Santo et al., 2005). Therefore, it is expected that people with low health literacy may benefit from health information as communicated via the auditory mode, whereas no specific differences are expected for people with high health literacy.

In sum, we aim to test the efficacy of two different fruit and vegetable promotion interventions delivered via a smartphone application that communicate persuasive health information via the auditory or textual mode. The efficacy of the auditory and textual intervention will be compared to a control condition in which no intervention is present, and the textual and auditory intervention will be compared to each other. The content of the intervention is tailored to relevant characteristics of the individual: Feedback on the perceived own fruit and vegetable consumption and personalized recommendations regarding the individual barriers to eat sufficient fruit and vegetables are included. Other evidence-based behavior change strategies (Abraham & Michie, 2008) applied in this intervention to assist behavior change are listed in Table 8.1. The dependent variables are self-reported fruit intake and self-reported vegetable intake at six-month follow-up as
assessed with a detailed and validated frequency questionnaire (Bogers, van Assema, Kester, Westerterp, & Dagnelie, 2004).

Table 8.1 Overview of behavior change techniques applied in the current intervention

<table>
<thead>
<tr>
<th>Behavior change technique</th>
<th>Example</th>
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<tbody>
<tr>
<td><strong>Tailored working mechanisms</strong></td>
<td></td>
</tr>
<tr>
<td>Provide feedback on performance</td>
<td>‘You indicate that you eat sufficient fruit and vegetables, that is very positive’ (baseline message)</td>
</tr>
<tr>
<td>Adaptation of the content</td>
<td>Provide information on how to overcome personal barriers; the inclusion of information about weight management, based on dieting status (baseline message)</td>
</tr>
<tr>
<td>Preference tailoring</td>
<td>Use of preferred conversational form throughout the intervention</td>
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<tr>
<td>Testimonial matching</td>
<td>Respondents were generally exposed to a testimonial of the same gender as themselves (follow-up moments)</td>
</tr>
<tr>
<td><strong>General working mechanisms</strong></td>
<td></td>
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<tr>
<td>Provide information about behavior-health link</td>
<td>Provide general health risk information: ‘Eating sufficient fruit and vegetables contributes to a good health’ (baseline message)</td>
</tr>
<tr>
<td>Provide information on consequences</td>
<td>Provide positive outcomes of performing the behavior: ‘The vitamins, minerals and fibers in fruit and vegetables affect your health in several ways (low blood pressure, improved physical stamina and decreased risk for diseases; baseline message)</td>
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Barrier identification

‘Different aspects can play a role in eating insufficient fruit / vegetables. Of the following reasons can you list maximally two aspects that apply to you?’ (assessed at baseline)

Use of follow-up prompts

Monthly follow-up moments are created to encourage respondents to re-visit the application

Provide opportunities for social comparison

The use of testimonials (follow-up moments)

Prompt specific goal setting

Respondents are encouraged to create own implementation intentions (general application content; menu button ‘action plan’)

Repetition

Respondents can be exposed to the tailored message multiple times (general application content; menu button ‘my advice’)

Method

Recruitment. Participants were recruited in October and November 2013 to join a smartphone intervention study aimed at stimulating fruit and vegetable intake. Those interested were eligible for participation if they were 16 years or older, lived in the Netherlands and owned an Android device (smartphone or tablet, Android version 2.2 or more) with an installed version of Adobe Air (if necessary, they were automatically directed to Google Play to install it safely)\(^1\). In addition, the invitation in the recruitment was specifically aimed at people who did not (yet) succeed in consuming two pieces of fruit and 200 grams of vegetables on a daily basis. After the two-month recruitment period, interested people who signed up could not participate anymore.

\(^1\) In collaboration with the programmers, we decided to focus solely on the Android operating system, as market research shows that the majority of the Dutch smartphone users owns an Android device (TNS NIPO, 2011).
Participants were recruited via several advertising campaigns as published on newspaper and (health) magazine websites, on the local university website, in the newsletter of the Netherlands Nutrition Centre and via social networking websites. In addition, a local newspaper focused on the topic of fruit and vegetable consumption and referred to our smartphone application, the “Fruit and Vegetables hAPP” (the addition of the ‘h’ to the word ‘app’ means in Dutch ‘snack’ or ‘bite’). All advertisements briefly mentioned the content and six-month duration of the study and provided a link to the smartphone application in Google Play where respondents could find more information and download it. Respondents were not informed on the existence of research conditions. They had a chance of winning different prizes (two Android tablet computers, ten books with vegetable recipes and twenty € 10 coupons) after completing the pre-test and post-test measurements. The study was approved by the ethical committee of the local faculty of Behavioral and Social Sciences for conducting human participants research (nr. 13012-N, trial registration: ISRCTN23466915).

We estimated the number of respondents to be included. The current intervention and the comparison between auditory and textual persuasion are novel so it is hard to predict what can be expected, but we aim to find medium effects for the intervention to be of practical relevance. This means at least 64 respondents need to be included in each condition at post-test (p set on .05, power .80; Soper, n.d).

**Research design and procedure.** The current study was a pre-test – post-test randomized controlled trial with two experimental conditions (text-based tailored health information and audio-based tailored health information) and a control condition in which respondents completed only the baseline measurements and post-test measurements at six-month follow-up. Those interested could download the smartphone application in Google Play and sign up for the research via the application itself. This was done by creating a personal log-in and account with an email address and password, which was necessary to combine the data of the different measurements. In addition, the sign-up procedure consisted of questions on gender, first name and preferred conversation form. This information was used for tailoring purposes throughout the assessment and intervention. Next, respondents were presented with an informed consent form that stated the procedure, duration and confidentiality of the research. After giving informed consent in the smartphone application, respondents were automatically assigned to one of the three conditions (sequentially, in order of registration). All assessment questions (one question per screen) and the tailored health information were delivered via the smartphone application. Figure 8.1 represents an overview of the design and the different elements of the study, which will be described below.

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2 In Dutch, a formal and polite conversation form (u, uw) and a more informal conversation form can be distinguished (ijíj, jou).
Respondents in all conditions were asked to complete the pre-test measures that consisted of baseline measures and questions for tailoring purposes. Respondents in the text-based and audio-based health information condition were then exposed to a tailored message (on the basis of decision rules) and additional evaluation measures. In total, this first contact took 20 minutes on average after which these respondents had access to the general smartphone application content. Respondents in the control condition were only exposed to a message screen addressing the end of the baseline questionnaire. They were thanked for their participation and it was explicitly mentioned that they could expect another questionnaire six months later. They did not have access to the content of the smartphone application.

Those respondents who did not complete the baseline questionnaire within one month were reminded by email to fill out the questionnaire. Further reminders were sent monthly; respondents who did not complete it during the research period were excluded from the study and informed about this by email.

In the months in-between pre-test and post-test assessment, respondents in the text-based and audio-based health information condition received monthly email invitations (with a maximum of four reminders during the month). They were asked to visit the smartphone application to complete follow-up tailoring measures (identical for each month) and were exposed to newly added (either textual or auditory) tailored health information based on their input. Finally, at 6-month follow-up, all respondents were sent an email invitation to fill out the post-test measures in the smartphone application (again with a maximum of four reminders during the month). Respondents who indicated they
were interested in receiving more information were debriefed via email when the 6-month post-test had been completed. For ethical reasons, respondents could notify the researchers during the trial when they were not interested in participating anymore. After this notification, they did not receive monthly email invitations anymore, but only a final invitation to complete the post-test measures.

**Intervention.** The experimental studies as presented in the current thesis helped to shape the current intervention that was developed in the perspective of Intervention Mapping (Bartholomew, Parcel, & Kok, 1998; Bartholomew, Parcel, Kok, Gottlieb, & Fernández, 2011; Kok, Schaalma, Ruiter, van Empelen, & Brug, 2004). The intervention is based on several social-cognitive determinants that are known to predict fruit and vegetable intake (Bandura, 1998). The core determinants include outcome expectations of eating sufficient fruit and vegetables and self-efficacy with regard to being able to eat sufficient fruit and vegetables. More specifically, the intervention focused on increasing positive outcome expectations and restructuring negative outcome expectations with regard to eating sufficient fruit and vegetables, and increasing self-efficacy. Different methods are used to address these factors. For instance, to target self-efficacy we identified the respondents’ experienced barriers to eat sufficient fruit and vegetables and provided relevant information to cope with these barriers (Abraham & Michie, 2008).

The intervention consisted of one main moment of exposure to the tailored information at baseline and five follow-up moments with exposure to smaller components of tailored information. After exposure to the main tailored message right after completing the pre-test measurements, respondents had access to additional functions of the smartphone application throughout the six months. These functions were presented as seven main menu buttons (Figure 8.2a), including a button where respondents were invited to formulate a personal action plan while making use of if...then formulations (implementation intentions; Figure 8.2b), a button with an alphabetical list of fruit and vegetables (Figure 8.2c) and fruit and vegetable recipes. Four extra recipes were uploaded to the smartphone application every month. In addition, one button included the most recent tailored message, in order to make it possible to read or listen to it again (Figure 8.2d).
Figure 8.2 Screenshots of the application content: a) main menu; b) action plan; c) alphabetical list of fruit and vegetables; d) tailored auditory advice. Screenshots a, b, d are translated from Dutch ↓
During the five follow-up moments in-between the pre-test and post-test assessment, respondents were each month exposed to a new, short tailored message that approached the topic of fruit and vegetable intake from distinct perspectives. Every month, the content was related to a general topic: The effect on well-being, the availability of fruit and vegetables, fruit and vegetables as a basic physical need, the lowered risk for chronic diseases, fruit and vegetable intake as a part of a healthy lifestyle, and objections people can have regarding fruit and vegetable intake, respectively. Additionally, a unique testimonial was included each month for sharing experiences on fruit and vegetable intake with the respondents. Testimonials are constructed stories in which successful personal experiences are shared to ‘directly or indirectly encourage the audience’ to perform the behavior themselves (Braverman, 2008). For example, a physician elaborated on the relevance of a healthy diet and a non-expert (without a specified occupation) expressed the experienced benefits of fruit and vegetables on the long term. To ensure that respondents were exposed to the information from different perspectives, the follow-up content was replaced in the smartphone application at all five follow-up moments.

- **The main tailored message.** At baseline, a number of tailoring questions were included to partly determine the content of the feedback. Firstly, respondents could indicate with two questions whether their fruit and vegetable consumption is sufficient or not (perceived (subjective) consumption of fruit and vegetables, respectively), according to the recommendations. Participants could answer these questions with ‘Yes, I do meet this guideline’, ‘No, I probably do not always meet this guideline’ and ‘No, I do not meet this guideline’. The second category was added to prevent people to over report their fruit and vegetable intake; the latter two answering options both reflected ‘not meeting the guideline’.

Based on the answers given, respondents could select one or two individual barriers to eat sufficient fruit and / or vegetables from a predefined list. Respondents who indicated that they already met the guideline of eating sufficient fruit and vegetable consumption were asked to think of barriers in a future period in which they possibly would eat less fruit or / and vegetables. Examples of barriers included in the list were ‘I don’t like the taste of fruit’ or ‘It takes a lot of time and effort to prepare vegetables’ (see also Brug, Lechner, & de Vries, 1995; Springvloet, Lechner, & Oenema, 2014).

Another tailoring question concerned health value, as assessed with one item (‘How important is health to you?’). Participants could indicate whether they believed health is ‘most important to them’ [2] or not (‘It is important to me, but not the most important aspect in life’ [1]). In addition, they could indicate the perceived difference between themselves and their ideal and ought self, respectively (‘In general, how large is the difference between who you actual are and who you prefer to be / who you should be?’). A scale was created by subtracting the score on the second item from the score
on the first item; answering options ranged from ‘very small’ [1] to ‘very large’ [7]. The combination of health value and self-discrepancy determined whether the baseline message focused on the positive outcomes of sufficient fruit and vegetable consumption or on the negative outcomes of insufficient fruit and vegetable consumption (Dijkstra, Schakenraad, Menninga, Buunk, & Siero, 2009). Finally, it was assessed whether respondents were frequent dieters (with answering options never [1], sometimes [2], regularly [3], often [4], based on Lowe & Timko, 2004), and whether they had a partner relationship or not. These answers were used to decide whether or not to include information on the outcomes of (in)sufficient fruit and vegetable consumption related to weight management and appearance benefits, respectively.

Based on the answers on the above-mentioned tailoring questions, the baseline message consisted of a short general introduction providing information on the behavior - health link, feedback on the own fruit and vegetable consumption, and adapted information on the outcomes of (in)sufficient fruit and vegetable consumption with possibly, information about appearance benefits and weight management. Then, feedback regarding one or two assessed individual barriers to perform the behavior with personal recommendations and formulation of relevant individual implementation intentions (Adriaanse, Vinkers, de Ridder, Hox, & de Wit, 2011; Chapman, Armitage, & Norman, 2009; Gollwitzer & Sheeran, 2006) were included. Throughout the smartphone application, the preferred conversation form 2 was used consistently. Transition sentences and closing sentences were created to ensure that the composed message was perceived as one fluent message (see Appendix 2, QR-code 10, for an example of a composed auditory health message at baseline).

• The follow-up tailored messages. During all follow-up moments, respondents had to answer maximally four tailoring questions. First, the two questions on the current self-perceived fruit and vegetable intake were assessed again. The recommendations were included and respondents could indicate whether they met this guideline in the previous two weeks (answering options ‘Yes’ / ‘Almost’ / ‘No’; the latter two answering options were considered as ‘not meeting the guideline’). In case of insufficient self-perceived fruit and/or vegetable consumption, we additionally asked whether the respondent had the intention to increase fruit and/or vegetable consumption in the following two weeks (answering options ‘No’ / ‘A little’ / ‘Yes’; the first two options reflected ‘no intention’).

Based on the given answers, respondents were then exposed to a short (textual or auditory) feedback message that addressed a certain theme at each follow-up moment. After this, the (textual or auditory) testimonial was included that matched the respondent’s own gender, except when it was one of the three testimonials that was only recorded with either a male or a female voice. This was decided in line with general expectations; for example, a dietician was only represented by a female voice.
Respondents who already perceived their fruit and vegetable consumption as sufficient were not exposed to the thematic information, but only to a short encouraging message and testimonial.

- **Mode of delivery.** The text-based and audio-based interventions varied only in their mode of delivery. The content information was partly composed in collaboration with the Netherlands Nutrition Centre and the auditory elements were developed in collaboration with a professional recording studio. An experienced female actress was selected for recording the baseline and follow-up feedback messages. She had a gender-congruent voice (feminine and high-pitched) and neutral sound without specific cultural or disturbing elements. After recording and arrangement sessions, the tailored audio-files (233 files for the pre-test and 114 for the follow-up moments, ranging from a single sentence to a text of 200 words) were mastered in 96 kHz 24 bit and converted to mono MP3 format (64 kbps) to use in the smartphone application. As it was important that the audio files of different parts could be arranged into one fluent message (without experiencing obvious transitions between parts), it was ensured that all recordings had a similar ‘tone-of-voice’. Natural pauses between sentences lasted approximately one second; after every part, a one-second pause was created as well to create natural transitions as good as possible. After a first evaluation round, the recording studio made some improvements and once the first author approved this, the audio files could be uploaded in the intervention system by the programmers. Before listening to the baseline message, respondents in the audio-based information condition were presented with an instructive recording on volume regulation. They could adjust the smartphone volume while listening, to ascertain that it was sufficient and convenient. On the next screen, they could listen to the tailored health message. The complete message at baseline consisted on average of about 900 words (approximately five minutes for the auditory recording), roughly varying between 600 words (approximately three minutes) and 1200 words (approximately six minutes). In addition, the shorter tailored messages at follow-up consisted on average of 180 words and lasted 1:10 minutes on average for the auditory recording.

Contrary to the other auditory content, the testimonials within the follow-up moments were recorded with non-professional voices. The first author gave instructions and the testimonials were recorded in an office environment with a headphone microphone with the software program ‘Praat’ (Boersma & Weenink, 2000) and arranged with the software program ‘Audacity’ (Audacity Team, 2012). The recordings were send to the professional recording studio to make sure that the testimonials had the same quality and default volume as the remaining auditory content, again to ensure that it could be composed together. In total, 11 expert and non-expert testimonials were created, among which four were recorded twice; that is, with a male and female voice. Three testimonials were only recorded for a man or a woman. On average, the testimonials
consisted of 244 words and lasted 73 seconds. In total, an average follow-up moment lasted two to three minutes.

**Measurements • Baseline measurement.** The following socio-demographic variables were assessed: age, cultural background and highest level of completed education. This latter item was dichotomized into low (primary education, lower general secondary education, intermediate vocational education) and high level of completed education (higher general secondary education, higher vocational education, university level). Then, health-related questions were asked. The perceived own health (based on CBS, 2013) could be indicated on a six-point scale ranging from (“my health is…”) ‘very good’ [1] to ‘very bad’ [6]. This item was recoded and high scores corresponded with good perceived health ($M = 4.86$, $SD = .72$). Self-reported height and weight were assessed to calculate body mass index (BMI) and we assessed whether respondents were having a chronic disease or dyslexia. In addition, two items assessed perceived difficulty of eating sufficient fruit and sufficient vegetables as a measure of self-efficacy: “How difficult is it for you to eat sufficient fruit (vegetables)”? Both items could be answered on five-point scales (‘not difficult at all’ [1] / ‘not difficult’ [2] / ‘neutral’ [3] / ‘difficult’ [4] / ‘very difficult’ [5]). A composite measurement was created ($r = .37, p < .001$; $M = 2.47$, $SD = .95$).

Then, we assessed the self-reported fruit and vegetable consumption in the previous month with a detailed and validated food-frequency-questionnaire (Bogers et al., 2004). Respondents were asked how often on average per week they ate or drank products from several fruit and vegetable categories during the previous month. The answer options ranged from ‘never or less than 1 day a week’ [0], ‘1 day a week’ [1] to ‘every day’ [7]. Next, they were asked to indicate the amount of intake per category of fruit or vegetables in terms of pieces of fruit and servings of vegetables, with the answering options ranging from ‘none’ [0], ‘one piece’ [1] to ‘five or more pieces’ [5]. The main categories were ‘cooked vegetables’, ‘raw vegetables / salad’, ‘fruit and vegetable juice’, ‘tangerines’, ‘oranges / grapefruits / lemons’, ‘apples / pears’, ‘bananas’, ‘other fruit’ and ‘apple sauce’. The category ‘fruit and vegetable juice’ was excluded as it made us unable to distinguish between fruit and vegetables. The number of days per week and the vegetable portions were multiplied for the first two categories and added to create a composite index of average weekly vegetable intake of the previous month. The average number of days per week and the fruit portions were multiplied for the remaining six categories and added to create a composite index of weekly fruit intake of the previous month.

Finally, we assessed respondents’ health literacy with three statements that could be answered on five-point scales ranging from ‘strongly disagree’ [1] to ‘strongly agree’ [5]. The three items were: ‘I think it is easy to understand… information about health and lifestyle’ / ‘…health information given by a physician, for example about a
disease or treatment’ / ‘...information about the effects of healthy nutrition’ ($\alpha = .85$, $M = 4.23, SD = .77$).

Process evaluation questions were included immediately after respondents in one of the two experimental conditions had been exposed to the tailored health information. These items were included to assess self-reported exposure (‘Did you read / listen to the fragment?’), answering options ranging from ‘Yes, completely’ [1] to ‘No, not at all’ [5]) and potential distracting elements while reading or listening (‘Was the reading or listening possibly disrupted, for example by other people, hard sounds, music or other distracting elements?’, with answering options ‘yes’ and ‘no’). In addition, the novelty and usefulness of the information were assessed with two statements (‘The information was new to me / useful for me’) that could be answered on a five-point scale ranging from ‘strongly disagree’ [1] to ‘strongly agree’ [5]. Finally, a general evaluation question was included (‘How would you rate the intervention?’). This item could be answered on a seven-point scale ranging from ‘very negative’ [1] to ‘very positive’ [7].

Post-test measurement. At 6-month follow-up, fruit and vegetable intake was again assessed with the same questionnaire as at baseline (Bogers et al., 2004). Again, two composite measures for respectively fruit and vegetable consumption were created. In addition, it was assessed how often respondents searched for information about health and fruit and vegetables besides the information in the smartphone application ($M = 3.03$, $SD = 1.03$), and to what extent they spoke to others about the topic in the past six months ($M = 2.71$, $SD = 1.08$). Both items could be answered on five-point scales with answering options ranging from ‘never’ [1] to ‘often’ [5]. Finally, seven questions were added to evaluate the information and smartphone application as a whole on a range of measures, such as personal applicability, novelty, credibility, the extent to which it is perceived as intense, usefulness, comprehensibility and visual attractiveness. These questions could be answered on five-point scales, with answering options ranging from ‘strongly disagree’ [1] to ‘strongly agree’ [5]. In addition, one item provided recipients with the opportunity to give qualitative feedback.

Results

Sample characteristics. In total, 342 respondents registered for the study and started the pre-test measurement, of whom 96.5% completed it ($n = 330$). Of these 330 respondents, 44.5% completed the final questionnaire at six-month follow-up as well.³ One respondent was excluded because of reporting being intolerant for fruit. The final sample for the analyses consisted of 146 respondents, of whom 73% females, 71% high educated, varying in age from 16 to 71 years ($M = 41.4$, $SD = 14.6$) with a mean

³ Thirty respondents (9%) were accidentally exposed to the same information during the first two follow-up moments (for technological reasons), instead of being exposed to different content information.
BMI of 25.2 ($SD = 5.5$). Recipients with a lower education reported a lower health literacy ($M = 4.01$, $SD = .77$), compared to recipients with a high education ($M = 4.32$, $SD = .76$, $p < .05$).

The composite index of fruit and vegetable intake at pre-test was treated as an objective indication of fruit and vegetable intake. The mean fruit intake was sufficient (14 portions is considered sufficient; scale ranging from 0 to 56; $M = 14.04$, $SD = 10.63$), whereas the mean vegetable intake was insufficient (28 portions is considered sufficient; scale ranging from 6 to 70; $M = 25.44$, $SD = 11.37$). Based on the answers given, 19.2% of the respondents was classified as consuming an insufficient amount of vegetables (but a sufficient amount of fruit), 16.4% was classified as consuming an insufficient amount of fruit (but a sufficient amount of vegetables), 48.6% was classified as consuming both insufficient amounts of fruit and vegetables, and 15.8% was classified as consuming sufficient amounts of both fruit and vegetables. At post-test, the scores on the composite index of fruit and vegetable intake were somewhat higher (fruit; scale ranging from 1 to 56.5; $M = 14.93$, $SD = 9.27$ and vegetables; scale ranging from 6 to 70; $M = 27.47$, $SD = 11.81$). The respondents were distributed over the conditions as follows: Textual health information ($n = 48$); auditory health information ($n = 40$); control condition ($n = 58$). Figure 8.3 represents a flowchart in which the drop-out rates per condition are depicted.

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4 If one of the two questions was answered with zero (‘never or less than 1 day a week’ or ‘no servings’), the total intake for that specific category was automatically set at zero as well (also when the pattern was not filled in consistently). This conservative approach means that the fruit and vegetable intake might be somewhat lower than in reality. Condition did not affect whether a question on fruit or vegetable intake was filled in consistently or not at baseline ($p = .66$) or post-test ($p = .64$).
Randomization check and attrition analyses. Univariate analyses (ANOVA, Chi-square) were conducted to analyze whether the respondents in the conditions differed on relevant pre-test measures. No significant differences between conditions were found regarding our set of 18 demographic and health-related baseline variables: gender ($p = .53$), age ($p = .11$), highest completed education ($p = .35$), cultural background ($p = .75$), dieting status ($p = .09$), relationship status ($p = .41$), the extent to which health is valued ($p = .25$), discrepancy between ought and ideal self ($p = .54$), having dyslexia ($p = .94$), perceived own health status ($p = .78$), having a chronic disease ($p = .84$), BMI ($p = .30$), self-efficacy ($p = .72$), self-reported (objective) fruit consumption ($p = .79$), self-reported (objective) vegetable consumption ($p = .16$), perceived (subjective) fruit and vegetable consumption ($p = .86$ and $p = .37$, respectively), and health literacy ($p = .07$).

In addition, it was investigated whether the respondents who dropped out after baseline ($n = 184$, 53.2 %) significantly differed from the respondents who completed both measurements. The groups did not significantly differ on the same pre-test measures as mentioned in the previous paragraph ($ps > .12$). Furthermore, condition
did not significantly affect whether respondents dropped out during the trial ($p = .08$). However, respondents who completed the study and who received either the auditory or textual feedback, reported a significantly higher extent of being exposed to the information ($p < .001$) and they had a slightly more positive general impression of the pre-test intervention content and measures compared to those who dropped out ($p = .06$). Finally, when exposed to the auditory feedback, respondents who dropped out reported being distracted while listening to the baseline intervention content more often compared to those who completed the whole study, $p < .05$. No significant differences were found on the extent to which the information was perceived as new or useful.

**Effects on fruit and vegetable consumption**

- **Main effects.** In all subsequent analyses on behavior, ANCOVAs were conducted for fruit and vegetable intake separately. Self-reported fruit or vegetable intake at baseline was included as a covariate, as well as age and highest completed education, since these two variables had a large variance within this community sample. First, we assessed whether condition affected the self-reported intake of fruit and vegetables six months after baseline. With regard to fruit intake, a significant main effect was found; $F(2, 140) = 3.08, p < .05, \eta^2_p = .04$ with the following estimated means: text ($M = 13.5, SE = 1.05$), audio ($M = 17.1, SE = 1.18$) and control ($M = 14.3, SE = .95$). The difference between text and audio was significant ($p = .018$), and between audio and control it was marginally significant ($p = .064$). The difference between text and control was not significant ($p = .53$). No significant main effect was found on vegetable intake; $F(2, 140) < 1, p = .99, \eta^2_p = .00$.

For fruit consumption, the raw means at pre-test and post-test were inspected to gain more insight into the actual differences per condition. The means remained quite similar in the textual feedback condition: $M_{pre-test} = 14.8 (SD = 11.1)$ vs. $M_{post-test} = 14.2 (SD = 6.9)$ and in the control condition: $M_{pre-test} = 13.4 (SD = 10.4)$ vs. $M_{post-test} = 13.8 (SD = 9.4)$. Thus, only small differences were observed here (- 0.6 pieces and + 0.4 pieces on average per week, respectively). In the auditory feedback condition, the fruit intake was most strongly increased (+ 3.3 pieces; $M_{pre-test} = 14.2 (SD = 10.6)$ vs. $M_{post-test} = 17.5 (SD = 11.1)$).

- **Moderation effects.** We assessed whether the effects of condition were similar in specific groups of respondents. Perceived own health status and health literacy were tested as moderators on fruit and vegetable consumption. First, a significant interaction was found between condition and perceived own health status on fruit intake; $F(2, 137) = 4.24, p < .05, \eta^2_p = .06$, but not on vegetable intake; $F(2, 137) < 1, p = .86, \eta^2_p = .00$. To further examine the meaning of this effect on fruit intake, simple main analyses were conducted at two different levels (low / high) of the moderator. The complete dataset was used to model respondents as scoring high or low, by adding and subtracting one standard deviation to the standardized means, respectively (Cohen, Cohen, West,
& Aiken, 2003). Figure 8.4 displays the mean fruit consumption for respondents with a poor and good perceived own health.

**Figure 8.4** The interaction between condition and perceived own health status on fruit consumption at six-month follow-up *** $p < .01$ ▼
In case of poor perceived own health status, condition did significantly affect fruit consumption at six-month follow-up; $F(2, 137) = 6.05, \ p < .01, \ \eta^2_p = .08$. The mean scores were as follows: text ($M = 14.2$), audio ($M = 20.5$) and control ($M = 13.2$). Post-hoc contrasts showed that the intake of fruit was significantly higher after listening to the information compared to the other two conditions ($ps < .01$). In case of good perceived own health status, condition had no significant effect; $F(2, 137) = 1.15, \ p = .32, \ \eta^2_p = .02$. The mean scores were as follows: text ($M = 13.3$), audio ($M = 13.8$) and control ($M = 15.9$). No significant contrasts were found.

Second, health literacy as assessed at pre-test was tested as a moderator. No significant interaction with condition was found on fruit intake; $F(2, 137) < 1, \ p = .78, \ \eta^2_p = .00$. However, we found a significant interaction on vegetable intake; $F(2, 137) = 8.42, \ p < .001, \ \eta^2_p = .11$. We examined the meaning of this effect by applying the same procedure as mentioned above (Cohen et al., 2003). Figure 8.5 displays the mean vegetable intake in the conditions for people with relatively low and high health literacy.
Figure 8.5 The interaction between condition and health literacy on vegetable consumption at six-month follow-up. * $p < .10$, ** $p < .05$, *** $p < .01$
In case of low health literacy, condition significantly affected vegetable consumption at six-month follow-up; \( F(2, 137) = 3.62, p < .05, \eta_p^2 = .05 \). The mean scores were as follows: text (\( M = 21.3 \)), audio (\( M = 23.1 \)) and control (\( M = 27.9 \)). Post-hoc contrasts showed that the intake of vegetables in this group was significantly higher in the control condition compared to the two interventions (\( ps < .05 \)). In case of high health literacy, condition significantly affected vegetable consumption at six-month follow-up as well; \( F(2, 137) = 4.53, p < .05, \eta_p^2 = .06 \). The mean scores were as follows: text (\( M = 30.1 \)), audio (\( M = 33.5 \)) and control (\( M = 25.6 \)). Besides the higher scores compared to respondents with low health literacy, post-hoc contrasts showed that the intake of vegetables in this group was lower in the control condition compared to the textual intervention (\( p = .07 \)) and the auditory intervention (\( p = .004 \)).

We further analyzed the effects in selections of respondents for whom the health information could be especially relevant. With regard to the effects on fruit intake, respondents were selected whose objective fruit intake was found to be insufficient (and the objective vegetable intake was either insufficient or sufficient, \( n = 95 \)). The main effect on fruit consumption was not significant anymore; \( F(2, 89) = 1.85, p = .16, \eta_p^2 = .04 \). The estimated means are lower, showing a similar pattern: text (\( M = 11.2, SE = 1.12 \)), audio (\( M = 13.7, SE = 1.25 \)) and control (\( M = 10.9, SE = 1.00 \)). Only the difference between audio and control was marginally significant (\( p = .07 \)). This pattern was again especially found within recipients with a poor perceived own health (moderation effect; \( F(2, 86) = 2.46, p < .10, \eta_p^2 = .05 \) with a significant main effect of condition in this specific group; \( F(2, 86) = 3.95, p < .05, \eta_p^2 = .08 \), showing significant differences between control (\( M = 8.9 \)) and audio (\( M = 16.3, p = .006 \)) and text (\( M = 10.5 \)) and audio (\( p < .05 \)). No significant differences between the conditions were found for recipients who perceived the own health as relatively good. As in the whole sample, health literacy did not moderate the effect on fruit intake.

In addition, the effects on vegetable intake were analyzed in a selection of respondents who indicated eating insufficient vegetables on forehand (and either insufficient or sufficient fruit intake, \( n = 99 \)). As in the whole sample, no significant main effect or moderation of perceived own health was found. The moderation of health literacy was however not significant anymore; \( F(2, 90) < 1, p = .93 \).

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5 The main effect of condition was not significant on a composite measure of fruit and vegetable consumption (\( p = .34 \)), neither was the interaction with perceived own health status (\( p = .16 \)). However, the interaction with health literacy was; \( F(2, 137) = 4.39, p < .05, \eta_p^2 = .06 \). The main effect of condition becomes then non-significant in respondents with low health literacy and only two of the four contrasts remain significant, showing that the control condition was most effective for low-literate respondents (compared to reading) and listening to the auditory information was most effective in high-literate respondents (compared to control).
**Intention to treat analyses.** At T2, 183 of the 330 (55.5%) respondents had dropped out despite reminders to fill in the follow-up measurement. In the intention to treat analyses, the post-test (T2) fruit and vegetable intake of these respondents was considered to be equal to their reported fruit and vegetable intake at pre-test. With these data, we again conducted the analyses on fruit consumption and vegetable consumption as reported above. The main effect on fruit consumption remained significant; $F(2, 323) = 3.18, p < .05, \eta^2_p = .02$ with the following means: text ($M = 13.5, SE = .52$), audio ($M = 15.3, SE = .52$) and control ($M = 14.3, SE = .51$). Now, the interaction between condition and perceived health status on fruit consumption was not significant anymore ($p = .33$). However, as expected, within respondents with a poor perceived health status, the effect of condition remained significant, $p < .05, \eta^2_p = .02$ with a similar pattern of means and significant contrasts ($ps < .05$) compared to the original analyses. The interaction between condition and health literacy on vegetable consumption remained significant as well; $F(2, 320) = 5.52, p < .01, \eta^2_p = .03$. Both within respondents with a low and a high health literacy, the effect of condition became marginally significant with only the contrasts between audio-based health information and the control condition being significant at $p < .05$. Overall, small(er) effect sizes were found.

**Process analyses.** Besides the above reported effects of the intervention on fruit and vegetable intake, the effects on two categories of process variables were inspected. These process measures are related to exposure to the intervention and a general evaluation with regard to the main tailored message at baseline and the intervention as a whole. When testing the differences between conditions, age and education were applied as covariates, as in the analyses on fruit and vegetable intake.

First, with regard to exposure, participants logged in 7.6 times on average ($SD = 4.5$) and, as expected, this was significantly more in one of the experimental conditions (text-based: $M = 10.1, SD = 3.7$, audio-based: $M = 9.4, SD = 4.2$) compared to the control condition ($M = 4.2, SD = 3.0$, contrasts $p < .001$, $F(2, 143) = 42.11, p < .001, \eta^2_p = .37$). No significant difference was found between the two interventions ($p = .35$).

On average, respondents completed 4.1 follow-up moment ($SD = 1.36$). There was a marginally significant difference between the two interventions: After reading, recipients completed slightly more follow-up moments ($M = 4.35, SD = 1.19$) compared to the recipients who listened to the information ($M = 3.83, SD = 1.50$), $F(1, 86) = 3.40, p = .069, \eta^2_p = .04$. In addition, 62.5% of the 88 respondents in one of the experimental conditions completed all five follow-up moments and at least two follow-up moments were completed by 95% of the respondents. Those respondents who completed four or five follow-up moments were selected (text: $n = 39$ and audio: $n = 25$) and compared to the control group ($n = 58$) with regard to the set of 18 baseline measures. The groups did not differ significantly from each other regarding these variables ($ps > .05$).
At baseline, respondents who were in one of the intervention conditions were asked to indicate the extent to which they were exposed to the main tailored message and the extent to which they experienced potential distracting elements. Slightly more respondents reported being only partly exposed after listening \( (F(1, 214) = 2.94, \ p < .10) \) and fewer respondents identified potential distracting elements after listening to the main tailored message compared to those who read the information \( (\chi^2(1) = 2.73, \ p < .10) \).

Second, differences between conditions were found on perceived usefulness and the general evaluation of the main tailored message \( (F(1, 214) = 12.27, \ p = .001, \ \eta^2_p = .05 \) and \( F(1, 214) = 12.10, \ p = .001, \ \eta^2_p = .05, \) respectively): Respondents who read the baseline information experienced it as significantly more useful \( (M = 4.21, \ SE = .08) \) and positive \( (M = 5.77, \ SE = .09) \) compared to the respondents who listened to the baseline information \( (M = 3.81, \ SE = .08, \ M = 5.33, \ SE = .09). \) No significant differences were found on the perceived novelty of the information \( (p = .29) \).

With regard to the evaluation of the smartphone application and intervention content at six-month follow-up, respondents who were exposed to the audio-based content reported to have looked more often for additional information about health and fruit and vegetables (mostly via Internet websites; \( F(2, 141) = 3.00, \ p = .053, \ \eta^2_p = .04 \), compared to respondents in the control condition \( (\text{contrast } p < .05). \) In addition, after the audio-based intervention respondents talked more about the topic with other people \( (F(2, 141) = 2.49, \ p < .10, \ \eta^2_p = .03) \), compared to the control condition \( (\text{contrast } p < .05). \) When comparing both interventions, the feedback and the smartphone application were experienced equally in terms of personal applicability, novelty, credibility, intensity, usefulness, comprehensibility and visual attractiveness.

**Discussion**

The current study addressed the efficacy of two tailored smartphone interventions in a sample of people that were invited to participate especially when they perceived the own fruit and vegetable intake as insufficient. The efficacy of the interventions was compared to a control condition in which no tailored health information was provided, and a comparison was made between the text-based and audio-based tailored intervention. Besides testing this main effect, two relevant moderators, referring to perceived own health status and health literacy, were included in this research.

It seemed that the results for fruit consumption and vegetable consumption are different. The results on fruit consumption were supported by the similar findings of the intention to treat analysis, and although the effects were less strong in the selection of respondents, the pattern of findings was still present in respondents with an objectively assessed fruit consumption that was insufficient. The significant main effect showed that
the audio-based intervention was more effective than both the text-based intervention and the control condition. The auditory mode of communication, but not the textual mode of communication, can lead to an increased fruit consumption with an average increase of three pieces of fruit a week. We did not expect specific differences between the efficacy of textual and auditory health information, but it is in line with previous studies on the potential efficacy of auditory information (e.g., Connell et al., 2001). The auditory information may have led to more attention (Alley et al., 2014; Lee, 2011) or it may have been perceived as more rich and personal to the recipient (Chaiken & Eagly, 1983), which is possibly translated into behavior change.

With regard to vegetable consumption, there was no significant main effect of condition. Instead, an interaction between condition and health literacy was found, which was supported by the intention-to-treat analysis, but the pattern of findings was not found in the selection of respondents with an objectively assessed vegetable consumption that was insufficient. Yet, there was no difference between the auditory and textual health information: Both the text-based and audio-based intervention led to a (marginal) significantly higher vegetable consumption in respondents with high health literacy, whereas this was not the case for respondents with relatively low health literacy (within the highly educated sample). For them, both interventions led to a significant decrease in self-reported vegetable consumption at six-month follow-up compared to the control condition. It seems that the current smartphone application was not helpful for people with relatively low health-literacy, at least not in improving a complex behavior such as vegetable intake.

We found that especially respondents who perceived their own health as relatively poor reported higher fruit consumption after being exposed to the auditory health information. It was initially expected that the health information in general would be more relevant for recipients with a poor perceived own health, as they might perceive the necessity to change and are willing to make more investments (Braverman, 2008; Pietersma & Dijkstra, 2011). In other words, there is a match between the persuasive health information and a characteristic of the recipient (Kruglanski & Thompson, 1999). Thus, it seems that recipients with a poor perceived own health did benefit most from the rich and personal auditory information. While speculating, this might be related to an optimal level of threat of the auditory information that was necessary to engage in behavior change, or the promise that the threat will be lowered once the recipient engages in the behavior. It is important to address these underlying processes in further research, as the findings on the current process evaluation measures are unlikely to explain this pattern.

The moderator effect on vegetable intake shows that the intervention in general seemed to have worked especially in respondents with high health literacy. It can be that recipients with relatively low health literacy did not understand all content information or
were not motivated to process the information (Norman & Skinner, 2006; Santo et al., 2005) and therefore discarded the information in general. For recipients with high health literacy it did not seem to matter how the information was communicated, as they may have been open to the content information, regardless of the mode of communication. It is important to unravel the different aspects of health literacy; for instance, education could have played a relevant role, as recipients with a lower education also reported lower health literacy in the current study, but it is also possible that low health literacy is related to a defensive reaction to threatening health information.

Thus, we observed a main effect on fruit intake, and within a subsample of respondents we could also find effects on vegetable intake. This finding on vegetable intake could however not be replicated within a subsample of recipients who indicated consuming insufficient vegetables. This suggests that the findings on vegetable intake are less robust than on fruit intake. In addition, according to a conventional rule of thumb (Cohen, 1992), overall, small to medium effect sizes are found for fruit intake, ranging between $\eta^2_p = 0.04$ and $\eta^2_p = 0.08$. It remains the question whether the absence of a main effect on vegetable intake was a matter of power, as the recommended amount of respondents per condition ($n = 64$) was not reached. Yet, the moderating effect of health literacy on vegetable intake showing contradicting results for recipients with relatively low and high health literacy may indicate that it is unlikely to find a main effect on vegetable intake.

The results suggest that not everybody did benefit equally from the intervention, and that lower scores on vegetable consumption can be observed. The tailored health information may thus have negative effects in subgroups of respondents, either when the information is communicated via a textual or auditory channel. This increased our awareness on possible side effects of persuasive health communication. For future research it seems worthwhile to investigate how individual characteristics can be assessed to optimize the practice of persuasive health communication and to increase knowledge on how “hard-to-reach” groups can benefit from it as well (Santo et al., 2005). Possibilities may not only lie in providing persuasive tailored health information via another communication modality (i.e., video-tailoring), but also in the use of other interactive methods and elements (i.e., the use of sensors, serious games, or avatars).

On forehand, we did not expect specific differences for fruit and vegetable intake. It may be that these differences are found because fruit and vegetables are products with different qualities with regard to taste, preparation and culinary uses (Trudeau, Kristal, Li, & Patterson, 1998), and perceived ease of increasing the consumption (Pietersma & Dijkstra, 2011). It may be that after a follow-up period of six months, the auditory intervention was only able to change fruit intake, as this is a relatively less difficult behavior to change. In addition, interventions may differentially lead to increased fruit and vegetable consumption (Chapman & Armitage, 2012). For instance, the context in
which the products are consumed might play a role: Vegetables are more likely to be consumed in a social context (at dinner, with the rest of the family), whereas fruit is more likely to be consumed individually. Therefore, environmental interventions may be more effective for increasing vegetable intake. It seems a rational choice to assess fruit and vegetable consumption separately in future studies.

The effects on the process measures showed that there were no differences between the text-based and audio-based interventions with regard to exposure. However, more follow-up moments were completed by recipients who read the information, compared to recipients who listened to the information. In addition, after the first contact, the baseline textual information was evaluated as more useful and positive compared to the auditory information. After six months however, the textual and auditory interventions were not evaluated significantly different on relevant measures, such as novelty, credibility, comprehensibility, and usefulness. Yet, recipients who were exposed to the auditory information searched more for health-related information and they discussed the topic more often with other people, compared to the control condition. Further research is needed to explain these findings and to investigate how characteristics of the textual and auditory information may possibly have contributed to these differences.

This research also has several limitations. First, a high percentage of respondents did not complete the whole study, which might have biased the current findings. High attrition rates are common in Internet-based health behavior change interventions (Brouwer et al., 2011; Crutzen, Viechtbauer, Spigt, & Kotz, 2015; Mason, Gilbert, & Sutton, 2012). Although initially one could reason that an app might lead to lower attrition rates because people can participate in the study anywhere and at any time, it seems that in smartphone applications it is still a challenge to keep respondents involved after their first visit. This might illustrate the quick and shallow relationship people have with the Internet and smartphone applications in general. Yet, it is found that respondents who dropped out from the research did not differ at relevant pre-test measures compared to the respondents who completed the study.

Although it was not a significant result in this study, more respondents dropped out in one of the intervention conditions, which is a common finding as well in health intervention research (Crutzen et al., 2015). Respondents in the intervention conditions were sent email reminders frequently and they were informed about the possibility to end their participation via email, whereas this was not the case for respondents in the control condition. These aspects of our research might additionally have contributed to differences in attrition between the conditions. A specific improvement may refer to sending reminders as smartphone notifications, instead of e-mail messages.

Secondly, we aimed to increase exposure by sending email prompts and providing regular updates of intervention content (Brouwer et al., 2011). However, it is difficult to detect the actual exposure to the intervention content. People may report that
they were fully exposed to the information, but still we do not know the quality of the exposure. In addition, we could not test intervention components separately, which means we do not know specifically why respondents showed certain improvements. Thus, we were not able to determine the unique contribution of each component of the current smartphone intervention and to make statements about the elements that affected fruit and vegetable intake specifically.

Thirdly, the sample was a selective community sample, which could have biased the results. Respondents were not necessarily a representation of the whole community, as they were mostly highly educated with a Dutch nationality and had to use an Android device to be included in the research. Furthermore, in our recruitment people were invited who did not eat sufficient fruit and vegetables which is obviously a selection of respondents who might be interested in the topic of health and changing their health behavior. In addition, people tend to generally overestimate their fruit and vegetable intake as assessed with self-report measures, as used in the current study (Lechner, Brug, & de Vries, 1997).

In our view, this application may be an effective channel to change fruit and vegetable intake, at least in certain groups of respondents. The development of the audio-based content was more costly and time-consuming compared to the text-based content, but it has shown to have beneficial effects on fruit consumption, or at least for subgroups. The results showed us that it is important to be aware of the possible side-effects of psychological health interventions and to take into account individual differences when exposing respondents to threatening health information and personal feedback on fruit and vegetable intake.

A next step may be to optimize the smartphone application. It is worthwhile to investigate possibilities to expose the subgroups to either one of the current interventions that was shown to be efficient, depending on the specific behavior one would like to change. Furthermore, tracking and sensor technologies can be added to use the smartphone application as an intervention channel to its fullest potential (Kratzke & Cox, 2012; Lathia et al., 2013), which means that recipients can keep track of their daily fruit and vegetable intake and may receive reminders to buy fruit and vegetables when they are in the supermarket. In addition, it would be worthwhile to ensure a higher level of interactivity between the recipient and the smartphone application as an interactive information system.

To the best of our knowledge, this is a first test of the efficacy of communication modalities in an evidence-based tailored smartphone application to stimulate fruit and vegetable intake. It provided us with new insights on the efficacy and processes involved, and we hope to inspire the testing and development of evidence-based smartphone applications in the field of health education and promotion.