# NutritionAvatar: Designing a Future-Self Avatar for Promotion of Balanced, Low-Sodium Diet Intention: Framework Design and User Study

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# NutritionAvatar: Designing a Future-Self Avatar for Promotion of Balanced, Low-Sodium Diet Intention

Framework Design and User Study

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## ABSTRACT

Excessive salt intake is increasingly seen as global health threat. As contemporary education campaigns and current mHealth solutions only reach health literate users, an often unaffected minority, there exists demand for more inclusive solutions. Avatar-based health interventions have been shown effective in such a context, but have not been tested for promoting low-sodium dieting specifically. Therefore, we designed, implemented and tested a novel smartphone-mediated and future-self avatar-based sodium reduction intervention (N = 28). Because most consumers remain unaware of the relationship between sodium intake and high blood pressure, the system was also tailored to support users in gaining risk awareness and intention for low-sodium dieting. Results indicate that participants significantly increase outcome expectancy, risk awareness and intention towards balanced, low-sodium dieting. The majority of users identify themselves with the future-self avatar and confirm the system's usefulness, ease of use, enjoyment.

## CCS CONCEPTS

• Consumer health • Human computer interaction (HCI) • Information visualization • Empirical studies in visualization

## KEYWORDS

Sodium reduction, future-self avatar, food record checklist, behavior change intervention, sodium intake monitoring, mHealth, persuasive design, human computer interaction



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## 1 Motivation

As excess salt intake is considered a key cause [58, 72] in diet-related mortality due to its etiologically relation to hypertension and cardiovascular diseases, it represents a major international health concern [69, 76]. However, current preventive interventions and policy-making by such stakeholders appear to fall short, as average salt intake globally continues to increase [16, 76]. In most countries today salt intake averages at around 9 to 12 grams of salt per day and more than 85% of populations consumed more salt than the 5 grams of salt per day recommended by the World Health Organization [22, 46]. Current mitigation strategies [11] have so far primarily focused optimization of sodium salt levels through recipe reformulation in foods and have proven effective, albeit insufficient [17]. Therefore, researchers call for a more holistic approach that involves the consumer [11], including bottom-up strategies such as monitoring of salt intake and promoting behavioral change as key strategies to achieve adequate sodium intake levels by the means of consumer awareness and behavioral change intention [16]. These contemporary bottom-up approaches usually involve of burden-some lab-based dietary monitoring procedures, resource-intensive educational campaigns or personnel-intensive counseling activities through dieticians [69]. Such resource intensity implies that a majority of the population cannot be reached by contemporary sodium intake monitoring and behavior change interventions, which additionally often face the challenge of low recruitment and retention rates [49].

In this study, we thus draw on the idea of cost-efficient, scalable mobile health (mHealth) applications and persuasive design to develop an effective sodium intake monitoring system and intervention. In contrast to contemporary bottom-up approaches, mHealth applications have the potential to increase the reach of nutritional interventions and cater to consumers with personalized diet recommendations at significantly reduced cost [15, 68]. Further, the concept of persuasive design appears promising to overcome a key drawback of contemporary nutritional mHealth applications: low engagement rates[51], especially in demographic segments that are prone to hypertension or obesity, mainly due to low health-literacy, self-motivation and involvement [51, 77].

Avatars [26, 56] and persuasive design [24] represent precisely successful strategies that have recently been explored in the dietary context of mHealth applications to increase user reach and the inclusion of health illiterate [8], unhealthy and uninvolved users [27, 60], but have not yet been applied to dietary sodium intake monitoring systems and interventions [50]. This paper adds to the growing body of research by providing insights into how avatar-based paradigms – previously predominantly only applied in a pediatric context [41] - can be extended to design smartphone-based sodium interventions, to increase currently lacking risk awareness [38, 78], intention and behavior changes [19] toward low-sodium dieting. Specifically, we designed a future-self avatar-based intervention predicting a user's very own long-term future health state based on current habits [25, 43], and examined the avatar's effect on 28 participants. Our findings suggest that practitioners and dieticians can leverage upon such automatic nutritional mHealth in their patient-consultations, as future-self avatar-based application usage correlates with a significant increase in risk awareness and intention to low-sodium dieting.

# 2 Related Work

We here provide current related work and approaches on sodium intake monitoring and behavioral change interventions. In said context, we then discuss the potential of mHealth applications and persuasive design.

## 2.1 Monitoring Sodium Intake

To assess an individual's dietary sodium intake level, different established [6, 53], yet burdensome and expensive methods exist. 24-hour urine sampling to date remains the most accurate, state of the art method [53, 64], followed by less accurate spot urine assessments [12, 53] in combination with paper-based food-record checklists or diaries [75]. As these methods require professional assistance and a lab setup, they lack scalability and repeatability. More scalable survey-based instruments include i) open 24h recall protocols or food diaries in which users manually record consumed food items [19, 21, 79], and ii) food-record checklists or food frequency questionnaires [3, 71], in which a user selects eaten food items from a pre-defined list of relevant, sodium-rich items. Since the latter approach features lower underreporting [30, 53] and higher external validity compared to 24h urine sampling [3, 23], the checklist-based approach is favored over the diary-based approach in sodium intake monitoring. Only recently, the transcription of paper-based instruments [3] to computer-mediated equivalents [71] emerged, omitting effort-intense transcription and calculation of hand-written entries.

## 2.2 Interventions in Sodium Intake Reduction

The lack of awareness of personal risk (risk awareness), being unknowledgeable about positive outcomes of change (outcome expectancies), and limited self-efficacy are key predictors of why people currently fail to engage in a healthy diets [63, 65]. Currently, most approaches to addressing individual's excessive salt intake include risk awareness [38, 78] and outcome expectancy [31, 38], which in turn can create the initial intention to a low-sodium diet behavior. This circumstance is explained by the fact that 60% of population are still unaware of the relationship between sodium and health, i.e. low outcome expectancy [38, 67], and as most consumers are unaware of their own excessive consumption of salt. Such that these two variables remain primary issues of sodium reduction in most interventions [19].

## 2.3 Mobile Health in Sodium Intake Reduction

Advantageous effects of nutritional mHealth have been reported on risk awareness, outcome expectancy, intention and dietary behavior [70, 73]. The main focus of nutritional mHealth has so far been put on weight loss [14], energy intake [57] or fruit and vegetable intake [10, 55] – however not yet on sodium intake. Moreover, such applications currently still lack integration of persuasive design. Human Computer Interaction (HCI) research propagates persuasive design [36] in nutritional mHealth [50, 74], achieving improved cognitive results [20], greater interest [18], positive attitudes [32] and involvement in dietary health [33]. Additionally, HCI can mitigate the limitations of high entry-barriers for the nutritionally illiterate and uninvolved, as well as foster acceptance and retention rates [60], attitude towards [32], intention to [32] and likelihood for health-beneficial behavioral change.

## 2.4 Future-Self Avatar based Persuasive Design

Avatars have long been applied in the HCI domain [34, 56] and related nutritional behavioral change mHealth [2, 34, 47], but not yet in sodium intake monitoring and interventions, despite their ability to precisely promote consumer awareness and stimulate intention to behavior change. Studies confirm the efficacy of persuasive avatars to change human behavior, especially when using a human-like appearance [35, 40]. Avatars have been proven effective in increasing persuasiveness [42], fostering intrinsic motivation [9], including previously neglected users [8, 13], increasing risk awareness [52, 66]. Furthermore, age-progressed visualizations of an individual (future-self) evoke more favorable decisions for the individual's future, as opposed to the instant gratification [40]. Such properties prove especially relevant for sodium intake, where negative health effects occur in the long-term future. Sodium intake monitoring and intervention mHealth can hence benefit from integrating (future-self) avatars based on persuasive design.

# 3 Design Science Approach

This study proposes to apply a future-self avatar intervention design within a smartphone-mediated sodium monitoring and intervention application. The design process was based on the design science research [29, 61], and HCI behavior change research [37].

In a first step, the available literature on avatar-based health interventions was reviewed. This search resulted in design guidelines D1 to D7 (see **Error! Reference source not found.**). First, we included a feedback functionality (D1) through which a future-self avatar system evaluates a user's behavior based on a comparison against nutritional intake recommendations, triggering corresponding messages and mechanics. Second, we implemented a human-like avatar (D2) instead of abstract avatars (e.g. animals) to support self-similarity and user self-identification. In line with this, we integrated customization (D5) which allowed users to configure their own avatar in correspondence to their own appearance by selecting facial features (e.g. hair color and length, eye color, glasses, beard, etc.) and clothes.

**Table 1: Future-self avatar design guidelines**

| No. | Design Guideline | Sources |
|---|---|---|
| D1 | Give feedback (positive & negative) | [1, 5] |
| D2 | Self-similarity (human-like) | [1, 56] |
| D3 | Reflect ideal-look and -behavior | [4, 45] |
| D4 | Provide encouragement and empathy | [5, 7] |
| D5 | Customization | [4, 45] |
| D6 | Simplicity | [48, 56] |
| D7 | Focus on outcome expectancy | [39, 44] |
| D8 | Provide background information | [54, 59] |
| D9 | Implications of behaviour and change | [28, 62] |
| D10 | Personal risk awareness & urgency | [1, 28] |
| D11 | Friendly, humorous, playful design | Workshop |
| D12 | Beware of adverse effects | Workshop |
| D13 | Use established visualization rules | Workshop |

Further, we integrated role-models (D3) which exemplify ideal behaviors, by showing users their own avatar in a perfect health state and respective instruction on how to achieve such state (e.g. reduction of salt intake). Additionally, we included encouragement (D4) via positive text prompts from the avatar (e.g. the best performance in each of the chosen nutrients). Finally, we included simplicity (D6), which was realized through integration of easy-to-use mobile food record checklists (mFRCL) (see Figure 1), instead of complex food diaries or text input search options.

In a second step, we integrated behavioral research recommendations. We incorporated outcome expectancy (D7) by displaying the expected health state (displayed in form of the future-self avatar) based on his current diet (Table 2). Next, we integrated important background information (D8) (e.g. excessive sodium intake increases blood pressure and negatively impacts the cardiovascular system), in laymen's terms. Further, the app displayed implications of current behavior (D9), by showing a transition animation from current and the last monitoring period. This helped explain the impact of consumed food on the body to the user. In addition, the literature recommended to include risk awareness as target construct for health interventions (D10). This was achieved by personalizing the future-self avatar's messages and appearance to forecast positive as well as negative outcomes of current behavior (see Figure 2).

In a final step, as suggested by Hekler [36], we followed a user-centered design process including iterations and pretests with prospective patients (N=5) and experts (N=5). Within a workshop, we generated insights by allowing to validate existing design prototypes with design artefacts ranging from mockup sketches to code-based prototypes with user testing methods and to generate new design ideas by participatory design. The experts contributed the system's mechanics (D11-D13), that such an avatar system should prevent detrimental design decision which might cause adverse effects (e.g. extreme diet behavior, obsession with beauty, anorexia). Further, the expert interviews provided valuable insights regarding the motivational and psychological effect of design decisions and underlying system rules. Specifically, user research suggests creating a friendly, humorous and playful design, to beware of adverse effects and to use tested visualization rules to depict information. Most importantly, user input also suggested that sodium intake alone seems not appealing enough, but it is desirable to not only track sodium, but also to receive further nutritional

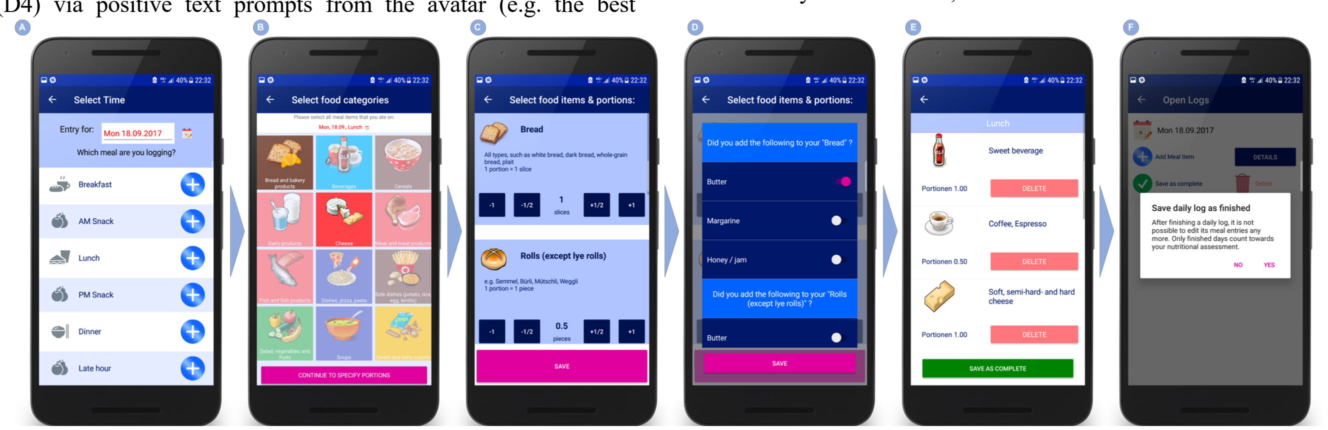


**Figure 1: Mobile food record checklist (mFRCL): a) selection of date and meal, b) gridview of relevant food categories, c) portion selection of consumed items, d) addition of toppings, e) summary of logged items, f) confirming completion of a daily log**

feedback to user behavior, i.e. fruit and vegetable as well as sugar intake. After consultation with contributing experts, the decision was made to extend the scope of the future-self avatar intervention beyond sodium intake to also track and improve fruit and vegetable, alcohol and sugar intake, while still primarily designing the system towards excessive sodium intake mitigation.

## 4 Implemented System

The avatar-based system was realized through Microsoft's cross-platform framework Xamarin, therefore the app could be provided for both Android and iOS devices. The avatar framework is JavaScript-based, producing a web-view displaying a user's future-self avatar after a URL-call with encoded states as defined by the system rules (Table 2).

### 4.1 Dietary Monitoring

As food record checklists (FRCL) promise less underreporting when compared to food diaries, the decision was made to integrate the most established and validated, paper-based FRCL in Switzerland [80] within the smartphone-mediated future-self avatar-based sodium intervention. The paper-based FRCL was converted into a mobile food record checklist (mFRCL) and included 12 food categories, 71 food items and 20 toppings, defined by an established, paper-based checklist instrument [36], and extended by relevant items from literature [9], [81] under support of the Swiss Society for Nutrition. For each of the items and toppings, the system provides underlying nutritional values for sodium, added sugar, fruit, vegetables, alcohol, such that the mFRCL instrument is able to assess the respective daily consumption of each user. The mFRCL is a multi-stage process: First, before logging food consumption, a user must select and confirm a date and meal for which the record is created (Figure 1.a). Second, a convenient gridview of food categories relevant for sodium-intake and derived from an established paper-based instrument [36] including the categories most relevant for sodium intake [9] is presented (Figure 1.b). After choosing one or more food categories the user is confronted with category-specific food items for which the user sets the consumed quantities in multiples of 0.5 portions (Figure 1**Error! Reference source not found.**.c). If necessary, a pop-up will ask the user to choose if relevant toppings (e.g. butter on bread; sauce with meat) were consumed as well (Figure 1.d). After each logging process, the user can find a daily summary of already logged items (Figure 1.e). Finally, the user has to confirm, that a daily protocol is complete and no more items were consumed than the logged ones (Figure 1.f), thereby minimalizing the probability of underreporting.

### 4.2 Avatar Design

The result of our avatar design iterations resulted in a customizable [82], [83], future-self [27], and human-like [84], [85] diet avatar in a simple 2D cartoon style (to prevent negative likeability, as suggested by the uncanny valley effect) [84], [86], illustrated in Figure 2**Error! Reference source not found.**. Its aim is to act as an informative yet encouraging [87], [88] mean of providing positive and negative feedback on the diet of a user [85], [88]. Based on expert input and the profile of workshop participants, the design was tailored toward an averagely healthy person without strong psychological diet-related symptoms (e.g. eating disorders).

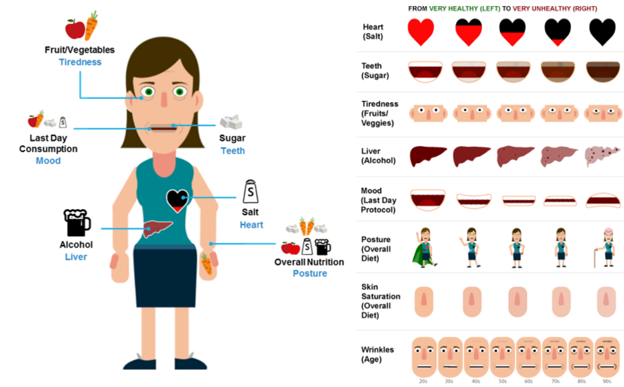


**Figure 2: Implemented system design with female example avatar (left) and stages of visual features (right)**

As illustrated in Figure 2, several parts of the avatar body are used as visual features depicting the future health status of a user based on their current diet (future-self). For example, alcohol influences the visual appearance of the liver. To maximize identification, users are able to customize their avatar to match their appearance (Figure 2). To the same end, it also breathes, blinks and chews, rendering a human-like appearance. The design was developed specifically with the aim to balance scientific accurateness with ease of comprehension. In terms of persuasive design, the avatar provides emotional feedback via smiling or looking sad, features an attractive body form [83] and displays idealistic behavior by eating vegetables and fruits [82].

The five-stage model mapping user nutrition to the avatar's visual features' health stage is depicted in Table 2. The negative, right-most stages aim to increase risk awareness and urgency to change for users following an unhealthy diet. However, humor is intended for by adding a funny old hat and a walking stick if a user reaches the last level. The visual features are calculated with self-reported diet behavior based on the defined system rules summarized by Table 2. The avatar's system rules were defined by the Swiss Society for Nutrition and included a mapping of nutrients and health stages (top part of Table 2), as well as visual features and respective underlying influencing factors (bottom part of Table 2). The future-self avatar also featured coaching messages. In each session in which the user opens the avatar view, the avatar would state at least one to two encouraging positive and include, if applicable, between zero to two negative feedback messages and instructions on how to improve the own health state. Additional feedback is provided via a transition animation which depicts the causal relationship of current diet and long-term outcomes. The animation visualizes the ingredient intake of the preceding day and shows its influence on the visualized variables. Specifically, the intake in salt obtrusively "flies" into the mouth of the avatar, resulting in an update of the heart's health stage. Additionally, personalized coaching messages presented in a speech bubble aim to be informative, awareness-raising, motivating. They inform about the overall health status of the avatar, render evaluations of the diet of the previous day, and point to personal improvement areas aside from the best maintained area (e.g. "I don't eat much salt, which is good for my heart").

**Table 2: System rules defining health stages per ingredient and visual features stages**

| Nutrient | Stage 1 (very healthy) | Stage 2 (healthy) | Stage 3 (average) | Stage 4 (unhealthy) | Stage 5 (very unhealthy) |
|---|---|---|---|---|---|
| Salt | < 5 g | 5-5.99 g | 6-7.99 g | 8-10 g | > 10 g |
| Added Sugar | < 25 g | < 50 g | < 70 g | < 85 g | > 85 g |
| Fruit / Vegetables | > 4.9 handful (hf) | 4-4.9 hf | 2-3.9 hf | 1-1.9 hf | < 1 hf |
| Alcohol | ≤ 0 units | ≤ 2 units | ≤ 2.5 units | ≤ 3 units | > 3 units |
| Last Day Average | < 1.5 (Stage) | < 2.5 | < 3.5 | < 4.5 | ≤ 5 |
| Overall Average | < 1.5 (Stage) | < 2.5 | < 3.5 | < 4.5 | ≤ 5 |

| Visual Feature | Primary Influencer | Primary Influence % | Secondary Influencer | Secondary Influence % |
|---|---|---|---|---|
| Heart | Salt | 80% | Fruit/Vegetables | 20% |
| Teeth | Added Sugar | 100% | | |
| Tiredness | Fruit/Vegetables | 75% | Added Sugar | 25% |
| Liver | Alcohol | 100% | | |
| Mood | Last Day Average | 100% | | |
| Posture | Overall Average | 100% | | |
| Skin Saturation | Fruit/Vegetables | 100% | | |

## 4.3 User Experience

After downloading the app, users were asked to provide background data, fill in a survey and give consent for the study. The user is then informed about diet logging and avatar usage through two sequential tutorials. On day 1, the user is taught how to log his dietary information. The user is then prompted each day to log information with a countdown display (to ensure user engagement). On day 5, the avatar is unlocked and during the first usage of the avatar, a tutorial explains the avatar features and illustrates how the person could look based on a healthy diet in ten years. Moreover, the system provides on-demand, pop-up details for users via tapping on the respective visual feature. In a final step, the user was asked to fill in a final survey.

# 5 Research Design

## 5.1 Study Design

The future-self avatar intervention was designed for an eight-day period: On each day, the users enter their diet through the mFRCL. During the first four days, diets are only logged, and no avatar feedback is received, as the FRCL is designed to assess health states after at least three complete daily logs. Starting with day five, users would receive daily feedback from their customized future-self avatar within the system (i.e. see the avatar's current visual design and receive the corresponding intervention messages). After the eighth day, the users were asked to participate in the final survey in which the motivational predictors of health behavior were measured, and to provide consent in the overall study.

## 5.2 Sample

67 individuals registered on the app, of which ultimately 28 users completed the full eight-day study and were thus selected for the present analysis. We were aware of high levels of attrition in similar studies and thus were content with 38 of 67 (56.7%) participants successfully completing the eight-day study. Unfortunately, ten of these users (14.9%) failed to submit a final, obligatory survey due to a non-ideal survey design that was not automatically displayed. The final sample thus included 17 men and 11 women, born from 1960 to 1993 (M=1985.6, SD=9.59).

## 5.3 Survey Design

We applied a pre- and post-test design to understand user's change in motivation a priori and posteriori to the intervention, i.e. the display of the self-future avatar. To do so, we applied paired-sample-t and Wilcoxon-Signed-Rank tests to evaluate the differences between pre- and post-test. Thereby, we drew on the Health Action Process Approach (HAPA) to test our assumption that persuasive design can increase motivation to adopt a more

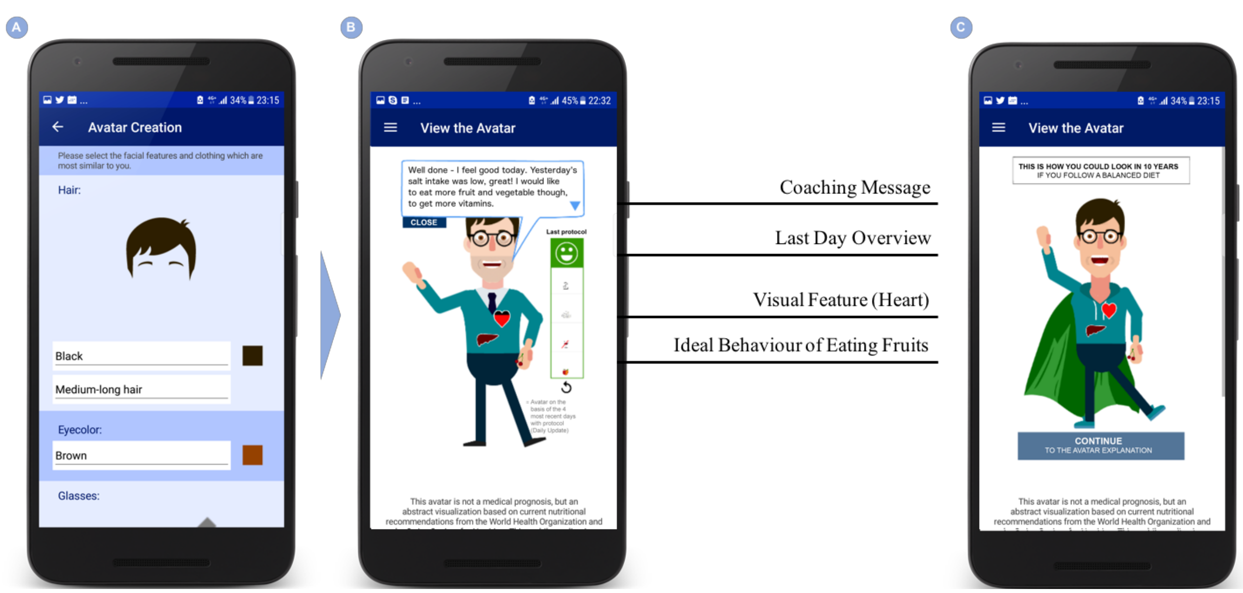


**Figure 3: Implemented system: a) personalization, b) avatar intervention, c) motivation element through positive future-self**

balanced, low-salt diet [89]. As an implicit state model, the HAPA allowed us to focus on the motivational factors specifically, excluding volitional factors. The model suggests that intention is shaped based on three social-cognitive predictors: outcome expectancies (OE), and risk awareness (RA), action self-efficacy, where we drew on previous measures from the literature [90]. Both questionnaires included HAPA measures based on the structure suggested by Schwarzer [91]. RA was evaluated with four seven-point Likert-type scales for the following salt-related diseases: hypertension, cardiovascular disease and heart attack, e.g. "How do you estimate the likelihood that you will ever suffer from (…)?". OE of a balanced or a low-salt diet were collected with six and two items respectively. They were recorded on four-point scales with the following structure: "If I stick to a balanced diet, then I will feel better". Answer options ranged from "Strongly Agree" to "Strongly Disagree". SE was determined by three items on a four-point scale, such as "I am confident that I am able to stick to a balanced diet, even if my health does not directly improve". Intention for balanced, low-salt diets was evaluated by two seven-point scale items. However, intentions were also evaluated separately for both balanced dieting and low-salt dieting.

For comparison, non-intenders and intenders were combined in two separate groups, whereas the first four and last three response categories of the seven-point intention score were used respectively. This is similar to HAPA studies using explicit stages of intention [39], [40]. Behaviour was assessed by five items for the intake of an overall balanced diet, salt, added sugar, alcohol and fruits/vegetables on a four-point scale. Self-reported behaviour was also measured by a calculated 4-day average based on the via the mFRCL self-reported food intake for salt, added sugar, alcohol, and fruit/vegetables, as recommended [36].

In addition to HAPA measures, the pre-test questionnaire gathered sociodemographic information including gender, age and nationality. The post-test questionnaire included user experience (UX) measures with eight items divided into further four categories: usefulness, ease of use, enjoyment and identification. The categories were derived from the User Acceptance of Information Technology Framework [92]. Agreement or disagreement was recorded on a seven-item Likert-type scale.

### 5.4 Research Questions and Hypotheses

Our research thus explored the question of whether an mHealth intervention featuring a human-like, future-self avatar of personal diet behavior leads to higher motivation to pursue a low-salt diet. Based on previous literature, we expected that the inclusion of an avatar would lead to higher $OE^S$ towards the effects of low-salt dieting post intervention (H1) and improved $OE^B$ towards a balanced diet overall post-intervention (H2). We also expected that the educational aspect of the avatar would increase the risk awareness post-intervention (H3); and intentions towards a balanced (H5a) and low-salt diet (H5b). However, as elaborated in our Design Science section, the avatar did focus on RA and OE, but not on self-efficacy (SE). Thus, we did not expect SE to increase (H4). Furthermore, for the purpose of completeness we also measured behavioral change. As previous state of the art studies highlighted the difficulty in change behavior after six months of intervening [93], we expected no significant effects from an eight-day program either (H6).

## 6 Results

To compare changes in HAPA variables between values before the intervention (pre) and after the intervention (post), paired-Sample t-Tests were used for normal and Wilcoxon Signed-Ranks Tests for skewed distribution. The mean scores of variables RA, low-salt dieting OE, and balanced, low-salt dieting intention increased significantly from pre- to post-assessment.
Overall, the avatar-intervention proved effective in respect to fostering low-salt diets. The results show that the avatar improved risk awareness, low-salt outcome expectations and also strengthened intentions toward a balanced, low-salt diet. As expected, the results also suggest that the avatar did not have a significant effect on self-efficacy, outcome expectations towards balanced dieting, as well as subsequent change in dieting behavior.

### 6.1 Influence on Outcome Expectancies

Among the first two hypotheses on OE, only the first hypothesis H1 was supported. As a significant difference in positive $OE^S$ towards the effects of a low-salt diet were found between pre- and post-test scores (signed-rank test, $Z = 2.298$, $p = 0.022$). Whereas no significant changes in pre- and post-test scores were found regarding positive or negative $OE^B$ towards effects of a balanced diet. Hypothesis H2 was hence rejected with p-values $p=0.79$. These findings suggest that the avatar intervention was successful in increasing OE in terms of positive low-salt dieting. Furthermore, users appeared to already possess high levels of OE for balanced dieting behavior (with a mean of 0.85 across the measurements), explaining the insignificance of positive OE relating toward a balanced diet.

### 6.2 Influence on Risk Awareness & Self-Efficacy

The results further suggest that the avatar intervention was highly effective (paired t-test, $t(27)=-5.299$, $p=.000$) in increasing the awareness of risks related to a high salt diet (H3). Specifically, this was tested with the risk awareness regarding the heart-related diseases hypertension, cardiovascular disease and heart attacks. Pre- and post- scores correlated strongly (paired t-test, $r=.729$, $p\leq.000$). On average, post RA means were 2.1 Likert points per item higher than before the intervention (95% CI [-11.593,-5.121]). As expected, the primarily towards risk awareness designed avatar system did not significantly increase SE (H4) (signed-ranks test, $p=.71$).

### 6.3 Influence on Intention and Behavior

In terms of intention (H5), the results suggest that the avatar intervention was effective in increasing the intention of users towards a low-salt diet (H5a), but not a balanced diet overall (H5b). This is because a significant increase was observed for low-salt dieting intentions (paired t-test, t(27)=2.925, p=.007), and pre- and post-means were positively correlated (r=.655, p=.000). For the balanced dieting intentions, we did not observe significant differences in pre- and post-test scores (signed-ranks test, Z=-1.95, p=0.051). As expected, the four-day mean consumption of all measured nutrients (salt, added sugar, fruit/vegetables, and alcohol) during the avatar-intervention measured by the mFRCL-mediated self-reporting of food intake did also not differ significantly from the mean of the time-period before using the avatar (Table 3) (B1-B4, Table 4). Likewise, the means for self-reported balanced dieting behavior at the post-test were not statistically different from the pre-test. Thus, as expected, H6 did not hold. Nonetheless, we believe it is worth pointing out that an overall salt-intake reduction was observed across the participant group, as the average, self-reported salt intake was reduced from 9.0g salt per day (pre-test) to 8.3g salt per day (post-test) (decrease of 7.1%). As the Swiss overall mean average daily salt intake is 9.1g salt per day, the sample seems in line with the overall Swiss population [9]. Further, improvements in added sugar intake from 37.1g added sugar per day (pre-test) to 34.6g added sugar per day (post-test) (decrease of 6.9%). In addition, consumptions of fruit and vegetable has not improved and remained constant at 301g per day (pre-test) and 300g per day (post-test) (unchanged, difference below 0.5%). Last, but not least, alcohol consumption improved as well, down from 10.8ml per day (pre-test) to 8.7ml per day (post-test) (decrease of 20.0%). The corresponding changes in observed behavior as assessed by the FRCL have been depicted in Figure 4.

**Table 3: Changes pre- & post- future-self avatar intervention**

| Construct | | Measurement | Test statistic | p-value |
|---|---|---|---|---|
| **Motivation** | | | | |
| $OE^B$ | Outcome Expectancy unbalanced diets | 2 items in pre-/post avatar, 4-Likert scale | W, Z .262 | .79 |
| $OE^S$ | Outcome Expectancy sodium intake | 2 items in pre-/post avatar, 4-Likert scale | W, Z 2.289 | 0.022* |
| SE | Self Efficacy | 3 items in pre-/post avatar, 4-Likert scale | W, Z -.36 | .71 |
| RA | Risk Awareness | 4 items in pre-/post avatar, 7-Likert scale | T, t(27)=5.299 | 0.000** |
| **Intention** | | | | |
| I1 | Intention to pursue balanced diet | 1 item in pre-/post avatar, 7-Likert scale | W, Z 1.950 | 0.051 |
| I2 | Intention to pursue low-sodium diet | 1 item in pre-/post avatar, 7-Likert scale | T, t(27)=2.748 | 0.007** |
| I3 | Combined Intention | Combined balues I1-I2 | T, t(27)=2.925 | 0.011* |
| **Self-reported active behavior** | | | | |
| A1 | Salt intake | 1 item in pre-/post avatar, 4-Likert scale | W, Z .542 | .58 |
| A2 | Sugar intake | 1 item in pre-/post avatar, 4-Likert scale | W, Z 2.204 | 0.027* |
| A3 | Fruit and Vegetable intake | 1 item in pre-/post avatar, 4-Likert scale | W, Z -.586 | .56 |
| A4 | Alcohol intake | 1 item in pre-/post avatar, 4-Likert scale | W, Z -.259 | .80 |
| A5 | Balanced diet | 1 item in pre-/post avatar, 4-Likert scale | W, Z -1.512 | .13 |
| **Observed behavior via FRCL** | | | | |
| B1 | Salt intake | grams, Estimated intakes from FRCL | T, t(27)=-1.062 | .30 |
| B2 | Sugar intake | grams, Estimated intakes from FRCL | W, Z .091 | .93 |
| B3 | Fruit and Vegetable intake | grams, Estimated intakes from FRCL | W, Z .000 | 1 |
| B4 | Alcohol intake | ml, Estimated intakes from FRCL | W, Z -.914 | .36 |

* : Significant at 5% level, ** : Significant at 1% level
T : paired samples t-Test for normal distributions, W : Wilcoxon signed-ranks test for skewed distributions

# 7 Discussions

## 7.1 Contributions

Our findings suggest that the future-self avatar-based intervention developed via the study's design guidelines can significantly increase outcome expectancy, risk awareness and intention to decrease excessive salt intake and to maintain healthy levels of sodium consumption. These motivational prerequisites are important predecessors of initiating a low-sodium dieting behavior, especially since 60% of population are still unaware of the relationship between sodium and health [12], [23], [42]. Although not significant, an overall reduced salt intake across the participant group was observed, which is in line with similar research on promising mHealth solutions and contributes to the current work on sodium intake monitoring [36], [81], [94] and behavioral change interventions in sodium reduction [3], [23], as the study observed measurable improvements in sodium consumption (decrease of 7.1%), added sugar consumption (decrease of 6.9%) and alcohol consumption (decrease of 20.0%). The strong difference of Δ=-0.64g salt intake per day can be regarded as a promising decrease, as contemporary national intervention strategies [3] only achieve sodium reductions 10-20% (in salt reductions through low-sodium production recipe reformulation by the food industry over the past 20 years) [23]. Therefore (future-self avatar based) mHealth-mediated sodium reduction can play a vital role in achieving the long-term aim of daily salt reduction to five grams recommended by the WHO [32].

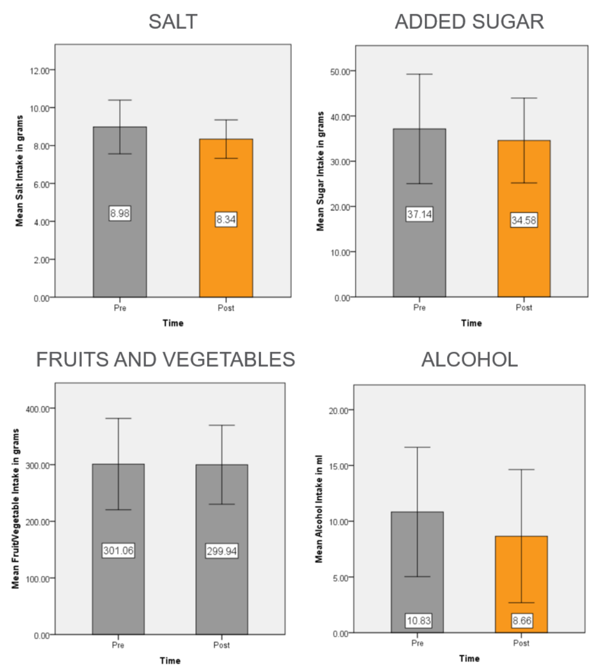


**Figure 4: Resulting dietary behavior (daily intakes) as measured by 4-day self-reported mFRCL pre- vs. post-avatar**

As the mHealth-mediated dietary used a mobile food record checklist (mFRCL) intake to monitoring nutritional intakes, it represents the first mobile-mediated checklist for sodium intake, thereby extending existing paper-based and computer-based checklist tools [36], [81], and enabling a direct communication channel to the end user which can be used to transmit tailored health interventions [95], e.g. as starting point for just-in-time adaptive interventions (JITAI) [96]. The observed sodium intakes were in line with the overall Swiss population [9], hence this paper suggests that future work should analyze their external validity compared to burdensome and cost-intensive 24h urine assessments, the contemporary state of the art method.

As participating users attest identification with the future-self avatar, and confirm the system's usefulness, ease of use, enjoyment, this paper suggests that future mHealth interventions can benefit from integration of future-self avatars via increased enjoyment to support user experience, especially to include the unhealthy and uninvolved users that are less likely to adopt (nutritional) mHealth.

Last but not least, the design science approach is worth discussing. Especially because the collaboration of dietitians, information system and human computer interaction researchers, medical experts in the design phase, which was enhanced by a parallel user workshop with hypertension patients and healthy consumers enabled to tailor the future-self avatar application to support the average consumer in sodium monitoring. While the avatar was pre-validated qualitatively with patients and healthy users, a potential improvement of the avatar design phase would be conduction of a large-scale quantitative pre-study of the avatar mechanics. Nevertheless, this study exemplifies that this study's interdisciplinary (future-self) avatar design framework can be drawn on by fellow researchers, dieticians and other stakeholders and also be applied in similar or related domains, e.g. weight loss, general healthy dieting, treatment of chronic diseases such as diabetes, obesity and hypertension.

## 7.2 Limitations

The lack of a control group may arguably represent a core limitation in our study. The latter thus represents a 'single groups study' that evaluates outcomes in a cohort of subjects who are managed with a single treatment strategy. Because such studies tend to "miss" a direct, concurrent comparison group, they are typically deemed non-informative regarding comparative effectiveness [97]. In the context of our before-after study however we argue that the initial user health status at baseline provides a plausible, valid estimate of the outcome that would have occurred in the absence of the avatar intervention over time. Meaning, that the lack of control group does not necessarily diminish the validity of causal inferences, we made. Nonetheless, the inclusion of a comparable control group would allow to further corroborate our findings. To increase the relevance of such studies, we furthermore suggest including groups with different treatment methods (e.g. non-digital methods and/or other mHealth system designs).

The reliability of our data may hence represent a more critical limitation. Based on the nature of mHealth applications and the utility of self-report questionnaires our study too relied on self-reported data. By drawing on established frameworks [98], we argue that we were able to ensure a higher reliability and internal validity of our study. Nonetheless, the self-reported data per se made our study subject to common reporting biases including users' memory, education and honesty. Such that a reduction in reliability cannot be ruled out. Although potentially costly, we thus suggest that further studies add complementary reliability measures such as urine samples [28], [31].

Another limitation stems from the sample and sampling process of our study. While the sample of 28 participants can be considered sufficient for statistical analysis - especially given the exploratory nature of the study, - the sample size does lower the external validity of our results. Hence, further studies should aim for higher sample sizes. Moreover, we assume that a more targeted sampling toward users with high-salt diets would further strengthen the external validity of such a study, as users who exerted a previously balanced diet in our study may have obscured our results regarding specific questions (see results).

## 7.3 Future Work

Finally, further improvements for subsequent research are suggested by the peripheral limitations of our study. For example, our study solely focused on the motivational phase of behavior change. Further research could include or focus on the volitional phase and build on our research. The latter could produce further insights as to not just triggering, but also effectively changing behavior toward low-salt dieting. We think that such an investigation however would require the addition of a time series analysis, strengthened by obtaining measurements over more time points [99], and allowing for withdrawal and re-exposure to salt interventions and the accounting for correlation between repeat measurements and underlying secular trends [100].

As this paper confirms the motivation- and health-beneficial effects of related studies to also work in the sodium domain, future work should be centered around implementing such mHealth interventions within (inter-)national sodium reduction strategies. Further research on leveraging state of the art technology to enrich user experiences of avatar interventions such as augmented reality (AR), virtual reality (VR), and three-dimensional (3D) visualization of avatars should be conducted. Also, new, automatic data collection methods such as inclusion of loyalty card data in forms of digital receipts, wearables and computer-vision seem promising to potentially substitute or improve the manual logging of checklist-based food items. As automatic data collection could increase easy-of-use and support long-term usage of such future-self avatar based mHealth applications, computer-vision, wearables and digital receipts represent promising potential to substitute manual logging.

# 8 Conclusion

This future-self avatar-based sodium intervention study provides several contributions to theory and practice. First, it extends the current body of research on sodium intake monitoring, behavioral change interventions, and the previously predominantly in the pediatric context applied avatar-based persuasive design in nutritional health, by exemplifying a new, scalable mHealth approach towards sodium reduction through mobile-mediated checklists and future-self avatar-based interventions. Second, this study proves that such avatar-based persuasive design can significantly increase consumers' risk awareness, outcome expectancy and the intention to mitigate excessive sodium dieting behavior – important prerequisites to initiate a low-sodium dieting behavior. Third, as the study observed measurable improvements in sodium consumption (decrease of 7.1%), added sugar consumption (decrease of 6.9%) and alcohol consumption (decrease of 20.0%) were achieved, thereby suggesting that future work should assess mHealth's potential to be included in future sodium reduction strategies as well as related interventions for consumption of alcohol, added sugar, fruit and vegetables.

We hope that future work can draw on the design principles aggregated in this research for the development of future-self avatars in dietary interventions. Such approaches can enable the average adult to monitor sodium intake and can become a vital part of effective sodium reduction strategies to achieve the required transition of global sodium intake from currently 9 to 12 grams of salt per day [7] down to five grams - as recommended by the WHO [32].

## 9 Presentation of the Application

A fully functional, live demonstration of the mHealth application will be shown at the conference. Attendees with smartphone device may download the application from the Google Play Store or Apple Appstore. Interested researchers can find the avatar framework and artwork publicly available for download and re-use: https://github.com/DanielMeusburger/FutureSelfAvatar/.

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