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SWISS FOODQUIZ: INDUCING NUTRITIONAL KNOWLEDGE VIA A VISUAL LEARNING BASED SERIOUS GAME

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SWISS FOODQUIZ: INDUCING NUTRITIONAL KNOWLEDGE VIA A VISUAL LEARNING BASED SERIOUS GAME

Prototype

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Abstract

Nutritional education programs have been proposed to counter the trend of excessive energy intake, identified as the main driver of overweight. Still, due to lack of resources, only a small part of society can be included in these personnel-intensive programs. Health information systems (HIS) in nutritional education have the potential to overcome these limitations, but still suffer under low end-user acceptance and interaction rates. Their current focus lies in abstract, too generic behavioural recommendations, which the end user cannot directly translate into health-beneficial real-world choices. In order to address these issues, we have built an automatic HIS prototype tailored to support the average consumer in gaining nutritional knowledge by applying paradigms from visual learning and serious gaming, established approaches in related fields to improve users' acceptance, motivation, intention and ultimately likelihood for health-beneficial behaviour changes. Preliminary results of a study with 350 users show high acceptance rates even for previously uninvolved users and measurable gains in nutritional knowledge over the usage phase. With the approach suggested in this paper, it can be shown that the extension of serious game principles to nutritional education can overcome contemporary HIS shortcomings of low acceptance and interaction rates among average, uninvolved and unhealthy users.

Keywords: Health information system, nutritional education, visual learning, serious gaming

1 Introduction

Due to the critically increasing numbers, obesity is becoming an alarming issue all over the world (Popkin, 2001; Sassi et al., 2009): In 2014 over 600 million adults and 42 million children were affected by obesity with growth rates of epidemic proportions (WHO 2015; Alexandratos & Bruinsma 2012). Because consequential diseases of obesity include chronic conditions, such as diabetes and cardio-vascular diseases, which often require long-term, cost-intensive medical treatment, the increased occurrences cause a significant, expanding financial burden for health-care systems around the world (Omran, 1982; Popkin, 2001, 2002; Srinath et al., 2004; Vorster, 2002; Puska, 2002).

In order to address these issues, nutritional education campaigns as part of multi-purpose programs have been proposed to counter the underlying excessive energy intake, identified as main driver of overweight (Dehghan et al. 2005; Swinburn et al. 2009). Since nutritional knowledge was found to play a pivotal role in behavioural change towards healthier diets (Spronk et al. 2014; Worsley 2002; Wardle et al. 2000; Young et al. 2011; Darnton 2008), experts recommend to foster nutritional

knowledge among all children and adults (WHO, 2003; Popkin, 2002). However, due to limited financial resources, the majority of population cannot be included in current personnel-intensive nutritional education programs, which additionally face the challenge of low acceptance rates (Kushner 1995).

Health information systems (HIS) have potential to spread nutritional knowledge towards broader audiences by providing personalized diet recommendations at significantly reduced costs over the internet (Brug et al. 2003; ChanLin et al. 2003). Still, also contemporary nutritional HIS experience low engagement rates, especially in demographic segments that are predestined for obesity, mainly due to low self-motivation and involvement (Williamson et al. 2006).

As serious games (Abt 1970) integrate education with the purpose of learning real-world relevant skills (Wattanasoontorn et al. 2014) into an entertaining environment (Landers et al. 2011), serious gaming offers a promising approach to mitigating low motivation and acceptance rates. The integration of serious gaming into HIS is already established in other health-related interventions, e.g. physical activity (Payne, Moxley, et al. 2015; Hamari & Koivisto 2013), but still relatively rarely seen in nutritional education (Lister et al. 2014; Majumdar et al. 2015).

The goal of this prototype is to exemplify that the extension of serious game principles to nutritional education can overcome contemporary nutritional HIS shortcomings of low acceptance and interaction rates, esp. among average, uninvolved and unhealthy users, and improve applicability of learnt educational content by visually representing locally available food items and healthier substitutes.

This paper adds to the body of existing research by providing insights into how serious gaming for nutritional HIS impacts high acceptance and interaction rates, esp. also among the nutritionally illiterate, unhealthy (adult) users that were previously unlikely to accept nutritional HIS (Williamson et al. 2006). Practitioners and dieticians can leverage upon similar, automatic nutritional HIS in their patient-consultations, as this paper proves that HIS usage correlates with measurable gains of directly applicable nutritional knowledge.

2 Related Work: Serious Gaming in Nutritional Education

Although the advantageous effect of nutritional HIS on health literacy and dietary behaviour has been confirmed (Tate et al. 2001; Turner-McGrievy & Tate 2011), their limited acceptance beyond the highly-interested, relatively healthy patients and low level of interaction rates are strongly criticized (Hebden et al. 2012; Block et al. 2015; Thomas et al. 2015; Casperson et al. 2015; Williamson et al. 2006). To overcome these issues of scaling HIS based interventions towards broader audiences and to increase interaction frequencies, serious games (Abt 1970; Deterding et al. 2011) as games with an educational or informative purpose were found to be effective (Hamari et al. 2014), e.g. at promoting physical activity (Hassan et al. 2012; Leahey & Rosen 2014; Thomas et al. 2015; Payne, Moxley, et al. 2015), digital medical interventions for (chronic) diseases (Kamel Boulos et al. 2015) and paediatric obesity prevention (Thompson 2014; Xu et al. 2014). Similar concepts remain to be rarely seen in nutritional education targeted towards adolescents and adults (Lister et al. 2014; Majumdar et al. 2015; Schneider et al. 2012).

Nutrition-related serious games teach nutritional knowledge or train food literacy (Wattanasoontorn et al. 2014; Lister et al. 2014) through a gamified, entertaining environment (Landers et al. 2011), e.g. by adding game design elements to an HIS (Hamari 2011; Deterding et al. 2011), such as badges, leaderboard, time constraint, goals, badges, levels, etc. (Deterding et al. 2011). As perceived benefits (Darnton 2008) lead to cognitive stimuli (Connolly et al. 2012), intrinsic motivation (Hamari et al. 2014), improved learning results (Connolly et al. 2012), greater interest (Cheong et al. 2013), positive attitude (Hamari & Koivisto 2013) and involvement in dietary health (van der Heijden 2004), the limitations of high entry-barriers for the nutritionally illiterate and uninvolved, as well as overall low acceptance and retention rates can be overcome (Payne, Lister, et al. 2015). Furthermore, besides improving acceptance, as serious games usually leverage upon proven health behaviour constructs, e.g.

goal-setting, self-monitoring and self-reward (Payne, Moxley, et al. 2015; Cugelman 2013), such games also improve users' motivation for (Connolly et al. 2012), attitude towards (Hamari & Koivisto 2013), intention to (Hamari & Koivisto 2013) and likelihood for (health-)beneficial behaviour change (Baranowski et al. 2008; Hamari et al. 2014).

The few available examples of serious games in adult nutritional education (Majumdar et al. 2015; Thompson et al. 2007) confirm the effectiveness of gamification (Deterding et al. 2011) enhanced HIS, but still lack real-world applicability of learnt knowledge as they only teach abstract, generic knowledge (Cornish & Moraes 2015; Andrews et al. 2000). Therefore, the integration of visual learning (Lu et al. 2011; ChanLin et al. 2003) of product packaging images promises superiority over contemporary education concepts, usually taught through reading and aural learning of abstract recommendations (Spronk et al. 2014), as the fast-paced product purchasing process hinders the required translation of abstract concepts towards a binary product-specific purchasing decision, esp. given the dependency on rarely used and difficult-to-interpret nutritional labels (Grunert et al. 2010; Spronk et al. 2014) and consumer confusion due to misleading product ad claims (Andrews et al. 2000; Cornish & Moraes 2015). Psychology research suggests that compared to learning based on reading or listening, image-based visual learning yields higher recognition and recall rates when facing visual examination tasks due to improved hypermnesia (Kroll & Potter 1984; Bergstein & Erdelyi 2008). As the visual examination of product packages plays a key role in the search-phase of purchasing decisions at the supermarket shelves (Breugelmans et al. 2006; Andrews et al. 2000; Clement 2007; Clement et al. 2013), packaging-image-based visual learning of nutritional attributes suggests better applicability of nutritional education. Besides integrations of serious gaming and visual learning, the prototype adheres to best-practices of traditional nutritional campaigns, including contemporary design (Rysdale 2008; Vignerová et al. 2011), regional-, cultural- and context-specific customization by including local product data (Lappalainen et al. 1998; Vignerová et al. 2011) and personalization towards the patient's food goals and knowledge, as users can choose to follow a pre-designed learning route or select topics of interest (Worsley 2002). To the best of our knowledge, this prototype is the first serious game based HIS in nutritional education applying visual learning through packaging images from a national, cross-retailer, cross-brand product dataset.

3 Design Science Approach

The HIS prototype was developed in close collaboration with the Swiss association for nutrition (SGE-SSN 2015) and involved dietitians, IS researchers, computer scientists, medical experts as well as adolescent and adult end users. The research process followed the design science research paradigm (Hevner et al. 2004; Peffers et al. 2008; Gregor & Hevner 2013), using an iterative development cycle including multiple test phases with users, thereby optimizing application's properties towards the main constructs: Ease of use (Koivisto & Hamari 2014) was achieved through an introductory tutorial, clear goals and clean user interface design utilizing large user buttons (Hamari et al. 2014). Social recognition (Hamari & Koivisto 2013) was realized through a publically visible leaderboard and rewards (Deterding et al. 2011), self-recognition (Okumus et al. 2015) through point scoring, visible round performance, post-round feedback and badges (Hamari et al. 2014), enjoyment (Cheong et al. 2013) was realized through colourful game design, themed statements between rounds and time constraints (Hamari et al. 2014). Perceived usefulness (Pereira et al. 2014) was attained through personalization of recommended dietary allowances, integration of educational content, visual representation of local products and the option to review and search all products of the database. The operationalization of main constructs orients itself towards relevant literature and similar applications (Hamari et al. 2014; Wattanasoontorn et al. 2014; Payne, Moxley, et al. 2015), as they tend to improve acceptance of (Okumus et al. 2015), satisfaction with (Zhang 2007) and prolong usage of HIS (van der Heijden 2004), which are the primary study goal. Besides improving acceptance and in order to support building health-beneficial attitudes, norms and perceived control as suggested by health behaviour theory (Glanz et al. 2008), "Swiss Foodquiz" also operationalizes goal setting (Payne, Moxley, et al. 2015)

through the optional choice of selecting a nutrient (e.g. salt) or product category (e.g. salty snacks) and self-monitoring (Payne, Moxley, et al. 2015) through integration of historic user performance statistics. The iterative design process of an up-to-date serious gaming approach in regards to user experience, game design elements (Deterding et al. 2011) and aesthetics (Kapp 2012) is non-trivial and requires significant development efforts. Furthermore, designing the question-building logic that selects two substitutable products from within a certain category of the product database (GS1 2016), which contain at least a significant enough difference of a relevant nutrient as defined by the national association for nutrition, required iterative development cycles and input from dietitians as well as computer scientists (Fig. 5.b).

4 Design of Prototype

The serious game design of “Swiss Foodquiz” was inspired by the world’s most played educational trivia game Quizup (QuizUp 2013), adapted to asking users to conduct a visual examination task requiring nutritional knowledge. The task simulates choosing products at the supermarket shelf, as the user has to choose the one out of two similar, visually presented food products with the higher content of a relevant given nutrient, e.g. identifying the cereal product with significantly higher amounts of sugar compared to its substitutable alternative (Fig. 1.c).

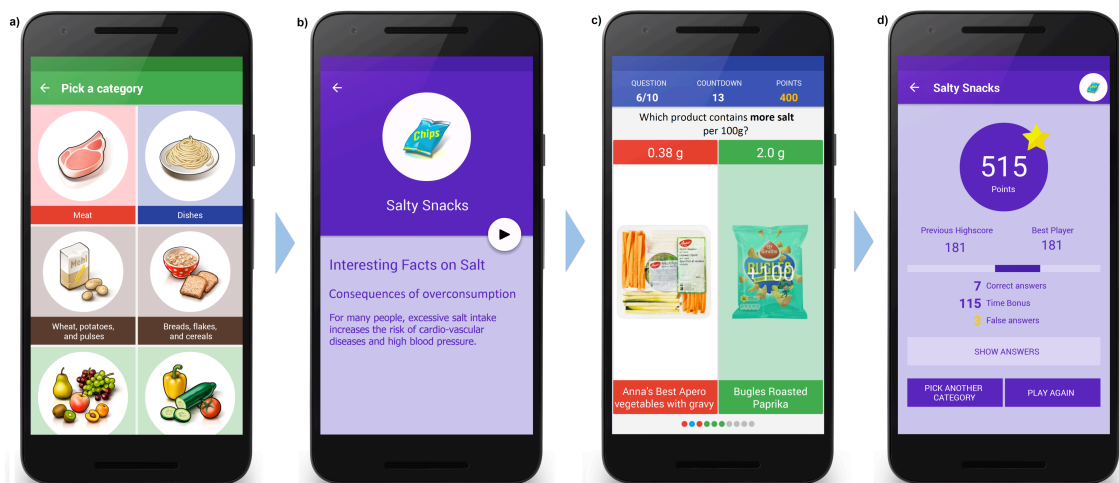


Figure 1. A round in the game consists of a) selecting a category, b) receiving relevant nutritional education about the upcoming category, c) answering ten visual examination tasks with instant feedback after each answer, d) receiving a score feedback

As the prototype design requires integration of a relevant product database, for which multiple alternatives were available, the national database featuring the highest data quality in regards to product package images and ingredient data was selected (GS1 2016). Alternative, although larger, but non-curated databases proved to be unusable due to unacceptable amount of flawed data entries. In this aspect, the EU Food Information Regulation (EU-1169/2011 2014) on the provision of food information online ratified in Dec. 2014 is paving the way for publicly accessible product databases covering multiple retailers and brands, enabling this and similar future HIS. In order to only include relevant comparisons of substitutable food items within the quiz, the currently 2996 products of the growing database were arranged into 19 main and 111 subcategories by the consumer-centric category design of the national association for nutrition. Further, for each subcategory, relevant nutrients and minimum nutritional differences between substitutable products were defined through a category-nutrient-mapping, hereby guaranteeing that the logic of the question-building algorithm only permits relevant questions about two substitutable, yet in regards to relevant nutritional content different food products (Fig. 5.b). Thus, the user not only receives relevant nutritional knowledge, but is also encouraged to apply gained knowledge in his purchasing routine through the visual discovery of healthier, substitutable products.

“Swiss Foodquiz” is implemented as a client-server application: The client side is a native Android application developed for Android smartphones and tablet-PCs, while the server side is realized as a RESTful, PHP-based API-framework, used to store user entries and performance, as well as to load the generated quiz rounds including nutritional and image data for each of the twenty products randomly selected for each round of ten questions by the question-building algorithm (Fig. 5.b).

When starting “Swiss Foodquiz” for the first time, users register through a mandatory, introductory survey asking for self-evaluations of their nutritional knowledge and involvement, as well as biomedical information, including body-mass-index and physical activity level, allowing the prototype to personalize nutritional recommendations towards the end-user, e.g. showing recommended dietary allowances. The questionnaire (Fig. 5.a) was completed by 74% of users, indicating high motivation to engage with the game. Before players can initiate the game, the game design mechanics are explained within an introductory tutorial enabling user self-efficacy (Kapp 2012). Depending on the game’s setting, the user can then play the next round by following a predefined, randomized path or choose a specific nutritional category (e.g. salt, sugar, etc.) or product category (e.g. cereals, salty snacks, etc.), following the idea of goal-setting (Payne, Moxley, et al. 2015) (Fig. 1.a). Prior to each new round, the player receives educational statements about the upcoming category and nutrients, aiming to educate the user through tailored, personalized messages, e.g. based on recommended daily intake, thereby increasing perceived usefulness (Payne, Moxley, et al. 2015; Pereira et al. 2014) (Fig. 1.b). A round within the game is composed of ten questions, each asking the user to choose the one out of two similar, visually presented food products with the higher content of a relevant given nutrient (Fig. 1.c). While playing the game, the user is confronted with game design elements (Deterding et al. 2011), such as time constraining countdowns (Fig. 1.c), point-based incentivization of a score bonus for correct (malus for incorrect) answers crediting correct answers with 100 bonus points, while 100 malus points are deducted for false answers, thereby eliminating positive average scores for answer strategies based on random guessing instead of applying nutritional knowledge. In order to incentivize time management (Payne, Moxley, et al. 2015), a relative minor bonus of one point per left second is granted for correct, fast answers (countdown starts at 20 seconds, max. theoretical bonus per round: 200 points). After each round, the HIS evaluates the player’s performance through a score-based performance feedback and potentially awards badge statuses, enabling self-recognition (Fig. 1.d) (Payne, Moxley, et al. 2015). Besides score feedback, the self-monitoring functionality (Payne, Moxley, et al. 2015) (Fig. 2.b) lets players review their performances across different category levels and explore areas of weaknesses they would need to address in order to gain scores. Social recognition as suggested by social cognitive theory (Bandura 1991) is applied by the leaderboard, which by default includes all peer players of the game, ranking them by performance (Fig. 2.c). In order to climb up the leaderboard, users have to perform well in all nutrients and product categories, since the sum of best respective level scores defines the position in the leaderboard, thereby incentivizing repeated iterations.

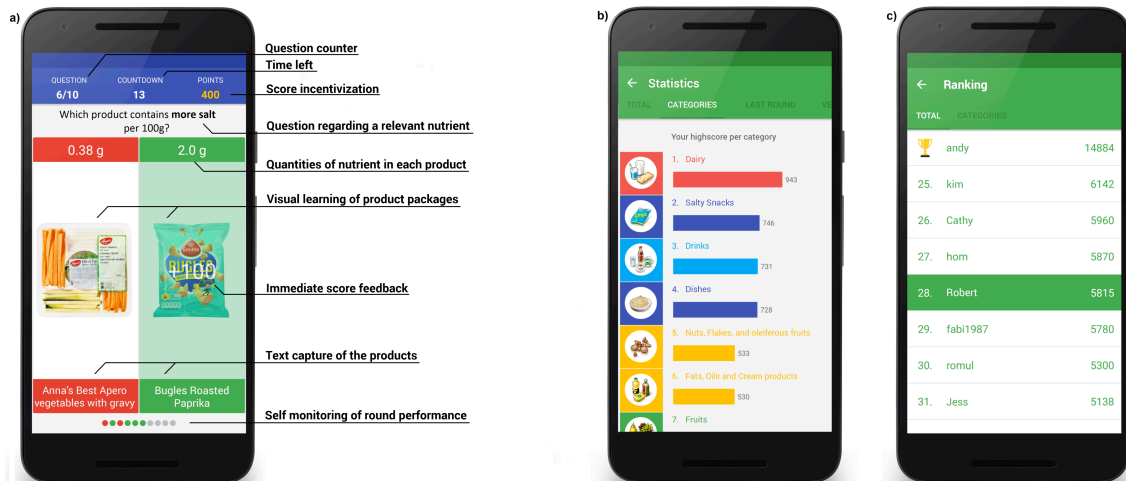


Figure 2. Gamification elements within the prototype are realized through a) game design elements, b) self-monitoring of task performance, c) leaderboard

All player inputs are logged on the server in order to assess user performances and HIS usage for further improvement of the application. Furthermore, future surveys in the post-signup usage phase will survey users regarding their satisfaction and potential suggestions for further development of the HIS, but also measure changes to the subjective self-evaluation of involvement and dietary behaviour.

5 Preliminary Results

The application was released under the name “Swiss Foodquiz” in the Swiss Google Android Play store, announced via social media and has recruited 475 downloads within a two-months preliminary testing period from Nov. 27th 2015 to Jan. 27th 2016. In total, 350 users (74%) completed the mandatory, introductory survey and were admitted for usage of the prototype. The dropout rate of users (26%) is very low, when considering that the introductory survey was compulsory.

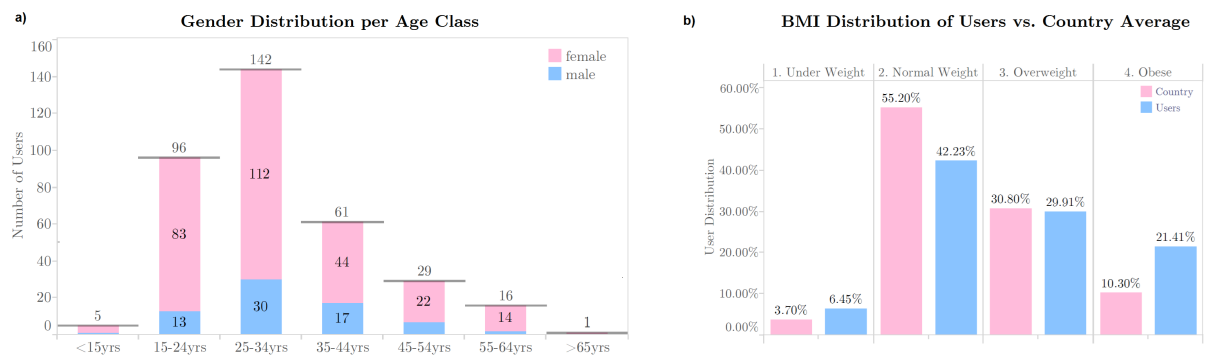


Figure 3. a) The prototype has high acceptance among adolescents and adults. The user base is an adequate sample of national population in terms of b) BMI distribution

The user distribution is composed of a majority of females (19.7% male, 80.3% female, Fig. 3.a), predominately adolescents and adults between 15 and 44 years of age (Fig. 3.a) and a realistic representation of the Swiss population’s BMI distribution (Fig. 3.b). Especially worth mentioning is that the majority of user base can be considered uninvolved in (nutritional) health, as they are physically rather inactive in their leisure time (58%) and state that their self-evaluation towards nutritional knowledge is average or limited (56%) (Fig. 5.b). User participation was entirely motivated through intrinsic, voluntary motivation, as there was no incentivizing scheme or enforced enrolment obligation applied within the recruitment process. Treatment duration within the prototype reached an average of 167 answered

questions (≈ 17 rounds) per user, which can be estimated to equal circa 50 minutes of nutritional education (Estimate: 15 sec. per question, add. 20% of time consuming educational content).

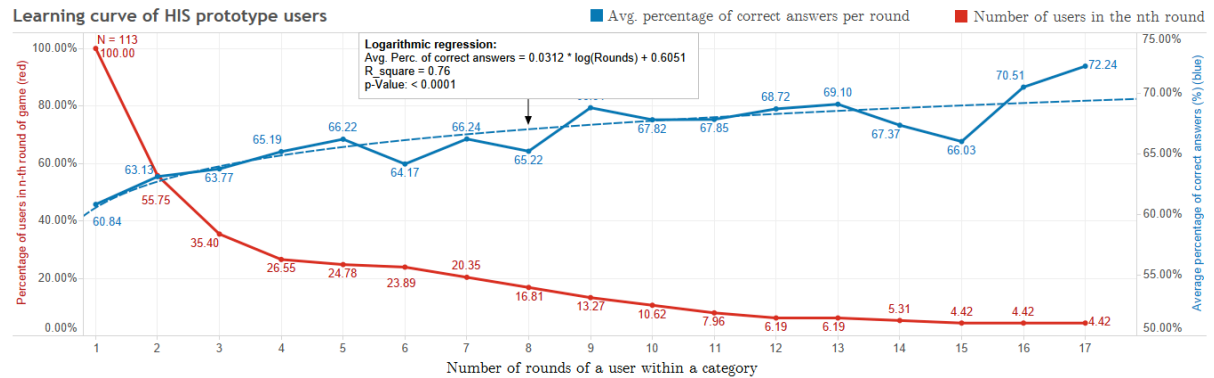


Figure 4. Performance of users increases over time, indicating a learning curve. In parallel, user retention wears off over time. A first, preliminary logarithmic regression yields significance regarding the improvement of task performance over time ($R^2 \approx 0.76$).

Our hypothesis is that by receiving nutritional information while engaging with the game, users eventually gain knowledge about products and nutrients, which is applied when answering future questions within the same category, thereby leading to higher task performances over time, measured by the percentage of correct questions per round. Learning curves show that player performance starts at below 61% and grows to above 72% throughout the game (Fig. 4), thereby doubling their performance when compared to pure guessing strategies (i.e. 50%). As learning curves follow logarithmic paths (Schilling et al. 2003), a logarithmic regression was applied on the subset of users who played multiple times within the same product category out of the 19 available main categories. Since the regression yields significance ($R^2 \approx 0.76$), the hypothesis of a positive learning effect is supported (Fig. 4). Additional analyses also proved that the positive learning effect holds true despite the dropouts of users, i.e. short- as well as long-term users of “Swiss Foodquiz” gained knowledge and increased performances.

Furthermore, voluntarily submitted user feedback explicitly mentioned experiencing learning effects especially on cereal products in regards to sugar impact, calories contained in processed food versus fresh food, salt intake via cheese consumption and an especially high interest in local foods and brands, thereby confirming the importance of context-sensitive customization of nutritional education towards locally present products and eating customs (Lappalainen et al. 1998; Vignerová et al. 2011).

6 Discussion

The preliminary results prove that the automatic HIS prototype can indeed address uninvolved as well as involved adolescent and adult users, thereby teaching quantifiable gains in nutritional education and achieving high acceptance and interaction rates. The user bias towards females is typical for nutritional HIS (Brug et al. 2003) and can be explained due to the announcement of the prototype in social media, where followers of the national association for nutrition are predominantly female. The overrepresentation of female users might be mitigatable through a more public presentation of the HIS in further outlets or adapting the serious game design towards men (Koivisto & Hamari 2014). Especially since the majority of users are relatively uninvolved in healthy nutrition or physically rather inactive (Fig. 5.a), and therefore unlikely to use other contemporary HIS (Williamson et al. 2006), the prototype’s promising potential of enrolling the previously uninvolved and uninterested users (Hebden et al. 2012), and to eventually change their subjective attitude, involvement and behaviour in regards to nutritional education and healthy dietary intake, should be assessed in more detail in the future.

Limitations of the current state of the prototype are that the product database still contains errors (e.g. 100 errors reports were filed by users through crowdsourcing, i.e. 3.3%) and that therefore performance in the game is very unlikely to reach 100%. Adding to this circumstance, often purchased and

well-known products are presented equally often as extremely rare and unknown products, for which users cannot estimate the nutritional content easily. Further, the question-building algorithm (Fig. 5.b) provides very hard questions, with the difference of two products sometimes being just 1%, making it tough even for dietitians and nutritional experts to score performances of above 95% in the game. The question, whether learning improvements occur, because users are learning nutritional facts of familiar products by heart instead of applying actual meta-knowledge, can be addressed by considering the combinatorics variety of possible product combinations provided by the question builder, currently offering multiple millions of possible questions, making it impossible to perform very well in the game without actually learning about fundamental nutritional concepts, provided by the educational elements (Fig. 1.b). Further, since little is yet known about excessive use of the prototype, a shut-off after one-hour usage per day is recommended in a productive scenario, for example by convincing the user to get physically active. Compared to currently available HIS applications, the results promise a more applicable gain of nutritional knowledge. Future work should therefore assess through detailed statistical analysis using t-tests or Bayesian methods, how much of the gained knowledge is stored in the short- and long-term memory and how users of the HIS prototype translate gained nutritional knowledge into changes of subjective intention and actual dietary behaviour (Darnton 2008). Together with the Swiss national association for nutrition, “Swiss Foodquiz” will be evaluated through further, longitudinal field studies and as part of existing obesity therapies and prevention programs, thereby measuring the education effect in the form of learning performance and its impact on dietary and purchasing behaviour, e.g. switching to healthier product alternatives discovered through the HIS prototype. In addition, future surveys will be conducted to evaluate improvements of subjectively perceived measures of attitude, intention and involvement (Darnton 2008). Future work on similar serious games in nutritional education should adhere to current best practice principles (Graafland et al. 2014).

7 Conclusion

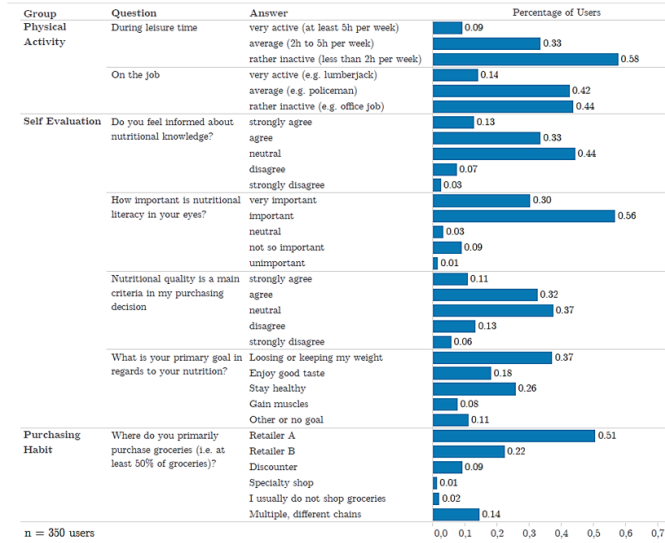
This HIS prototype provides several contributions to theory and practice. First, it extends the current body of research (L. Hebden et al. 2012; Payne, Moxley, et al. 2015) on serious gaming in physical activity HIS towards nutritional HIS by exemplifying a new, scalable approach towards high acceptance and interaction rates within broader, adult audiences, esp. including the physically inactive and uninvolved users that were previously unlikely to accept (nutritional) HIS (Williamson et al. 2006). Second, the HIS offers high applicability of quantifiable knowledge gains due to integration of images representing locally available, real-world products. Third, it provides an instrument that is co-designed by dietitians, IS researchers, computer scientists, consumers and medical experts thus tailored to support the average consumers in gaining nutritional knowledge. Fourth, with the approach suggested in this paper, realizing a similar automatic and scalable HIS approach in nutritional education either as stand-alone or multi-purpose-HIS-integrated application becomes relatively straightforward and should encourage more data-owners to provide product ingredient data and product images publicly. As democratizing nutritional knowledge is a key element of promising obesity prevention strategies (WHO 2003; Finkelstein et al. 2012; Chopra et al. 2002), such automatic, scalable, serious gaming based HIS approaches aimed towards educating the adolescent as well as adult public can become a vital part of effective nutritional education and obesity prevention strategies.

8 Presentation of the Prototype

A fully functional, live demonstration of the prototype will be shown on an Android tablet-PC. The screen of the presentation device can be mirrored to larger projection screens. Attendees with an Android device may download the application from the Google Play Store.

9 Appendix

a) Results of Prototype User Survey



b) Question-Building Algorithm

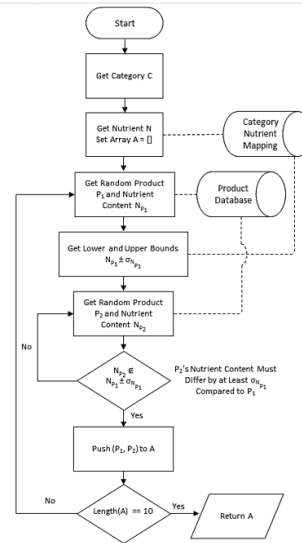


Figure 5. a) Results of introductory survey, b) Question-Building Algorithm

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