# Healthy Pleasures: Integrating Food Well-Being and Simple Eating Behaviour Interventions

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# Table of Contents

Danksagung .......... i

Vorveröffentlichungen der Dissertation .......... iii

Table of Contents .......... iv

Summary .......... 1

Zusammenfassung .......... 4

1. General Introduction .......... 8

1.1. From food as health (risk) to food as well-being .......... 9

1.2. From complex guidelines to simple strategies .......... 14

1.3. Implementation in mobile interventions .......... 19

1.4. Outline and research aims of the present dissertation .......... 22

2. To use or not to use: A behaviour stage model approach for describing the process of adopting nutrition and fitness apps .......... 24

2.1. Abstract .......... 25

2.2. Introduction .......... 27

2.3. Methods .......... 32

2.3.1. Design and procedure .......... 32

2.3.2. Ethics .......... 33

2.3.3. Sample .......... 33

2.3.4. Measures .......... 34

2.3.5. Statistical analysis .......... 38

2.4. Results .......... 39

2.4.1. Mobile devices, nutrition and fitness app use .......... 39

2.4.2. Stages of behavioral adoption .......... 40

2.4.3. Sociodemographic correlates .......... 41

2.4.4. Behavioral correlates .......... 42

2.4.5. Psychological correlates: Preference for Intuition and Deliberation in Eating Decision-making .......... 43

2.5. Discussion ........................................................................................ 44
2.5.1. Stages of behavioral adoption ................................................................ 45
2.5.2. Limitations .............................................................................................. 51
2.6. Conclusions ........................................................................................ 51
3. Colourful = healthy? Exploring meal colour variety and its relation to food consumption ........................................................................................ 57
3.1. Abstract ............................................................................................... 58
3.2. Introduction ......................................................................................... 59
3.3. Material and methods .......................................................................... 61
3.3.1. Sample .................................................................................................. 61
3.3.2. Procedure .............................................................................................. 62
3.3.3. Materials ................................................................................................ 63
3.3.4. Statistical analysis ................................................................................. 64
3.4. Results ................................................................................................. 66
3.4.1. Accuracy of colour perception ............................................................... 66
3.4.2. Colour and food group variety in lunch meals ....................................... 66
3.4.3. Relationships between perceived meal colour variety and food consumption ........................................................................................ 68
3.5. Discussion ........................................................................................... 69
3.6. Conclusions ......................................................................................... 73
4. Boosting vegetable consumption by meal colour variety in an Ecological Momentary Intervention ........................................................................ 75
4.1. Abstract ............................................................................................... 76
4.2. Introduction ......................................................................................... 77
4.3. Method ................................................................................................. 79
4.3.1. Sample .................................................................................................. 79
4.3.2. Design and procedure ............................................................................ 80
4.3.3. Materials ................................................................................................ 82

4.3.4. Statistical analysis ........ 84

4.4. Results ........ 86

4.4.1. Colour and food group variety in lunch meals ........ 86

4.4.2. Relationships between perceived meal colour variety and food intake .. 86

4.4.3. Impact of the prompt to eat a colourful lunch on food consumption ....... 89

4.4.4. Evaluation of the prompt ........ 91

4.4.5. Control analysis: Change in BMI ........ 91

4.5. Discussion ........ 93

4.5.1. Limitations and avenues for future research ........ 96

4.5.2. Conclusion ........ 96

4.5.3. Implications ........ 96

5. General Discussion ........ 99

5.1. Motivational differences between mHealth app users and non-users........ 101

5.2. Need for alternative approaches to eating behaviour change........ 102

5.3. Introducing an alternative approach........ 103

5.3.1. Food as well-being ........ 104

5.3.2. Consumer-oriented recommendations ........ 106

5.3.3. Enabling healthy and enjoyable food choices ........ 108

5.4. Boosting healthy and enjoyable food choices ........ 110

5.5. Implications and outlook ........ 113

5.6. Concluding remarks ........ 117

References ........ 119

List of Contributions ........ 160

## Summary

Although eating behaviour is influenced by a variety of motives, when aiming to change eating behaviour the focus is often laid on health and weight control motives, supporting a view of food as health. Dietary guidelines based on this view usually consist of complex, normative, and restrictive rules that are difficult to put into practice for lay persons. The present dissertation proposes an alternative approach. It aimed to shift the focus towards a perspective of food as well-being to acknowledge the psychological benefits of eating. The view of food as well-being was further integrated with simple intervention strategies to simplify behaviour change by reducing the complexity of both triggers and the target behaviour itself. Moreover, the present dissertation provides insights into how this alternative approach might be suited to extend the reach and audience of mHealth apps.

Accordingly, the present dissertation had two aims. Firstly, it aimed to shed light on underlying motivations and barriers to mHealth app use using an adaptation of the Precaution Adoption Process Model (PAPM). Specifically, Preference for Intuition and Deliberation in Eating Decision-making (E-PID) was included as a psychological transition barrier to inform the development of mobile interventions that target new user groups. The second aim of the present dissertation was to identify and test a simple intervention strategy for facilitating healthy food choices using a simple visual cue. Specifically, a ‘colourful equals healthy’ association was established and tested using data collected in real-life eating situations.

In a first step, a behaviour stage model describing the process of nutrition and fitness app adoption was developed based on the PAPM. The model consists of five stages (Stage 1 ‘unengaged’; Stage 2 ‘decided to act’; Stage 3 ‘decided not to act’; Stage 4 ‘acting’; Stage 5 ‘disengaged’). The stage model was tested for nutrition and fitness apps within the fourth measurement point of the longitudinal cohort study Konstanz Life-Study ($N$ = 1,236 participants). Additionally, potential sociodemographic (age, gender, level of education), behavioural (healthy eating style, BMI) and psychological (E-PID) correlates were assessed to examine potential transition barriers. Analysis of the five behaviour adoption stages showed that participants differed in their readiness to adopt mHealth apps. Stage 1 (‘unengaged’) was the most prevalent stage for nutrition apps (52.4%), while 8.1% of participants currently used a nutrition app (stage 4, ‘acting’). Therefore, data indicates that there is great potential to target new user groups for nutrition apps. Age and E-PID emerged as potential transition barriers. Importantly, ‘unengaged’ non-users showed a preference for an intuitive decision-making style, while ‘acting’ users showed a preference for a deliberative decision-making style, indicating that new user groups might be better reached by designing apps that address a more intuitive decision-making style. Finally, the model revealed differences between non-user groups that might contribute to a better understanding of the motivational underpinnings of (not) using mHealth apps.

In a second step, the view of food as well-being was integrated with a simple intervention strategy. A ‘colourful equals healthy’ association that was based on meal colour variety as a visual cue for healthy food choice was established and tested. The ‘colourful equals healthy’ association was established in an observational Ecological Momentary Assessment study with 108 participants who recorded their lunch meals for at least four consecutive days using a mobile visual food record. Analysis of intra-individual relationships between perceived meal colour variety and the consumption of seven food groups (fruit, vegetables, grains and starches, protein sources, dairy, fried foods, sugary extras) revealed that an increased perceived meal colour variety was related to an increased consumption of vegetables and a decreased consumption of sugary extras. Notably, the strength of the relationship between perceived meal colour variety and vegetables did not differ between participants, suggesting a universal relationship between perceived meal colour variety and dietary healthiness. Thus, meal colour variety might be used as a simple cue for healthy food choices.

To test this assumption, an Ecological Momentary Intervention was conducted with 80 participants who recorded their lunch meals for a period of three weeks. In the second week of the study, participants received a prompt that was tailored to their individual lunch meal times, asking them to eat a colourful lunch meal. After the study period, participants were asked to evaluate the prompt. Again, perceived meal colour variety was positively related to vegetable consumption. Furthermore, it was negatively related to the consumption of sugary extras, fruit and grains and starches. In the second week of the study, participants consumed more vegetables and less dairy than in the baseline week, indicating that the prompt was successful in changing their eating behaviour. Moreover, participants evaluated eating colourful lunch meals as enjoyable and easy to put into practice. Hence, prompting consumers to eat colourfully is a simple yet effective intervention strategy for promoting healthy food choices in daily life.

Low nutrition app use rates highlight that eating behaviour interventions are not a ‘one size fits all’ approach and thus, alternative approaches need to be explored. Traditional approaches focus on the food as health perspective, provide normative guidelines, and are often constraining. The present dissertation complements traditional approaches by introducing an alternative approach that highlights the food as well-being perspective, and demonstrating that encouraging approaches can also result in effective eating behaviour interventions. Based on this alternative approach, simple but effective intervention strategies might be developed and subsequently communicated to consumers to promote health and well-being.

## Zusammenfassung

Obwohl eine ganze Reihe von Motiven das Essverhalten beeinflussen wird oft ein Fokus auf Gesundheit und Gewichtskontrolle gelegt, wenn das Essverhalten gezielt verändert werden soll. Damit vertreten viele Präventionsprogramme die Sichtweise, dass Essen primär der Erhaltung der Gesundheit dient („food as health“). Ernährungsrichtlinien, die auf dieser Sichtweise aufbauen, bestehen normalerweise aus komplexen, normativen und restriktiven Verhaltensregeln, die für Laien oft schwer umzusetzen sind. Die vorliegende Dissertation schlägt einen alternativen Ansatz vor. Sie hatte zum Ziel, den Fokus darauf zu verschieben, dass Essen auch maßgeblich zum Wohlbefinden beiträgt („food as well-being“). Dieser „food as well-being“ Ansatz wurde in der vorliegenden Dissertation mit einfachen Verhaltensänderungsstrategien verknüpft. Sie reduzieren die Komplexität des Zielverhaltens und dessen Auslösern und sollen so Verhaltensänderungen einfacher machen. Die vorliegende Dissertation beleuchtet zusätzlich, inwieweit dieser alternative Ansatz eine vergrößerte Reichweite der immer zahlreicher werdenden Gesundheits-Apps ermöglichen könnte.

Die vorliegende Diskussion hatte zwei Ziele. Das erste Ziel dieser Dissertation war, Motivationen und Barrieren für die Nutzung von Gesundheits-Apps zu untersuchen. Dazu wurde eine adaptierte Version des „Precaution Adoption Process“ Modells (PAPM) verwendet. Insbesondere wurde die Präferenz für Intuition und Deliberation in essensbezogenen Entscheidungen (E-PID) als psychologische Barriere für Stufenübergänge untersucht, um die Erschließung neuer Nutzergruppen zu unterstützen. Das zweite Ziel der vorliegenden Dissertation war es, eine einfache Verhaltensänderungsstrategie zu identifizieren und zu testen, die auf einfachen visuellen Hinweisreizen beruht. Dazu wurde eine „bunt ist gesund“ Assoziation im Alltag von ProbandInnen untersucht.

In einem ersten Schritt wurde aufbauend auf dem PAPM ein Prozessmodell entwickelt, das die Bereitschaft zur Nutzung von Ernährungs- und Fitness-Apps beschreibt. Dieses Modell besteht aus fünf Stufen (Stufe 1: „uninformiert“, Stufe 2: „entschieden zu handeln“, Stufe 3: „entschieden nicht zu handeln“, Stufe 4: „handelnd“, Stufe 5: „nicht mehr handelnd“). Das Modell wurde getrennt für Ernährungs- und Fitnessapps in der vierten Erhebungswelle der Konstanzer Life-Studie angewandt ($N$ = 1.236). Zusätzlich wurden potentielle soziodemografische (Alter, Geschlecht, Bildungsjahre), verhaltensbasierte (gesunder Ernährungsstil, Body-Mass Index) und psychologische Barrieren (E-PID) für die Annahme von Ernährungs- und Fitness-Apps erfasst. Die Daten zeigten, dass sich die ProbandInnen stark in ihrer Bereitschaft, Gesundheits-Apps zu nutzen, unterschieden. Stufe 1 („uninformiert“) war die am häufigsten gewählte Stufe (52.4%) für Ernährungs-Apps, während nur 8,1% der ProbandInnen zur Zeit eine Ernährungs-App nutzten (Stufe 4, „handelnd“). Die Ergebnisse legen also nahe, dass großes Potential besteht, weitere Nutzergruppen für Ernährungs-Apps zu erschließen. Alter und E-PID stellten Barrieren für die Nutzung von Ernährungs-Apps dar. ProbandInnen in Stufe 1 („uninformiert“) zeigten eine Präferenz für Intuition, während ProbandInnen in Stufe 4 („handelnd“) eine Präferenz für Deliberation zeigten. Dementsprechend könnten neue Nutzergruppen für Ernährungs-Apps erschlossen werden, indem in neuen Apps ein intuitiver Entscheidungsstil angesprochen wird. Außerdem zeigte das Prozessmodell auch Unterschiede zwischen Untergruppen der Nichtnutzer auf, die dazu beitragen können, die (Nicht-)Nutzung von Gesundheits-Apps besser zu verstehen.

In einem zweiten Schritt wurde der „food as well-being“ Ansatz mit einfachen Verhaltensänderungsstrategien zusammengeführt. Eine „bunt ist gesund“ Assoziation wurde basierend auf dem Zusammenhang der wahrgenommenen Farbvielfalt von

Speisen und deren Gesundheit etabliert und getestet. Zunächst wurde die „bunt ist gesund“ Assoziation in einer beobachtenden Ecological Momentary Assessment Studie etabliert, für die 108 ProbandInnen über mindestens vier Tage ihre Mittagsmahlzeiten mit Hilfe von Fotos aufzeichneten. Die Analyse von intraindividuellen Zusammenhängen zwischen der wahrgenommenen Farbvielfalt und dem anteiligen Verzehr von sieben Lebensmittelgruppen (Obst, Gemüse, Getreideprodukte, Proteinquellen, Milchprodukte, frittierte Speisen und Süßspeisen) ergab, dass eine erhöhte wahrgenommene Farbvielfalt mit einem größeren anteiligen Verzehr von Gemüse und einem geringeren anteiligen Verzehr von Süßspeisen assoziiert war. Dabei war die Stärke des Zusammenhangs zwischen der wahrgenommenen Farbvielfalt und dem anteiligen Verzehr von Gemüse zwischen den ProbandInnen vergleichbar, was auf einen verallgemeinerbaren Zusammenhang zwischen wahrgenommener Farbvielfalt und der Gesundheit von Speisen hindeutet. Die wahrgenommene Farbvielfalt von Speisen könnte also als ein einfacher Hinweisreiz für gesunde Nahrungsauswahl in Präventionsprogrammen genutzt werden.

Diese Annahme wurde in einer Ecological Momentary Intervention getestet, in der 80 ProbandInnen ihre Mittagsmahlzeiten für einen Zeitraum von drei Wochen aufzeichneten. In der zweiten Woche der Studie wurden sie kurz vor dem Mittagessen durch eine Benachrichtigung auf dem Smartphone dazu angeregt ein buntes Mittagessen zu essen. Nach der Studie wurden die ProbandInnen gebeten die Benachrichtigung zu bewerten. Wieder war eine erhöhte wahrgenommene Farbvielfalt mit einem größeren anteiligen Verzehr von Gemüse assoziiert. Die wahrgenommene Farbvielfalt war außerdem negativ mit dem Verzehr von Süßspeisen, Obst und Getreideprodukten assoziiert. In der zweiten Woche der Studie verzehrten die

ProbandInnen mehr Gemüse und weniger Milchprodukte als in der ersten Woche der Studie, was darauf hindeutet, dass die Benachrichtigung das Essverhalten der ProbandInnen erfolgreich beeinflusste. Außerdem gaben die ProbandInnen an, dass bunt zu essen ihnen Freude macht und leicht fällt. KonsumentInnen anzuregen, bunte Mahlzeiten zu essen, ist also eine einfache aber gleichzeitig effektive Strategie um eine gesunde Ernährung im Alltag zu fördern.

Die geringe Anzahl von Nutzern von Ernährungs-Apps unterstreicht, dass es kein Universalkonzept für die Förderung einer gesunden Ernährung gib. Dementsprechend ist es wichtig, alternative Ansätze zur Förderung einer gesunden Ernährung zu untersuchen. Traditionelle Ansätze, die gesundheitsbezogene Konsequenzen der Ernährung in den Vordergrund stellen, basieren auf normativen Empfehlungen und sind oft einschränkend. Die vorliegende Dissertation ergänzt diese traditionellen Ansätze. Der alternative in dieser Dissertation präsentierte Ansatz zeigt, dass auch basierend auf dem „food as well-being“ Ansatz erfolgreiche Verhaltensänderungsstrategien entwickelt werden können, die die Entscheidungskompetenzen der Konsumenten stärken. Basierend auf diesem alternativen Ansatz können neue, einfache, aber effektive Verhaltensänderungsstrategien entwickelt und an KonsumentInnen vermittelt werden, um Gesundheit und Wohlbefinden zu fördern.

# 1. General Introduction

When eating and food choice are discussed publicly, e.g. in the media, but also in research, diverse recommendations on what and how much to eat can be found. These recommendations commonly focus on the impact of eating on health and weight control. Accordingly, the quality of any given food is usually defined by its nutritional value, i.e. its micro-, macronutrient, phytochemical and energy content. These findings are rooted in epidemiological studies and generally lead to important insights into how nutrient composition and energy content are related to the potential physiological consequences of consumption, including non-communicable diseases, such as obesity and cardiovascular diseases, or mortality (e.g. Dehghan et al. (2017); Onvani, Haghighatdoost, Surkan, Larijani, and Azadbakht (2017)). For example, sugary foods and drinks contain a high amount of energy that potentially contributes to the development of obesity (e.g. Vartanian, Schwartz, and Brownell (2011)), while the consumption of chemical components contained in processed meat may cause cancer (e.g. Bouvard et al. (2015)). Therefore, recommendations for the consumption of these foods predominantly advise reduction or avoidance to promote weight loss (maintenance) and health (e.g. Biesalski and Grimm (2011); Rösch and Jungvogel (2013); U.S. Department of Health and Human Services and U.S. Department of Agriculture (2015)). However, despite the wide range of eating recommendations currently available, dieting seldom leads to the desired weight loss (Mann et al., 2007), and obesity is still on the rise (Mendis, 2014).

Considering both the negative consequences of being overweight and the limited success of viewing food as a health risk, the question arises whether a negative view of eating is necessary to induce change. Eating behaviour is influenced by a range of reasons such as social, situational, economic and emotional motives, and thus clearly has more functions than just providing the body with energy (e.g. Jackson, Lynne Cooper, Mintz, and Albino (2003); Renner, Sproesser, Strohbach, and Schupp (2012); Steptoe, Pollard, and Wardle (1995); Stok et al. (2017); Van Strien, Frijters, Bergers, and Defares (1986)). For example, pleasure is an important eating motive (Jackson et al., 2003). Stereotypically, pleasure has been associated with eating unhealthy foods (Raghunathan, Naylor, & Hoyer, 2006), yet recent research suggests that the belief that 'unhealthy equals tasty' might not always be true (Werle, Trendel, & Ardito, 2013). To advance this alternative line of reasoning, the present dissertation advocates focusing on the healthy – instead of guilty – pleasures of eating. In order to facilitate healthy and enjoyable food choices, this dissertation integrates a view of food as an important contributor to well-being (Block et al., 2011) with simple strategies to facilitate behaviour change. To demonstrate the potential of this approach, the specific example of a 'colourful equals healthy' association is presented.

## 1.1. From food as health (risk) to food as well-being

According to the World Health Organisation, excess body weight is one of the main causes of death, with 2.8 million deaths per year being attributed to overweight and obesity (World Health Organization, 2009). Overweight is related to increased risk for the development of a range of non-communicable and potentially deadly diseases, such as diabetes, cardiovascular diseases and certain cancers (Alwan, 2011; Mendis, 2014). Fighting overweight therefore is a main goal of health promotion programs and health policy making (Mendis, 2014; OECD, 2017). As overweight is caused by the combination of too little physical activity and excess energy intake, it is argued that food consumption, especially the consumption of foods high in fat, sugar and salt, needs to be reduced in order to stop the obesity epidemic (World Health Organization, 2000, 2007).

To reach this goal, public health institutions and nutrition experts publish guidelines in which they provide recommendations about which foods to consume frequently and which foods to consume occasionally. These guidelines are based on empirical studies investigating the link between consumed foods and health-related outcomes (e.g. Bouvard et al. (2015); Onvani et al. (2017); Vartanian et al. (2011)). Foods that contain high amounts of energy-dense fat and sugar but comparably low amounts of micronutrients such as vitamins have been related to unfavourable health outcomes, and thus receive recommendations for limited consumption. On the other hand, foods containing high amounts of valuable micronutrients and low amounts of fat or sugar were shown to have health benefits, and thus receive recommendations for frequent consumption and larger portions. Thus, the guidelines reflect the view of *food as health* – or, if one does not follow the guidelines, food as health risk.

Following this notion, the media and lay people often simplify these guidelines to label foods as either ‘good’ or ‘bad’. At a first glance, this dichotomy might seem helpful in navigating the obesogenic environment of industrial countries, where large quantities of food are readily available almost anywhere (Swinburn, Egger, & Raza, 1999; Swinburn et al., 2011). However, applying this dichotomy also requires the constant exertion of self-control in order to restrict intake and thus avoid eating either too much or ‘bad’ foods (Herman & Polivy, 2004). By viewing eating as a potential health risk, eating becomes associated with worrying about its negative consequences for health and appearance (Rozin, Bauer, & Catanese, 2003; Rozin, Fischler, Imada, Sarubin, & Wrzesniewski, 1999), which in turn may lead to decreased psychological well-being.

While the view of food as health is frequently promoted and widespread today, health promotion mostly neglects to acknowledge the psychological consequences of eating, especially positive outcomes such as experiencing pleasure. However, researchers have recently suggested that the focus on food as health might be too narrow. In this regard, Block et al. (2011) introduced the concept of *food as well-being,* which refers to ‘a positive psychological, physical, emotional, and social relationship with food’ (p. 6) including – but not limited to – positive cognitions and beliefs about and emotions towards eating, such as enjoyment. But would a focus on food well-being not lead to an increase in unhealthy food consumption and an even greater increase in obesity rates? Early studies support this notion as they found that pleasure was derived from eating unhealthy foods like ice cream and cookies (Dallman et al., 2003; Locher, Yoels, Maurer, & Van Ells, 2005; Wansink, Cheney, & Chan, 2003). Therefore, they suggest a trade-off between eating to increase physiological health and eating to increase psychological well-being (see also Stroebe, Papies, and Aarts (2008); Stroebe, Van Koningsbruggen, Papies, and Aarts (2013)): Unhealthy foods are enjoyable and tasty, while healthy foods are not.

More recent research, however, shows that is it not necessarily eating unhealthy foods that increases psychological well-being but eating in general (Wagner, Ahlstrom, Redden, Vickers, & Mann, 2014) or even especially eating healthy foods like fruit and vegetables (e.g. Mujcic and Oswald (2016); Warner, Frye, Morrell, and Carey (2017); White, Horwath, and Conner (2013)). For instance, in a recent study investigating real-life eating episodes, both eating vegetables and eating sweets were associated with above-average enjoyment during consumption (Wahl et al., 2017). Thus, evidence is accumulating that eating can simultaneously contribute to physiological health and psychological well-being. For example, fruit and vegetables contain many micronutrients such as vitamins and thus are beneficial to health. At the same time, their consumption is associated with increased well-being during and after eating. A recent longitudinal study supports this view as it indicates that a positive view of one's eating behaviour (e.g. 'Eating is a pleasure for me.') is associated with a decrease in health risk factors after six months (Sproesser et al., 2017). Hence, the food as well-being perspective might be a promising avenue for promoting healthy eating in behaviour interventions.

However, most behaviour interventions predominantly focus on the traditional view of food as health, and thus use normative and restrictive guidelines based on the relationship between energy or nutrient intake and health outcomes (e.g. Onvani et al. (2017)). The energy or nutrient content of foods can be analysed by objectively measuring their biochemical components. Food well-being, on the other hand, is a subjective construct that is related to the perceptions, emotions and attitudes of the individual (Block et al., 2011). Objectively assessing perceptions, emotions and attitudes often is far more difficult, if not impossible (Greenwald, Poehlman, Uhlmann, & Banaji, 2009; Mauss & Robinson, 2009), and typically relies on introspection and self-report. Furthermore, perceptions of the emotions elicited by and attitudes towards food and eating can vary greatly between individuals (e.g. Canetti, Bachar, and Berry (2002); Papies, Stroebe, and Aarts (2009)), and no objectively defined basic truth exists for which foods all people like or dislike. Thus, designing behaviour interventions to promote healthy eating that build up on the view of food as well-being might also imply shifting towards a more individualistic and consumer-oriented view that acknowledges that individuals have different needs and preferences (Block et al., 2011).

Shifting towards this more individualistic view of food as well-being includes revisiting how behaviour change is initiated. Traditionally and in accordance with the food as health perspective, scientific dietary guidelines communicate to the public the ideal diet for preventing disease. The German Nutrition Society (DGE), for example, recommends daily serving sizes for seven food groups, including 400g of vegetables, 250g of fruit, etc. Similarly, the campaign ‘5 a day’ recommends eating five portions of fruit and vegetables per day. These guidelines provide a *criterial reference norm* as they enable comparison with an absolute criterion (Brunstein & Heckhausen, 2008; Dickhäuser & Rheinberg, 2003; Heckhausen, 1974). In Germany, however, 87.4% of the population do not eat sufficient vegetables (i.e. 3 portions or 400 g), and 59% do not consume sufficient fruit (i.e. 2 portions or 250 g; Max-Rubner-Institut (2008)), indicating that adherence to the guidelines is rather low (see also Mensink et al. (2013)). This might be due to the inflexible and highly demanding nature of the existing guidelines in that the same goals are set for all people independent of behaviour, skills or means. Consequently, the goals might be too ambitious for those whose current behaviour deviates considerably from the recommendation. For instance, eating five portions of fruit and vegetables a day might be easily achievable for those who already consume four portions per day. However, the average German adult only consumes 2.4 (males) to 3.1 portions (females) of fruit and vegetables per day (Mensink et al., 2013). Notably, 11.9% of females and 19.3% of males consume less than one portion of fruit and vegetables per day, and another 49.2% of females and 56% of males consume between one and three portions per day. Thus, attempting to increase fruit and vegetable consumption to the recommended level of five portions per day can be considered demanding for these people and it is more likely that the goal will not be reached. Failure to reach the goal can be frustrating and can lead to goal disengagement in the long term (Bandura, 1977; Locke & Latham, 2002; Wrosch, Scheier, Carver, & Schulz, 2003).

Alternatively, goals can be tailored to an individual's past behaviour and existing competences using an *individual reference norm* which allows intraindividual comparison (Dickhäuser & Rheinberg, 2003; Heckhausen, 1974). Using individual reference norms has been shown to be especially beneficial for boosting motivation, e.g. in the context of teacher feedback to pupils (see Brunstein and Heckhausen (2008) for a summary). Individual reference norms refer to prior achievement rather than objective criteria and have been shown to be beneficial for all, independent of prior achievement. It has also been suggested that they are especially beneficial for those who have performed poorly on a task (Krampen, 1987). Hence, individual reference norms might be a promising technique for attempting eating behaviour change at a population level.

Furthermore, individual reference norms might be especially beneficial for interventions rooted in the food as well-being perspective, as it might not always be possible to provide a normative goal related to well-being. For example, it might be difficult to determine the level of well-being everyone should reach when attempting to increase psychological well-being experienced while eating. Instead, a goal could be to experience *more* well-being from eating compared to the well-being experienced in the previous week, thus focusing on an intraindividual comparison of the subjective experience. Therefore, improvement of food well-being might often need to be defined on the individual level rather than from a criterial reference norm.

## 1.2. From complex guidelines to simple strategies

When providing a criterial reference norm for healthy eating, dietary guidelines, such as the guidelines published by the DGE, usually provide a range of information about (1) the amount of calories that should be consumed daily, (2) the amount of foods that should be consumed per food group and (3) the ideal ratio of macronutrients consumed per day. Ideally, the food consumed within a day fulfils all three criteria. This might be a highly complex endeavour as several characteristics of the food have to be taken into account when evaluating what and how much to eat. While these guidelines are important for experts like nutritionists evaluating an individual's diet, the guidelines might be difficult for lay persons to understand and to put into practice on their own. Estimating a meal's calorie content (e.g. Chandon and Wansink (2007)) or estimating a food's weight (Lee et al., 2012) are difficult and can lead to erroneous assumptions about one's food intake. Furthermore, when encouraging people to adopt a new behaviour, it is recommended to provide the individual with knowledge about how to put the new behaviour into practice (Guillaumie, Godin, & Vézina-Im, 2010; Shaikh, Yaroch, Nebeling, Yeh, & Resnicow, 2008). However, as de Ridder, Kroese, Evers, Adriaanse, and Gillebaart (2017) pointed out, dietary guidelines seldom provide this information. For example, based on the guidelines, it might be unclear how the ideal breakfast, lunch and dinner have to be composed so that the total amount of food consumed in one day meets all given criteria and is therefore healthy. Mötteli, Keller, Siegrist, Barbey, and Bucher (2016), for instance, instructed participants to select the foods that they would eat either in a normal day or a healthy day from a Fake Food Buffet. Although the foods selected in the healthy day condition contained higher dietary fibre and protein as well as lower saturated fatty acids than foods chosen in the normal day condition, they still contained twice as much sugar and salt than recommended by scientific dietary guidelines. Thus, designing new interventions targeting eating behaviour may also require new ways to make relevant information more accessible and new behaviours more easily practicable for consumers.

One promising avenue might be to reduce complexity of the behaviour change process by revisiting both the triggers and the target behaviour itself. In the Fogg

Behaviour Model (FBM), Fogg (2009a, 2009b) argues that reducing the complexity and difficulty of behaviour change may lead to increased likelihood of success. This may be achieved by creating simple intervention strategies that consist of *simplified behaviours* and corresponding *simplified triggers*. Firstly, the target behaviour needs to be simplified. This can be achieved by segmenting a demanding and complex behaviour (e.g. healthy eating) into a sequence of small actions that are more easily accomplished (‘tiny habits’, Fogg (2011); e.g. taking an apple to work, eating the apple in the coffee break). These simplified behaviours are resource-conserving because they require lower output regarding time, money or cognitive or physical resources and are therefore easier to integrate into existing daily routines than complex behaviours. Moreover, Fogg (2009a) argues that the familiarity of the behaviour and the time span in which the new behaviour needs to be performed might also play an important role in simplifying a behaviour. Familiar behaviours are easier to put into practice than unfamiliar behaviours. Moreover, short-term changes, i.e. for a limited period, are more easily accomplished than long-term changes. Finally, familiarity and time span act in combination: While engaging in an unfamiliar behaviour for the indefinite future or completely ceasing a familiar behaviour might prove very difficult, increasing the frequency or intensity of a familiar behaviour for a limited time, e.g. a week, might be easier to accomplish. For example, adhering to the DGE guidelines for the rest of one’s life might be highly demanding, but adding a side salad to the lunch meal for the next week might be more easily achieved. To sum, *simplified behaviours* are small actions that increase the frequency or intensity of a familiar behaviour which, at least initially, only needs to be adapted for a short period of time.

Secondly, to elicit the simplified behaviour, triggers that can act as a cue to action need to be identified (Fogg, 2009b). Triggers can have different functions: They might act as a motivator to change, e.g. a text or video describing the positive or negative consequences of a behaviour; indicate when a behaviour is easy to perform, e.g. highlighting a healthy choice on the cafeteria menu; or act as a reminder, e.g. a daily smartphone reminder to eat a healthy lunch (Fogg, 2009b). Ideally, triggers are simplified, i.e. easily perceived and understood (see also Mohr, Schueller, Montague, Burns, and Rashidi (2014)), and frugal, requiring little effort or resources. Many dietary recommendations focus on calories and macronutrients as the main indicators for whether a food should be eaten or not. However, this nutritional information is usually only available for packaged foods and therefore difficult to obtain in many eating situations, e.g. in a restaurant or at a friend's house. Furthermore, studies have shown that consumers often have difficulties in interpreting caloric information (for reviews, see Campos, Doxey, and Hammond (2011); Tarabella and Burchi (2016)). Thus, caloric information may seldom prove an appropriate trigger for healthy food choices in daily life.

One alternative might be to use environmental cues or prompts consisting of short pieces of written information that people can easily identify and understand, which can serve as a reminder to perform a behaviour (Fogg, 2009b; Lally & Gardner, 2013). To maximise the fit between the trigger, the constraints of the food choice environment and the individual's natural decision-making strategies, these cues should be directly derived from real-life decision-making scenarios (Gigerenzer & Gaissmaier, 2011; Hertwig & Grüne-Yanoff, 2017; Todd & Gigerenzer, 2007). For example, when intending to eat an apple during the afternoon coffee break, the coffee cup could act as a reminder to perform the new behaviour 'eating an apple'. Thus, *simplified triggers* for a behaviour are cues or prompts that are easily and quickly perceived and processed and have been identified in real-life eating situations. Finally, simplified behaviours and simplified triggers can be combined into simple intervention strategies by formulating trigger – behaviour links. The resulting strategies can then be communicated to consumers to further improve – or boost – their food choice competences (Grüne-Yanoff & Hertwig, 2016).

It can be argued that shifting from complex dietary guidelines to simple intervention strategies can well support the paradigm shift from food as health to food as well-being. According to many dietary guidelines, foods are evaluated based on how much fat, carbohydrates, protein or calories they contain. However, people do not consume single nutrients, but meals (Block et al., 2011), and information about the nutritional value or calorie content is seldom readily available. Relying on this information to induce behaviour change thus might not fit the food choice environments that they navigate. Adopting the food as well-being perspective and incorporating individual reference norms might open up opportunities for introducing alternative cues for healthy eating that people can more easily identify, such as sensory characteristics of food. For example, one can focus on visual properties like size or colour, which in numerous studies have shown to impact what and how much is eaten (e.g. Piqueras-Fiszman and Spence (2014); Renner, Sproesser, Stok, and Schupp (2016); Scheibehenne, Todd, and Wansink (2010); Schulte-Mecklenbeck, Sohn, de Bellis, Martin, and Hertwig (2013); Wansink and Kim (2005); Wansink, Painter, and North (2005)). Exploring sensory characteristics as cues for food choice may not only allow detachment from solely viewing food as a contributor to physiological health but also enable acknowledging the sensations and well-being that can arise from eating. While it is difficult to pinpoint normative guidelines from sensory cues, these cues allow greater focus on the perception and experiences of the individual, thus supporting a consumer-oriented view. Following this notion, the present dissertation aimed to identify a visual cue that is not only easily perceived and processed but also leads to both healthy and enjoyable food choices. Moreover, the cue was tested as an intervention strategy to examine whether it is able to boost healthy food choices as well as whether it is feasible in and applicable to daily life.

### 1.3. Implementation in mobile interventions

After identifying an intervention strategy that boosts healthy and enjoyable food choices, the next step is to disseminate the strategy. Ideally, also the dissemination method should fit the consumer's lifestyle and decision-making strategies, while requiring little time, effort and cognitive resources. Interventions can be disseminated in different ways, e.g. mass media campaigns, leaflets or counselling sessions, but these are often absent when the new behaviour should occur. In recent years, however, behaviour interventions have been increasingly distributed via mobile applications (mHealth apps; Kay, Santos, and Takane (2011)), which accommodate the individual's immediate needs through the timely provision of information and intervention materials per the consumer's request (Nahum-Shani, Hekler, & Spruijt-Metz, 2015; Riley et al., 2011). For instance, the consumer can thus access information on healthy eating on their smartphone while deciding what to eat. Two factors make mHealth apps the ideal tool for this process: Users tend to use smartphones briefly but frequently and half of all smartphone interactions occur on the locked screen, where only short messages can be displayed (Andrews, Ellis, Shaw, & Piwek, 2015; dscout Inc., 2016). Thus, when apps are used to deliver an intervention, they can best engage with users' smartphone interaction tendencies by offering concise messages.

Using smartphones to disseminate behaviour interventions became popular because of the increasing popularity of smartphones. More than two thirds of Australian, Canadian, German or U.S. adults own a smartphone (Pew Research

Center, 2016), and smartphone ownership rates are projected to rise even further in coming years (eMarketer, 2016). Therefore, both policy makers, like the European Union (European Commission, 2012, 2014, 2017), and companies (for summaries, see e.g. Aitken and Gauntlett (2013); research2guidance (2015); Sama, Eapen, Weinfurt, Shah, and Schulman (2014)) are promoting the development and use of mHealth apps. At the same time, only 21% of smartphone owners in Germany use mHealth apps. Thus, public interest in using those apps is rather low (Conway, Campbell, Forbes, Cunningham, & Wake, 2016; Ernsting et al., 2017; Statista, 2015).

Apps targeting eating behaviour mainly focus on self-monitoring of food intake, feedback about caloric intake and expenditure, and goal-setting (Breton, Fuemmeler, & Abroms, 2011; Pagoto, Schneider, Jojic, DeBiasse, & Mann, 2013; Rohde, Dawczynski, Lorkowski, & Brombach, 2016), while other Behaviour Change Techniques (BCTs; Abraham and Michie (2008)) are seldom applied. For example, Direito et al. (2014) reviewed 40 popular nutrition and fitness apps available for iOS and found that some BCTs (time management; relapse prevention; agree on behavioural contract; teach to use prompts or cues) in Abraham and Michie's (2008) taxonomy were never used, while the top three BCTs (provide instruction, set graded tasks, prompt self-monitoring of behaviour) were used in more than 60% of the studied apps. This analysis suggests that the range of BCTs used in nutrition apps might be limited. Moreover, as most nutrition apps are designed for weight management or weight loss, the focus again lies on the restriction of food intake and therefore represents a view of food as health. Many people, however, do not intend to restrict their food intake. For instance, a representative German survey revealed that 84.1% of German adults are interested in healthy eating, but only 28.7% show interest in dieting, i.e. restricting their food intake (Institut für Demoskopie Allensbach, 2016). If the main purpose of nutrition apps is not in line with potential users' interests and goals, this might limit nutrition app uptake. Thus, there might be a niche for the development of mHealth apps that incorporate and facilitate food well-being in order to promote healthy eating.

To be able to better understand the contribution that integrating simple strategies for facilitating healthy and enjoyable food choices in nutrition apps could make, it is important to gain an understanding of current nutrition app users and non-users: Who is satisfied with apps promoting the normative view of food as health that are currently available? Who would benefit from integrating the food as well-being view and simple strategies in mHealth apps? Previous studies investigating mHealth app use rates or reasons for mHealth app (non-)use compared users to non-users in sociodemographic or behavioural characteristics such as age, gender or body mass index (BMI; e.g. Ernsting et al. (2017); Krebs and Duncan (2015)). These studies provide important first insights about potential target groups, but more studies are needed to gain insight in psychological characteristics such as motivations underlying mHealth app use. These motivational underpinnings would in turn allow a systematic assessment of changes in mHealth app use and predictors of change as well as further promoting the tailoring of mHealth apps to potential target groups. Drawing on models of health behaviour change, the present dissertation presents a behaviour stage model that was developed using the Precaution Adoption Process Model (PAPM; Weinstein (1988); Weinstein, Rothman, and Sutton (1998); Weinstein and Sandman (1992)), which allows investigating the process of mHealth app adoption from being unengaged, through deciding whether to use an app, to actual use and/ or disengagement from use. Using the model, characteristics of each stage of mHealth app adoption can be explored and barriers to adopting mHealth apps identified.

Specifically, we aimed to better understand whether the health-orientation and focus on restriction that is incorporated in many available nutrition apps is a barrier to adoption, especially for people who do not deliberately plan and restrict their food consumption. Finally, this allows gathering information about potential new user groups who would be attracted to nutrition apps based on the view of food as well-being.

### 1.4. Outline and research aims of the present dissertation

The first aim of the present dissertation was to examine the motivational structure of adopting mHealth apps with a focus on nutrition (and fitness) apps (Chapter 2). Using a behaviour stage model based on the PAPM, the use of mHealth apps and correlates of mHealth app use were explored in a sample of 1,236 participants. Extending previous research that primarily focused on sociodemographic correlates such as age, gender and education, or behavioural outcomes such as BMI, Preference for Intuition and Deliberation in Eating Decision-making (E-PID; König, Sproesser, Schupp, and Renner (in prep.)) was included as a potential psychological transition barrier.

The second aim of this dissertation was to identify and test a simple intervention strategy for boosting healthy and enjoyable food choices using visual cues. In this case, healthy eating was operationalised as eating more foods that are high in nutritional value but low in energy, such as fruit and vegetables, and eating less foods that are low in nutritional value but high in energy, such as fried and sugary foods (Onvani et al., 2017). Specifically, a ‘colourful equals healthy’ association was tested in two studies.

Firstly, the ‘colourful equals healthy’ association was established. An observational Ecological Momentary Assessment (Shiffman, 2014; Shiffman, Stone, & Hufford, 2008) study was conducted in which 108 participants recorded their lunch meals on at least four consecutive days and rated the meals' perceived meal colour variety (Chapter 3). Trained research staff then quantified the intake of seven food groups according to German dietary guidelines (Koelsch & Brüggemann, 2012). Data was analysed using multilevel modelling to account for the data's hierarchical structure and to analyse within-person relationships between perceived meal colour variety and food consumption.

Secondly, the 'colourful equals healthy' association was tested as an intervention strategy for promoting both healthy and enjoyable food choices in an Ecological Momentary Intervention (Heron & Smyth, 2010) with 80 participants (Chapter 4). Participants recorded their lunch meals and perceived meal colour variety over a period of three weeks. In addition, they received a prompt to eat a colourful lunch in the second week of the study. Again, trained research staff quantified the food intake. Multilevel modelling was used to quantify the impact of the prompt on eating behaviour. Furthermore, acceptability and feasibility of the intervention were examined.

The present dissertation introduces an alternative approach for facilitating healthy food choices that is based on a consumer-oriented food as well-being view on eating behaviour (Block et al., 2011). Instead of focusing solely on the healthiness of diet, it also takes into account that eating contributes to psychological well-being. The food as well-being perspective is integrated with an approach to simplifying interventions (Fogg, 2009a, 2009b). Specifically, the benefits of simple interventions targeting food well-being and delivered via mobile technology will be discussed, taking the 'colourful equals healthy' association as an example.

## 2. To use or not to use: A behaviour stage model approach for describing the process of adopting nutrition and fitness apps

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## 2.1. Abstract

Background: Although mobile technologies such as smartphone applications are promising means for motivating people to adopt a healthier lifestyle (‘mHealth apps’), previous studies have shown low adoption and continued use rates. Developing the means to address this issue requires further understanding of mHealth app nonusers and adoption processes. The present study utilized a stage model approach based on the Precaution Adoption Process Model, which proposes that people pass through qualitatively different motivational stages when adopting a behavior.

Objective: To establish a better understanding of between stage transitions during app adoption the present study investigated (1) the adoption process of nutrition and fitness app usage and (2) the sociodemographic and behavioral characteristics and decision-making style preferences of people at different adoption stages.

Methods: Participants ($N$ = 1,236) were recruited onsite within the cohort study Konstanz Life-Study. Use of mobile devices and nutrition and fitness apps, five behavior adoption stages of using nutrition and fitness apps, preference for intuition and deliberation in eating decision-making (E-PID), healthy eating style, sociodemographic variables, and BMI were assessed.

Results: Analysis of the five behavior adoption stages showed that Stage 1 (‘unengaged’) was the most prevalent motivational stage for both nutrition and fitness app use, with half of the participants stating that they had never thought about using a nutrition app (52%), while less than one third stated they had never thought about using a fitness app (29%). ‘Unengaged’ nonusers (Stage 1) showed a higher preference for an intuitive decision-making style when making eating decisions, while those who were already ‘acting’ (Stage 4) showed a greater preference for a deliberative decision-making style ($F(4, 1012) = 21.83$, $p < .001$). Furthermore, participants differed widely in their readiness to adopt nutrition and fitness apps, ranging from having ‘decided to’ but not yet begun to act (Stage 2; nutrition: 6.6%, fitness: 9.0%) to being ‘disengaged’ following previous adoption (Stage 5; nutrition: 13.3%, fitness: 14.7%).

Conclusions: Using a behavior stage model approach to describe the process of adopting nutrition and fitness apps revealed motivational stage differences between nonusers (being ‘unengaged’, having ‘decided not to act’, having ‘decided to act’, and being ‘disengaged’), which might contribute to a better understanding of the process of adopting mHealth apps and thus inform the future development of digital interventions. The study highlights that new user groups might be better reached by apps designed to address a more intuitive decision-making style.

## 2.2. Introduction

In recent years, services supporting medical and public health practices via mobile technology (mHealth) (Kay et al., 2011) such as smartphone apps have become increasingly popular: More than 70,000 mHealth apps are currently available for download on Android and iOS smartphones (research2guidance, 2015), and more apps are released every year (Albrecht, Höhn, & von Jan, 2016). The proportion of smartphone owners currently using a mHealth app ranges between 36% (Bhuyan et al., 2016) and 58% (Krebs & Duncan, 2015) in the U.S. and between 11% (Statista, 2015) and 21% (Ernsting et al., 2017) in Germany, where the present study was conducted. Although mHealth apps have the potential to deliver effective interventions (Fanning, Mullen, & McAuley, 2012; Godino et al., 2016; Müller, Alley, Schoeppe, & Vandelanotte, 2016; Pellegrini, Pfammatter, Conroy, & Spring, 2015; Widmer et al., 2015) and cut healthcare costs (Albrecht, 2016b; European Commission, 2014), e.g. because medical interventions can be delivered remotely instead of in person, a large proportion of the population does not actively use mHealth apps (Conway et al., 2016). The European Union therefore set a goal to make online health promotion, including mHealth apps, more effective, user-friendly, and widely acceptable (European Commission, 2012, 2017).

A first step to reaching this goal is to identify who is currently using mHealth apps and who is not. Usually, studies divide participants into a ‘user group’, comprising participants who currently use an mHealth app (e.g. Statista (2015)) or have one installed (e.g. Bhuyan et al. (2016); Carroll et al. (2017)), and a ‘nonuser group’, which typically lacks further specification. Few studies have described mHealth app users and nonusers using sociodemographic and health-related characteristics or assessed further information about nonusers, such as discontinued mHealth app use (e.g.

Haithcox-Dennis, Brinkley, Richman, DeWeese, and Byrd III (2012); Krebs and Duncan (2015)) or interest in mHealth app use (e.g. Haithcox-Dennis et al. (2012); Ramirez et al. (2016)). As compared to nonusers, mHealth app users tend to have more education and are younger (Carroll et al., 2017). All genders use mHealth apps equally often (Bender et al., 2014; Bhuyan et al., 2016; Ernsting et al., 2017; Krebs & Duncan, 2015; Statista, 2015; YouGov, 2016). Regarding health-related parameters, such as current health status or BMI, research yielded mixed results. While some suggest that mHealth app users tend to be healthier and less likely to be overweight (Dennison, Morrison, Conway, & Yardley, 2013; Helander, Kaipainen, Korhonen, & Wansink, 2014), others report more comorbidities and a higher BMI for users (Bhuyan et al., 2016; Ernsting et al., 2017).

However, more than a basic understanding of the core sociodemographic characteristics of users and nonusers is needed to increase mHealth app adoption rates. That is, we require a better understanding of the motivational processes underlying the decision-making for adopting mHealth apps. In health behavior research, stage theories of behavior change (Armitage & Conner, 2000; Renner & Schwarzer, 2003; Schwarzer, 2008; Sniehotta & Aunger, 2010) suggest that people can be differentiated according to the levels of awareness of and motivation to adopt a healthier life style, such as quit smoking (Borrelli et al., 2002), become more physically active (Schwarzer, Cao, & Lippke, 2010), or change dietary behaviors (Blalock, 2007; Brick, Redding, Paiva, Harlow, & Velicer, 2017; De Vet, De Nooijer, Oenema, De Vries, & Brug, 2008; Sniehotta, Luszczynska, Scholz, & Lippke, 2005), or to take preventive action, such as increasing calcium intake to prevent osteoporosis (Blalock, 2007). Specifically, stage models such as the Transtheoretical Model of Health Behaviour Change (TTM) (Prochaska, Redding, & Evers, 2013; Prochaska &

Velicer, 1997), the Health Action Process Approach (HAPA) (Schwarzer, 2008; Schwarzer & Luszczynska, 2015) or the Precaution Adoption Process Model (PAPM) (Weinstein, 1988; Weinstein et al., 1998; Weinstein & Sandman, 1992) assume that people pass through qualitatively different motivational stages when adopting a behavior (see Renner and Schwarzer (2003); Sheeran, Klein, and Rothman (2017) for an overview). For example, the PAPM claims that people pass through seven distinct stages of decision-making for health behavior, including being 'unaware', 'becoming engaged', 'starting to make a decision', 'decided to act', 'decided not to act', 'acting', and finally 'maintaining' (or 'disengaging') from the behavior (Weinstein, 1988; Weinstein, Sandman, & Blalock, 2013). Importantly, the PAPM introduced differentiation between people who have 'decided not to act' and people who are yet undecided. People who have already formed an opinion about an issue might be more difficult to persuade than people who did not yet form an opinion and therefore might require different intervention approaches (Weinstein et al., 1998; Weinstein & Sandman, 1992). Furthermore, in the PAPM, stages are defined by psychological characteristics instead of external factors such as time, as in the TTM (Sniehotta & Aunger, 2010; Weinstein et al., 1998), which has been criticized as being a rather arbitrary criterion (Brug et al., 2004). Using stage models to describe a person's position in the behavioral adoption process has been shown to improve recruitment, retention, and progress in the behavior change process (Prochaska et al., 2013; Prochaska & Velicer, 1997) by providing information about barriers of change for individual stages as well as methods to facilitate stage transitions (Prochaska et al., 2013; Weinstein & Sandman, 1992; Weinstein et al., 2013). Drawing on the stage model conception from health psychology research and especially the PAPM, we used a stage model approach to assess five different stages in the adoption process of mHealth apps. In particular, the five different stages include those who have never thought about using mHealth apps (‘unengaged’), intend to use mHealth apps in the future (‘decided to act’), have decided against using mHealth apps (‘decided not to act’), are currently using mHealth apps (‘acting’), and have ceased to use mHealth apps (‘disengaged’). The later stage was added based on a previous adaptation of the PAPM (Renner & Hahn, 1996), because comparing ‘disengaged’ non-users to other groups, especially ‘acting’ users, provides valuable information about when and why mHealth app use is maintained or discontinued (Murnane, Huffaker, & Kossinets, 2015). Thus, the present stage model also includes the perspective of models of engagement with digital behavior change interventions that focus on preventing the transition from the ‘acting’ stage to disengagement.

When stages of mHealth app adoption have been identified, a second and important step is to characterize the people at each stage in order to identify potential transition barriers (Weinstein et al., 2013). Characterizing groups at each stage is important to both tailoring and improving the services according to users’ needs and preferences and thereby enhancing user engagement and promoting the use of mHealth apps to new user groups (Berkovsky, Freyne, & Oinas-Kukkonen, 2012; Folta, Brown, & Blumberg, 2015; Yardley, Morrison, Bradbury, & Muller, 2015). The extent of mHealth app use, for example, seem to covary with health consciousness, health information orientation, and eHealth literacy (Cho, Park, & Lee, 2014). These results suggest that mHealth apps are more likely to be adopted by people who are conscious of their health. Research in health screening decision-making furthermore showed that decision-making styles affect information processing. Specifically, people with a rational decision-making style engaged more with intervention materials such as leaflets than those with an intuitive decision-making style (Ghanouni, Renzi, & Waller, 2017). As mHealth apps that are currently available predominantly focus on self-regulatory strategies such as self-monitoring, providing instruction or feedback, and goal setting (Direito et al., 2014; Middelweerd, Mollee, van der Wal, Brug, & te Velde, 2014; Yang, Maher, & Conroy, 2015), using mHealth apps might necessitate self-regulatory competencies such as a deliberative decision-making style. Similarly, previous research suggests that self-regulatory constructs that support goal-directed, intentional behaviors (e.g. self-efficacy, attitudes) may act as transition barriers in the PAPM (De Vet et al., 2008). Consequently, people who use a deliberate style when making health-related decisions, such as preferring to rely on health recommendations, may be more likely to adopt mHealth apps. A preference for deliberation might help to exert the self-control needed to perform the behavior. Conversely, people who prefer an intuitive decision-making style, i.e. relying on affect and heuristics (Betsch, 2004, 2008), might be less likely to adopt mHealth apps as such apps tend to stand in stark contrast to their preferred decision-making strategies. Accordingly, decision-making style preferences might systematically relate to stages in the adoption process.

While mHealth apps have different functionalities, the majority of available apps are targeted at lifestyle and well-being, with the majority being designed to monitor eating behavior and physical activity (Aitken & Gauntlett, 2013; Sama et al., 2014). Previous research, however, predominantly focused on investigating use and non-use of mHealth apps in general instead of investigating the (non-)use of different categories separately (e.g. Bhuyan et al. (2016); Ernsting et al. (2017); Krebs and Duncan (2015)). However, the use of mHealth apps that target different behavioral domains, e.g. eating or physical activity, might be correlated with different sociodemographic, behavioral or psychological characteristics. For instance, women are more strongly preoccupied with eating (Tapper & Pothos, 2010), thus one might expect that women are more interested in nutrition apps than men. Therefore the present study focused on nutrition apps, but also includes fitness apps in order to examine whether the results are behavior-specific or generalize across behavioral domains.

The aims of this study are twofold. Firstly, it aimed to investigate different stages in the adoption process of nutrition and fitness apps by utilizing a newly developed stage model based on the PAPM. Secondly, building upon and extending previous research, the study aimed to investigate sociodemographic, behavioral, and psychological characteristics of people at the different adoption stages for nutrition apps in order to inform a better understanding of stage transitions. Specifically, we assumed that an intuitive decision-making style might act as a transition barrier and thus is more pronounced in participants who are not 'acting'.

## 2.3. Methods

### *2.3.1. Design and procedure*

Data were collected as part of the Konstanz Life-Study, an ongoing longitudinal cohort study that was launched in spring 2012 with 1,321 participants (for more details, see Klusmann, Musculus, Sproesser, and Renner (2015); Klusmann, Sproesser, Wolff, and Renner (in press); Renner, Sproesser, Klusmann, and Schupp (2012); Sproesser et al. (2017); Sproesser, Klusmann, Schupp, and Renner (2015)). The overarching aim of the study is to investigate psychological influences on eating behavior, physical activity, and health within the general population across time (Renner, Sproesser, Klusmann, et al., 2012). The study was part of the SMARTACT research project funded by the German Federal Ministry of Education and Research. Further points of measurement, 2, 3, and 4, took place in autumn 2012, spring 2013, and spring 2016, respectively. For each point of measurement, participants were recruited via flyers, posters, and newspaper articles. Additionally, participants of the preceding points of measurement were re-invited via email and phone calls. People aged 18 and older without acute infectious diseases were eligible for participation. The measurements included the collection of fasting blood samples, questionnaires, as well as a standardized check-up including anthropometric measures and cognitive and physical fitness tests. As compensation for participation, participants received feedback about their objective health status referenced to current norms. This paper presents questionnaire and anthropometric data collected in the fourth point of measurement (spring 2016).

#### *2.3.2. Ethics*

For data processing and security, a register of processing operations was developed in cooperation with and approved by ZENDAS in 2012 and reviewed in 2016 (Zentrale Datenschutzstelle der Baden-Württembergischen Universitäten / Center for Data Protection of the Universities in Baden-Württemberg) and reviewed by the Landesdatenschutz-Beauftragte, Baden-Württemberg (Commissioner for Data Protection in Baden-Württemberg). All participants gave written informed consent prior to participation. The study adhered to the guidelines of the German Psychological Society (Deutsche Gesellschaft für Psychologie; see http://www.dgps.de/index.php?id=96422; see paragraph C.III) and the Declaration of Helsinki, and was conducted in compliance with relevant laws and institutional guidelines. The study protocol was approved by the University of Konstanz ethics committee.

#### *2.3.3. Sample*

In total, $N$ = 1,236 participants were recruited for the fourth wave. For $n$ = 21 participants, no questionnaire data was obtained, reducing the sample analyzed to $N$ = 1,215 (for a detailed overview, see Figure 2.1). The sample had a mean age of 41.11

years (SD = 17.56) and 64.4% were female. BMI ranged from 16.77 to 42.45 kg/m² (*M* = 24.21, *SD* = 3.63). The majority of participants had a university entrance diploma (70.6%), and 52.6% had a university degree. Compared to the German population, the sample consisted of 13.7 percent more females, was 3.19 years younger, and had a lower BMI by 1.69 points (Statistisches Bundesamt, 2016a, 2016c). Furthermore, the present sample was better educated than the general German population, in that 29.5% have a university entrance diploma and 16.3% have a university degree (Statistisches Bundesamt, 2016b).

### *2.3.4. Measures*

#### *2.3.4.1. Mobile device ownership and nutrition and fitness app use*

Participants were asked to indicate whether they owned a smartphone or tablet ((1) yes, (2) no). If participants owned a mobile device, they were subsequently asked to indicate whether they had ever installed an app to monitor their physical activity (fitness app) or their eating behavior (nutrition app) on a four point Likert scale ranging

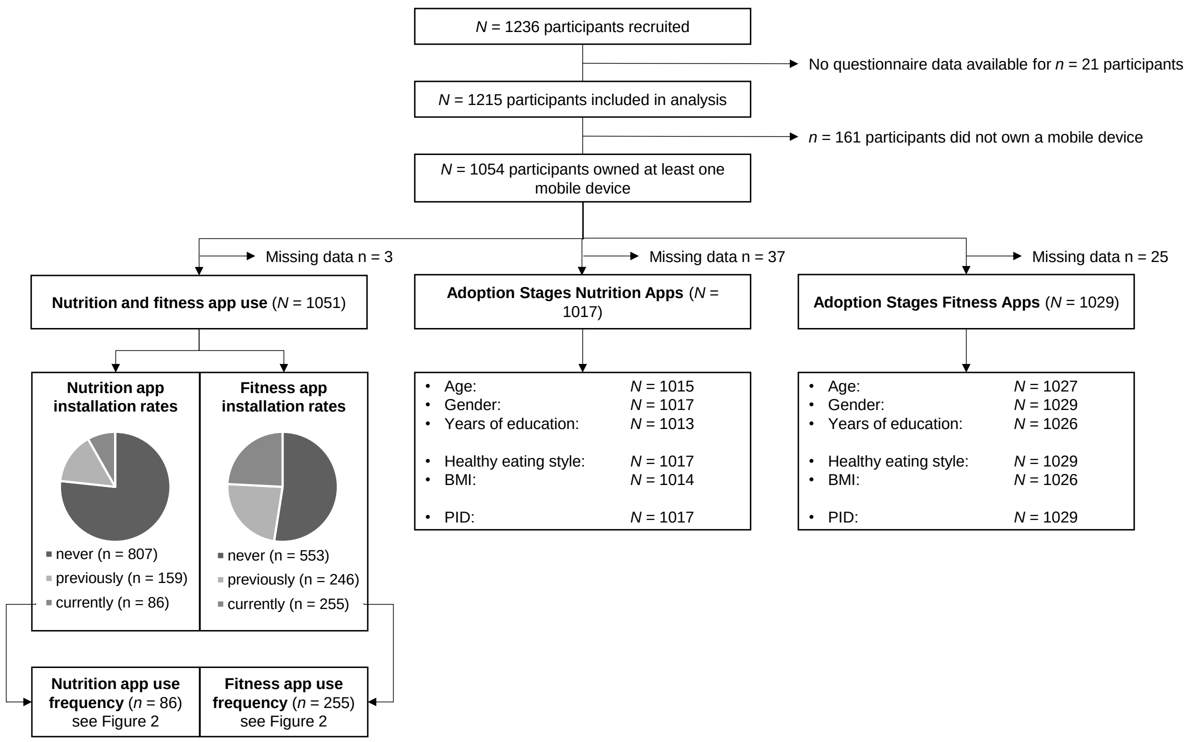


**Figure 2.1.** *Flow chart of the study sample.*

from (1) never to (4) currently. If they indicated that they currently had a fitness or nutrition app installed on their mobile device, they were further asked to indicate the frequency of use on a five-point Likert scale ranging from (1) once a month or less to (5) at least once a day.

*2.3.4.2. Stage model for the adoption process of mHealth apps (nutrition and fitness)*

For this study, in accordance to the PAPM (Weinstein & Sandman, 1992) and an adaptation of the PAPM by Renner and Hahn (1996) (see also Multimedia Appendix 1), we defined each participant's stage in the adoption process based on their response to five different statements representing the different stages. Participants were asked to choose the one statement they would agree with most regarding the usage of a mHealth app for physical activity or food intake, respectively. Participants were categorized using the following five behavior adoption stages: (Stage 1) being 'unengaged' ('I have never thought about using an app for that *[nutrition / fitness]*.'), (Stage 2) 'decided to act' ('I have thought about using an app for that *[nutrition / fitness]*, but so far I did not do it'), (Stage 3) 'decided not to act' ('I have thought about using an app for that *[nutrition / fitness]*, but it is not necessary for me to do it.'), (Stage 4) 'acting' ('I am currently using an app for that *[nutrition / fitness]* and intend to continue to use it.'), and (Stage 5) being 'disengaged' ('I have used an app for that *[nutrition / fitness]*, but I do not use it anymore.'). Stages 1-3 and 5 encompass nonusers, while Stage 4 includes current users.

*2.3.4.3. Preference for Intuition and Deliberation in Eating Decision-making (E-PID)*

A seven-item scale was used to measure the habitual preference for an intuitive or deliberate style in eating decision-making (E-PID; König et al. (in prep.); see also

Multimedia Appendix 1). The E-PID scale, consisting of two subscales, was developed based on the inventory for preference for intuition and deliberation by Betsch (2004). Participants answered each item on a five point Likert scale from (1) I do not agree to (5) I agree. A confirmatory factor analysis was conducted using a latent structural equation model in MPlus to test the hypothesized two factor structure. The comparative fit index (CFI = .988), root mean square error of approximation (RMSEA = .048, 90% CI .034; .062) and the standard root mean square residual (SRMR = .024) indicated a good model fit (Hu & Bentler, 1999). All items showed statistically significant factor loadings (*p*s < .001), indicating convergent validity. The first factor 'preference for intuition' (E-PI) consisted of three items (e.g. 'When deciding what to eat, I rely on my gut feeling.'; *M* = 3.34, *SD* = 0.83, α = .78) that describe decision-making based on feelings or affect (c.f. Betsch (2004)). The second factor 'preference for deliberation' (E-PD) consisted of four items (e.g. 'I prefer making plans about my eating behavior instead of leaving it to chance.'; *M* = 3.19, *SD* = 0.95, α = .84) that describe decision-making based on deliberation and planning.

*2.3.4.4. Healthy eating style*

Healthy eating style was measured with 16 items assessing general food consumption patterns (e.g. 'I do not eat fast food.', 'I only eat foods containing little salt.', 'If I eat sweets or cakes, I only eat little.', 'I eat a lot of fruit and fresh vegetables.') using a seven point Likert scale from (1) strongly disagree to (7) strongly agree (cf., Renner, Hahn, von Lengerke, and Schwarzer (1996), Leppin (1994)). To investigate the factor structure, an exploratory factor analysis was conducted using a principal component analysis and promax rotation. Global diagnostic indicators showed adequate factorability of the correlation matrix, with Kaiser-Meyer-Olkin = .82 and a significant Bartlett's test of sphericity ($\chi^2(120) = 3106.12$, $p < .001$). Both the eigenvalues on the scree-plot as well as the MAP test (O'Connor, 2000) suggested a one factor solution. Four items were excluded because they loaded less than $\lambda = .30$ on the factor, yielding a 12 item scale that accounted for 29.39% of the variance. Items were aggregated, and a higher score represents a healthier eating style (*M* = 4.34, *SD* = 0.90, α = .77).

*2.3.4.5. Body-Mass Index (BMI)*

BMI was calculated using the height and weight measurements taken by trained research staff following a standardized procedure: Participants wore light indoor clothing and were asked to take off their shoes. Height was measured using a wall-mounted stadiometer, and weight was measured using a digital scale (Omron Body Composition Monitor, BF511).

*2.3.4.6. Sociodemographic variables*

Participants' age and gender were assessed. Additionally, participants' level of education was assessed and converted into years of education.

Means and standard deviations are listed in Table 1 for Nutrition apps and in Multimedia Appendix 2 for Fitness apps.

**Table 2.1**

Descriptive statistics of correlates of nutrition app adoption.

| | Gender[1] | | | Age | Years of education | BMI | Healthy eating style |
|---|---|---|---|---|---|---|---|
| | Female | Male | *p* | *M* (*SD*) | *M* (*SD*) | *M* (*SD*) | *M* (*SD*) |
| Stage 1 'unengaged' | 312 (-3.25) | 221 (3.25) | .001 | 41.33 (15.88) | 16.18 (2.33) | 24.01 (3.24) | 4.28 (0.92) |
| Stage 2 'decided to act' | 44 (-0.07) | 26 (0.07) | .944 | 37.33 (16.28) | 15.06 (2.54) | 24.86 (4.17) | 4.08 (0.94) |
| Stage 3 'decided not to act' | 126 (0.77) | 66 (-0.77) | .441 | 35.15 (15.35) | 15.89 (2.43) | 23.63 (3.32) | 4.26 (0.79) |
| Stage 4 'acting' | 58 (1.47) | 24 (-1.74) | .142 | 32.93 (14.14) | 15.10 (2.44) | 24.44 (3.49) | 4.50 (0.84) |
| Stage 5 'disengaged' | 103 (2.73) | 37 (-2.73) | .006 | 32.16 (12.91) | 15.69 (2.28) | 24.23 (4.26) | 4.29 (0.86) |

*Note.* [1] For gender, the number of participants in the cell and the standardised adjusted residuals (in brackets) are displayed. Due to multiple comparisons, the significance level was adjusted to $\alpha = .005$.

### *2.3.5. Statistical analysis*

Analyses were performed using IBM SPSS Statistics (Version 23). Missing values were 0% for gender, 0.1% for healthy eating style and E-PID, 0.2% for age and BMI, 1.4% for years of education and ownership of mobile devices, and 6.1% for fitness and 7.7% for nutrition app adoption stages. Participants with missing data on a variable relevant to an analysis were excluded for that specific analysis only. Descriptive statistics are reported for the full data set (N = 1,215). All analyses on differences between nutrition and fitness app use stages were conducted using a subsample that had indicated owning at least one mobile device (N = 1,054). To investigate differences between nutrition and fitness app use stages by age, years of education, BMI, and healthy eating style, one-way ANOVAs were conducted. Post hoc analyses were conducted using Bonferroni correction. Levene-Tests were conducted to test for the precondition of homogeneity of variances. This precondition was not met for analyzing differences in age ($F(4, 1010) = 7.84$, $p < .001$) or BMI for nutrition app adoption stages ($F(4, 1009) = 3.23$, $p = .011$) or for age differences between fitness app adoption stages ($F(4, 1022) = 8.00$, $p < .001$). To analyze these relationships, Welch-Tests and Games-Howell post hoc tests were conducted. Gender differences were examined using chi-square tests. Post hoc tests were performed using standardized residuals and Bonferroni correction (García-Pérez & Núnez-Antón, 2003). Adoption stage differences in preference for intuition and deliberation were analyzed using mixed ANOVAs, with Stages of Behavioral Adoption as a between-subjects factor and Preference for Intuition and Deliberation in Eating Decision-making (E-PID) as a within-subjects factor. Significant results were followed up by simple effects (c.f. Page, Braver, and MacKinnon (2003)). For these comparisons, the α-level was adjusted to α = .001 to account for multiple comparisons.

## 2.4. Results

### *2.4.1. Mobile devices, nutrition and fitness app use*

Of the total sample, 83.1% of participants indicated owning a smartphone, and 39.5% owned a tablet. Taken together, $n = 1,054$ (86.8%) of the study population owned at least one mobile device that allowed them to use apps.

Installation rates of nutrition and fitness apps were further investigated in the subsample that owned at least one mobile device (see Figure 2.1). Whereas 76.7% ($n = 807$) of them indicated that they never had installed a nutrition app, 15.1% ($n = 159$)

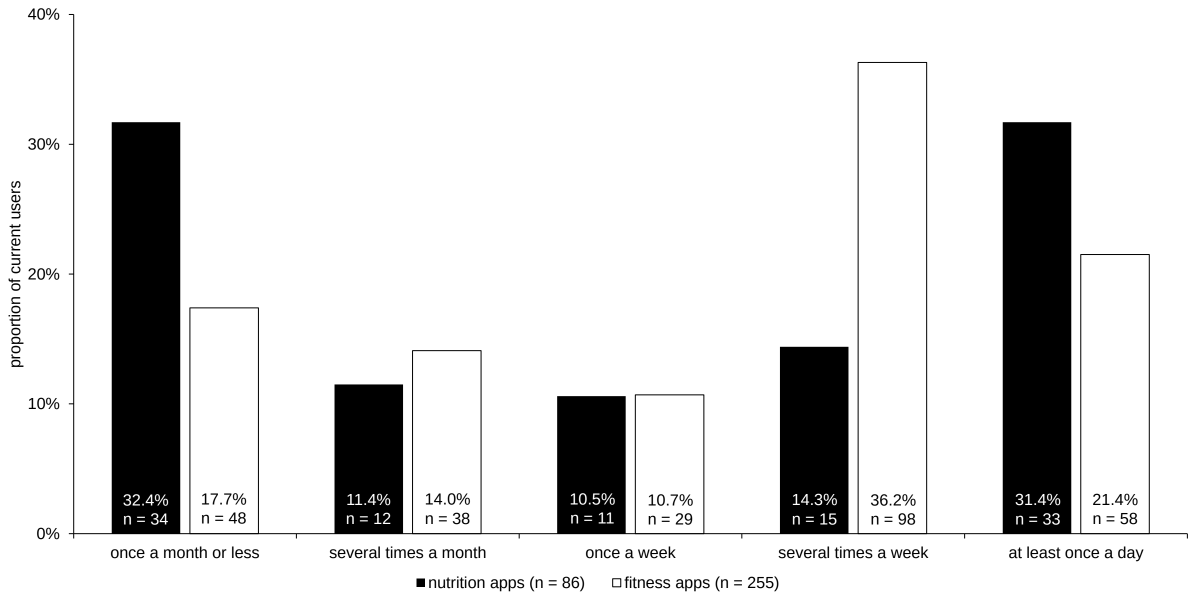


**Figure 2.2.** *Frequency of use of nutrition (n = 86) and fitness apps (n = 255).*

had previously installed one and 8.2% (*n* = 86) reported having one currently installed on their mobile device. For fitness apps, 52.3% (*n* = 553) reported never having had a fitness app installed, 23.4% (*n* = 246) had had one installed previously, and 24.2% (*n* = 255) currently had one installed on their smartphone or tablet.

In a next step, frequency of use was investigated in those participants who had indicated having a currently installed nutrition (*N* = 86) or fitness app (*N* = 255) on their mobile device (for a summary, see Figure 2.2). For nutrition apps, most participants indicated using the app at least once a day (*n* = 34, 32.4%), while for fitness apps, the largest proportion of participants indicated that they used a fitness app several times a week (*n* = 98, 36.2%).

### *2.4.2. Stages of behavioral adoption*

Of all participants who owned a mobile device (see also Figure 2.3; means and standard deviations are listed in Table 2.1), 52.4% indicated that they had never thought about using a nutrition app and were therefore classified as ‘unengaged’ nonusers (Stage 1). Another 6.9% indicated that they are planning to use a nutrition app in the future and were thus categorized as ‘decided to act’ nonusers (Stage 2), 18.9% were classified as ‘decided not to act’ nonusers (Stage 3) as they indicated having decided against using a nutrition app. Moreover, 8.1% indicated that they were currently using a nutrition app and categorized as ‘acting’ users (Stage 4), and 13.8% reported having previously used a nutrition app and were categorized as ‘disengaged’ nonusers (Stage 5).

In relation to the five stages of fitness app adoption, 29.3% of the participants who owned a mobile device were categorized as ‘unengaged’ (Stage 1), 9.2% as ‘decided to act’ (Stage 2), 20.8% as ‘decided not to act’ (Stage 3), 25.7% as ‘acting’ (Stage 4), and 15.1% as ‘disengaged’ (Stage 5) (see also Figure 2.3).

#### *2.4.3. Sociodemographic correlates*

Significant age differences between the five stages of behavioral adoption of nutrition apps emerged ($F(4, 252.00) = 16.85$, $p < .001$, $\omega^2 = .06$), with participants in Stage 1 (‘unengaged’) ($M = 41.33$, $SD = 15.88$) being older than participants in Stage 2 (‘decided to act’) ($M = 37.33$, $SD = 16.28$, $p < .001$), Stage 4 (‘acting’) ($M = 32.93$, $SD = 14.14$, $p < .001$), and Stage 5 ('disengaged’) ($M = 32.16$, $SD = 12.91$, $p < .001$). Furthermore, a significant association between stages of behavioral adoption of nutrition apps and gender emerged ($\chi^2 (4) = 13.95$, $p = .007$, *Cramer* $V = .12$). More men were more often in Stage 1 (‘being unaware’) than women. Also, significant stage differences were found for years of education ($F(4 ,1008) = 6.65$, $p < .001$, *partial* $\eta^2 = .03$). Post hoc tests revealed that participants in Stage 1 (‘unengaged’) ($M = 16.18$, $SD = 2.33$) were better educated than participants in Stage 2 (‘decided to act’) ($M = 15.06$, $SD = 2.54$, $p = .002$) and Stage 4 (‘acting’) ($M = 15.10$, $SD = 2.44$, $p = .001$).

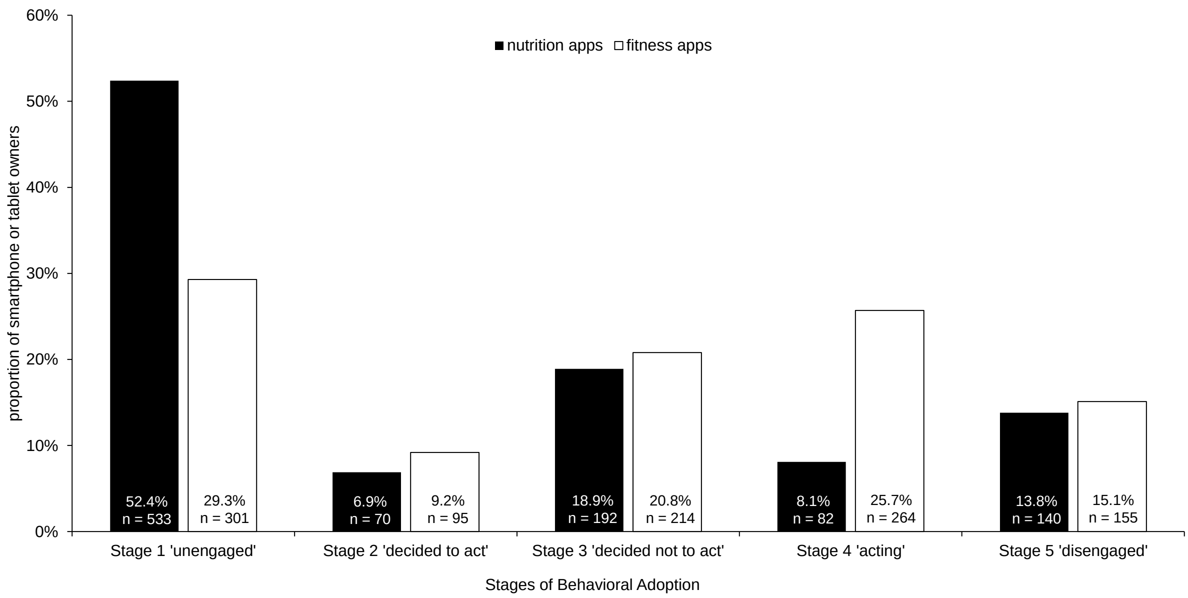


**Figure 2.3.** *Stages of Behavioral Adoption of nutrition and fitness apps.*

Further analysis of the differences between the stages of fitness app adoption showed similar age differences as for nutrition app adoption, ($F$(4, 398.29) = 22,38, $p < .001$, $\omega^2$= .08). Participants in Stage 1 (‘unengaged’) ($M$ = 45.31, $SD$ = 16.61) were significantly older than participants in the remaining four stages (Stage 2 ‘decided to act’: $M$ = 37.14, $SD$ = 15.64, $p < .001$; Stage 3 ‘decided not to act’: $M$ = 36.18, $SD$ = 15.37, $p < .001$; Stage 4 ‘acting’: $M$ = 34.76, $SD$ = 13.95, $p < .001$; Stage 5 ‘disengaged’: $M$ = 33.74, $SD$ = 13.52 $p < .001$). No significant differences were found both for gender ($\chi^2(4)$ = 8.67, $p$ = .07) and years of education ($F$(4, 1021) = 2.16, $p$ = .07).

### *2.4.4. Behavioral correlates*

For nutrition apps, no significant differences for the five stages of behavioral adoption were found for both healthy eating style ($F$(4, 1012) = 2.10, $p$ = .08) and BMI ($F$(4, 240.01) = 1.72, $p$ = .15).

For fitness apps, analyzing stage differences in healthy eating style ($F$(4, 1024) = 2.92, $p$ = .02, $\eta^2$= .011) revealed a tendency for Stage 1 participants (‘unengaged’) to report a healthier eating style (*M* = 4.43, *SD* = 0.94) than Stage 4 participants ('acting') (*M* = 4.23, *SD* = 0.84; *p* = .07). Regarding BMI, no significant stage differences were found (*F*(4, 1021) = 1.71, *p* = .15).

#### ***2.4.5. Psychological correlates: Preference for Intuition and Deliberation in Eating Decision-making***

The characteristics of the different stages of behavioral adoption of nutrition apps show that participants differed significantly in terms of their preference for a deliberative or an intuitive style when making eating-related decisions (see Figure 2.4; see also see Table 2.1). Specifically, a 5 *Stages of Behavioral Adoption (Nutrition)* x 2 *E-PID* mixed ANOVA yielded significant results. Both a main effect for the between-subjects factor *Stages of Behavioral Adoption* (*F(*4, 1012) = 6.96, *p* < .001, *partial* $\eta^2$ = .03) and a main effect for the within-subjects factor *E-PID* (*F(*1, 1012) = 5.18, *p* = .02, *partial* $\eta^2$ = .01) emerged. Also, the interaction of the two factors was significant (*F(*4, 1012) = 21.69, *p* < .001, *partial* $\eta^2$ = .08). The interaction effect was followed up by simple effects to test differences between *Preference for Intuition (E-PI)* and *Preference for Deliberation (E-PD)* at all levels of the *Stages of Behavioral Adoption*. Significant differences emerged between Stage 1 ('unengaged') (*F*(1,1012) = 49.55, *p* < .001) and Stage 4 ('acting') (*F*(1,1012) = 32.80, *p* < .001). While Stage 1 ('unengaged'), participants preferred on average a more an intuitive eating decision-making style, Stage 4 ('acting') participants preferred on average a more deliberative eating decision-making style.

A 5 *Stage of Behavioral Adoption (Fitness)* x 2 *E-PID* mixed ANOVA was conducted to analyze stage differences in terms of the preference for deliberative or intuitive style when making eating related decisions in order to examine whether the stage characteristics are behavior-specific or also generalize to the fitness app

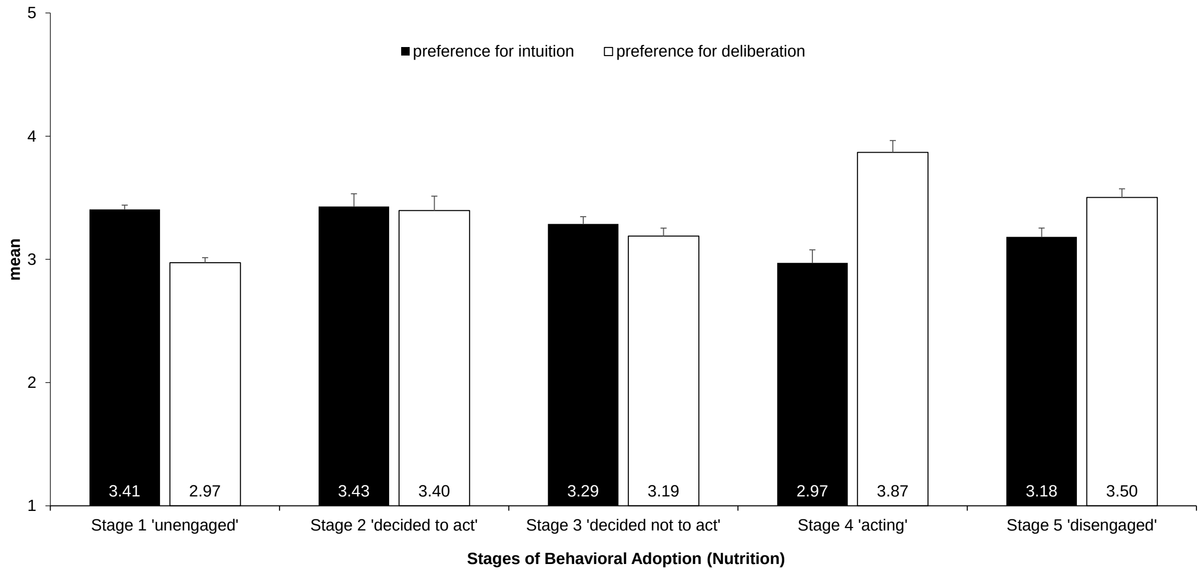


**Figure 2.4.** *Differences in Preference for Intuition and Deliberation between Stages of Behavioral Adoption of nutrition apps.*

adoption process. The interaction between the between-subjects factor *Stage of Behavioral Adoption (Fitness)* and the within-subjects factor *E-PID* reached significance ($F(4, 1024) = 6.17$, $p < .001$, *partial* $\eta^2 = .02$). The interaction effect was followed up by simple effects, testing differences between *Preference for Intuition* (E-PI) and *Preference for Deliberation* (E-PD) at all five stages. A significant difference emerged only for participants in Stage 1 ('unengaged'), with a higher preference for an intuitive style when making eating decisions ($M_{\text{E-PI}} = 3.41$, $SD_{\text{E-PI}} = 0.84$; $M_{\text{E-PD}} = 3.00$, $SD_{\text{E-PD}} = 0.98$; $p < .001$).

## 2.5. Discussion

In the present research, the adoption process of nutrition and fitness apps and associated characteristics were investigated using a stage model approach. The present data show that there is a great potential for mHealth apps since more than 80% of the participants owned a mobile device while only 8% of them were using a nutrition app and 25% were using a fitness app. In line with other studies, the results show that fitness apps are more popular than nutrition apps, with three times as many fitness app than nutrition app users. For example, in a representative survey in Germany, 17% reported to use a mHealth app, of which 67% were using a fitness app and 39% a nutrition app (YouGov, 2016). In addition, fitness apps were mostly used several times a week, while nutrition apps were typically used on a daily basis. This mirrors the actual frequency of the behavior since fitness apps are used to track specific activities such as running or working out, (West et al., 2012) whereas nutrition apps often require that all meals are logged in order to provide meaningful measures and feedback. Hence, one obvious reason for the marked difference in usage of nutrition and fitness apps might be that physical activity often is tracked automatically by using smartphone sensors (Miller, 2012) or wearables (Morris & Aguilera, 2012; YouGov, 2016), while food intake has to be tracked manually. Manual entries in food journals can be effortful and time-consuming (Cordeiro et al., 2015; Mummah, King, Gardner, & Sutton, 2016), and therefore fewer people might be willing to monitor their diet. Some attempts have been made to reduce effort in food journaling, e.g. by including barcode scanners, digital scales (Kumar et al., 2016), or reducing extensive food databases to a list of food groups (Andrew, Borriello, & Fogarty, 2013), but these features have yet to be included in commercially available nutrition apps.

### *2.5.1. Stages of behavioral adoption*

By using a stage model approach, the present research expanded the dichotomy of mHealth app ‘users’ and ‘nonusers’ and shed more light on the psychological differences between non-acting participants. In the behavior adoption process it is assumed that people move from a state of being unaware but starting to form opinions (Stage 1) to a decision-making stage where they become engaged. They may decide to adopt the behavior (Stage 2) or decide not to take action (Stage 3). In the present study, the two behavioral domains differed particularly in respect to the prevalence of Stage 1 as half of the participants stated that they had never thought about using a nutrition app and less than one third stated they had never thought about using a fitness app. In comparison, similar prevalence rates for Stages 2 (‘decided to act’) and 3 (‘decided not to act’) emerged for nutrition and fitness apps. Previous research has shown that people who have not yet decided often show different responses to information and are often less resistant to persuasion than people who have reached a definite position on an issue, even if they have not yet acted on their opinions (Weinstein et al., 2013). Accordingly, there seems to be greater potential to increase nutrition app uptake by using tailored information to foster the transition from being ‘unengaged’ to becoming engaged, e.g. by recommending apps that specifically and effectively target the potential user’s health issues. These results also underline the importance of developing quality criteria and guidance in order for consumers and medical personnel to decide which apps to use or recommend (IMS Institute for Healthcare Informatics, 2013).

A substantial number of participants stated that they had ‘decided not to act’ (Stage 3), which poses a qualitatively different transition barrier and therefore requires a different approach to changing beliefs and attitudes than for people in Stage 1 or 2. A wealth of psychological research shows that people have a tendency adhere to their own beliefs, which is challenging to overcome. In this case, providing information for example about the pros and cons of the target behavior, which has been effective for supporting people in the early stages of the behavioral adoption process (Weinstein et al., 2013), might be less effective. Transition might be more likely to be motivated by social influences such as significant others or social norms (De Vet et al., 2008; Stok, de Ridder, de Vet, & de Wit, 2014; Wallace, Buckworth, Kirby, & Sherman, 2000). One might even argue that it is too costly to target this group and therefore more effective to focus on other groups of nonusers.

Although the present study recorded few nonusers who had ‘decided to act’ (Stage 2), this group represents a qualitatively different and important target group for interventions. A great body of research suggests (1) that there are important gaps between intending to act and carrying out this intention, and (2) that helping people develop specific implementation plans which spell out the when, where, and how of goal striving in advance can reduce these barriers (Gollwitzer, 1999; Gollwitzer & Sheeran, 2006). Such, detailed implementation information is however seldom effective for people in Stages 1 (‘unengaged’) or 3 (‘decided not to act’). Likewise, perceived self-efficacy seems particularly important for the transition from ‘decided to act’ to taking action (e.g. De Vet et al. (2008); Partridge, McGeechan, Bauman, Phongsavan, and Allman-Farinelli (2017); Renner, Spivak, Kwon, and Schwarzer (2007)).

Participants in the ‘acting’ stage (Stage 4) showed a significant different pattern of preference for a deliberative or an intuitive style when making eating-related decisions. As expected, current nutrition app users showed higher preference for deliberation than intuition, while ‘unengaged’ nonusers (Stage 1) showed a greater preference for intuition than deliberation. Accordingly, nutrition apps seem to be especially appealing to people who tend to decide what to eat after conscious reflection. mHealth apps are targeted towards this deliberative decision-making style by helping to gain insight into and control over energy intake, e.g. by allowing self-monitoring and providing instruction (Direito et al., 2014). Interestingly, participants in Stage 2 (‘decided to act’) expressed interest in using nutrition apps although reporting a lower preference for deliberation and a higher preference for intuition than current app users. This might indicate that the mismatch between the design of current available apps and preferred decision-making styles creates a significant transition barrier. Developing apps which are more tailored to an intuitive decision-making style might motivate higher stage transition rates. For example, this might be achieved by associating health behaviors with positive emotions (e.g. Baranowski et al. (2003)) or including game-like features, which might also increase the likelihood of habit formation (DeSmet et al., 2014). However, it has yet to be investigated which app features and behavior change techniques (Michie et al., 2013) best support an intuitive decision-making style, and whether including these features actually leads to increased mHealth app adoption. As differences in preferred decision-making style between fitness app adoption stages were similar but less pronounced than differences between nutrition app adoption stages, results highlight that psychological correlates of mHealth app use are behavior specific and therefore need to be investigated separately for different health behaviors (c.f. Pachur and Spaar (2015)). Also, it is important to note that preferred decision-making style was only assessed for eating-related decisions. Thus, future studies need to test for further differences between fitness app adoption stages and the preferred decision-making style for physical activity.

In line with previous research (Krebs & Duncan, 2015), participants in the ‘acting’ stage (Stage 4) were younger than ‘unengaged’ nonusers (Stage 1). This might be due to a general higher interest in the use of mobile technology, as indicated by a higher proportion of younger smartphone owners (Pew Research Center, 2016) and younger people being more convinced of the efficacy of mHealth apps (Bhuyan et al., 2016). Moreover, the present results show that current nutrition app users are less educated than ‘unengaged’ nonusers. This contrasts with previous studies describing mHealth app users as being more educated. One reason for this difference might be that the present sample was recruited onsite as part of a cohort study, rather than online as with most previous studies. The present sample includes a broader age range and potentially less technology savvy participants. Moreover, the continuous measure used might also have had an impact as previous studies compared participants with high school and university degrees (Bender et al., 2014; Bhuyan et al., 2016; Krebs & Duncan, 2015). The participants in the present study were generally highly educated, and the found effect was small (Cohen, 1988). In contrast, no such relationships were found for fitness apps, suggesting that gender and education differences might be more pronounced for nutrition than for fitness app use.

Although no differences in psychological, behavioral and sociodemographic variables were found between ‘acting’ users (Stage 4) and ‘disengaged’ nonusers (Stage 5), the two groups differ substantially in their mHealth app use behavior. While one might argue that ‘disengaged’ nonusers ceased using an app because they had reached their goal, research suggests that most ‘disengaged’ nonusers might rather have abandoned their goal (Murnane et al., 2015). This lack of engagement could for example be overcome by using effective behavior change techniques that help maintain the intention or the behavior (Perski, Blandford, West, & Michie, 2016), e.g. by boosting self-efficacy or prompting planning (Schwarzer & Luszczynska, 2015). Moreover, users might disengage from the app because tracking is too time consuming or not interesting enough in the long term (Krebs & Duncan, 2015). Developments in mobile technologies such as image based assessment methods for dietary intake (Boushey, Spoden, Zhu, Delp, & Kerr, 2016) hold great promise for reducing user burden, which might in turn boost user motivation. Thus, when further developing and testing the stage model presented in the present research, models of engagement with digital behavior change interventions can provide valuable insights as they have already identified many potential transition barriers and enablers for the transition from ‘acting’ to ‘disengagement’ (c.f. Short, Rebar, Plotnikoff, and Vandelanotte (2015)). Furthermore, engagement models might also provide further insights into transition barriers as well as enablers for the transition to the ‘acting’ stage and reengagement (O'Brien & Toms, 2008).

In line with previous research (Bhuyan et al., 2016; Dennison et al., 2013; Helander et al., 2014), no significant differences between stages of adopting nutrition apps were found with respect to a healthy eating style and BMI, and differences found between stages of adopting fitness apps were small (Cohen, 1988). This might be explained by the various reasons for using mHealth apps: While some people use them to lose weight (Murnane et al., 2015), others use them without any intention to change their behavior, e.g. to maintain their weight (Tang, Abraham, Stamp, & Greaves, 2015) or to learn more about their physical activity or eating patterns (Cordeiro et al., 2015). However, to examine the effect on actual changes in dietary patterns or related outcome such as BMI, longitudinal studies such as randomized control trials are needed. Although there has been much enthusiasm for delivering interventions through mobile devices such as smartphone apps, academic research on the development and evaluation of these mobile devices is at an early stage. Most currently available devices and programs have not been empirically evaluated, and existing studies have predominantly focused on clinical samples, including text message-based mobile interventions (Afshin et al., 2016; Albrecht, 2016a; Bacigalupo et al., 2013; Free et al., 2013; Heron & Smyth, 2010). Recently, Schoeppe et al. (2016) identified 27 studies in 6,926 publications from 2006 to 2016 that used a smartphone app to improve diet and/or physical activity as a health precaution with mixed results:

Only seven of the 13 studies targeting diet and 14 of the 21 targeting physical activity reported significant improvement. Since most current mHealth apps focus more on user interface aspects in order to keep consumers engaged than evidence-based behavior change methods (Mummah, Mathur, King, Gardner, & Sutton, 2016; Okorodudu, Bosworth, & Corsino, 2015), incorporating effective behavior change techniques (Michie et al., 2013; Stok et al., 2017; Webb, Joseph, Yardley, & Michie, 2010) might be a promising avenue for further research.

#### *2.5.2. Limitations*

A strength of the study is the large sample, which represents a wide age range and was recruited onsite, from the community. While mean BMI and age was comparable to the general German population, females were overrepresented and both the university entrance diploma and the university degree rate were above the national average, potentially limiting the generalizability of the findings. Furthermore, the study was advertised as a health check, thus participants might have been more interested in their health than the average citizen, possibly boosting mHealth use rates.

### 2.6. Conclusions

Still, the mHealth app usage rates found both in the present study and in previous research (e.g. Statista (2015); YouGov (2016)) were low, underlining the potential to engage more people in the use of mHealth apps. Using a behavior stage model approach to describe the process of adopting mHealth apps revealed motivational stage differences between nonusers, including being ‘unengaged’, ‘decided not to act’, ‘decided to act’, and being ‘disengaged’, which might contribute to a better understanding of the process of adopting behavior changes and tailoring interventions to foster transitions between stages.

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All authors were involved in the concept and design of the study, and data acquisition. LK conducted data analysis with input from BR. LK and BR drafted the manuscript with critical revisions from GS and HS. All authors approved the final version of the manuscript.

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**Conflict of Interest**

None declared.

## Multimedia Appendix 1

### Table 2.2

Generation of adaptations of the PAPM (Weinstein & Sandman, 1992) and Preference for Intuition and Deliberation (Betsch, 2004)

| **Measure used in the current study** | **Original measure** | **Adaptation** | **Items (translated)** |
|---|---|---|---|
| Stage model for the adoption process of mHealth apps (nutrition and fitness) | Precaution Adoption Process Model (Weinstein & Sandman, 1992) | The adaptation is based on the Stage Model of Health-related Awareness and Action (*Stufenmodell gesundheitlichen Bewusstseins und Handelns*, Renner and Hahn (1996)) that consists of six stages:<br>- Stage 0: ‘unaware of issue’<br>- Stage 1: ‘unengaged by issue’<br>- Stage 2: ‘deciding about acting’<br>- Stage 3a: ‘decided to act’/ Stage 3b: ‘preparation’/ Stage 3c: ‘decided not to act’<br>- Stage 4: ‘acting’<br>- Stage 5: ‘break off acting’<br>As only participants were included who owned a mobile device, it was very unlikely that these participants did not know mhealth apps at all. Hence, we decided to drop Stage 0. As downloading an app is a simple process involving little or no costs as well as little preparatory effort and to make the model economical, we decided to drop Stages 2 and 3b. Stage 5 was | *If you own a smartphone or tablet:* Do you think about using an app to track your fitness/ nutrition? *Please choose one option per column.*<br>(1) I have never thought about using an app for that. *(Stage 1)*<br>(2) I have thought about using an app for that, but so far I did not do it. *(Stage 2)*<br>(3) I have thought about using an app for that, but it is not necessary for me to do it. *(Stage 3)*<br>(4) I am currently using an app for that and intend to continue to use it. *(Stage 4)* |

| Measure used in the current study | Original measure | Adaptation | Items (translated) |
|---|---|---|---|
| | | renamed ‘disengaged’ to take on common terminology in accordance with the literature on engagement with smartphone apps. | (5) I have used an app for that, but I do not use it anymore. *(Stage 5)* |
| Preference for Intuition and Deliberation in Eating Decision-making (E-PID; König et al. (in prep.)) | Preference for Intuition and Deliberation (Betsch, 2004) | The original measure consists of 19 items that measure a general preference for intuition and deliberation when making decisions. As Pachur and Spaar (2015) noted, these preferences may differ between domains. Therefore, we developed an concise measure for eating-related decision making preferences by rephrasing the seven items that were directly transferable to eating-related decisions. For the E-PI subscale, these were items no. 4, 12 and 18 from the original questionnaire. For the E-PD subscale, items no. 1, 5, 6 and 6 were adapted (c.f. Betsch (2004)). | (1) When deciding what to eat, I rely on my gut feeling.[a] (2) With most eating decisions, it makes sense to completely rely on your feelings.[a] (3) I am an intuitive eater.[a] (4) Before I make eating decisions, I usually think about it.[b] (5) I think more about my plans and goals relating to my eating behavior than other people.[b] (6) I prefer making plans about my eating behavior instead of leaving it to chance.[b] (7) I reflect on my eating behavior.[b] Scale: (1) I do not agree to (5) I agree |

*Note.* [a] E-PI, [b] E-PD

## Multimedia Appendix 2

**Table 2.3**

Descriptive statistics of sociodemographic and behavioral correlates of fitness app adoption.

| | Gender[1] | | Age | Years of education | BMI | Healthy eating style |
|---|---|---|---|---|---|---|
| | Female | Male | *M* (*SD*) | *M* (*SD*) | *M* (*SD*) | *M* (*SD*) |
| Stage 1 ‘unengaged’ | 253 (1.1) | 130 (-1.1) | 47.18 (17.00) | 15.86 (2.39) | 24.15 (3.46) | 4.47 (0.93) |
| Stage 2 ‘decided to act’ | 69 (1.4) | 29 (-1.4) | 37.34 (15.68) | 15.60 (2.52) | 23.62 (3.11) | 4.20 (0.88) |
| Stage 3 ‘decided not to act’ | 155 (0.9) | 78 (-0.9) | 37.51 (16.28) | 16.21 (2.39) | 23.93 (3.93) | 4.30 (0.88) |
| Stage 4 ‘acting’ | 151 (-2.8) | 115 (2.8) | 34.96 (14.12) | 15.73 (2.40) | 24.27 (3.41) | 4.23 (0.85) |
| Stage 5 ‘disengaged’ | 101 (-0.3) | 60 (0.3) | 34.00 (13.68) | 15.74 (2.39) | 24.18 (3.99) | 4.25 (0.84) |

*Note.* [1] For gender, the number of participants in the cell and the standardised adjusted residuals (in brackets) are displayed.

**Table 2.4**

Descriptive statistics of psychological correlates of fitness app adoption.

| | Preference for intuition<br>*M* (*SD*) | Preference for deliberation<br>*M* (*SD*) |
|---|---|---|
| Stage 1 ‘unengaged’ | 3.41 (0.84) | 3.00 (0.98) |
| Stage 2 ‘decided to act’ | 3.32 (0.85) | 3.32 (0.95) |
| Stage 3 ‘decided not to act’ | 3.29 (0.80) | 3.28 (0.92) |
| Stage 4 ‘acting’ | 3.18 (0.85) | 3.36 (0.96) |
| Stage 5 ‘disengaged’ | 3.41 (0.80) | 3.19 (0.92) |

# 3. Colourful = healthy? Exploring meal colour variety and its relation to food consumption

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## 3.1. Abstract

Visual properties of food including colour are important cues when deciding what and how much to eat. Colour variety might be an intuitive cue for healthy food choices. In order to explore a colourful equals healthy association, the present study examined 486 real-life meal choices recorded by 108 participants. Participants recorded their lunch meals via mobile visual food recording, indicated the perceived meal colour variety, and added a short meal description using smartphone based ecological momentary assessment. All visual food records and description were coded by trained experts according to seven main food groups (fruit, vegetables, grains and starches, protein sources, dairy, fried foods, sugary foods). Supporting the colourful equals healthy association, increased perceived meal colour variety was related to an increased intake of vegetables and a decreased intake of sugary foods. Hence, eating colourfully seems to be a promising avenue for promoting a more intuitive but also healthy food choice strategy in consumers.

## 3.2. Introduction

Although sufficient food is available in industrialised countries, most populations risk malnutrition by failing to ingest the recommended amount of micronutrients (Cordain et al., 2005; Heseker, 2012; Troesch et al., 2015). Scientific nutritional societies such as the U.S. Department of Agriculture (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015) or the German Nutrition Society (Rösch & Jungvogel, 2013) therefore recommend a varied diet to provide the body with a sufficient variety of nutrients. In a similar vein but taking a different route, traditional Japanese cuisine addresses this issue by recommending cooks to include the five colours red, yellow, green, black and white in every meal to ensure nutritional value and diversity. This notion is supported by research on phytonutrients, i.e. bioactive substances including vitamins and minerals (Liu, 2013) that both increase nutritional value and give the foods their colours (e.g. alpha- and beta-carotene; Murphy, Barraj, Spungen, Herman, and Randolph (2014); Nutrilite Health Institute (2014)) . Thus, eating colourful meals might increase both nutritional value and variety of nutrients consumed, increasing the likelihood of meeting nutritional guidelines everyday.

When deciding what and how much to eat, people often need to rely on their perception of food since nutritional facts and information are seldom readily available. Visual properties of foods, including colour, are indeed important cues for food choice (Clydesdale, 1993; Renner et al., 2016; Scheibehenne et al., 2010; Schulte-Mecklenbeck et al., 2013; Van der Laan, De Ridder, Viergever, & Smeets, 2011; Wansink et al., 2005). For instance, food and beverage colours induce pre-consumption expectations about flavour identity (DuBose, Cardello, & Maller, 1980). Furthermore, colour intensity may be a cue for quality (Francis, 1995; Valentin, Parr, Peyron, Grose, & Ballester, 2016) or a more intense taste (e.g. Calvo, Salvador, and Fiszman (2001); for reviews, see also Spence (2015); Spence and Piqueras-Fiszman (2016)). Food colour also elicits expectations of nutritional value, with red foods being perceived as having a higher energy density than green foods (Foroni, Pergola, & Rumiati, 2016). Although most research on the effect of food colour on food perception has been conducted using single coloured food stimuli, food colour variety has also been shown to impact both taste perception and the amount consumed (for a summary, see Piqueras-Fiszman and Spence (2014)). For instance, multi-coloured candy was rated as more pleasant and was consumed in greater amounts compared to single coloured candy (Rolls, Rowe, and Rolls (1982); see also Kahn and Wansink (2004) for a similar study). While these results indicate that manipulating meal colour variety might be used to increase or decrease the amount of food consumed, research is so far limited to the consumption of single types of candy.

The present study aimed to expand this line of research by exploring whether the relationship between colour variety and the amount of food consumed can be extended to a broader range of types of food. As both candy and fruit and vegetables are rich in colours, the question arises whether increased colour variety also leads to increased fruit and vegetable consumption. Due to low energy density and high nutritional value, the consumption of fruits and vegetables is encouraged in public health campaigns (e.g. Rösch and Jungvogel (2013); U.S. Department of Health and Human Services and U.S. Department of Agriculture (2015)). Thus, colourful meals would be considered healthier if they contained more fruits and vegetables than less colourful meals, and the suggestion to eat colourfully might be used to facilitate healthy eating.

To achieve this goal, the present study focused on lunch meals, which are the main meal of the day in Germany. Firstly, participants' food colour perception accuracy was established by comparing participants' colour perception with a colour coding by trained research staff. Secondly, colour and food group variety in lunch meals was explored to investigate whether variance in meal colours and food groups consumed was due to variability between participants or meals. Thirdly, the relationship between perceived meal colour variety and food consumption was investigated, testing a colourful equals healthy association. To maximise ecological validity and avoid the selective analysis of palatable foods such as desserts that are commonly shared on social media (Mejova, Abbar, & Haddadi, 2016; Spence, Okajima, Cheok, Petit, & Michel, 2016), data was collected in the participants' natural food consumption setting using smartphone-based ecological momentary assessment (Shiffman, 2014; Shiffman et al., 2008). The data thus represents real-life food choices with a high ecological validity (Boushey et al., 2016), and allowed studying intrapersonal variation.

## 3.3. Material and methods

### *3.3.1. Sample*

A sample of $N$ = 108 participants (81% females) was recruited using the online study pool of the University of Konstanz and short notices distributed around the university building. People were eligible for participation unless they had defective colour vision. Participants were aged 18 to 47 years ($M$ = 22.14, $SD$ = 4.36). Ninety-six percent of participants were students including Psychology (79%), Law (6%) or Political Science (4%) students. Participants received 0.5 hours of course credit or two vouchers for coffee at the university café (total value: 2.60€) as compensation. In total, $N$ = 500 meals were logged. Logging was aborted before a picture was taken for $n$ =

12 meals and no picture was available for $n$ = 2 meals. Therefore, the present analyses report $N$ = 486 meals.

### *3.3.2. Procedure*

Prior to the study period, participants were invited to the laboratory. They gave written informed consent in accordance with the Declaration of Helsinki and the guidelines of the German Society for Psychology. Participants with Android smartphones were then asked to install the smartphone application (app) movisensXS (movisens GmbH Karlsruhe; version 0.8.4203; available on Google Play for Android smartphones) and download the questionnaires. Participants without an Android smartphone (n = 32) received a smartphone with the app and questionnaires installed. After this session, participants were asked to record their lunch meals for four days or more over the following week. Using the app, they first filled out a questionnaire on demographic variables. Subsequently, they were asked to record their lunch meals by (1) taking a picture (see Figure 3.1 for examples), (2) describing the meal and (3) rating the meal's colours, and (4) healthiness and appearance. Questionnaire data and food

**Figure 3.1.** *Examples of meal pictures taken by participants.*

pictures were transferred to the server by mobile data or Wi-Fi connection. After recording at least four meals, participants returned to the laboratory to delete the questionnaires and uninstall the app or return the smartphone. Afterwards, they were compensated for participating.

### *3.3.3. Materials*

*Perceived meal colour variety*

To assess the participants' meal colour perception, two measures were applied. Firstly, participants rated the meal's colour on a 100-point visual analogue scale ranging from 'one colour' to 'very many colours'.

#### *3.3.3.1. Perceived meal colours*

Secondly, participants were asked to indicate whether the meal contained the following colours ((0) no/ (1) yes): yellow / orange, red, green, blue, white, and other.

#### *3.3.3.2. Coded meal colours*

Colours were coded by trained research staff based on the meal descriptions and pictures provided by the participants. For all foods consumed in the study, a standard colour was specified in a coding manual (e.g. green for lettuce, yellow / orange for bananas, red for tomato sauce). In cases in which more than one colour was possible (e.g. bell peppers, which can be yellow / orange, red, or green), the colour was verified using the picture. In line with the questionnaire, the presence of the colours yellow / orange, red, green, blue, white, and other was coded in binary ((0) no/ (1) yes).

#### *3.3.3.3. Food consumption: Meal composition and portion size*

Similar to colour, meals were coded by trained research staff based on the food pictures and meal descriptions submitted in an open-ended text field. The foods were divided into seven food groups based on German dietary guidelines (Koelsch &

Brüggemann, 2012): vegetables, fruit, grains and starches, animal and other protein sources (further referred to as ‘protein’), dairy, fried foods, and desserts and other sugary foods (further referred to as ‘sugary extras’). The latter two categories consisted of foods that should only be eaten in limited amounts (c.f. Onvani et al. (2017); Rösch and Jungvogel (2013)). All food items were assigned to one of the seven categories. In addition, portion sizes were estimated based on the same German dietary guidelines (Koelsch & Brüggemann, 2012). A final score for each meal was computed by dividing the portion sizes of all seven categories by the total number of portions per meal, representing the proportion of the given category in the whole meal to control for meal size.

*3.3.3.4. Demographic variables*

Participants were asked to indicate their gender, age, current occupation and field of study when they first used the app. Additionally, the participants’ dietary habits (e.g. vegetarian or vegan) were assessed.

### *3.3.4. Statistical analysis*

To investigate colour perception accuracy, inter-rater agreement between perceived and coded meal colours was computed in IBM SPSS 23 using Cohen’s kappa (Cohen, 1960).

To account for the data’s hierarchical structure, the variety in colours and food groups consumed per meal as well as the relationships between perceived meal colour variety and intake of the seven food groups were analysed with multilevel linear modelling (Hox, Moerbeek, & van de Schoot, 2010) in R 3.2.3 using the packages lme4 version 1.1-11 (Bates et al., 2016) and lmerTest 2.0-30 (Kuznetsova, Brockhoff, & Christensen, 2016). The individual meals define Level 1 (the lower level) of the hierarchy and were nested within participants who define Level 2 (the higher level).

Variety of meal colour and food groups consumed was analysed using an intercept only model, which separates the total variance into variance between meals and variance between participants. Using this model, intraclass correlations (ICC) were computed, which estimate the proportion of variance explained by the participants compared to the total variance.

The intake of seven food groups was modelled as a function of perceived meal colour variety within participants to test whether the proportion of the respective food category changed as a function of perceived meal colour variety. Perceived meal colour variety as a Level 1 predictor was group-mean centred, as recommended by Enders and Tofighi (2007). For each food category, two models were computed. First, a random slopes model allowing both intercept and slope to vary was computed in order to model whether participants differ both in mean consumption and the relationship between perceived meal colour variety and consumption. Secondly, a random intercept model allowing only the intercept to vary was computed to model whether participants differed only in mean consumption and not in the relationship between perceived meal colour variety and consumption. Standardised regression coefficients were computed following the procedure suggested by Hox et al. (2010). If significant, both models were then compared using a deviance test (Hox et al., 2010). A non-significant deviance test indicates that the less complex model (i.e. random intercept model) is preferred, while a significant deviance test indicates that the more complex model (i.e. random slopes model) is preferred. In the latter case, the percentage of positive and negative slopes was computed following the procedure suggested by Hox et al. (2010).

## 3.4. Results

### *3.4.1. Accuracy of colour perception*

To test the accuracy of colour perception, Cohen's kappa (Cohen, 1960) was computed for all six colours. While agreement for the colours red and green was substantial ($\kappa_{red} = .69$, $\kappa_{green} = .77$), agreement for the other colours was fair to moderate ($\kappa_{yellow\,/\,orange} = .45$, $\kappa_{blue} = .10$, $\kappa_{white} = .33$, $\kappa_{other} = .34$).

### *3.4.2. Colour and food group variety in lunch meals*

#### *3.4.2.1. Colour variety*

Average perceived colour variety was moderate, but data showed a substantial variation between meals (*M* = 52.26, *SD* = 24.36, range 0 – 100, ICC = 0.13). The ICC indicated that 13% of variance was due to differences between participants and 87% of variance was due to differences between meals. Of all recorded meals, 83.7% contained the colours yellow or orange, 66.2% contained red, 61.2% contained green, 12.4% contained blue, 61.6% contained white and 61.0% contained other colours.

#### *3.4.2.2. Food group variety*

The most frequently consumed food groups were vegetables (in 79.0% of meals; ICC = 0.23) and grains and starches (78.8%; ICC = 0.07). Dairy was present in 42.1% of meals (ICC = 0.05), while 18.4% of meals included fruit (ICC = 0.29) and 16.7% included fried foods (ICC = 0.02). Another 35.1% of meals contained protein (ICC = 0.11) and 11.0% of meals contained sugary extras (ICC = 0.10). Again, substantial variation between meals was found for all food groups as indicated by the ICC: while 2-29% of variance was due to differences between participants, 71-98% of variance was due to differences between meals.

**Table 3.1**

Results of the multilevel models to analyse the relationship between perceived meal colour variety and consumption of seven food categories.

| | Random slopes model (fixed effects) | | | | | Random intercept model (fixed effects) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Predictor | *b* | *SE* | *t* | *df* | *p* | *b* | *SE* | *t* | *df* | *p* |
| *Model 1: proportion of vegetables* | | | | | | | | | | |
| Intercept | 0.286 | 0.014 | 20.63 | 104.3 | < .001 | 0.286 | 0.014 | 20.67 | 104.00 | < .001 |
| Perceived meal colour variety | 0.003 | 0.001 | 4.99 | 65.58 | < .001 | 0.003 | 0.000 | 5.89 | 373.00 | < .001 |
| *Model 2: proportion of sugary extras* | | | | | | | | | | |
| Intercept | 0.042 | 0.008 | 5.34 | 106.73 | < .001 | 0.042 | 0.008 | 5.38 | 101.30 | < .001 |
| Perceived meal colour variety | -0.001 | 0.000 | -3.06 | 87.62 | .003 | -0.002 | 0.000 | -4.97 | 371.10 | < .001 |
| *Model 3: proportion of fruit* | | | | | | | | | | |
| Intercept | 0.064 | 0.011 | 6.04 | 97.53 | < .001 | 0.063 | 0.010 | 6.07 | 96.40 | < .001 |
| Perceived meal colour variety | -0.000 | 0.000 | -0.36 | 43.90 | .721 | -0.000 | 0.000 | -1.04 | 364.90 | .301 |
| *Model 4: proportion of protein* | | | | | | | | | | |
| Intercept | 0.094 | 0.008 | 11.95 | 102.41 | < .001 | 0.094 | 0.008 | 11.97 | 102.30 | < .001 |
| Perceived meal colour variety | 0.000 | 0.000 | 1.11 | 67.93 | .269 | 0.000 | 0.000 | 1.35 | 373.20 | .179 |
| *Model 5: proportion of grains and starches* | | | | | | | | | | |
| Intercept | 0.272 | 0.009 | 30.28 | 104.61 | < .001 | 0.272 | 0.009 | 30.30 | 104.30 | < .001 |
| Perceived meal colour variety | -0.001 | 0.000 | -1.20 | 81.40 | .235 | -0.000 | 0.000 | -0.73 | 376.80 | .464 |
| *Model 6:proportion of dairy* | | | | | | | | | | |
| Intercept | 0.129 | 0.009 | 14.66 | 115.86 | < .001 | 0.129 | 0.009 | 14.79 | 101.00 | < .001 |
| Perceived meal colour variety | -0.000 | 0.000 | -0.92 | 84.37 | .363 | -0.000 | 0.000 | -0.55 | 373.90 | .583 |
| *Model 7: proportion of fried foods* | | | | | | | | | | |
| Intercept | 0.058 | 0.007 | 7.92 | 135.05 | < .001 | 0.058 | 0.007 | 7.94 | 106.30 | < .001 |
| Perceived meal colour variety | -0.000 | 0.000 | -0.33 | 102.78 | .746 | -0.000 | 0.000 | -0.87 | 380.00 | .386 |

### *3.4.3. Relationships between perceived meal colour variety[1] and food consumption*

Multilevel models were computed separately for all seven food groups. A significant positive relationship with perceived meal colour variety emerged for vegetables, indicating a higher proportion of vegetables in meals perceived as more colourful. When comparing the random slopes (β = 0.27, $t(65.58) = 4.99$, $p < .001$) and random intercept models (β = 0.28, $t(373.00) = 5.89$, $p < .001$), the random intercept model assuming no differences in the individual slopes was preferred ($\chi^2(df = 2) = 4.20$, $p = .122$). Thus, the found relationship between meal colour variety and proportion of vegetables consumed was comparable between participants (see Figure 3.2).

Furthermore, a significant negative relationship emerged between perceived meal colour variety and the proportion of sugary extras. When comparing the random slopes (β = -.22, $t(87.62) = -3.06$, $p = .003$) and random intercept models (β = -0.25, $t(371.10) = -4.97$, $p < .001$), the random slopes model was preferred ($\chi^2(df = 2) = 71.20$, $p < .001$), indicating that the relationship between perceived meal colour variety and the proportion of sugary snacks consumed differed between participants. Sixty-six percent of slopes were negative, indicating that a greater perceived meal colour variety was associated with a lower proportion of sugary extras, while 34% of slopes were positive, indicating that a greater perceived meal colour variety was associated with a higher proportion of sugary extras (see Figure 3.3).

[1] Similar results emerged when coded meal colours were used as a predictor. The more colours the meal contained, the more vegetables ($b = 0.022$, $t(135.85) = 2.01$, $p = .046$) and less sugary extras ($b = -0.020$, $t(132.44) = -2.50$, $p = .014$) were consumed. For both food groups, the random slopes models were preferred ($\chi^2$s($df = 2$) ≥ 11.55, $p$s ≤ .003), indicating differences in the magnitude and direction of the effect between participants. For vegetable consumption, 69% of slopes were positive, while 31% of slopes were negative. For the consumption of sugary extras, 70% of slopes were negative, while 30% of slopes were positive. Furthermore, the more colours the meal contained, the more protein ($b = 0.020$, $t(318.20) = 2.79$, $p = .006$) was consumed. As the random intercept model was preferred ($\chi^2(df = 2) = 0.56$, $p = .754$), no differences between participants were assumed for this relationship.

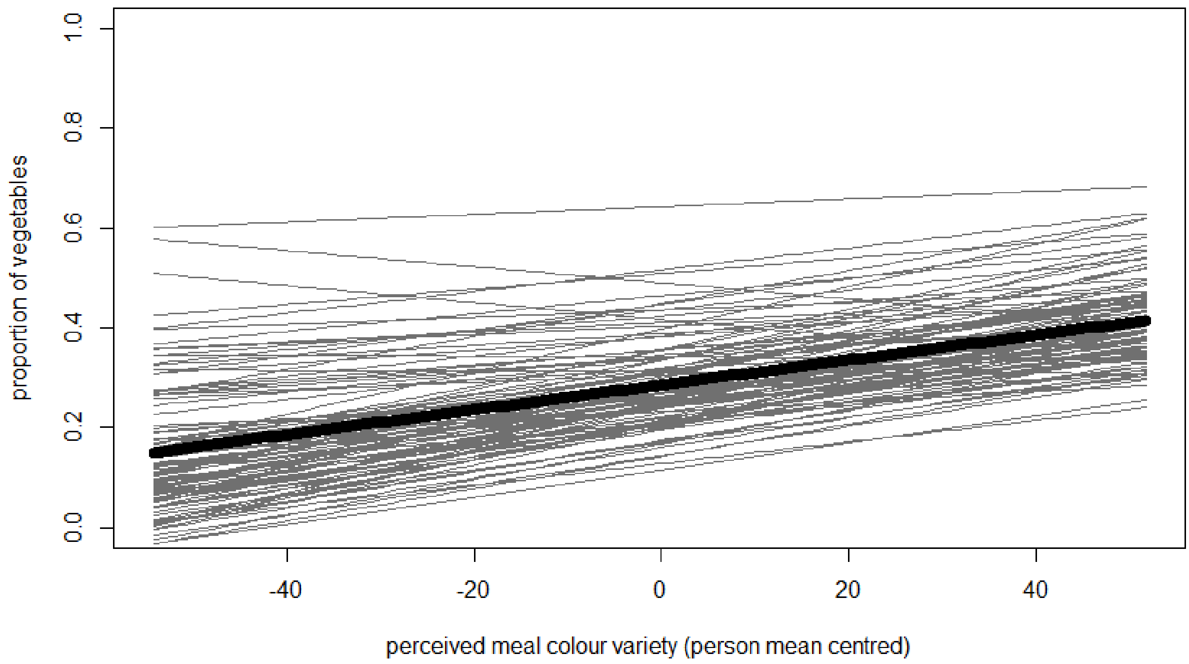


**Figure 3.2.** *Association between perceived meal colour variety and proportion of vegetables consumed in the meal. Each thin grey line represents a regression line for one participant. The thick black line represents the overall regression line.*

For all other food groups, no significant relationships with perceived meal colour variety were found (see Table 3.1 for a summary of all models).

### 3.5. Discussion

In the present research, the perceived colour variety of lunch meals and its relationship to the consumption of seven food groups was investigated. Perceived meal colour variety and the consumption of different food groups varied substantially between meals, indicating a great variability of eating behaviour within participants. Furthermore, results revealed that increased perceived meal colour variety was associated with an increased proportion of vegetables consumed and a decreased proportion of sugary extras consumed. As a greater proportion of vegetables and a smaller proportion of sugary extras increases the overall nutritional value of the meal, these results provide support for the proposed colourful equals healthy association.

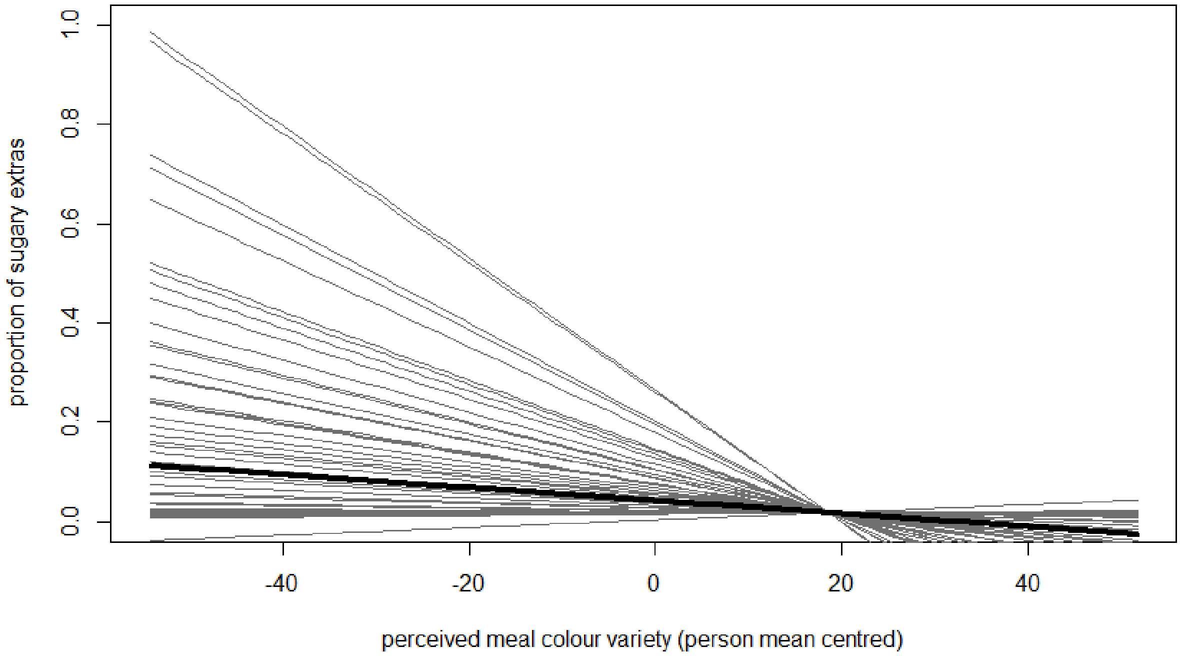


**Figure 3.3.** *Association between perceived meal colour variety and proportion of sugary extras consumed in the meal. Each thin grey line represents a regression line for one participant. The thick black line represents the overall regression line.*

As most people consume too little fruit and vegetables (Hall, Moore, Harper, & Lynch, 2009) and too much sugar, the need for public health initiatives to facilitate healthier diets is high (World Health Organization, 2007). Many diet programs have been shown to be devoid of beneficial long-term effects (Mann et al., 2007), possibly due to shortcomings like a focus on restrictions or complex set of rules (Freedman, King, & Kennedy, 2001; Hession, Rolland, Kulkarni, Wise, & Broom, 2009) that makes them hard and frustrating to adhere to (Julia et al., 2014). According to the present research, 'eat[ing] your colours' (Pollan, 2009, p. 57) might be a simpler way to facilitate healthy eating. Focusing on visual cues is a natural approach to making food choices (Renner et al., 2016; Schulte-Mecklenbeck et al., 2013). Moreover, the present research showed that food colours can be accurately identified by participants and that eating colourfully might therefore be an implicitly understood instruction. Interestingly, increased perceived meal colour variety was associated with an increased proportion of vegetables consumed across participants. This suggests that eating colourfully might be a way to improving the healthiness of meals by increasing the proportion of vegetables without the need to take individual moderators such as gender or food preferences into account.

Interestingly, while one could have expected a similar relationship to emerge for fruit, no significant association was found between perceived meal colour variety and the proportion of fruit consumed. This might be explained by the fact that fruits like apples or bananas, which are the most commonly consumed fruits in Germany (Bundesministerium für Ernährung und Landwirtschaft, 2013), are usually consumed as one piece, while vegetables are often consumed as mixed vegetables on the side or in stews.

Contrary to the universally positive relationship between perceived meal colour variety and vegetable consumption, differences between participants emerged regarding the magnitude and direction of the relationship between perceived meal colour variety and the proportion of sugary extras consumed. For two thirds of the sample, a negative relationship was found, meaning that more colourful meals contained a smaller proportion of sugary extras, while the opposite effect was observed for the remaining participants. This difference between participants indicates that the relationship might be influenced by moderators that were not assessed in the present study. For example, participants might differ in the types of sweet foods that they prefer. Some sweets like the candy used in previous research (Kahn & Wansink, 2004; Rolls et al., 1982) are multi-coloured and therefore induce a high perceived meal colour variety, but many other sweet foods like rice pudding, chocolate or confectionery are less colourful, and thus might be associated with a lower perceived meal colour variety. In the literature, other moderators of the relationship between colour and food perception have been discussed, such as culture (Shankar, Levitan, & Spence, 2010; Velasco et al., 2016; Woods, Marmolejo-Ramos, Velasco, & Spence, 2016) and age (Philipsen, Clydesdale, Griffin, & Stern, 1995). As the present sample consisted of white, western students in a comparably narrow age range, systematically testing these moderators for the colourful equals healthy association is open to future research. Furthermore, as the present study investigated meal colour variety in lunch meals where only a small proportion contained sugary extras, limited conclusions can be drawn about associations between meal colour variety and snack consumption or other meals such as breakfast and dinner. Other colourful foods such as breakfast cereals, which are calorie dense and high in sugar, might contradict the general colourful equals healthy association. Therefore, future studies should test to what extent the present findings can be transferred to other types of meals to investigate the generalizability of the colourful equals healthy association to other study populations and types of meals.

In the literature, it is suggested that colourful meals might lead to eating more due to increased pleasure or decreased sensory-specific satiety (Piqueras-Fiszman & Spence, 2014), which might also lead to an increased calorie intake. While the presented results suggest that eating colourfully induces a greater consumption of vegetables, participants also consumed fewer sugary extras, which have a higher energy density than vegetables. Thus, consuming more colourful meals may not increase caloric intake. However, this interpretation is speculative since the present data preclude definite conclusions about calorie consumption.

To keep the burden on participants low, the present study assessed food consumption by asking the participants to take a picture of their food before they ate. However, no picture was taken at the end of the meal, precluding accurate records of exactly how much food was consumed. Although research suggests people usually eat everything they serve themselves (Wansink & Johnson, 2015), future studies should account for leftovers when estimating the amount of food consumed.

Another limitation of the study was the comparably low accuracy of participants when identifying blue foods. As many foods categorised as blue in the coding manual look and were perceived by participants as being purple (e.g. aubergines, plums), the questionnaire needs to be adapted in future studies to better reflect the nuances of foods' colours.

### 3.6. Conclusions

The present study investigated the relationship between perceived meal colour variety and the consumption of seven food groups in participants' real-life lunch consumption setting. Increased perceived meal colour variety was associated with a healthier eating pattern, indicated by an increased proportion of vegetables and a decreased proportion of sugary extras consumed, supporting a colourful equals healthy association. This research has laid the foundation for future behaviour change interventions by showing that eating colourful meals might be a promising avenue for promoting a more intuitive but also healthy food choice strategy in consumers. Hence, making the fabled colourful equals healthy association explicit might contribute to 'boosting' healthy food choices (c.f. Gigerenzer and Gaissmaier (2011); Grüne-Yanoff and Hertwig (2016)).

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## 4. Boosting vegetable consumption by meal colour variety in an Ecological Momentary Intervention

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## 4.1. Abstract

Background: Dietary guidelines usually focus on complex rules which many people find difficult to put into practice. The present study proposes a simple intervention strategy for boosting healthy food choices by prompting consumers to eat a colourful lunch.

Purpose: To test the effectivity and feasibility of a boosting intervention for healthy food choices.

Methods: For a period of three weeks, 80 participants recorded a total of 1,210 lunch meals via mobile visual food recording, indicated the perceived meal colour variety and added a short meal description using smartphone based ecological momentary assessment. In the second week, participants additionally received a daily smartphone prompt to eat a colourful lunch. All pictures and descriptions were coded by a trained expert according to seven main foods groups. After the study, participants were asked to evaluate the prompt.

Results: Increased perceived meal colour variety was related to increased vegetable intake and decreased sugary extras, fruit, and grains and starches intakes. During the intervention, more vegetables and less dairy were consumed. Participants evaluated the prompt as pleasant and easy to follow.

Conclusions: Hence, prompting consumers to eat colourfully is a simple yet effective intervention strategy for promoting healthy eating.

## 4.2. Introduction

Despite the wide range of guidelines and suggestions for healthier food choices and eating currently available in the media and the recommendations scientific societies and federal agencies provide on what and how much to eat (e.g. the German Nutrition Society, the U.S. Department of Agriculture), most people do not follow a 'healthy' diet (e.g. Krebs-Smith, Guenther, Subar, Kirkpatrick, and Dodd (2010); Mensink et al. (2013); Moore and Thompson (2015)). For example, 87.4% and 59% of Germans do not consume the recommended amount of vegetables and fruit per day, respectively (Max-Rubner-Institut, 2008). Although fruit and vegetable consumption has been on the rise, recent data suggests that the trend is about to be reversed (Heseker, 2016).

Many commonly available guidelines or diets focus on restrictions such as avoiding or limiting the consumption of sweets, fried foods, carbohydrates, etc. However, this requires constant and sometimes large amounts of self-control (Herman & Polivy, 2004; Hession et al., 2009). Restraint and dieting are often difficult because they induce a conflict between the goal to lose weight or eat healthily and the goal to enjoy eating (Cornil & Chandon, 2016; Stroebe et al., 2008). Furthermore, adhering to a diet's comparably complex rules often is challenging (Julia et al., 2014) because it is difficult to achieve several goals at the same time. Moreover, many diets focus on normative goals set independently of ability or current behaviour. Although goal setting is an important technique to achieve behaviour change (e.g. Michie et al. (2013); for a review, see e.g. Maes and Karoly (2005)), goals may cause negative emotions when they are not achievable (Carver & Scheier, 1990), i.e. when the goal is fixed instead of adaptive and the desired state differs widely from the status quo. More importantly, as expected or experienced failure negatively impacts self-efficacy, it subsequently affects both intention and the ability to perform (Bandura, 1977; Locke & Latham, 2002; Oettingen & Gollwitzer, 2010; Rothman, 2000; Wrosch et al., 2003).

Alternatively, when motivating people to adopt a healthier diet, one might also focus on pre-existing capacities and strengths. Recent research suggests that eating healthy foods such as fruit and vegetables is as pleasant as eating unhealthy snacks (Wahl et al., 2017), and that having a positive relationship with eating is related to a better health status after six months (Sproesser et al., 2017). Instead of promoting deliberate restrictions, eating recommendations could also be more intuitive, e.g. by focusing on simple decision rules (Fogg, 2007; Gigerenzer & Gaissmaier, 2011). Studies suggest that food choice can be modelled using only one important cue, such as price or visual appeal (Scheibehenne, Miesler, & Todd, 2007; Schulte-Mecklenbeck et al., 2013). When identified, the simple rules can used by consumers to increase – or 'boost' – their food choice competences (Grüne-Yanoff & Hertwig, 2016). In addition, these simple dietary decision rules should be adaptive so that the goal lies within the ability of the individual (Locke, 1996; Lustria, Cortese, Noar, & Glueckauf, 2009; Weinstein et al., 1998). This means that motivation and thus the probability of goal attainment are increased.

Promoting healthy eating in a positive, simple and adaptive way could be achieved by prompting people to eat colourful meals. Meals that are perceived to be colourful have been shown to contain more vegetables and less sweets than less colourful meals (König & Renner, 2018). Eating colourfully does not restrict, but enables people to eat a more varied diet of a selection of foods they like. Furthermore, visual cues, especially colour, have been shown to be important in choosing what and how much to eat (e.g. Foroni et al. (2016); for reviews, see Spence (2015); Spence and Piqueras-Fiszman (2016)), suggesting that eating colourful meals might be a natural and simple approach that is understood implicitly. Moreover, information about a food's colours are often more readily available than information about energy or micro- and macronutrient content. Finally, increasing meal colour variety is adaptive because it takes the individual level of meal colourfulness as a starting point without setting a fixed goal for everyone.

The present study therefore aimed to replicate and extend the study by König and Renner (2018). Firstly, it aimed to replicate the results regarding meal colour perception and food intake for seven food groups, including vegetables and sweets. Secondly, the present study aimed to test whether prompting participants to eat colourful lunches boosts vegetable consumption. Thirdly, the study served as a real-life feasibility test by evaluating whether eating colourfully is pleasant and easy to follow prompt. The study was conducted using smartphone-based ecological momentary assessment and intervention (Heron & Smyth, 2010; Shiffman, 2014; Shiffman et al., 2008), allowing an assessment of ecologically valid data in real-life eating situations (Boushey et al., 2016) and to intervene just in time (Nahum-Shani et al., 2015), i.e. shortly before foods are chosen.

## 4.3. Method

### *4.3.1. Sample*

As sample size estimation in intensive longitudinal studies is difficult when little information about the effects of interest is available (Bolger & Laurenceau, 2013), $N$ = 108 participants were recruited according to a previous study (König & Renner, 2018). Recruitment in the university online study pool took place in three waves: 1) June 2016 ($n$ = 46), 2) October 2016 ($n$ = 34), 3) November 2016 ($n$ = 28). Data collection was finished in January 2017. People were eligible for participation unless they had defective colour vision or took part in previous studies assessing perceived meal colour variety. Several participants had to be excluded 1) because they did not complete the study (*n* = 4), 2) because they had difficulties using the study app (*n* = 1), 3) due to data loss because of incorrect settings on the smartphone (*n* = 2) or 4) due to data loss because of a server error in the second recruitment wave (*n* = 21).

The final sample consisted of *N* = 80 participants (88% female). Participants were aged 18 to 43 years (*M* = 22.41, *SD* = 4.00) and their body mass index (BMI) was in a normal range (*M* = 22.86, *SD* = 3.52). No differences in age, gender or BMI emerged due to recruitment wave (age: $F(2,77) = 0.99$, $p = .377$; gender: $\chi^2(df = 2) = 3.40$, $p = .183$; BMI: $F(2,76) = 0.81$, $p = .449$). Ninety-nine percent of participants were students: Psychology (51%), Teacher Training Programs with various majors (8%), Law (5%). Other academic majors were represented by less than 5% of the sample. Participants received 2 hours of course credit or 20€ as compensation.

In total, *N* = 1327 meals were logged. Recorded data was incomplete for *n* = 117 meals (e.g. due to missing pictures). Therefore, the present analyses report *N* = 1210 meals.

#### *4.3.2. Design and procedure*

The study protocol adhered to the Declaration of Helsinki and was approved by the university ethics committee. Prior to the study period, participants were invited to the laboratory for individual sessions. They were informed about the study procedure and gave written informed consent. Participants with Android smartphones (*n* = 38) were then asked to install the smartphone application (app) movisensXS (movisens GmbH Karlsruhe; version 0.8.4203; available on Google Play) and download the questionnaires. Participants without an Android smartphone (*n* = 42) received a smartphone with the app and questionnaires installed. Furthermore, height and weight were measured. After this session, participants first filled out a pre-study questionnaire assessing demographic variables and indicated the time of day they usually prepared their lunch or went to have lunch.

Subsequently, participants were asked to record their lunch meals in real life for three weeks starting the following day by (1) taking a picture (see Figure 4.1 for examples), (2) describing the meal, (3) rating the meal's colours, (4) healthiness and appearance, and (5) taking a picture of the leftovers. Additionally, participants were able to record missing events by indicating (1) that they forgot to record their lunch or (2) that they did not have lunch that day by pressing respective buttons on the app's home screen. The study used a single-group within-subjects design. Lunch meals recorded during the first week represent baseline food consumption. During the second week of the study that served as the intervention period, participants additionally received a daily prompt reminding them to eat a colourful lunch. The time they received the prompt was tailored to the individual by setting it to the time participants indicated to usually prepare or go to have lunch. During the third week (follow-up), participants

**Figure 4.1.** *Examples of meal pictures taken by participants.*

again only recorded their lunches without receiving prompts. Questionnaire data and food pictures were transferred to the server by mobile data or Wi-Fi connection.

After three weeks, participants were asked to fill out a post-study questionnaire to evaluate the prompt. Subsequently, they returned to the laboratory to delete the questionnaires and uninstall the app or to return the smartphone. Afterwards, their weight was measured again and they were compensated for participating.

#### ***4.3.3. Materials***

Measures are based on König and Renner (2018).

##### *4.3.3.1. Perceived meal colour variety*

To assess the participants' meal colour perception, two measures were applied. Firstly, participants rated the meal's colour on a 100-point visual analogue scale ranging from 'one colour' to 'many colours'.

##### *4.3.3.2. Perceived meal colours*

Secondly, participants were asked to indicate whether the meal contained the following colours ((0) no/ (1) yes): yellow/ orange, red, green, blue/ purple, white and other.

##### *4.3.3.3. Coded meal colours*

Colours were coded by trained research staff based on the meal descriptions and pictures provided by the participants. For all foods consumed in the study, a standard colour was specified in a coding manual (e.g. green for lettuce, yellow/ orange for bananas, red for tomato sauce). In cases in which more than one colour was possible (e.g. bell peppers, which can be yellow/ orange, red or green), the colour was verified using the picture. In line with the questionnaire, the presence of the colours yellow/ orange, red, green, blue/ purple, white and other was coded in binary ((0) no/ (1) yes).

*4.3.3.4. Food intake*

Food intake was coded by trained research staff using the meal descriptions submitted in an open-ended text field and the food pictures. The foods were divided into seven food categories based on German dietary guidelines (Koelsch & Brüggemann, 2012): vegetables, fruit, grains and starches, animal and other protein sources (further referred to as ‘protein’), dairy, fried foods, and desserts and other sugary foods (further referred to as ‘sugary extras’). All food items were assigned to one of the seven categories based on a coding manual. In addition, portion sizes were estimated based on the same German dietary guidelines (Koelsch & Brüggemann, 2012) by taking into account the pictures taken before and after the meal. A final score of food intake was computed by dividing the portion sizes of all seven categories by the total amount of portions per meal, representing the proportion of the given category in the whole meal.

*4.3.3.5. Body Mass Index (BMI)*

BMI was calculated from measured height and weight. Participants wore light indoor clothing and were asked to take off their shoes. Height was measured before the study using a wall-mounted stadiometer, and weight was measured before and after the study using a digital scale (Omron Body Composition Monitor, BF511).

*4.3.3.6. Evaluation of the prompt*

The prompt to eat a colourful lunch was evaluated on two 100-point visual analogue scales. Participants indicated whether they found it easy/ pleasant to eat colourful meals. Additionally, participants were asked to indicate whether they payed attention to the prompts on a 100-point visual analogue scale to assess perceived compliance.

*4.3.3.7. Demographic variables*

Participants were asked to indicate their gender, age, current occupation, field of study and dietary habits when they first used the app.

### *4.3.4. Statistical analysis*

To investigate colour perception accuracy, inter-rater agreement between perceived and coded meal colours was computed in IBM SPSS 24 using Cohen’s kappa (Cohen, 1960).

To account for the data’s hierarchical structure, the variety in colours and food groups per meal, the relationships between perceived meal colour variety and intake of the seven food categories and differences in food intake between baseline, intervention and follow-up week were analysed with multilevel linear modelling (Hox et al., 2010) in R 3.2.3 using the packages lme4 version 1.1-11 (Bates et al., 2016) and lmerTest 2.0-30 (Kuznetsova et al., 2016). The individual meals define Level 1 (the lower level) of the hierarchy and were nested within participants who define Level 2 (the higher level). Variety of meal colour and food groups consumed was analysed using an intercept only model, which separates the variance into variance between meals and variance between participants. Using this model, intraclass correlations (ICC) were computed as they estimate the proportion of variance explained by the participants compared to the total variance.

Intake of the seven food categories during the whole study period was modelled as a function of perceived meal colour variety within persons, testing whether the proportion of the respective food categories changed as a function of perceived meal colour variety. Perceived meal colour variety as a Level 1 predictor was group-mean centred, as recommended by Enders and Tofighi (2007). For each food category, two models were computed using restricted maximum likelihood (REML) estimation. First, a random slopes model was computed that allowed the intercept and the slope to vary in order to model that participants differ both in the mean consumption and the relationship between perceived meal colour variety and consumption. Secondly, a random intercept model was computed that allowed variation of the intercept only to model that participants differed only in mean consumption and not in the relationship between perceived meal colour variety and consumption. If significant, the two models were then compared using a deviance test (Hox et al., 2010). A non-significant deviance test indicates that the less complex model (i.e. random intercept model) is preferred, while a significant deviance test indicates that the more complex model (i.e. random slopes model) is preferred. In the latter case, the percentage of positive and negative slopes was computed following the procedure suggested by Hox et al. (2010).

Differences between baseline, intervention and follow-up weeks were modelled as a function of time. Multilevel models were separately computed to evaluate the difference between baseline and intervention weeks as well as the difference between baseline and follow-up weeks, following the procedures suggested by Lischetzke, Reis, and Arndt (2015). Again, random slopes and random intercept models were compared as described above. For all multilevel models, *quasi*-$R^2$ was calculated as an estimate for the effect size, comparing the preferred model to the intercept only model.

Changes in BMI were evaluated using a dependent samples t-test.

## 4.4. Results

### *4.4.1. Colour and food group variety in lunch meals*

Average perceived colour showed a substantial variation between meals (*M* = 51.52, *SD* = 23.58, range 0 – 100, ICC = 0.21). The ICC indicated that 20.6% of variance was due to differences between participants and 79.4% of variance was due to differences between meals. Of all recorded meals, 82.6% contained the colours yellow or orange, 68.7% contained red, 61.3% contained green, 10.1% contained blue, 56.3% contained white and 66.4% contained other colours.

The most frequently consumed food groups were grains and starches (in 82.3% of meals; ICC = 0.13) and vegetables (in 81.7% of meals; ICC = 0.09). Dairy was present in 36.7% of meals (ICC = 0.12), while 16.4% of meals included fruit (ICC = 0.08), 34.5% contained protein (ICC = 0.18) and 16.9% included fried foods (ICC = 0.08). Another 5.6% of meals contained sugary extras (ICC = 0.05). Again, substantial variation between meals was found for all food groups, as indicated by the ICC: 5-18% of variance was due to differences between participants and 82-95% of variance was due to differences between meals.

### *4.4.2. Relationships between perceived meal colour variety and food intake*

To test the accuracy of colour perception, Cohen’s kappa (Cohen, 1960) was computed for all six colours. Agreement for the colours red and green was substantial ($\kappa_{red}$ = .73, $\kappa_{green}$ = .76), and agreement for the other colours was moderate ($\kappa_{yellow/orange}$ = .45, $\kappa_{blue}$ = .37, $\kappa_{white}$ = .36, $\kappa_{other}$ = .31).

Separate multilevel models were computed for all food groups. A significant positive relationship with perceived meal colour variety emerged for vegetables. When comparing the random slopes (*b* = 0.003, *t*(72.79) = 7.728, *p* < .001, *quasi-R*² = .11)

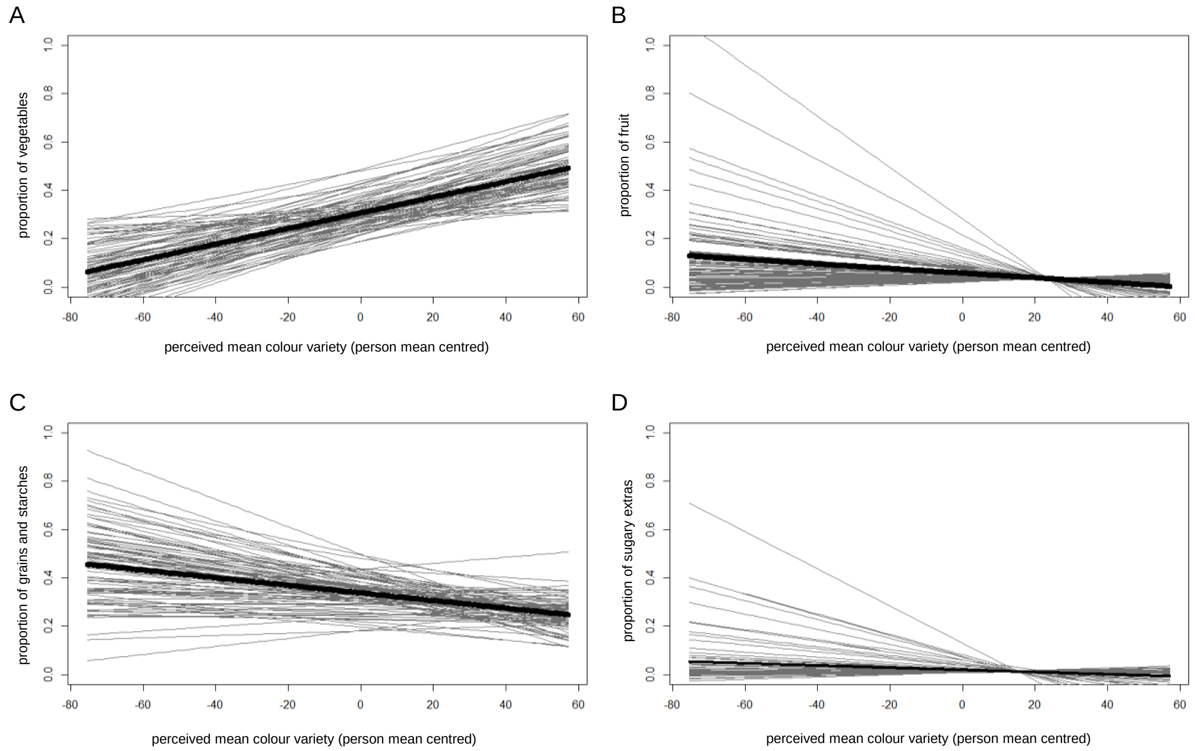


**Figure 4.2.** *Associations between perceived meal colour variety and proportion of food groups consumed in the meal. Each thin grey line represents a regression line for one participant. The thick black line represents the overall regression line.*

and random intercept models ($b$ = 0.003, $t$(1132.30) = 9.55, $p$ < .001, *quasi*-$R^2$ = .07), the random slopes model assuming differences in the individual slopes was preferred ($\chi^2$($df$ = 2) = 9.82, $p$ = .007). Thus, the relationship between meal colour variety and proportion of vegetables consumed differed between participants (see Figure 4.2A). Ninety-four percent of slopes were positive, indicating that increased perceived meal colour variety was associated with a higher proportion of vegetables consumed, while 6% of slopes were negative, indicating that increased perceived meal colour variety was associated with a lower proportion of vegetables consumed.

A significant negative relationship emerged between perceived meal colour variety and the proportion of fruit consumed. When comparing the random slopes ($b$ = -.001, $t$(81.17) = -2.81, $p$ = .006, *quasi*-$R^2$ = .10) and random intercept models ($b$ = -

.001, $t(1130.00) = -3.96$, $p < .001$, *quasi*-$R^2 = .01$), the random slopes model was preferred ($\chi^2(df = 2) = 66.36$, $p < .001$), indicating that the relationship between perceived meal colour variety and the proportion of fruit consumed differed between participants. Sixty-seven percent of slopes were negative, indicating that a greater perceived meal colour variety was associated with a lower proportion of fruit consumed, while 33% of slopes were positive, indicating that a greater perceived meal colour variety was associated with a higher proportion of fruit consumed (see Figure 4.2B).

A significant negative relationship also emerged between perceived meal colour variety and the proportion of grains and starches consumed. When comparing the random slopes ($b = -.002$, $t(65.54) = -3.87$, $p < .001$, *quasi*-$R^2 = .07$) and random intercept models ($b = -.002$, $t(1130.30) = -5.18$, $p < .001$, *quasi*-$R^2 = .02$), the random slopes model was preferred ($\chi^2(df = 2) = 15.03$, $p < .001$), indicating differences between participants in the relationship between perceived meal colour variety and the proportion of fruit consumed. Seventy-six percent of slopes were negative, indicating that a greater perceived meal colour variety was associated with a lower proportion of grains and starches consumed, while 34% of slopes were positive, indicating that a greater perceived meal colour variety was associated with a higher proportion of grains and starches consumed (see Figure 4.2C).

Lastly, a significant negative relationship emerged between perceived meal colour variety and the proportion of sugary extras consumed. When comparing the random slopes ($b = -.002$, $t(1130.30) = -2.05$, $p = .044$, *quasi*-$R^2 = .11$) and random intercept models ($b = -.000$, $t(1126.20) = -2.93$, $p = .003$, , *quasi*-$R^2 = .01$), the random slopes model was preferred ($\chi^2(df = 2) = 72.37$, $p < .001$), indicating that the relationship between perceived meal colour variety and the proportion of fruit consumed differed between participants. Sixty-two percent of slopes were negative, indicating that a greater perceived meal colour variety was associated with a lower proportion of sugary extras consumed, while 38% of slopes were positive, indicating that a greater perceived meal colour variety was associated with a higher proportion of sugary extras consumed (see Figure 4.2D).

For fried foods, a significant negative relationship emerged for perceived meal colour variety for the random slopes model ($b$ = -.000, $t$(141.01) = -1.98, $p$ = .049, *quasi*-$R^2$ = .01). However, the deviance test ($\chi^2$($df$ = 2) = 4.21, $p$ = .122) comparing the random slopes to the random intercept model preferred the random intercept model ($b$ = -.000, $t$(1123.70) = -1.76, $p$ = .079, *quasi*-$R^2$ = .00), which did not reach significance.

For the categories protein and dairy no significant relationships with perceived meal colour variety were found (see Table 4.1 for a summary of all models).

### *4.4.3. Impact of the prompt to eat a colourful lunch on food consumption*

#### *4.4.3.1. Differences between baseline and intervention weeks*

A significant difference between the baseline and intervention weeks emerged for vegetables consumed. When comparing the random slopes ($b$ = 0.04, $t$(548.80) = 2.16, $p$ = .031, *quasi*-$R^2$ = .02) and random intercept models ($b$ = 0.04, $t$(768.20) = 2.20, $p$ = .028, *quasi*-$R^2$ = .02), the random intercept model assuming no differences in the individual slopes was preferred ($\chi^2$($df$ = 2) = 0.69, $p$ = .709). Thus, the difference between baseline and intervention weeks regarding the proportion of vegetables consumed was comparable between participants. Results indicate that participants consumed a greater proportion of vegetables during the intervention week compared to the baseline week.

**Table 4.1**

Results of the multilevel models to analyse the relationship between perceived meal colour variety and the consumption of seven food categories.

| Predictor | Random slopes model (fixed effects) | | | | | Random intercept model (fixed effects) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *b* | *SE* | *t* | *df* | *p* | *b* | *SE* | *t* | *df* | *p* |
| *Model 1: proportion of vegetables* | | | | | | | | | | |
| Intercept | 0.307 | 0.011 | 27.67 | 80.33 | < .001 | 0.307 | 0.011 | 27.66 | 80.40 | < .001 |
| Perceived meal colour variety | 0.003 | 0.000 | 7.73 | 72.79 | < .001 | 0.003 | 0.000 | 9.55 | 1132.30 | < .001 |
| *Model 2: proportion of fruit* | | | | | | | | | | |
| Intercept | 0.057 | 0.007 | 7.86 | 79.83 | < .001 | 0.057 | 0.007 | 8.02 | 77.50 | < .001 |
| Perceived meal colour variety | -0.001 | 0.000 | -2.81 | 81.17 | 0.006 | -.001 | .000 | -3.96 | 1130.00 | < .001 |
| *Model 3: proportion of grains and starches* | | | | | | | | | | |
| Intercept | 0.338 | 0.011 | 29.96 | 78.71 | < .001 | 0.338 | 0.001 | 29.98 | 78.80 | < .001 |
| Perceived meal colour variety | -0.002 | 0.000 | -3.87 | 65.54 | < .001 | -.001 | 0.000 | -5.18 | 1130.30 | < .001 |
| *Model 4: proportion of sugary extras* | | | | | | | | | | |
| Intercept | 0.019 | 0.004 | 4.83 | 69.97 | < .001 | 0.018 | 0.004 | 4.91 | 72.80 | < .001 |
| Perceived meal colour variety | -0.001 | 0.000 | -2.05 | 74.45 | < .001 | -0.000 | 0.000 | -2.93 | 1126.20 | .003 |
| *Model 5: proportion of protein* | | | | | | | | | | |
| Intercept | 0.110 | 0.010 | 10.80 | 81.00 | < .001 | 0.110 | 0.010 | 10.79 | 81.00 | < .001 |
| Perceived meal colour variety | 0.000 | 0.000 | 1.09 | 68.74 | .278 | 0.000 | 0.000 | 1.16 | 1131.90 | .248 |
| *Model 6: proportion of dairy* | | | | | | | | | | |
| Intercept | 0.115 | 0.009 | 13.45 | 80.30 | < .001 | 0.115 | 0.009 | 13.45 | 80.20 | < .001 |
| Perceived meal colour variety | -0.000 | 0.000 | -0.87 | 556.20 | .387 | -0.000 | 0.000 | -0.83 | 1131.70 | .409 |
| *Model 7: proportion of fried foods* | | | | | | | | | | |
| Intercept | 0.054 | 0.006 | 8.93 | 73.19 | < .001 | 0.054 | 0.006 | 9.00 | 71.70 | < .001 |
| Perceived meal colour variety | -0.000 | 0.000 | -1.98 | 141.01 | .049 | -0.000 | 0.000 | -1.76 | 1123.70 | .079 |

A significant difference between baseline and intervention weeks emerged for dairy consumed. When comparing the random slopes ($b$ = -0.04, $t$(81.50) = -3.16, $p$ = .002, *quasi*-$R^2$ = .02) and random intercept models ($b$ = -0.04, $t$(766.80) = -3.17, $p$ = .002, *quasi*-$R^2$ = .02), the random intercept model assuming no differences in the individual slopes was preferred ($\chi^2$($df$ = 2) = 0.79, $p$ = .675). Thus, the difference between baseline and intervention weeks regarding the proportion of vegetables consumed was comparable between participants. Results indicate that participants consumed a smaller proportion of dairy products during the intervention week compared to the baseline week.

For all other food categories, no significant differences emerged between baseline and intervention week (see Table 4.2).

*4.4.3.2. Differences between baseline and follow-up week*

Between baseline and follow-up week, no significant differences were found ($b$s ≤ |0.02|, $t$s(≥ 74.40) ≤ |1.31|, $p$s ≥ .190), indicating that food consumption during the follow-up week approached the baseline level when prompts were no longer sent.

### ***4.4.4. Evaluation of the prompt***

Participants indicated that eating colourfully is something that is rather easy for them to do ($M$ = 57.96, $SD$ = 24.87). They also indicated that eating colourfully is pleasant ($M$ = 70.79, $SD$ = 27.95). Self-rated compliance was satisfactory ($M$ = 60.36, $SD$ = 26.88).

### ***4.4.5. Control analysis: Change in BMI***

In a dependent samples t-test, no difference between BMI before and after the study emerged ($t$(78) = 1.44, $p$ = .154).

**Table 4.2**

Results of the multilevel models to compare differences in food consumption between baseline and intervention weeks.

| Predictor | Random slopes model (fixed effects) | | | | | Random intercept model (fixed effects) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *b* | *SE* | *t* | *df* | *p* | *b* | *SE* | *t* | *df* | *p* |
| *Model 1: proportion of vegetables* | | | | | | | | | | |
| Intercept | 0.287 | 0.015 | 19.34 | 89.80 | < .001 | 0.287 | 0.016 | 18.55 | 150.40 | < .001 |
| Time[1] | 0.035 | 0.017 | 2.16 | 548.80 | .031 | 0.037 | 0.017 | 2.20 | 768.20 | .028 |
| *Model 2: proportion of fruit* | | | | | | | | | | |
| Intercept | 0.056 | 0.008 | 6.63 | 154.57 | < .001 | 0.056 | 0.009 | 5.97 | 174.00 | < .001 |
| Time[1] | 0.003 | 0.012 | 0.27 | 152.02 | .791 | 0.003 | 0.011 | 0.23 | 769.60 | .821 |
| *Model 3: proportion of grains and starches* | | | | | | | | | | |
| Intercept | 0.339 | 0.014 | 24.56 | 97.60 | < .001 | 0.339 | 0.015 | 22.61 | 141.70 | < .001 |
| Time[1] | 0.005 | 0.016 | 0.32 | 333.90 | .747 | 0.006 | 0.016 | 0.35 | 766.20 | .726 |
| *Model 4: proportion of sugary extras* | | | | | | | | | | |
| Intercept | 0.018 | 0.005 | 3.56 | 63.44 | < .001 | 0.018 | 0.005 | 3.88 | 246.00 | < .001 |
| Time[1] | -0.001 | 0.007 | -0.22 | 113.23 | .830 | -0.001 | 0.006 | -0.19 | 780.10 | .849 |
| *Model 5: proportion of protein* | | | | | | | | | | |
| Intercept | 0.109 | 0.012 | 9.02 | 81.70 | < .001 | 0.109 | 0.012 | 8.94 | 113.00 | < .001 |
| Time[1] | 0.001 | 0.012 | 0.09 | 746.70 | .927 | 0.001 | 0.012 | 0.10 | 765.00 | .923 |
| *Model 6: proportion of dairy* | | | | | | | | | | |
| Intercept | 0.132 | 0.011 | 12.25 | 79.87 | < .001 | 0.132 | 0.010 | 12.08 | 152.90 | < .001 |
| Time[1] | -0.037 | 0.012 | -3.16 | 81.50 | .002 | -0.037 | 0.012 | -3.17 | 766.80 | .002 |
| *Model 7: proportion of fried foods* | | | | | | | | | | |
| Intercept | 0.068 | 0.008 | 7.07 | 74.34 | < .001 | 0.057 | 0.008 | 7.23 | 75.21 | < .001 |
| Time[1] | -0.009 | 0.010 | -0.92 | 75.21 | .361 | -0.009 | 0.009 | -0.91 | 766.10 | .365 |

Note: Time: 0 = baseline week, 1 = intervention week

### 4.5. Discussion

In the present research, increased perceived meal colour variety was associated with consuming a larger proportion of vegetables and a smaller proportion of sugary extras, replicating previous findings (König & Renner, 2018). Furthermore, an increased perceived meal colour variety was associated with a smaller proportion of fruit and grains and starches consumed. Additionally, the present study tested the colourful equals healthy association as an intervention strategy to boost vegetable consumption in an Ecological Momentary Intervention. When prompted to eat a colourful lunch meal, participants consumed a larger proportion of vegetables. The differences in vegetable consumption between baseline and intervention weeks were comparable between participants, suggesting that prompting to eat a colourful lunch might be a generic approach to facilitating healthy eating. Moreover, the prompt might be appealing to many people regardless of their intentions to eat more healthily because it does not refer to dietary healthiness: Eating colourfully might also be appealing for people who aim to enjoy their food more or increase their general well-being.

At the same time, when prompted to consume colourful meals, participants consumed a smaller proportion of dairy, suggesting a compensation of increased energy intake from vegetables by reduced energy intake from dairy. Thus, eating colourful meals might not lead to an increased consumption of energy as previously suggested (Piqueras-Fiszman & Spence, 2014). Furthermore, compensation was specific: The consumption of dairy itself was not related to perceived meal colour variety, but when participants are prompted to increase colour variety in their meals, dairy might be substituted because of its mainly white colour. Consumption of other food groups was unaffected by the prompt. For fruit and sweet extras, this might be because these two categories are rarely consumed for lunch or less available in lunch settings such as cafeterias. Grains and starches on the other hand, despite similar colouring, are usually readily available is most settings and may also be considered a satiating meal component not suitable for substitution.

The observed differences in consumption between the baseline and intervention weeks are small yet meaningful, considering that the present study tested the effectiveness of prompting as one single behaviour change technique (BCT) compared to only self-monitoring of food intake in baseline and follow-up weeks. Most online and web-based dietary interventions combine several BCTs (e.g. Godino et al. (2016); see also Pagoto et al. (2013)). For example, a prompt to 'eat your colours' (p. 34) was used among other prompts in a text-messaging intervention and additionally paired with health information (Brookie, Mainvil, Carr, Vissers, & Conner, 2017). Similarly, challenges to eat vegetables of a certain colour were used in a gamified app to facilitate vegetable consumption, again amongst other challenges and BCTs (Mummah, King, et al., 2016; Mummah et al., 2017). To further increase the efficacy of the presented intervention, future studies should combine the prompt with other BCTs such as goal setting or feedback (Abraham & Michie, 2008; Michie et al., 2013).

After the intervention week, vegetable and dairy consumption returned to baseline levels as one week is not long enough to form a new habit. The literature suggests that forming a new habit takes at least 14 (Gardner, Sheals, Wardle, & McGowan, 2014) and up to 254 days (Lally, Van Jaarsveld, Potts, & Wardle, 2010), with longer intervention periods potentially further increasing automaticity (Gardner et al., 2014; Wood & Neal, 2016). While the present study provides first evidence that prompting people to eat colourful meals induces behaviour change, future studies need to test whether the immediate change in vegetable consumption translates into long-term behaviour change.

The present study showed that apart from increasing dietary healthiness, the prompt to eat a colourful meal also was feasible in an Ecological Momentary Intervention. Participants indicated that eating colourful meals was both easy and pleasant, and self-rated compliance to the prompt was satisfactory. Previous qualitative studies support this result, as colourful meals have been shown to stimulate the consumer’s senses and enhance meal satisfaction (Andersen & Hyldig, 2015; Murphy, Holmes, & Brooks, 2017). Colourful dishes might be preferred because intense colours are a cue for nutritional value and quality (Foroni et al., 2016; Francis, 1995; Valentin et al., 2016). At the same time, increasing a meal’s colour variety is an adaptive goal that people feel they can reach, again inducing positive emotions (Carver & Scheier, 1990). Thus, eating colourfully is a positive approach that does not evoke frustration by being complex and has the potential to facilitate long-term behaviour change (Julia et al., 2014; Mata, Todd, & Lippke, 2010).

Furthermore, eating colourful meals is an intuitive strategy compared to other strategies often applied in mobile apps, such as calorie counting (Davis et al., 2016). While previous research has shown that people struggle to correctly estimate a meal’s calorie content (e.g. Chandon and Wansink (2007)) and therefore need training (e.g. Liu, Bettman, Uhalde, and Ubel (2015)), choosing colourful meals relies on simple and natural cues (Schulte-Mecklenbeck et al., 2013) and does not require knowledge or training. For example, preparing colourful meals was identified as an intuitive strategy for caregivers to provide children with nutritious food (Moore, Tapper, & Murphy, 2010).

#### *4.5.1. Limitations and avenues for future research*

While the present study presented a promising strategy to boost healthy meal choices, some limitations need to be acknowledged. The present study focused on lunch meals reported by western students. Although this strategy could be effective for dinner as the same items usually comprise both meals, breakfasts and snacks typically incorporate colourful but unhealthy items. Thus, despite being especially rich in colours, breakfast cereals and snacks foods, particularly candy, often contradict the colourful equals healthy association.

Furthermore, the direction of effects differed between participants for associations between perceived meal colour variety and sweet extras, fruit, and grains and starches: A negative relationship was found for two thirds of the sample and a positive relationship was found for the remaining participants. These results suggest influences by moderators that were not assessed in the present study, such as food preferences or culture (e.g. Velasco et al. (2016); Woods et al. (2016)). Therefore, testing the generalisability of the findings to other meal types or other populations as well as investigating potential moderators is open to future research.

#### *4.5.2. Conclusion*

The present study tested the colourful equals healthy association in an Ecological Momentary Intervention. As boosting vegetable consumption by meal colour variety was shown to be easy, positive and effective, the present study provides a promising foundation for future (mobile) health promotion programs.

#### *4.5.3. Implications*

**Practice:** Simple, intuitive and adaptive intervention strategies can be used to facilitate healthy eating in smartphone-based interventions.

**Policy:** Policymakers who aim to facilitate healthy eating may integrate simple, intuitive and adaptive boosting interventions in health promotion programs and further promote their use.

**Research:** Inventing simple, intuitive and adaptive boosting intervention strategies to target health behaviours is a promising avenue for future research.

**Author statements**

The findings reported in this manuscript are not published or submitted elsewhere.

The findings have been previously reported at the 13th Congress of Health Psychology, in Siegen, Germany (Abstract: König, L. M., & Renner, B. (2017). „Eat a colourful lunch today." Increasing vegetable consumption by increasing meal colour variety in an Ecological Momentary Intervention. In A. Schorr (Ed.), Health Psychology 2017: Kurzfassungen, 77-78. Lengerich: Pabst Science.).

The authors have full control of all primary data and agree to allow the journal to review the data if requested.

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**Conflict of interest**

None declared.

**Human and animal rights and informed consent**

Written informed consent was obtained from all participants prior to participation. The study was conducted in accordance with the Declaration of Helsinki and the study procedure was approved by the University of Konstanz ethics committee.

This article does not contain any studies with animals performed by any of the authors.

# 5. General Discussion

Many traditional eating behaviour interventions are rooted in the view of food as health. They emphasize the relationship between eating and health-related outcomes and focus on communicating complex and restrictive rules to facilitate healthy eating. The present dissertation aimed to present an alternative approach that induces change by focusing on the healthy – instead of guilty – pleasures that can arise from eating, thereby representing a view of food as well-being (Block et al., 2011). It further demonstrated how this view of food as well-being could be integrated with simple intervention strategies consisting of simplified behaviours and simplified triggers (Fogg, 2009a, 2009b). The main findings of this dissertation are summarised in Table 5.1.

In a first step, the underlying motivations for nutrition (and fitness) app use were explored using a behaviour stage model based on the PAPM. Only a small proportion of the sample used nutrition apps, and these users showed rather high levels of preference for deliberation when making eating-related decisions, which matches the BCTs used in available apps. Especially unengaged non-users, however, showed rather high levels of preference for intuition, indicating that alternative intervention approaches might be needed to target new nutrition app users.

In a second step, this dissertation presented an example for an alternative approach to eating behaviour change by introducing the ‘colourful equals healthy’ association. Firstly, perceived meal colour variety was established as a potential trigger for healthy food choices. Secondly, perceived meal colour variety was shown to be related to an increased consumption of vegetables, thus increasing dietary healthiness. At the same time, eating colourful meals was also perceived to be enjoyable, underlining the potential of the approach to facilitate food choices that increase both health and well-being.

**Table 5.1.**

Aims, results and conclusions of the present dissertation.

| Aim | | Results | Conclusions |
|---|---|---|---|
| 1 | To examine the motivational structure of adopting nutrition (and fitness) apps.<br><br>To identify potential barriers of nutrition app adoption to inform the development of mobile interventions that target new user groups. | A behaviour stage model with five stages revealed motivational differences between nutrition (and fitness) app users and four subgroups of non-users:<br><br>1) Stage 1: 'unengaged'<br>2) Stage 2: 'decided to act'<br>3) Stage 3: 'decided not to act'<br>4) Stage 4: 'acting'<br>5) Stage 5: 'disengaged'<br><br>Stages differed in sociodemographic characteristics and Preference for Intuition and Deliberation in Eating Decision-making (E-PID). Specifically, 'acting' participants (Stage 4) showed a higher preference for deliberation than for intuition, while the opposite pattern emerged for 'unengaged' participants (Stage 1). | The behaviour stage model for the adoption process of nutrition and fitness apps enables to study characteristics of the stages as well as potential stage transitions and transition barriers.<br><br>E-PID emerged as a potential transition barrier for nutrition app adoption. Existing nutrition apps might target users who have a high preference for deliberation as they focus on deliberative behaviour change techniques such as planning and providing instruction. New user groups might be targeted by including behaviour change techniques that address a more intuitive decision-making style, such as teaching to use prompts or cues. |
| 2A | To identify and test a simple intervention strategy for facilitating healthy food choices:<br><br>To establish a 'colourful equals healthy' association. | Increased perceived meal colour variety was associated with a healthier eating pattern, characterised by an increased proportion of vegetables consumed and a decreased proportion of sugary extras consumed. | Meal colour variety might be used as a natural cue for healthy food choices in future health behaviour interventions. |
| 2B | To test whether the 'colourful equals healthy' association promotes healthy and enjoyable food choices in daily life. | When prompted to eat a colourful lunch, participants increased their proportional vegetable intake while decreasing their proportional dairy intake. Eating colourful meals was perceived to be easy to put into practice and to be enjoyable. | Prompting people to eat colourful meals is an effective strategy to facilitate healthy and enjoyable food choices. |

## 5.1. Motivational differences between mHealth app users and non-users

The first aim of the present dissertation was to shed light on the motivational structure of nutrition and fitness app adoption and to identify potential barriers to nutrition and fitness app use. Chapter 2 underlines the potential of promoting apps for health behaviour change as more than 80% of the studied sample owned a mobile device that allowed the use of apps. Although a large proportion of the sample had the technical means to use a nutrition or fitness app, use of nutrition apps was found to be particularly low as Chapter 2 revealed that only 8% of the sample currently used a nutrition app. Thus, available mHealth apps might fall short of reaching their full effective potential and new user groups should be targeted to promote the use of mHealth apps in general and nutrition apps in particular.

On that account, it is important to better understand who is using, and especially who is not (yet) using, nutrition apps so that the services can be tailored to potential users' needs and preferences. To shed light on the motivational underpinnings of nutrition (and fitness) app use, a behaviour stage model for the adoption process of nutrition and fitness apps was developed based on the PAPM (Weinstein, 1988; Weinstein & Sandman, 1992; Weinstein et al., 2013). This model made it possible to study differences between nutrition app users and non-users in greater detail. As Chapter 2 showed, 92% of mobile device owners were currently not using a nutrition app and were thus classified as 'non-users'. In previous research, mHealth app non-users were often studied as one homogeneous group, e.g. when comparing mHealth app users and non-users in sociodemographic characteristics such as age and gender (e.g. Bender et al. (2014); Bhuyan et al. (2016); Elavsky, Smahel, and Machackova (2017)). However, the behaviour stage model used in Chapter 2 revealed that non-users are a rather heterogeneous group. Specifically, non-users differ considerably in their motivation to adopt nutrition (and fitness) apps, and thus show great variation in active engagement as well as in previous experience. These differences between non-users might need to be taken into account when targeting non-users as potential future users of mHealth apps.

## 5.2. Need for alternative approaches to eating behaviour change

Findings from Chapter 2 also demonstrated that 52% of participants had not yet thought about using a nutrition app, and so were classified as ‘unengaged’ non-users (Stage 1). For nutrition apps, Stage 1 therefore represented the largest (non-)user group identified by the behaviour stage model. Different potential reasons for being ‘unengaged’ by nutrition apps can be inferred from the existing literature. For instance, some people might be ‘unengaged’ because they do not know that these apps exist (Haithcox-Dennis et al., 2012). Others might not see a need to change their eating behaviour (e.g. Dennison et al. (2013); Krebs and Duncan (2015)). Interestingly, Chapter 2 suggests another potential explanation: There are people who know that nutrition apps exist and might also be generally interested in changing their eating behaviour, but the features used in available nutrition apps to induce behaviour change do not match their preferences and needs.

Specifically, Chapter 2 showed that the preferred decision-style when making eating-related decisions (E-PID; König et al. (in prep.); see also Betsch (2004, 2008)) might act as a transition barrier to using nutrition apps. ‘Acting’ participants (Stage 4) showed rather high levels of preference for deliberation when making eating-related decisions. For this group of users, available nutrition apps might be appealing because they often employ self-regulatory BCTs (e.g. Edwards et al. (2016); Pagoto et al. (2013); Rohde et al. (2016)), and this focus might match their preferred decision-making style. On the other hand, especially people who were currently ‘unengaged’ by nutrition apps (Stage 1) showed a comparably low preference for deliberation, while simultaneously showing rather high levels of preference for intuition. This suggests that they might be unengaged because the self-regulatory techniques used in many such apps do not match their preferred decision-making style. Therefore, although self-regulatory eating behaviour interventions are common and shown to induce small to moderate changes in behaviour (e.g. Adriaanse, Vinkers, De Ridder, Hox, and De Wit (2011); Michie, Abraham, Whittington, McAteer, and Gupta (2009)), they might not be a ‘one size fits all’ solution to eating behaviour change. These findings highlight the need to seek alternative avenues, and to include them in nutrition apps to target new user groups and ultimately increase the number of nutrition app users.

## 5.3. Introducing an alternative approach

The present dissertation aimed to complement established traditional behaviour interventions that focus on health and self-regulation by introducing one potential alternative approach to eating behaviour change. Using this alternative approach, the present dissertation aimed to shift the focus of traditional eating behaviour interventions on viewing food as health to viewing food as an important contributor to well-being (Block et al., 2011). It further combined this view of food as well-being with simple intervention strategies that consist of simplified triggers and simplified behaviours (Fogg, 2009a, 2009b), in order to reduce the complexity of behaviour change and potentially increase adherence (c.f. Mata et al. (2010)). To demonstrate the benefits of this alternative approach using an example, the second aim of the present dissertation was to establish and test a ‘colourful equals healthy’ association (Chapters 3 and 4). The ‘colourful equals healthy’ association is rooted in the view of food as well-being, as it focuses on meal colour variety as a visual cue for food choice, instead of referring to health-related parameters such as energy content or macronutrients. By prompting participants to choose a colourful lunch meal, vegetable consumption was increased in an intervention week compared to a control week in which no prompt was sent. The ‘colourful equals healthy’ association thus succeeded in facilitating healthy lunch meal choices, demonstrating the success of a simple intervention strategy that consists of: (1) meal colour variety as a simplified visual cue, and (2) an increased vegetable consumption for lunch as a simplified behaviour.

Both traditional approaches to eating behaviour change and the alternative approach presented in this dissertation aim to improve individual and societal welfare. They differ, however, (1) in their understanding of the main purpose of eating, (2) the reference norms and indicators inferred from the goal, and (3) in the techniques they employ to facilitate behaviour change. For a summary, see Table 5.2. In the following sections, the differences will be outlined in greater detail.

#### *5.3.1. Food as well-being*

Traditional approaches to eating behaviour change and the alternative approach presented in this dissertation differ in their understanding of the primary goal of eating. Traditional eating behaviour interventions are rooted in a view of food as health, i.e. the primary purpose of food and eating are preserving or increasing physiological health. Consequently, they aim to communicate scientific dietary guidelines, such as the guidelines published by the DGE that are based on the relationship between diet and health. Their success is evaluated by assessing their impact on healthy food choices or diet-related health improvements, such as a reduction in weight or BMI (for reviews, see e.g. Bacigalupo et al. (2013); de Ridder et al. (2017); Hardeman et al. (2002); Lara et al. (2014)). For example, in a recent systematic review on the efficacy of mHealth apps targeting lifestyle behaviours including diet, 11 out of 27 studies reported changes in weight status in addition to evaluating changes in diet (Schoeppe et al., 2016). Thus, traditional eating behaviour interventions have a strong focus on health and weight control.

Although health generally is an important eating motive (e.g. Januszewska, Pieniak, and Verbeke (2011); Renner, Sproesser, Strohbach, et al. (2012); Steptoe et al. (1995)), it is important to note that the relative importance of health compared to other motives likely differ between people. For instance, a cross-cultural comparison by Rozin (2005) suggests that people differ in the meaning that food and eating have in their lives. These different meanings and reasons why to eat are also reflected in a great variety of eating motives that have been identified in the literature (e.g. Jackson et al. (2003); Renner, Sproesser, Strohbach, et al. (2012); Steptoe et al. (1995); Stok et al. (2017)). For some people, food is primarily a source of nutrients and health, thus interventions that build up on the view of food as a gateway to health might fit to their attitudes and preferences. There are others, however, who focus on alternative aspects of eating, such as sensory pleasure or well-being. Therefore, purely health-motivated interventions may not always be the most effective motivator to induce change in all people.

**Table 5.2**

Summary of differences between traditional eating behaviour interventions and the alternative approach presented in this dissertation.

| | **Traditional eating behaviour interventions** | **Alternative approach presented in this dissertation** |
|---|---|---|
| *Primary goal of eating* | Health | Well-being |
| *References / indicators* | Normative, criterial | Individualistic, consumer-oriented |
| *Strategies for behaviour change* | Constraining and limiting | Supporting and encouraging |

This concept is not yet represented in many lifestyle interventions, and so potential outcomes that go beyond behavioural and physiological changes, such as changes in well-being, are rarely integrated (Sturgiss, Jay, Campbell-Scherer, & van Weel, 2017). For instance, in the same systematic review, impact on quality of life was only reported in two studies (Schoeppe et al., 2016). To better reflect the variety of eating-related goals, the approach presented in this dissertation shifts the focus towards a view of food as well-being. The view of food as well-being acknowledges that people may have different needs, goals and preferences related to their eating behaviour that are not necessarily, but can be, health-related (Block et al., 2011; Bublitz et al., 2011). In contrast to focusing solely on physiological health, the view of food as well-being expands potential goals of eating behaviour interventions and enables the flexibility to address individual goals, preferences and needs.

#### *5.3.2. Consumer-oriented recommendations*

In addition to their different views on food and eating, the two approaches also differ in the indicators and reference norms used to facilitate changes in eating behaviour. Based on the view of food as health, traditional eating behaviour interventions often communicate complex and normative dietary guidelines, e.g. the guidelines published by the DGE, to encourage people to adopt a healthier diet. Often, calorie or macronutrient content serve as objective indicators for healthy food choices, and feedback is based on criterial reference norms (Brunstein & Heckhausen, 2008; Heckhausen, 1974). For instance, tools like calorie counters are implemented in many commercial apps such as Lifesum[2], Lose it![3] or noom Coach[4], and also in apps

[2] https://www.lifesum.com/
[3] https://www.loseit.com/
[4] https://www.noom.com

developed as part of research projects (e.g. Carter, Burley, Nykjaer, and Cade (2013); Lee, Chae, Kim, Ho, and Choi (2010)).

Caloric information, however, has been shown to be difficult for lay people to understand (e.g. Block et al. (2013); Campos et al. (2011); Chandon and Wansink (2007); Mötteli, Barbey, Keller, Bucher, and Siegrist (2017); Rothman et al. (2006)), especially for those with lower health literacy (Berkman, Sheridan, Donahue, Halpern, & Crotty, 2011). Simpler and more effective means to convey health-related information have been investigated, e.g. using 'traffic-light' nutrition labelling instead of providing solely numeric information (e.g. Roberto et al. (2012); Sacks, Rayner, and Swinburn (2009); Sonnenberg et al. (2013)). Despite using colours instead of numerical information to facilitate understanding (Grunert, Bolton, & Raats, 2012), traffic-light nutrition labelling still focuses on normative health-related information, uses criterial reference norms, and implies health as the primary goal of eating.

Alternatively, the food as well-being perspective allows researchers to explore a greater variety of indicators for food choice, as well as their potential to induce dietary changes that facilitate health and well-being. For instance, it allows for the investigation of emotions or perceptions as potential subjective cues for food choice that might be more easily perceived and processed than numerical information. Following this notion, the 'colourful equals healthy' association presented in Chapters 3 and 4 focused on meal colour variety as a visual cue for healthy food choices. Although no objective information about the meals' healthiness was provided, participants consumed a larger proportion of vegetables when prompted to eat a colourful meal. Moreover, participants indicated that eating more colourful meals was rather easy to do. These findings demonstrate that visual cues like colour can be suitable triggers to facilitate healthy eating, and that providing health-related information might not always be necessary to induce change.

Providing objective indicators or criterial reference norms for food choice is not always possible. When designing eating behaviour interventions based on the food as well-being perspective, one might need to rely on individual reference norms, i.e. intra-individual comparison (Brunstein & Heckhausen, 2008; Heckhausen, 1974). Again, the 'colourful equals healthy' association tested in this dissertation underlines the efficacy of this approach. While participants varied in their mean perceived meal colour variety, they comparably increased vegetable consumption when they were prompted to eat a colourful lunch. Thus, these results highlight the fact that also subjective indicators and individual reference norms can be suited to induce changes in eating behaviour.

### *5.3.3. Enabling healthy and enjoyable food choices*

Finally, the approach presented in this dissertation differs from traditional eating behaviour interventions in the techniques promoted to change behaviour. Based on a view of food as health, traditional approaches to eating behaviour change often aim to facilitate healthy eating by pointing out deficits in people's behaviour that need to be corrected. Therefore, traditional approaches often promote a constraining and limiting view on eating. For example, the actual eating behaviour is compared to an optimal state, e.g. dietary guidelines, and based on the differences between actual and desired behaviour, goals are set (e.g. Kerr et al. (2016)). The goal might be to increase a behaviour, e.g. to eat more fruit or vegetables, but it can also be to decrease or cease a behaviour, e.g. to eat less or no sweets. This means that the intervention limits previously available food choice options (Freeland-Graves & Nitzke, 2013). Ceasing a familiar behaviour might be demanding and frustrating for the consumer (Julia et al., 2014), thus lowering motivation to put further effort into adhering to the regime (e.g. Wrosch et al. (2003)).

Alternatively, the approach presented in this dissertation does not limit choice options, but promotes a more supporting and encouraging view on eating. The ‘colourful equals healthy’ association, for instance, does not systematically exclude certain types of food, but allows the individual to choose out of a selection of foods that they like. It aims to facilitate healthy and enjoyable food choices by providing a simple intervention strategy. Simple intervention strategies increase the likelihood for action because they are more easily integrated into daily routines and, as also suggested in Chapter 4, therefore might be easier to put into practice (Fogg, 2009a, 2009b, 2011). When prompted to eat a colourful lunch, participants built up on a behaviour that they were already familiar with, i.e. eating vegetables for lunch, and increased the intensity of this behaviour by consuming a greater amount of vegetables. These results suggest that restricting food intake and limiting choice options are not necessary to induce eating behaviour change. Alternatively, eating behaviour interventions could focus on strengthening beneficial behaviours by supporting competences that people already have.

Preserving choice alternatives, avoiding coercive and authoritarian language, and allowing people to follow their own interests are means to support people’s feeling of autonomy (Silva, Marques, & Teixeira, 2014). Autonomy is a core construct of the Self-Determination Theory (SDT; Deci and Ryan (2000, 2008)), according to which it is an important and innate human need. A feeling of autonomy is characterised by the perception that a behaviour is self-authored, meaningful and interesting (Deci & Ryan, 2000; Silva et al., 2014). If fulfilled, it leads to increased psychological well-being. Moreover, increased autonomous motivation has been linked to more favourable health outcomes, such as a healthier diet and successful weight maintenance (Ng et al., 2012; Verstuyf, Patrick, Vansteenkiste, & Teixeira, 2012). Thus, the success of eating behaviour interventions may depend on preserving or even increasing people's feeling of autonomy by both acknowledging individual differences in the importance of eating motives and by limiting choice options as little as possible.

To conclude, traditional eating behaviour interventions and the alternative approach presented in this dissertation complement each other because they are rooted in different views on food and eating, provide different indicators and references and employ different techniques for behaviour change. By offering different routes to eating behaviour change, people might better able to select the interventions that best fit their preferences and needs, which in turn might increase the success of eating behaviour interventions (Hardcastle & Hagger, 2016).

### 5.4. Boosting healthy and enjoyable food choices

One could argue that there are conceptual overlaps between the alternative approach to eating behaviour change presented in this dissertation and the boosting approach that was recently introduced by Grüne-Yanoff and Hertwig (2016) (see also Hertwig (2017); Hertwig and Grüne-Yanoff (2017)). Boosting interventions are defined as 'interventions that target competences rather than behaviour' (Hertwig & Grüne-Yanoff, 2017, p. 5) by addressing 'the individual's skills, knowledge, the available set of decision tools, or the environment in which the decisions are made' (Grüne-Yanoff & Hertwig, 2016, p. 152).

The boosting approach and the approach presented in this dissertation share three goals. First, both aim to make behaviour change simple, although they are informed by different frameworks. While the present dissertation was informed by the FBM, the boosting approach is rooted in the simple (or fast-and-frugal) heuristics framework. Heuristics are defined as ‘processes that ignore information and enable fast decisions’ (Gigerenzer, Hertwig and Pachur, 2011, p. xvii; see also Gigerenzer and Gaissmaier (2011)), e.g. by using a reduced number of cues. As many decision-making processes, e.g. food choice, medical decision-making (Scheibehenne et al. (2007); Wegwarth, Gaissmaier, and Gigerenzer (2009); see also Gigerenzer and Gaissmaier (2011)), can be modelled using simple heuristics, it is suggested that heuristics are natural decision-making strategies. Using heuristics for making decisions is beneficial as it reduces effort (Shah & Oppenheimer, 2008), therefore, employing heuristics in real life environments with limited available information and limited resources such as time can be adaptive (Gigerenzer & Todd, 1999). Similarly, Fogg (2009b) argues that simplifying a behaviour leads to increased likelihood of acting, because simpler behaviours require less resources and therefore are more easily integrated into daily routines.

Secondly, both approaches aim to identify simple intervention strategies (this dissertation) or *boosts* (boosting approach) that can be communicated to the public in order to strengthen existing competences or establish new ones. Both approaches also aim to provide the individual with procedural knowledge, or information about how to put a behaviour into practice (Anderson, 2015). Providing procedural knowledge might be important for the success of behaviour interventions. For instance, procedural knowledge about healthy eating was associated with an increased vegetable consumption (Dickson-Spillmann & Siegrist, 2011). Providing solely declarative knowledge, i.e. information about facts (Anderson, 2015), on the other hand, might not be related to healthier food choices (Bucher, van der Horst, & Siegrist, 2013). Furthermore, the competences that both approaches aim to establish can be generalised across situations. The ‘colourful equals healthy’ association, for example, can be used in different eating environments, such as at home, in restaurants or in cafeterias. Finally, it is suggested that once the competence is learnt, the effect on behaviour might persist even if the intervention source is removed, thereby creating sustainable behaviour change (Hertwig & Grüne-Yanoff, 2017).

Thirdly, the two approaches share the goal of preserving consumer autonomy and acknowledge the heterogeneity of consumer goals. In the boosting approach, autonomy is preserved by offering boosts for specific goals, e.g. healthy eating or increasing retirement savings, that people can choose to adopt or ignore (Grüne-Yanoff & Hertwig, 2016; Hertwig & Grüne-Yanoff, 2017). Specific to the context of eating, the food as well-being perspective is responsive to the fact that people might eat for a variety of reasons, such as health, but also pleasure, comfort or community. It further highlights that the normative model of eating to sustain health should not be imposed on people as this might lead to an impaired relationship with health, and aggravate societal health issues such as the obesity epidemic in the long term (Block et al., 2011).

In sum, both approaches aim to promote simple strategies that enable change by increasing the perceived ability to perform a behaviour while acknowledging heterogeneity of consumer goals. So far, however, Grüne-Yanoff and Hertwig (2016) only presented boosting from a theoretical perspective (see also Grüne-Yanoff and Hertwig (2016); Hertwig (2017)) and the concept warrants further empirical testing. Furthermore, their definitions focus on distinguishing boosting from nudging interventions, while only providing vague starting points for explaining how boosting interventions could be designed and implemented. The present dissertation extends this line of reasoning by providing a more detailed suggestion of how to design simple intervention strategies in the domain of health behaviours based on the FBM: Identify simple triggers and simple target behaviours.

Furthermore, the ‘colourful equals healthy’ association presented in this dissertation might provide a first empirical test of a boost targeting healthy and enjoyable food choices. For instance, Grüne-Yanoff and Hertwig (2016) suggested that external representations of information may be used as a boost if they fit natural decision-making strategies of the consumer. In the ‘colourful equals healthy’ association, perceived meal colour variety is used as an external cue for food choice. As visual cues have been shown to be important for choosing what and how much to eat in previous research (e.g. Imram (1999); Renner et al. (2016); Schulte-Mecklenbeck et al. (2013); Spence (2015)), it might be concluded that visual cues are natural cues for eating decision-making. Based on the test of efficacy and feasibility provided in Chapter 4, it can be concluded that perceived meal colour variety could be able to boost healthy and enjoyable food choices.

### 5.5. Implications and outlook

The findings of the present dissertation provide three starting points for future research, and subsequently also inform health promotion practices. A first important issue is studying underlying motivations for mHealth app use. As the behaviour stage model for the adoption process of nutrition and fitness apps highlights, mHealth app non-users might differ substantially in their motivation to use mHealth apps. Therefore, future research might need to study several subgroups of non-users instead of treating them as one homogeneous group to gain valuable insights into how to promote mHealth apps.

At the same time, it is important to note that future research might be needed to gain a better understanding of ‘disengaged’ non-users in particular. As Chapter 2 showed, discontinuation of nutrition app use is common. Often, discontinuation is seen as a sign of failure, but this is not necessarily the case. Although previous research has shown that many people who discontinued to use an mHealth app did fail to reach their goal (Murnane et al., 2015), discontinued use can also be a criterion for success, showing that the goal was reached. Ideally, the app becomes redundant when the new behaviour becomes habitual and the new behaviour is still shown even when the intervention is removed (see also Hertwig and Grüne-Yanoff (2017). Successful and unsuccessful 'disengaged' non-users should therefore be examined separately in future studies, as both are able to inform the development of future mHealth apps in different ways. 'Disengaged' non-users who did not reach their goal might provide valuable insights into how to make mHealth apps more engaging (e.g. Greenhalgh et al. (2017)) or less effortful and time-consuming to use (Cordeiro et al., 2015). 'Disengaged' non-users who successfully changed their eating behaviour, on the other hand, might act as success stories and indicate techniques that helped them to successfully change their behaviour.

Finally, the behaviour stage model can be used to identify groups of non-users that are difficult to target with mHealth apps. Specifically, people who decided against using a nutrition app might be difficult to target as they already formed an opinion about the issue. People tend to adhere to their own beliefs (Jelalian & Miller, 1984; Kruglanski & Higgins, 2007), and overcoming this belief perseverance is challenging, as people tend to more readily accept information that is in accordance with their beliefs (Guenther & Alicke, 2008; Klayman, 1995). For this group, digital behaviour interventions might not be suited. Instead of trying to convince this user group of the advantages of mHealth app use, it might be suggested to not target this user-group at all, but to provide analogue eating behaviour interventions, such as nutritional counselling, skills training in face-to-face sessions, or using print materials (e.g. Hardeman, Griffin, Johnston, Kinmonth, and Wareham (2000); Noar, Benac, and Harris (2007); Pritchard, Hyndman, and Taba (1999)).

A second issue that arises from the present dissertation is the investigation of alternative routes to eating behaviour change. Using the example of the 'colourful equals healthy' association, the present dissertation demonstrates that alternatives to traditional eating behaviour interventions are also able to induce meaningful changes in eating behaviour. Specifically, the present dissertation provided a starting point for the development of alternative eating behaviour interventions for shifting towards a view of food as well-being (c.f. Block et al. (2011)). This shift promotes a broader spectrum of triggers used to facilitate the food choices that increase both health and well-being. To discover more triggers based on the food as well-being perspective, further studies on the relationship between eating and well-being are needed. Most research that has been conducted on well-being derived from eating was retrospective and/ or cross-sectional (e.g. Blanchflower, Oswald, and Stewart-Brown (2013); White et al. (2013)). Prospective designs are needed, and data should be collected in daily life to further explore detailed associations between the social and physical context of individual eating occasions, a variety of foods, and food well-being. For instance, using smartphone-based EMA, Wahl et al. (2017) recently investigated the relationship between eating happiness and 14 food categories, showing that vegetables contributed the greatest overall share to eating happiness. These results further support the notion that healthy foods are enjoyable, and suggest that eating enjoyment might be a cue for healthy food choices. After being identified, these cues warrant further testing, preferably using experimental longitudinal designs in real-life, such as

Ecological Momentary Interventions (Heron & Smyth, 2010), to test their efficacy and feasibility in ecologically valid eating situations.

After potential new strategies have been identified, they need to be communicated to the public in order to boost healthy and enjoyable food choices on a population level. For example, it could be communicated to the public that healthy meals can be as or even more enjoyable than unhealthy treats (c.f. Raghunathan et al. (2006); Werle et al. (2013)), and that contrary to the widespread belief, there seems to be no trade-off between benefits for physiological health and psychological well-being (Cornil & Chandon, 2016; Wahl et al., 2017). Similarly, the 'colourful equals healthy' association could be further promoted by pointing out that eating colourful meals is enjoyable (short-term enjoyment), but also increases dietary healthiness (long-term health goal). Delaying immediate rewards in order to pursue long-term goals, also referred to as delay of gratification (Mischel, Shoda, & Rodriguez, 1989), has been shown to be a demanding task for many people. Alternatively, pointing out short-term rewards from pursuing long-term goals might be a promising strategy to facilitate behaviour change (Woolley & Fishbach, 2016). In this vein, fruit and vegetables might lose the negative stereotype of being boring or not tasty, leading to an increase in their consumption.

While the present dissertation focused on alternative eating behaviour interventions delivered via mHealth apps, a third issue is the transfer of these interventions to other behavioural domains and modes of delivery. Importantly, the alternative approach to eating behaviour change is not limited to being delivered on mobile devices. Simple intervention strategies such as the 'colourful equals healthy' association could also be communicated via mass media campaigns online or using traditional media such as leaflets or television advertising. It also could be implemented at the workplace to specifically target the eating behaviour of employees, e.g. via newsletters or bulletins in the canteen. For instance, a recent study reported that an organisational environment that encourages healthy eating might increase fruit consumption (Sonnentag, Pundt, & Venz, 2017). Thus, promoting simple intervention strategies for healthy and enjoyable food choices at work has the potential to positively impact both employees' health and well-being, and it might simultaneously increase satisfaction with the employer via a positive organisational health climate (Sonnentag & Pundt, 2016).

Moreover, the use of simple intervention strategies can be extended to other health behaviours. For example, the increase in sedentary behaviour has gained greater attention in recent years due to its relationships with mortality and the development of non-communicable diseases (de Rezende, Lopes, Rey-López, Matsudo, & do Carmo Luiz, 2014). Office workers in particular spend many hours a day sitting (e.g. Thorp et al. (2012)), highlighting the need for simple interventions that they can easily integrate in their daily routines. In a qualitative study, De Cocker et al. (2015) collected employees' ideas of how sitting at work could be reduced. For instance, interviewees suggested to stand up when taking phone calls, and drinking out of smaller cups to increase the number of times required to get up to refill it. Both suggestions could be translated into simple behaviour change strategies by identifying a trigger (the phone rings/ the cup is empty) and a behaviour (getting up), underlining the potential of the approach to simplify behaviour change across behavioural domains.

## 5.6. Concluding remarks

The present dissertation contributes to the development of new eating behaviour interventions by providing an alternative to traditional approaches of eating behaviour change. It integrated a view of food as well-being with simple intervention strategies consisting of simplified triggers and simplified behaviours. The ‘colourful equals healthy’ association was established and tested in real-life eating situations, and demonstrated that also simple interventions using simplified and not explicitly health-related triggers are effective in inducing behaviour change. Furthermore, it highlighted that eating behaviour change might not need to be frustrating if a focus is laid on the healthy pleasures that can arise from eating.

While the restrictive focus of many eating behaviour interventions, including available nutrition apps, is beneficial for some people, the present dissertation indicates that there is no ‘one size fits all’ approach to health behaviour change. Therefore, individual preferences, needs, and goals might need to be taken into account when developing interventions. By including alternative approaches to health behaviour change, such as the approach presented in this dissertation, the number of people who successfully adopt healthier behaviours might be increased.

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For Chapter 2, BR, HS, Dr. Gudrun Sproesser (GS) and Laura König (LK) designed the study and collected the data. LK conducted the analyses with input from BR. LK and BR drafted the manuscript with critical revisions from GS and HS.

For Chapters 3 and 4, LK and BR designed the studies and collected the data. Analyses and first draft of the manuscripts were prepared by LK. BR edited both analyses and manuscripts.

All authors approved the final manuscripts (applying to all chapters).