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„On Cognition and Eating Behavior: an Anthology of Studies investigating Learning, Memory and Restrictive Dieting“

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Abstract

Background: Cognitive processes play a predominant role in eating behavior. The lack of solid public health nutrition interventions may, to a great extent, be due to a gap in fundamental knowledge about the complexity of individuals' eating behaviors. This thesis is constructed to further our understanding of three distinguished, but interconnected areas, reflecting on learning, memory and restrictive health-directed eating behavior. Food-related cognitions are common vehicles for all three levels of concern. First, this thesis investigates how individuals' food cognitions are minted by environmental factors, e.g., as the result of learned scripts via media environments (e.g., from television watching). In detail, we investigate how food advertisements are addressed to different target groups (children and gender). Secondly, the thesis analyzes how repetitive food-related and memory-based cognitions affect subsequent food intake. Research shows that individuals' eating simulations (mental imagery) can reduce subsequent consumption. In this thesis, one original research and one opinion article investigate the role of repetitive food-related cognitions of eating behavior and its boundary conditions. The third section investigates health-directed eating behaviors. We investigate, on the one hand, the obsessive fixation on healthy eating and the rigidity of self-imposed dieting (orthorexia nervosa), as well as the underlying rationale for a novel gluten-free diet.

Methodology: Mixed methods were used for analysis. Food advertisements targeted at children were analyzed according to national dietary recommendations, as well as the EU Pledge Nutrition Criteria for television food marketing *(Publication #1)*; television data were coded in line with gender-specific coding schemes *(Publication #2)*. To investigate the effect of mental imagery on food intake, we used within-subjects designs, camouflaged as regular food taste tests. We manipulated the number of repetitions *(Publication #3, study 1)* and introduced an ego-depletion paradigm to deplete self-regulatory resources *(Publication #3, study 2)*. *Publication #4* is based on current literature on the topic of mental imagery and food consumption. To investigate orthorectic eating behavior, a large online sample and a confirmatory factor analysis were applied to test the translated version of the original ORTO-15 questionnaire by means of internal validity and self-reported behavioral correlates

(Publication #5). *In publication #6,* food databases were used to analyze food composition facts in order to evaluate the nutritional content of gluten-free products.

Results: Food products targeted at children are in discordance with the EU Pledge Nutrition Criteria (*Publication #1)* and traditional stereotypical portrayals of men and women are prevalent in food advertisements (*Publication #2)*. Furthermore, we could demonstrate that repetitive mental imagery (18 or 36 repetitions) decreased subsequent food intake, but this effect was only prevalent when self-regulatory resources were available (*Publication #3)*. We addressed this finding in an opinion article, arguing the importance of mental simulation processes and cognitive resources for possible interventions (*Publication #4)*. *Publication #5* analyzed the assessment method of a special health-directed dieting regimen. Following a thorough translation process and statistical analysis, results showed that the ORTO-9-GE tool is only of mediocre internal quality. The study also indicated that dieting frequency is associated with orthorectic tendencies. Analyzing the gluten-free dieting regimen by means of food composition, we could show that gluten-free products do not provide additional health benefits from a nutritional perspective while they are also more expensive *(Publication #6)*.

Conclusions: The present thesis combines three different lines of research investigating cognitive processes determining eating behavior. Findings from all three levels of analysis (learning, memory and restrictive health-directed eating behavior) provide new insights into the complex interaction between food cognitions and human eating behavior.

Zusammenfassung

Hintergrund: Beim Ernährungsverhalten spielen kognitive Prozesse eine entscheidende Rolle und sind mitunter der Grund dafür, warum viele Ernährungsinterventionen aus dem Public Health Bereich scheitern. Die vorliegende Dissertation untersucht daher drei thematisch verbundene Teilbereiche (Lernmechanismen, Gedächtnisprozesse und restriktives Ernährungsverhalten) mit dem übergeordneten Ziel, kognitive Dimensionen der Ernährung und schlussendlich Ernährungsverhalten genauer beschreiben zu können. Zunächst werden Umweltfaktoren am Beispiel von Lebensmittelwerbung untersucht. Insbesondere, wie Lebensmittelwerbung im Fernsehen zielgruppenspezifisch dargestellt wird. Als besonders empfängliche Zielgruppe wird hier der Fokus auf Kinder gelegt; zudem werden genderspezifische Lebensmittelwerbungen im Fernsehen analysiert (Lernmechanismen). Als zweites wird der Einfluss von Gedächtnisvorgängen auf das Ernährungsverhalten untersucht. Studien haben gezeigt, dass wiederholtes vorstellen von Essvorgängen anschließenden Verzehr von Speisen verringern können. Im Speziellen wird untersucht, inwiefern wiederholte Vorstellungsübungen der Nahrungsaufnahme nachfolgende Aufnahmemengen beeinflussen und die Verfügbarkeit von Ressourcen für Selbstregulation als Randbedingungen eine Rolle spielen (Gedächtnisprozesse). Im dritten Teilbereich werden spezielle, gesundheitsorientierte Ernährungsformen untersucht. Zum einen wird die obsessive Fixierung auf gesunde Ernährung selbst aufgestellter Ernährungsregeln (Orthorexia Nervosa), zum anderen die ernährungsphysiologische Grundlage einer gesundheitsorientierten glutenfreien Ernährungsform untersucht (restriktives Ernährungsverhalten).

Methoden: Unterschiedliche methodische Ansätze kommen im Rahmen der Dissertation zur Anwendung. Kodierte Lebensmittelwerbungen werden mit nationalen Ernährungsempfehlungen und den EU Pledge Nutrition Criteria analysiert *(Publikation #1)*; zudem werden Lebensmittelwerbungen nach einem genderspezifischen Kodierschema untersucht *(Publikation #2)*. Weiters werden experimentelle Beobachtungsstudien durchgeführt. Hierbei kommen Zwischensubjekt-Studiendesigns zum Einsatz, um einerseits die Anzahl an Wiederholungen bei den Vorstellungsübungen *(Publikation #3, Studie 1)* und andererseits die Rolle zu untersuchen, die Ressourcen für Selbstregulation in diesem

Paradigma spielen *(Publikation #3, Studie 2)*. *Publikation #4* basiert auf einer breit angelegten Literaturrecherche zum Thema Vorstellungsübungen in Bezug auf Ernährungsverhalten. Zur Untersuchung orthorektischen Ernährungsverhaltens wird die Validität des übersetzten ORTO-15 Fragebogens an einem heterogenen online sample mittels konfirmatorischer Faktorenanalyse geprüft *(Publikation #5)*. Ein weiterer methodischer Ansatz wird in *Publikation #6* angewendet, nämlich die Verwendung von Lebensmitteldatenbanken um glutenfreie Lebensmittel ernährungsphysiologisch zu analysieren.

Resultate: Lebensmittelwerbungen für Kinder gehen nicht mit den Vorgaben der EU Pledge Nutrition Criteria konform und zeigen, entgegengesetzt zu den aktuellen Ernährungsempfehlungen vor allem hochkalorische Lebensmittel mit hohem Fett- und Zuckergehalt *(Publikation #1)*. Genderspezifische Lebensmittelwerbungen reproduzieren klassische Rollenbilder und Stereotypen in Bezug auf Ernährung *(Publikation #2)*. In *Publikation #3* wird dargestellt, dass wiederholtes Visualisieren von Nahrungsaufnahme vor einer Mahlzeit (18 oder 36 Wiederholungen) die anschließende Menge an verzehrten Lebensmitteln reduziert, dies funktioniert jedoch nur, wenn Ressourcen für Selbstregulation zur Verfügung stehen. Dieses Thema wurde in einem weiteren Artikel erläutert und in einen breiteren Kontext gesetzt *(Publikation #4)*. *Publikation #5* zeigte auf, dass das übersetzte und validierte Untersuchungsinstrument nach konfirmatorischer Faktorenanalyse in seiner Endversion (ORTO-9-GE) nur von geringer Qualität ist. Die Studie zeigt zudem, dass die Anzahl an Diätversuchen mit orthorektischen Ernährungsverhaltens assoziiert ist. *Publikation #6* zeigt, dass in Österreich erhältliche glutenfreie Lebensmittel keine ernährungsphysiologischen Vorteile beinhalten und gleichzeitig mit höheren Kosten verbunden sind.

Schlussfolgerung: Die vorliegende Dissertation kombiniert drei Forschungsansätze welche sich mit der Frage beschäftigen, ob und inwiefern kognitive Prozesse das Ernährungsverhalten beeinflussen. Die Resultate dieser drei Untersuchungsebenen (Lernmechanismen, Gedächtnisprozesse und restriktives Ernährungsverhalten) liefern neue Erkenntnisse zur komplexen Interaktion zwischen Ernährungsverhalten und kognitiven Einflussfaktoren.

Glossary

appetite - sum total of processes influencing eating (Blundell and Halford, 1994)

BMI - Body Mass Index

CI - Confidence Interval

EDNP - energy-dense and nutrient-poor products

FFQ - Food Frequency Questionnaire

fullness - conscious sensation concerning state of repletion, usually focused on the stomach (Blundell and Halford, 1994)

GF - gluten-free

habituation - a decrease in responsiveness to a stimulus when that stimulus is presented repeatedly or for a prolonged time (e.g., Groves and Thompson, 1970)

HELENA - Healthy Lifestyle in Europe by Nutrition in Adolescence

hunger - conscious sensation reflecting a mental urge to eat; can be traced to changes in physical sensations to various body parts; can have strong cognitive influence (Blundell and Halford, 1994)

OR - Odds Ratio

ON - Orthorexia Nervosa

LTM - long-term memory

satiation (intra-meal satiety) – controls meal termination (meal size). Rapid signaling from taste, stomach, upper intestine (Benelam, 2009)

satiety (post-prandial satiety) - Inhibition of eating, modulation of hunger in post-ingestive period (Blundell and Halford, 1994)

SMD - Standardized Mean Difference

WEIRD - Western, Educated, Industrialized, Rich, and Democratic populations

WHO - World Health Organization

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1. INTRODUCTION

Eating behavior is the result of the dynamic interplay between homeostatic, hedonic and cognitive mechanisms (Berthoud, 2011; Hall et al., 2014). There is a profound level of cognitive processing involved in daily decisions concerning food (Herman and Polivy, 2014). In humans, all aspects of eating are controlled by a goal-directed system (Rangel, 2013), and the motivation to seek out and consume food is based on the assumption that eating is highly rewarding and pleasurable (Woods, 1991). Simultaneously, we are able to control food intake based on individual cognitive goals (e.g., dieting, losing weight, vegetarianism). To enhance our understanding how cognitions shape and are shaped by eating behavior, the present thesis provides an anthology of studies investigating three distinct, but interrelated cognitive domains relevant to eating behavior namely, learning, memory and restrictive health-directed eating behavior.

The quality and quantity of food intake is a pivotal lifestyle factor in the prevention of non-communicable diseases (NCDs). Systematic analyses from large observational studies suggest the number of annual worldwide deaths in all age groups add up to almost 55 million individuals in 2013. As reported by Lozano (2013), 70% of deaths are caused by NCDs. Problematic and disordered eating behavior plays a dominant role in the development of NCDs (e.g., obesity, eating disorders, malnutrition), thus leading to personal, societal and financial burden worldwide. Consequently, pathology-driven approaches studying eating behavior have become very dominant in nutrition research. Likewise, to tackle eating-related problems, it is important to understand a variety of behavioral aspects of normal eating in the absence of pathology. This strategy may help to identify relevant factors underlying eating behavior and compile future strategies to prevent pathological drivers and changes in eating behavior.

As noted by Sloman (2015), cognition is central to most aspects of human psychology, however, there are no clear definitions in particular to food-related cognitions. In this thesis, a broad stance on cognition, defined as *"mechanisms by which animals acquire, process, store and act on information from the environment"* is taken (Shettleworth, 1998, Page 5).

Cognitive processes involved in eating behavior have been identified as important moderators for what and how much people eat (Schachter and Gross, 1968; Wansink, 2004; Ogden, 2012). First, individuals' motivation to eat is influenced by an array of experiences with and learning about food. Modern media environments contribute to learning about the food environment (Swinburn et al., 1999). Secondly, as described in the *satiety cascade*, concurrent and subsequent food cognition during food choice and food intake affects consumption (Blundell and Halford, 1994). Research showed that food memory (short-term; episodic) can modulate food intake and determine eating patterns (Higgs et al., 2008a). Preliminary research on the effect of repetitive memory retrieval of consumption via mental imagery, indicate promising results showing reduced consumption (Morewedge et al., 2010). Research to examine the boundary conditions of this effect is rare (e.g., availability of self-regulatory resources; number of repetitions). Thirdly, individual decision-making about food is guided by rationalizing about food, therefore facilitating self-regulation processes. The ability to alter dominant responses (e.g., impulses, urges, thoughts) and replace them with different, higher-order goals (e.g., to eat only healthy food), uses self-control capacities (Baumeister et al., 1998). While the ability for self-control is hypothesized within a limited resource paradigm (Baumeister and Alquist, 2009), research suggests depletion of self-regulatory resources can lead to self-control failures or unwanted health outcomes (Baumeister and Heatherton, 1996). Continuous health-directed and restricted eating behavior with a strong and obsessive drive to eat only healthy food is called orthorexia nervosa. Individuals with orthorectic tendencies follow a strict dieting regimen that reduce food variety (Bratman and Knight, 2001). One

novel dieting regimen with increasing popularity is called gluten-free diet, which is based on the underlying rationale that gluten-free foods are perceived as healthier than their gluten-containing counterparts (Dunn et al., 2014; Priven et al., 2015). However, from a nutritional perspective this assumption may be a fallacy (Staudacher and Gibson, 2015).

In summary, the present thesis provides a collection of three lines of research to enhance our understanding in the domains of learning, memory and restrictive health-directed eating behavior. The first section briefly describes how our current food environment (Austria) is constituted and how individuals learn about food information in these environments (learning). In this section, a special focus is on the depiction of foods during television advertisements. The second section investigates how memory affects eating behavior (memory). In particular, how a specific and repetitive form of memory retrieval, called mental imagery, influences subsequent food intake. The third section investigates how health-directed behaviors influence how individuals consume food (restrictive health-directed eating behavior). A special form of self-regulation, with a strong and obsessive drive to eat only healthy food, called orthorexia nervosa, as well as the underlying rationale for a novel food regimen called gluten-free diet, is investigated.

1.1. Learning

Learning about the immediate food environment is central in the concept of how eating behaviors are shaped. When eating a particular food (current exposure) and the outcome of eating (rewarding properties) are associated, memories are eventually formed. In succession, external food cues (e.g., food advertisement) can elicit pre-cephalic responses and trigger the desire to eat in another situation (Wooley and Wooley, 1973; Nederkoorn et al., 2000). Predictions (expectations) about the consequences of food intake from past experiences with the current food exposure are generated (Balleine and O'Doherty, 2010; Dickinson, 2012). If the former experience is not dissuasive, future experience with the same or similar food will facilitate eating if the predicted outcome is a desirable goal at that moment. This goal-directed behavior in eating situations depends on the state of satiety. As such, food is more attractive and indulgent when individuals are hungry, and less appealing when sated (Cabanac, 1971). Over time, eating behavior becomes habitual and partly automatic (Dickinson, 1985; Aarts and Dijksterhuis, 2000), likely provides orientation in different food environments, but it may also facilitate eating in the absence of hunger. The idea to predict eating behavior outcomes as a function of past experiences and learning about the food environment is intriguing. However, outcome probabilities of human eating behavior show a very wide range, and individuals' food choices vary greatly over time (Ramsay and Woods, 2014).

In this section, research of environmental factors determining eating behavior via learning mechanisms is described. This segment investigates i) current health environments and how these shape eating behavior; ii) basic learning concepts relevant for eating behavior; iii) research of television food advertisements targeted at children and iv), gender depictions in television advertisements.

1.1.1. Modern Health Environments

Learning mechanisms need to be understood in the context of current food environments. Societal and nutritional changes from food scarcity, to highly abundant environments, have lead to so-called *obesogenic* environments (Swinburn et al., 1999). *Obesogenic* environments show increased availability of calorically dense, easily accessible, and relatively inexpensive palatable food (Hill and Peters, 1998; Drewnowski, 2004; Duffey and Popkin, 2013), therefore encouraging excess energy intake and overeating (Swinburn et al., 2009; Berthoud, 2011). Prevalence rates and trends of overweight and obesity are well described in the literature. Recent data suggests that in the USA, 33% of children aged 6-19 years are either overweight or obese (Ogden et al., 2014), reflecting excess weight gain. According to the latest Austrian Nutrition Report (2012), 24% of Austrian schoolchildren (aged 7-14 years) are either overweight or obese (Elmadfa, 2012); Ng and colleagues (2014) also report 17% overweight and obesity rates for individuals aged < 20 years in the Austrian population. On average, overweight and obesity rates of 23% are reported for Western European countries for ages < 20 years. Obesity is a health problem that persists throughout life, tracking from childhood into adulthood. As reported by Guo et al. (2002), both obese male and female children (at age 12 years; above 95th percentile BMI-for-growth charts) grow into obese adults with a predictive value of 44%. If obesity persists to age 18 years, the predictive value increases to 72.5%.

The term *obesogenic* environment was first introduced by Swinburn et al. (1999) to conceptualize micro and macro environmental levels responsible for the rise in obesity within a common framework. For instance, elements on a micro level include settings where people work and live, e.g., community and recreational facilities. On a macro level, factors affecting eating behavior and physical activity include urban and rural development programs, food production and marketing. Food marketing in the form of advertisement is part of the

obesogenic environment. Food advertisement is a legitimate way for companies to promote their products, increase sales, shape consumer preferences and stimulate purchasing behavior. To market food products, strategies involve evoking attention, produce meaningfulness of the advertised food, and therefore facilitate concepts of self-identity, social interaction and cultural identity (Ogden, 2011). Food products are frequently advertised on television, potentially influencing attitudes and values of target audiences (Boyland and Halford, 2013). One additional layer of food advertisement pertains to targeting specific groups (e.g., male, female, young, old). Particularly, food marketers have recognized children as important targets for marketing and advertisement which shows in increased industry spending targeting children (Galbraith-Emami and Lobstein, 2013), because young consumers are potential future customers with high current and accumulating purchasing power (Nestle, 2013).

1.1.2. Learning in Modern Food Environments

There are a myriad of learning opportunities to acquire knowledge about foods throughout one's lifetime. On average, individuals make more than 200 food-related decisions per day (Wansink and Sobal, 2007). Contemporary food environments may facilitate learning processes to increase food consumption. However, understanding learning theory may help in developing programs to dampen overeating (Boutelle and Bouton, 2015).

The most prominent learning concept states that food cues are associated via Pavlovian conditioning (Rescorla and Wagner, 1972). Pavlovian conditioning occurs when a neutral stimulus is paired with a biologically important and rewarding stimulus, thus causing the neutral stimulus to produce eliciting functions and behavior. For instance, when pairing the Golden Arches from McDonalds™ (conditioned stimulus = CS) with a food item (Chicken McNuggets™, unconditioned stimulus = US), increased craving or salivation can be predicted

while exposed to the Golden Arches. These food cues (McDonalds™ Golden Arch) are directly associated with the food outcome (Chicken McNuggets™), triggering a cue-food association. However, the reinforcing effects of eating can also be driven by voluntary operant actions; for review, see Bouton (2011). Both processes act simultaneously. The quote below gives the essence of Bouton's reasoning:

"Given the number of palatable foods out there, and the known behavioral effects of Pavlovian and operant learning processes, it is not surprising that we eat, and are tempted to eat, in the presence of so many CSs and contexts." (Bouton, 2011, Page 57)

It has been suggested that repetitive cue exposure (response priming) is more pronounced for high-caloric foods or snacks (e.g., Lovibond and Colagiuri, 2013; Colagiuri and Lovibond, 2015). Lovibond and Colagiuri (2013) report that repeated presentation of food cues made participants work harder to acquire food. In their study, they used a Pavlovian-to-Instrumental Transfer (PIT) paradigm: first, repeatedly pressing a button leading to a chocolate reward (instrumental-acquisition phase); second, the chocolate reward was paired with a CS (red or blue light; Pavlovian-acquisition phase) and third, by randomly presenting the CS (red or blue light), the number of button presses were observed (transfer-test phase). They could demonstrate when confronted with a CS, and paired with a chocolate reward, mean button-presses significantly increased compared to the unpaired stimuli. What Lovibond and Colagiuri (2013) found out was that in this case, neutral stimuli, paired with chocolate, can facilitate voluntary and goal-directed action to obtain chocolate. This shows that Pavlovian stimuli indirectly influence choice and ultimately eating behavior.

The frequency of presented food cues is important for eliciting behavioral outcomes. As described in the *mere-exposure effect* (Bornstein, 1989), repetitive exposure to food products

can facilitate Pavlovian conditioning eliciting, for instance short-term food cravings (Watson et al., 2014). Mere-exposure to food cues is a pivotal part of *obesogenic* environments. Watson and colleagues (2014) argue that, as a result of Pavlovian conditioning, cues like food advertisements, may come to elicit food craving and prolong craving effects, even while not being hungry. This was also demonstrated in a recent systematic review by Boswell and Kober (2016). They could show an overall medium effect across 45 studies (overall 2,948 participants) of food cue reactivity and craving on eating and weight-related outcomes (r = 0.33; CI: 0.27-0.38, z = 10.69, $p < 0.001$); explaining 11% of the variance. Interestingly, BMI, age and dietary restraint did not influence effect sizes, but exposure to real food was associated with similar effect size, as were visual food cues (e.g., videos, pictures). The fact that mere exposure to food advertisements can bias food choice highlights the significance about the *obesogenic* environment in dietary behavior, while merely reminding individuals of palatable foods (e.g., via advertisement, advergaming) can be enough to trigger response behavior to obtain those foods.

1.1.3. Food Advertisement Targeted at Children

As stated by the WHO (2012), food marketing is identified as one important target to prevent childhood overweight and obesity (Garde et al., 2012). Recommendations and proposed frameworks for regulation are based on strong and consistent data, showing that food marketing influences preferences, purchase and consumption behavior in children (Cairns et al., 2013). Marketing influence of children may not be a problem in itself, as it can be part of educating children towards healthier food choices as well. More problematic is the quality of advertised foods, undermining national recommendations for healthy eating and the guidelines for disease prevention. For instance, Kelly et al. (2010) report data from a

multinational study investigating this discrepancy across 13 different countries (5 different continents). Their results show that 53 - 87% of all food advertisements were for energy-dense and nutrient-poor products (EDNP). In this study, EDNPs were more often shown during children's peak viewing times (Kelly et al., 2010).

Food for children is advertised dissimilar to food advertisements targeted at adults. As such, brand mascots and cartoon media characters are frequently used when food is advertised towards children. A systematic review of 11 studies investigated the effect of food companies' mascots and entertainment companies' media characters on cognitive, behavioral and health outcomes for children < 12 years (Kraak and Story, 2015). For example, they analyzed Disney media characters or Sesame Workshop's Elmo and how these characters influence food preferences. Familiar media character branding can have a powerful influence on children's food preferences, choices and intake. This is problematic when advertised foods are energy dense and nutrient poor (e.g., candy, cookies or chocolate). A landmark study by Harris et al. (2009) showed that elementary school-aged children are highly susceptible to food advertising effects. When exposed to food advertisement prior to consumption, children consumed 45% more snacks. In fact, a recent systematic review and meta-analysis reviewing the evidence between acute exposure to unhealthy food advertising and food consumption showed a small-to-moderate effect size for advertising of food consumption in all age groups (SMD: 0.37; 95% CI: 0.09; 0.65; I^2 = 98%). However, subgroup analysis showed that greater food intake was only significant for children (SMD: 0.56; 95% CI: 0.18, 0.94; I^2 = 98%) compared to adults (SMD: 0.00; 95% CI: 20.08, 0.08; I^2 = 8%). Even though these results should be interpreted conservatively (substantial heterogeneity between included studies), the meta-analysis indicates acute exposure to food advertising affects children differently than adults (Boyland et al., 2016).

Currently, there is no well established theoretical model specifically addressing how food cues in advertising influence eating behavior in children. Folkvord and colleagues (2016) introduced a new framework for future research in the field *(Figure 1)*. The Reactivity to Embedded Food Cues in Advertising Model (REFCAM) is based on three assumptions: first, food cues induce physiological and psychological reactivity to food (advertising effect process) which leads to a reciprocal relationship with eating behavior (incentive-sensitization process). The second assumption is that messages, such *as* the level of integration of food cues influence their effect, because it is embedded in media contexts. The third assumption is, that inter-individual dispositional factors determine susceptibility to food cues in advertisements.

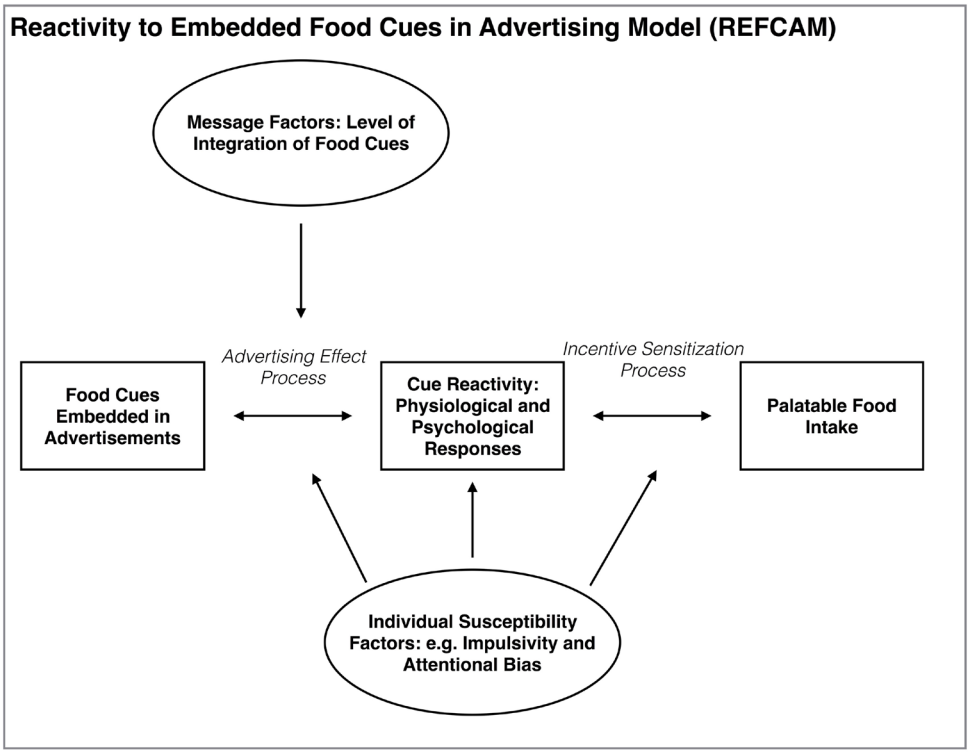

Figure 1. *Reactivity to Embedded Food Cues in Advertising Model (REFCAM), adapted from Folkvord et al. (2016).*

In addition, the effect of food advertisement on children can be discussed on an ethical and legal level as well. Television watching is often hardly limited within families and for younger family members. Children as young as three years old are capable of identifying advertisements during television programs, but are not fully able to understand their persuasiveness (Graff et al., 2012). This makes, as some argue, food advertisement for children a deceptive way to propose commercial transactions to children and should therefore be restricted (Pomeranz, 2010).

The EU Pledge Nutrition Criteria

In the EU, a voluntary initiative to restrict food and beverage advertisements towards children < 12 years on television, print media and the internet was pledged by 20 companies responsible for at least 80% of the television food marketing in the EU (EU Pledge Nutrition Criteria, 2015). It is designed as a self-regulatory and voluntary initiative. The pledge employs a dual strategy: i) to encourage healthy food components (e.g., high fiber and protein content), and ii) aim to restrict unhealthy food components (e.g., high amounts of sugar, saturated fatty acids) in advertisements. The commitment started in 2012 and participating members pledged to implement the suggested guidelines by 31st of December, 2014. Briefly, the EU Pledge Nutrition Criteria uses 9 different food categories to arrange food advertisements and fully restrict certain foods and food groups (i.e. soft drinks, or sugar and sugar-based, products shown with fast-food products, such as burgers or fries). Depending on the presented food category, nutrient-based thresholds are defined for different nutrients (e.g., total energy in kcal/portion, sodium in mg/100 g or 100 ml; saturated fats in mg/100 g or 100 ml, or total sugars in g/100 g or 100 ml). The following nutrients and food groups are qualified as positive and should be encouraged: protein and calcium in milk and dairy products, plus fiber and whole grain in cereal-based products (EU Pledge Nutrition Criteria,

2015). A short communication by Lobstein (2013) called out for more research to analyze the applicability of nutrient profiling schemes restricting food marketing to children. Currently there is no baseline assessment of the pledged criteria for television food advertisement in Austria.

Aims of Publication #1

The aim of *Publication #1* was to investigate the quality and extent of advertised foods on Austrian television to provide a current report on the progress of implementation of the EU Pledge Nutrition Criteria. The main objectives of the study were to compare the quality of advertised foods for children with i) current dietary guidelines (Austrian Food Pyramid) and ii) the EU Pledge Nutrition Criteria.

1.1.4. Gender Roles in Food Advertisement

Besides food advertisement for children, gender advertisements in the food domain are of interest. Food advertisements facilitate concepts of social and cultural meanings of food simultaneously. Concepts of self-identity, social interaction and cultural identity are reproduced by advertisements (Ogden, 2011). Presently, there is now some evidence from one prospective cohort study (n=9671), showing nonconformity in females with gender expression[1] is associated with increased BMI (Bryn Austin et al., 2016). However, how gender roles or norms within an eating context develop in the first place, is still unclear. To identify the social influences (e.g., via television advertisement) contributing to the perceptions of gender expressions influencing eating and health behavior is important.

[1] "*the degree to which one presents oneself in a way consistent with culturally defined expressions of masculine or feminine*" (Bryn Austin et al., 2016, Page 507).

There are some marked biological gender differences between men and women (Meyers-Levy and Loken, 2015). However, when individuals learn about food and eating, social and cultural norms influence the way men and women form eating habits (Diel, 1983; Rozin et al, 2012). As a strategy for gendered presentation, either the amount of consumed food, or the foods themselves, are associated with gender, as this is an integral part of the theoretical framework describing how gender concepts are prevalent and shape how individuals eat (Beardsworth et al., 2002). Gender roles are patterns of interactions between women and men which are socioculturally defined and replicated via human interaction (West and Zimmerman, 1987).

One example of gender roles in the food domain is the association between food and health. Food-related activities, such as cooking and shopping, are traditionally reported as female-centered gender roles. However, eating behavior gender roles are prevalent for men as well. For instance, a content analysis from the UK investigated newspapers on the topic of men and their diet showed that in most of the 44 examined newspapers, hegemonic masculinity[2] is mirrored in health-defeating diets, cooking of hearty meals for special occasions, and general distancing from dieting. Simultaneously, when it comes to diet and health, men are constructed as vulnerable and naive, while women are depicted as experts in the food domain (Gough, 2007).

As in the example above, gender roles, like hegemonic masculinity (for men) and food expertise (for women), are ascribed features in newspapers. These roles are influenced by gender; the perception of how men and women *are*. The research on *doing gender* aims to clarify how gender and the perception of it is constructed, which can lead to gender stereotyping (West and Zimmerman, 1987).

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[2] men as emotionally and physically strong, less likely to admit pain; compare report by Connell and Messerschmidt (2005).

Mass media, and especially television, imparts normative, social and cultural information to broad audiences. This is why messages transported via television can manifest gender roles through repetitive exposure (Gauntlett, 2008). The role of advertisement of many different products in media communication has been researched thoroughly. For instance, a meta-analysis by Eisend (2010) investigating the role of gender on television and radio advertisements showed that gender stereotyping is highly prevalent in the advertising of many different products (body, home, food, auto, sports, leisure, entertainment, services, finance, other). In the eating behavioral context, understanding how gender roles are depicted in the media environments, especially in a food context, is of great relevance.

Aims of Publication #2

The aim of this study was to investigate how food advertisements are depicted on Austrian television in terms of gender. Gender research is an under-investigated field in the eating behavior domain, although highly relevant for food choices and food intake. In the presented study, we i) investigated how gender roles are depicted in food advertisements and ii) analyzed the food quality shown when men or women are involved characters in advertisements.

1.2. Memory

Meal consumption is, to a large degree, not solely physiologically driven (McSweeney and Murphy, 2000; Bellisle, 2013), and although physiological cues are relevant for the formation of intrusive thoughts leading to feelings of hunger, eating simulations are often triggered by food-related cues.

Remembering food and eating guides future behavioral actions and determines what foods to eat and which foods to avoid (Davidson et al., 2005; Davidson et al., 2007; Kanoski and Davidson, 2011). Rozin et al. (1998) reported that two amnesic patients with hippocampal damage and severe memory loss would eat two subsequent meals without noticing substantial feelings of satiety. They usually begin to consume a third meal if offered. In both cases, no explicit memory for prior eating occasions could be stored in their short-term memory, due to their medical condition. Memory of recent eating occasions is involved in regulating eating behavior. Further research of amnesic patients demonstrated that hyperphagia is a result of diminished memory capacity of a recent meal. This effect is accompanied by the loss of the actual subjective meal experience (hunger and fullness VAS scores) shortly after the meal was consumed (Higgs et al., 2008b).

In this section, research on short and episodic memory forming eating behavior is described. In detail, i) a framework of memory and self-regulation and how memory processes affect eating behavior; ii) an anecdotal approach to mental imagery[3]; iii) repetitive mental imagery and eating behavior; and iv) the effect of mental imagery on habituation and food consumption are presented.

[3] The term mental imagery and mental simulations will be used interchangeably throughout the thesis.

1.2.1. Working Memory, Self-regulation and Theories of Desire

On a behavioral level, there are several examples how implicit or explicit memory of recent eating episodes influences food choice and subsequent meal intake. Mounting evidence demonstrates attentive eating and episodic memory manipulation influences eating behavior. In a series of studies, Higgs and coworkers could demonstrate that subsequent food intake is reduced if individuals are asked to recall details of the last meal and enhance the memory of the meal experience (Higgs, 2002; Higgs, 2005). A systematic review and meta-analysis by Robinson et al. (2013), pooling results from 6 experiments, reported enhancing the memory of food consumed via different recall paradigms, reduced subsequent food intake (SMD: 0.40; 95% CI: 0.12, 0.68; I^2 = 0%). Again, this meta-analysis must be interpreted with caution, because the pooled studies in this analysis were all from one research group (all from Higgs et al.); however, it indicates the important role of memory on subsequent food intake.

Working Memory

Working memory is conceptualized as a dedicated system temporarily maintaining and storing short-term information which underlies the human thought processes. The theoretical concept of working memory assumes a system with limited capacity providing an interface between human perception of their environments, how information is stored in long-term memory and how actions and behavior are generated (Miyake and Shah, 1999; Baddeley, 2003). The most influential framework is called the multi-component model of working memory first described by Baddeley and Hitch (1974). Primarily, the updated versions of the model describe several interconnected systems that form working memory (Baddeley, 2007). As depicted in *Figure 2*, the visuospatial sketchpad holds visual and spatial information, while the phonological loop holds verbal and acoustic information. The episodic buffer system

forms an interface between long-term memory, the other storage systems and the central executive component. All three components (episodic buffer, phonological loop and visuospatial sketchpad) are of limited capacity for the information it can maintain.

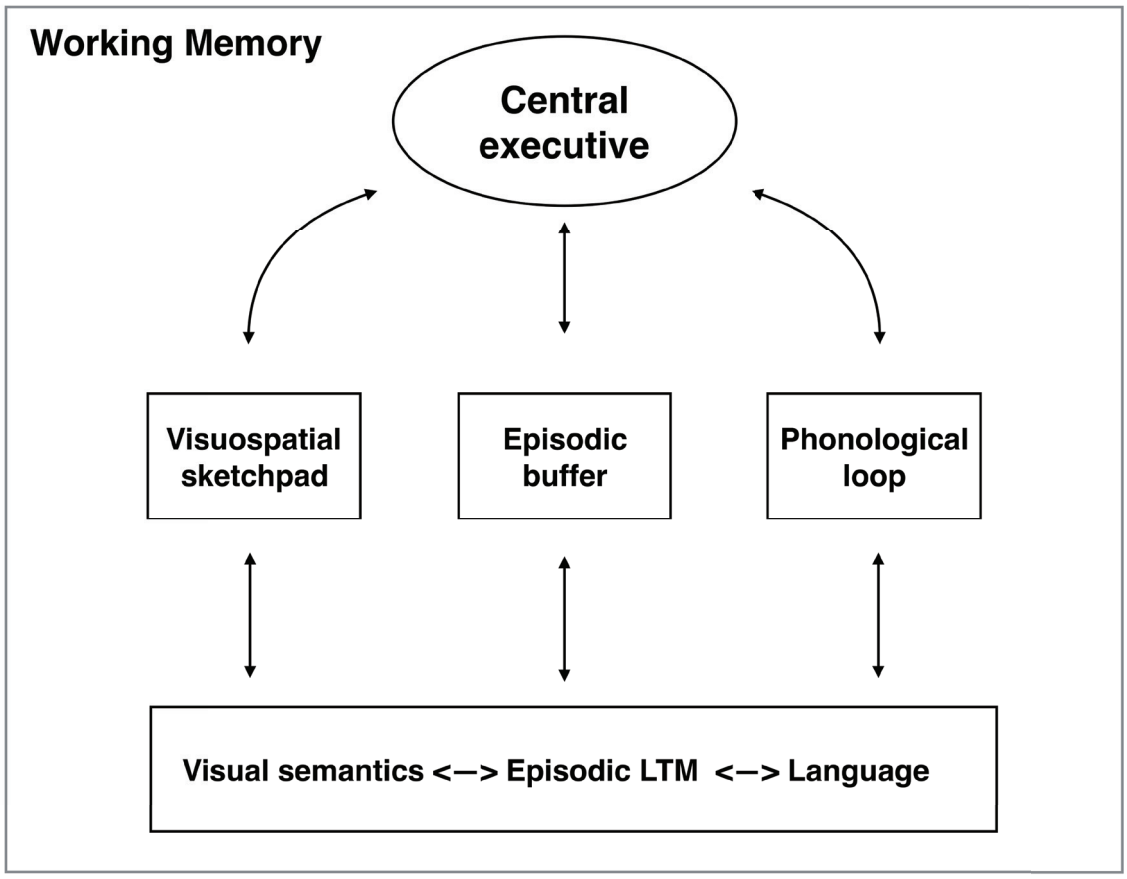

Figure 2. *Schematic multi-component model of working memory, adapted from Repovš and Baddeley (2006).*

Working Memory and Self-regulation

Research on working memory capacity suggests memory mechanisms directly relate to processes involved in self-regulatory goal pursuits. For instance, how well people manage to pursue long-term goals, such as maintaining a balanced diet and good health, or how well they inhibit unwanted behavioral responses (e.g., food habits and impulsivity). Accomplishing self-regulatory goals depend on the availability of working memory capacities, as working

memory is of limited resource. One dominant theory argues that self-regulatory capacity is akin to a muscle that gets depleted over time (resource depletion model) (Baumeister et al., 1998; Baumeister and Alquist, 2009). Ego depletion primarily drains the type of mental resources underpinning the central executive component (Hofmann et al., 2011). The muscle analogy has been challenged elsewhere (Inzlicht and Schmeichel, 2012; Inzlicht et al., 2014), but the assumption that depleting self-regulatory resources interfere with executive functioning and modulate top-down control processes, which would otherwise regulate impulses (e.g., food consumption), is intriguing.

Secondly, working memory is involved in the regulation of so-called *hot* processes (e.g., emotions, desires, and cravings) (Hofmann et al., 2011). Research from social and health psychology has focused on the ways in which desires affect cognition and ultimately guide eating behavior (Hofmann and Nordgren, 2015). However, there is only little knowledge how food desires arise in the first place. What mechanisms underlie the psychological processes leading to the desire of indulging in tasty food. For instance, desires for drinking water (Veltkamp et al., 2011) or smoking cigarettes (Tiffany et al., 2000) can arise even when no physiological deprivation exists. This reasoning applies to eating as well and is testimony to the concept of hedonic hunger, which is defined as food intake in the absence of food deprivation und hunger sensations (Lowe and Butryn, 2007). A key question is: how are desires and the motivated behavior linked to obtain food? There are two important theories describing this process: i) Elaborated Intrusion Theory and ii) Grounded Cognition Theory of Desire and Motivated Behavior.

The Elaborated Intrusion Theory of Desire

The Elaborated Intrusion (EI) Theory of Desire describes how physiological cues (e.g. hunger), external cues or cognitive activity (e.g., just thinking about a food) can trigger associative processes and result in spontaneous and food-related thought and desire (Kavanagh et al., 2005). Craving research has produced a bulk of results using the EI theory. For instance, based on self-reported data, an individuals craving is accompanied by intrusive thoughts, vivid sensory experiences and images (May et al., 2008). Craving can be described as an episode of cognitive elaboration, based on intrusive thoughts about food, with a strong imagery-based component. Intrusive thoughts often mark the beginning of craving episodes for individuals, since it is the first thought that they are aware of. According to the EI theory, intrusions can prompt the retention and elaboration of this information in working memory, which serves to further maintain the craving episode (May et al., 2012). Food craving is regarded as a strong motivational state urging individuals to seek and consume a particular kind of food where mental imagery plays a key role (Kemps and Tiggemann, 2014). This motivational component is important, because craved foods are often EDNPs (Martin et al., 2011). Another, more distinguished theory not merely focusing on mechanisms underlying desire, but taking into account mechanisms producing motivated behavior as well, is based on the Grounded cognition theory (Barsalou, 2008).

A Grounded Cognition Perspective

In Grounded cognition theory, the cognitive representation of concepts (e.g., food concept) are grounded in related modal systems (e.g., motor system) (Barsalou, 2008). Grounded cognition suggests that partial reenactment or simulation of earlier perceptual experiences in the relevant modalities is necessary to retrieve information about objects (Barsalou, 2009).

Historically, theories in the cognitive sciences refer to cognitions as amodal and, for example, are not based on modal representations of motor behavior. Former theories had implied that individuals can think about eating in the same way, whether or not they can move their mouth and tongue at that very moment (Dove, 2011). By contrast, the basic idea of the grounded cognition approach assumes thinking about an object is always related to perception and motor behavior. This means humans cannot think about food without simultaneously activating related perceptions, simulating motor behavior related to the stimulus. The mode of thinking is related to the mode of perception and the mode of action. According to the grounded cognition approach, thinking about food, or just reading food-related words, evokes mental eating simulations. This was elegantly demonstrated by Papies (2013), who could show, when participants were asked to list features of random food words (neutral as well as tempting foods), actual eating situations were most often listed compared to any other food features. Papies' (2013) study supports the assumption that simulation of food concepts is grounded in the representation of food.

A theory based on grounded cognition and seen as an extension is called Grounded Cognition Theory of Desire and Motivated Behavior. This theory states, that eating simulations support different forms of cognitive processes, such as high-level perception, attention, working-, and long-term memory, which in turn can lead to desire and consumption behavior (Papies and Barsalou, 2015). Besides motor action, bodily states, settings and various internal states (e.g., emotions, rewards and goals) can be elicited as well. Most interestingly, the theory further relates how food concepts are initially formed and stored in memory networks (situated conceptualization), how they are retrieved and ultimately guide motivated behavior (pattern completion inferences, plus multimodal simulation). Briefly, food concepts, which are integrated into neural networks, are a result of internal states (e.g., cognitive, affective), bodily states (e.g., interoception, taste) and actions (e.g., executive, motoric) during a learning

phase. Multisensory food features, such as tactile, olfactory, visual and gustatory cues, are important to form flavor and ultimately food memories (Krishna, 2012; Spence, 2015a). Cognitive representation of a food category is grounded in related modal systems and produces a memory network storing rewarding eating experiences in a given situation. Food memory is formed as a global representation of the experience that is integrated within different streams of information (situated conceptualization) (Caramazza et al., 2014; Papies and Barsalou, 2015). To retrieve the stored memory, a distributed memory pattern can potentially be cued by any of its associated elements. This can then be re-activated with trigger simulations of these perceptions in the form of eating simulations and vivid mental images. This retrieval activity may thus color the subjective experience of the current situation and the control behavior (e.g., consumption quantity), simulating a real interaction with the food.

1.2.2. An Anecdotal Approach to Mental Imagery

The ability to use mental simulations to re-enact former and anticipate future events, is referred to as mental imagery (Pylyshyn, 2002). A mental image is the experience of visualizing objects, scenes or events, not available to somebody else's senses (Ishai and Sagi, 1995). Individuals are able to form visual mental images as a consequence of explicit instructions, e.g., to imagine eating certain foods (Morewedge et al., 2010). Mental images can also be elicited spontaneously (Paivio, 1969; Petrova and Cialdini, 2005; Elder and Krishna, 2012).

Mental imagery is a memory-based mechanism (Pearson and Kosslyn, 2013). It is described in both scientific and nonscientific literature. For instance, in Ralph Ellison's classic novel *Invisible Man*, in one scene the unnamed protagonist (originally from the Southern part of the

USA), walks down the streets of New York City and inhales the odor of baking yams from a vendor, reminding him of his Southern roots:

"I stopped as though struck by a shot, deeply inhaling, remembering, my mind surging back, back. At home we'd bake them in the hot coals of the fireplace, had carried them cold to school for lunch, munched them secretly, squeezing the sweet pulp from the soft peel as we hid from the teacher behind the largest book, the World's Geography. Yes, and we'd loved them candied, or baked in a cobbler, deep-fat fried in a pocket of dough, or roasted with pork and glazed with the well-browned fat; had chewed them raw - yams and years ago. More yams than years ago though the time seemed endlessly expanded, stretched thin as the spiraling smoke beyond all recall." (Ellison, 2010, Page 202 - 203)

In this example, external cues (the smell of yams) trigger a cascade of vivid intrusions in the unnamed protagonist, manifesting as very vivid mental images. These intrusions are associated with a particular concept of a food memory. This effect is termed *Proust Effect* (Chu and Downes, 2000), named after the famous writer Marcel Proust, who described an emotionally-laden and vivid recollection of a childhood experience. In his novel *In Search of Lost Time* (Proust, 1913), long lost memories were evoked by the simple smell of biscuit soaked in tea (Madeleine, a French specialty). The extent to which vivid intrusions influence behavior depend on how they are elaborated in working memory, as described, e.g., in the EI theory (Kavanagh et al., 2005). However, not only favorable memories, but also aversive memories can be triggered by e.g. orosensory imagery (Toffolo et al., 2012).

1.2.3. Repetitive Mental Imagery and Eating Behavior

One puzzling aspect of mental simulation of food consumption is that it does not necessarily lead to increased and anticipatory consumption of the imagined food, but rather, under certain circumstances, lead to decreased consumption. Research showed, that a decrease in enjoyment and consumption can take place when individuals repetitively judge food (Larson et al., 2014), or imagine eating food (Morewedge et al., 2010).

This phenomenon was first reported in a landmark study by Morewedge et al. (2010), reporting on five separate experiments on the topic. They could demonstrate that consumption of two different food items (M&M's; cheese-cubes) could be reduced after previously imagining food intake (30 repetitions). Participants were asked to imagine eating either 3 or 30 M&M's. A subsequent reduction in consumption could only be observed after 30 repetitions. After the imagery task, participants were allowed to eat M&M's ad libitum in a taste test situation. Participants who imagined eating the 30 M&M's ate less of the product, compared to those who imagined eating only 3 M&M's and to those in a control condition (imagining throwing 3 vs. 30 coins into a laundry machine). The effect was shown to be sensory-specific, meaning that it was only present when the imagined food was congruent with the consumed food. The effect was not evident when the imagined food (e.g., M&M's) was dissimilar to the consumed food (e.g., cheese-cubes) (Morewedge et al. (2010); Experiment 4).

Larson et al. (2014) tapped into the same mechanisms, reporting data from two experiments investigating the effect of repeated sensory evaluation on enjoyment of particular foods. In Experiment 1, they showed that repeated evaluations of visual depictions of food (60 repetitions of food ratings) cause a decrease in liking of a food with similar sensory properties (i.e. all salty). In Experiment 2, they used three interventions (food rating, food choice and brightness rating) prior to rating the overall enjoyment of peanuts. They demonstrated

enjoyment of the target food could only be reduced when the repeated sensory evaluation was not diverted from the attention of the food (e.g., when evaluating the brightness of the food). In other words, individuals' enjoyment could only be reduced when repetitive mental imagery was performed in a taste-focused way. This finding concurs with findings of Morewedge et al. (2010), who also reported no decreased consumption when solely imagining moving M&M's around on a table (Morewedge et al. (2010); Experiment 3).

Given the link between memory processes and simulating prior experience (mental imagery), it is interesting to note that mental imagery can color subjective value (e.g., enjoyment) and influence the motivation for satisfying basic needs (e.g., consumption). As pointed out by both studies in this section, mental imagery effects are sensory-specific (Morewedge et al., 2010; Larson et al., 2014). One possible explanation for the sensory-specific nature of this phenomenon is that habituation processes are involved.

1.2.4. Habituation, Food Consumption and Mental Imagery

Habituation is a very simple form of implicit learning (Schacter, 1987). In general terms, habituation is defined *"as a behavioral response decrement that results from repeated stimulation and that does not involve sensory adaptation/sensory fatigue or motor fatigue"* (Rankin et al., 2009, Page 2). Habituation occurs when the strength of the response decreases with the repeated exposure to a cue (Groves and Thompson, 1970; Epstein et al., 2009).

Translated to food intake, habituation is understood as a process leading to a decrease in both the physiological and behavioral responses to an eating episode, accompanied by a decrease in enjoyment with repeated consumption (Epstein et al., 2009). People habituate to foods in a sensory-specific manner (Rolls et al., 1981; Hetherington, 1996; Havermans and Mallach,

2014). Indeed, research showed that humans tend do habituate to the presentation of the same food with same sensory properties, but this may only be mediated by short-term effects (Thrailkill et al., 2015).

Findings on long-term habituation to complete meals are very controversial. For instance, when presenting individuals with the same food (decrease in food variety) over a short, compared with a longer time span, consumption volume can decrease (Epstein et al., 2011). In their study, Epstein et al. (2011) analyzed temporal effects of exposure to palatable food. For five weeks, they randomly assigned obese and normal weight women (16 individuals per intervention group) to receive a palatable macaroni and cheese meal, presented 5 times either daily for 1 week, or once per week. They found that energy intake was reduced in both obese and normal weight women, when the same food was presented daily, compared to weekly presentations. However, the concept of long-term habituation as a predictor of long-term food intake is a highly controversial concept. As pointed out in a Letter to the Editor in the *American Journal of Clinical Nutrition* by Møller and Köster (2012), boredom with repeated food stimuli may be a more adequate explanation to the results of Epstein et al.'s results (2011). Boredom is a described phenomenon in motivational psychology of eating behavior and can contribute to why new product lines may often fail (Köster et al., 2007). In contrast, increasing the variety of food and therefore sensory pleasure, sensory satisfaction may be a more promising approach to reduce consumption (Møller, 2015). Recent research from marketing research concurs with this idea, showing that individuals who focus on the pleasurable experience of eating (epicurean) prefer smaller portions and demonstrate higher well-being (Cornil and Chandon, 2015a). This finding is totally in contrast to the concept of habituation as proposed by Epstein et al. (2011), who argue that reducing variety (and consequently pleasure) is necessary to decrease food intake.

Another, more mechanistic problem occurs when investigating the disputed mechanism provided by Epstein et al. (2011). Their findings are explained by extending Wagner's connectionist approach to memory called the Sometimes Opponent Processes (SOP) model (1981). According to this memory-based theory, habituation occurs when the presentation of new stimuli is no longer surprising. In other words, information already containing information stored in short-term memory leads to a reduction in stimulus response (Wagner, 1981; Epstein et al., 2009). One main principle of the SOP model is when a stimulus is presented, it is represented in the form of a memory node, which is then activated to a high state of activity (maximally active; the A1 state). Over time, the activity decays, leading to a lower level of activation (processing is more peripheral; the A2 state), and after further decay, such activity becomes inactive (the I state). Information flow is unidirectional from the A1 to A2 to I states. Thus, processing in the other direction (from A2 to A1) cannot occur. During food intake, a switch between a state of maximum activity (A1) to a less active and more peripheral processing state (A2) occurs. The SOP model has been used in other studies as well. As reported by Thrailkill et al. (2015) on several experiments with Wistar rats, variety has illustrated to effect short-term food habituation only, rather than have long-term effects.

The SOP model is a very useful model describing habituation in short-term memory. Extending the model to long-term habituation of eating behaviors may be problematic though, since habituation in humans need self-regulatory resources to occur. Self-regulation and executive functioning (when to start and stop eating) are proposed to share similar resources. In humans, self-regulatory resources are of limited capacity (Baumeister et al., 1998; Baumeister and Alquist, 2009). However, memory mechanisms are easily disrupted by subtle distractors (e.g., the availability of self-regulatory resources). As shown by Wagner and Heatherton (2013), who asked participants to watch a 7-minute nature documentary while preventing reading of words presented at the bottom of the screen (depletion condition), lead

to a reduction in habituation measured as response to emotional pictures (decreased response in brain areas, e.g., the amygdala) (Wagner and Heatherton, 2013). Since self-regulatory depletion already impedes habituation on the level of very basic brain processes (e.g., emotional processing), habituation during vivid and repetitive recall of food intake should decrease when one's individual self-regulatory resources are depleted.

Repeatedly thinking about consuming a certain food can be seen as a simulation of real food intake, without being physically exposed to the food. Simulating eating through mental imagery emulates mental processes engaged in actual eating (Barsalou, 2008; Krishna and Schwarz, 2014), without actual interaction with food.

Aims of Publication #3 & 4

The aim of *Publication #3* was to investigate the effect of repetitive mental imagery on subsequent food consumption. The study aims were twofold. First, we wanted to replicate previous findings of Morewedge et al. (2010) with different numbers of repetitions (18 vs. 36) and with another food item (gummy bears). In Experiment 1, we used a 2 (*number of repetitions*: 18 vs. 36) × 2 (*imagery item*: gummy bears vs. coins) between-subjects design. Secondly, we wanted to understand the role of self-regulatory resources as a prerequisite for habituation to occur. In Experiment 2, we introduced another food item (walnuts) and used a 2 (depletion vs. non-depletion of self-regulatory resources) × 2 (*imagery item*: walnuts vs. coins) between-subjects design. Both studies aimed to further our understanding of the phenomenon of both habituation and self-regulatory processes in eating behavior. To put the findings of *publication #3* into perspective, we drafted an opinion piece on this topic. The article aimed to provide a broader perspective on mental simulation, its effects on judgment, behavior and ultimately, consumption of foods (*publication #4)*.

1.3. Restrictive Health-directed Behavior

Although information about nutrition has never been so easily accessible and transparent in most parts of society; yet nutritional knowledge is only modest among young adolescents in the EU, as reported by the HELENA study consortium (Sichert-Hellert et al., 2011). In contrast, odd beliefs about food and eating practices are widely prevalent. For example, unprocessed foods are assumed to be better for your digestive system, because they seemingly put your stomach to work (Knight, 2012), while milk products, gluten-containing foods and food additives may be unhealthy for your body (Bugge, 2015; Staudacher and Gibson, 2015). Myths and presumptions about obesity and overweight are also highly prevalent (Casazza et al., 2013; Casazza et al., 2015). As a result, restrictive diets[4] have become very popular among large parts of society, especially with the purpose to loose weight and improve physical functions. However, research revealed that restrictive diets are not effective to loose weight in the long-term (Tomiyama et al., 2013; Mann et al., 2015). People who actually are on a diet are associated to have more diet-related health concerns (de Ridder et al., 2014). Data from the follow-up of the Eating Among Teens (EAT-I) longitudinal cohort study (4,746 adolescents) indicate that dieting predicts outcomes related to disordered eating (Neumark-Sztainer et al., 2006). Although studies are rare for dieting on a community level as a whole, rates for men and women (data from the USA) who attempted a diet is estimated at 25-65% (women) and 10-40% (men) (Andreyeva et al., 2010).

In this section, current research on self-regulatory aspects of food intake will be presented. In detail, i) a model of self-regulation in a restrained dieting context, ii) orthorexia nervosa, a special form of health-directed eating, and iii) an overview about health-directed eating behavior, with special focus on gluten-free diets will be presented.

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[4] Excluding foods and food groups (e.g., dairy), special dieting regimen (e.g., paleo diet), or the avoidance of certain food components (e.g., gluten) leads to a reduction of food variety in the diet.

1.3.1. Modeling Self-regulation in a Restrained Dieting Context

Self-regulation allows individuals to make plans for the future, control instant impulses, and regulate appetitive behavior (Heatherton and Wagner, 2011). Successful self-regulation requires a balance between both the strength of a reward cue (e.g., food cue), and the cognitive capacity to track them. Kelley et al. (2015) define three main threats to this balance: i) the exposure to tempting cues (e.g., food, drugs), ii) emotional and social distress, and iii) depletion of self-regulatory resources. Different models have emerged for self-regulation in human eating behavior. In this section, our argument will be constructed within the Boundary Model of the Regulation of eating (Herman and Polivy, 1983).

Herman and Polivy (1983) introduced the boundary model with their seminal work on dietary restraint. According to the boundary model, biological pressures help to maintain food consumption within a specific range. It is designed to help protect against undernutrition and overnutrition (in the long-run) and therefore maintain body weight and physical functions. On one end of the spectrum, processes involved to keeping consumption below a maximum level (e.g., satiation, satiety) lead to meal initiation, while feelings of hunger keep food intake above the minimum threshold of the lower spectrum. Normal food consumption lies between both described boundaries, leading people to start eating when hungry and to stop when satiated (Herman and Polivy, 2005; Herman and Polivy, 2014). Within this *zone of biological indifference,* in which individuals are neither genuinely hungry nor highly sated, other than aversive biological pressures determine food intake (Herman and Polivy, 1983).

In a classic experiment, Herman and Mack (1975) could show that when provided with a high-caloric preload (milkshake), a subset of individuals with high dietary restraint subsequently consumed more food. The explanation for this observed phenomenon was, as a consequence of self-determined *diet boundaries*, counter-regulation was initiated in restrained eaters. Instead of eating less, restrained eaters consumed more. In other words, high levels of

restraint lead to a low boundary (threshold). When transgressing self-set dieting rules, eating is disinhibited in an all-or-nothing manner. Recent research reported by Hofmann et al. (2015) may provide additional data from the field of neuroscience for this phenomenon. In a clinical sample of 34 obese patients and 24 matched healthy controls, timing of early (occipital P100) and late (occipital P300) event-related potentials (ERP) responsible for cortical processing of foods was measured when showing a set of appetizing food images. Hofmann and colleagues (2015) could show that dietary restraint make individuals more vulnerable to visual food-cues in both groups. The more individuals try to restrain their food intake, the more salient the presented food becomes, as visible in higher reactivity patterns. In the context of weight reduction this can be problematic, as most weight reduction programs propagate dietary restraint to achieve weight loss. A more important implication of this study is that dietary restraint increases the vulnerability to food-cues for normal weight individuals, likewise.

1.3.2. Orthorexia Nervosa: obsession with Healthy Eating

Orthorexia nervosa (ON) is a food regimen dedicated to consuming only healthy, pure and mostly unprocessed food (Vandereycken, 2011). The term orthorexia nervosa is derived from the Greek words orthos (=accurate) and orexis (=hunger). ON describes a pathological obsession with healthy nutrition, accompanied by fears and worries about health, eating, and the quality of food. ON is characterized by a restrictive diet, rigid avoidance of certain foods believed to be unhealthy or impure, accompanied by ritualized patterns of eating (Donini et al., 2004). The rigid avoidance of certain foods can lead to abnormal preoccupations with healthy food, demonstrated in significant psychopathological overlappings with other eating disorders (e.g., anorexia nervosa), as well as psychiatric disorders (e.g., obsessive-compulsive disorder, *see Figure 3)*. Besides similarities, there are some marked differences between

eating disorders and ON as well (Brytek-Matera et al., 2015). ON is currently not described as an actual eating disorder, neither in the DSM-5 (APA, 2013), nor in the current version of the ICD-10 criteria (WHO, 1992).

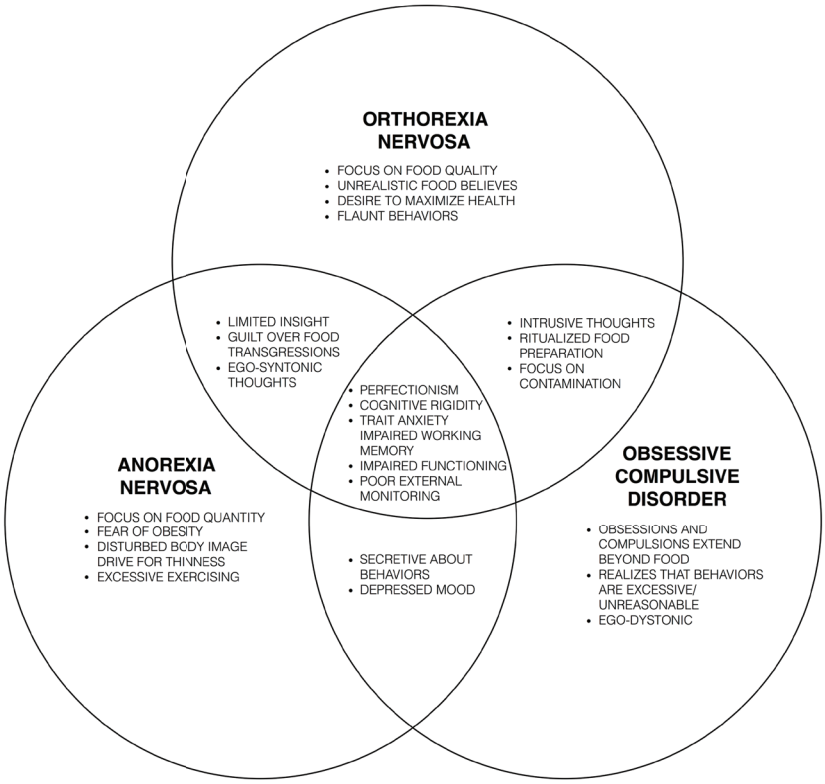

Figure 3. *Venn diagram showing unique and overlapping features of orthorexia nervosa, anorexia nervosa, and obsessive–compulsive disorder (OCD), adapted from Koven and Albry (2015).*

When self-imposed dietary rules are transgressed, intense feelings of anxiety, guilt and shame, followed by more stringent dietary restrictions can lead to a vicious cycle, as shown by a case report from Moroze et al. (2014). In their study, Mr. A, a 28-year-old male patient with a 3-year history of poor nutritional intake, resulting in a 31.75 kg weight loss, is described (BMI = 12.3 kg/m^2). The severely undernourished patient showed metabolic signs of malnutrition (e.g., constipation, bradycardia, osteoporosis, poor dentition, metabolic alkalosis). Mr. A was highly obsessed with the purity and the quality of his diet, referred to broccoli as being a food with magical properties. The patient was not actively psychotic, but showed prominent

orthorectic tendencies and most importantly, was highly confident of his reasoning about food intake (ego-syntonic). This example describes very well a severe form of ON and that the content of thoughts and beliefs about food and eating are perceived as ego-syntonic (Mathieu, 2005; Musolino et al., 2015).

Since first described by Bratman and Knight (2001), major gaps in the literature regarding the assessment tools, epidemiology and pathology of ON have been identified (Varga et al., 2013; Dunn and Bratman, 2016). Since then, ON has been enjoying high popularity in the popular media, while not receiving comparable interest in professional databases (Vandereycken, 2011). Different assessment tools to identify individuals with orthorectic tendencies have been developed. The most commonly used and translated version is the ORTO-15, based on the original Italian version by Donini et al. (2005). However, there is no translated and validated German version available. Although the number of studies on ON are increasing[5], there is still a paucity of documentation in the scientific literature on the assessment of ON.

Aims of Publication #5

In this study, we investigated the assessment tool of ON. The aim of the study was, to i) translate the ORTO-15 Questionnaire and assess the internal validity of the questionnaire, and ii) to reveal major self-reported personality characteristics associated with ON in a highly heterogeneous German-speaking study sample.

[5] Pubmed search hits for search term "orthorexia nervosa": 1999-2010: 11 hits vs. 2011 - 2016: 20 hits (27th of January, 2016).

1.3.3. Health-directed Eating Behavior: a Case for Gluten-free Diet

Reciting and embodying beliefs about food and eating have been argued as unintentional retention of erroneous beliefs (Lilienfeld et al., 2009). However, this reasoning may be too short-sighted, especially in the face of health-directed eating behavior. In fact, beliefs about the healthfulness or harmfulness of lifestyle actions (e.g., food content, eating pattern, physical activity, etc.) are in many cases useful vehicles to obscure disordered eating behavior by tinkering with ascribed health aspects (Musolino et al., 2015).

There are a variety of specialized diets and dieting regimens. One special dieting regimen of growing popularity is called the gluten-free (GF) diet[6]. For patients with diagnosed celiac disease, adhering to a GF diet is not only challenging (Mulder et al., 2015), but currently also the only effective treatment of the disease (Green, 2009). Individuals with celiac disease show high levels of intestinal inflammation when exposed to foods containing gluten (Ludvigsson et al., 2013). In western countries, celiac disease occurs in approximately 1% of the population (Gujral et al., 2012). The prevalence rates in Europe vary between countries; e.g., from 0.3% (Germany) to 2.4% (Finland) (Mustalahti et al., 2010).

Adhering to a GF diet has become very fashionable among a large group of individuals without diagnosed celiac disease (Mardini et al., 2015). This is indicated by increased sales of GF products world-wide (Strom, 2014). A cross-sectional study (n=1184) conducted in Australia reported that 79.3% of consumers who avoided wheat-based products did so to help relieve symptoms such as bloating or abdominal pain (Golley et al., 2015).

Foods containing gluten are mostly staple foods based on cereals (e.g., pasta, bread). To assist patients with celiac disease in their dietary choices, food companies have reformulated products originally based on wheat, rye and barley to create similar food without gluten.

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[6] Gluten: a mixture of proteins (glutenins, prolamines) associated lipids, and soluble and unsoluble pentosanes which are important for dough forming (Belitz et al., 2009).

Although some sensory and food characteristic problems arise in the formulation of these foods, in general, product quality has become suitable to replace traditional cereal-based products (Pellegrini and Agostoni, 2015). However, reports indicate that GF products may have some disadvantage in nutritional qualities (Miranda et al., 2014; Mazzeo et al., 2015), as well as higher product cost (Singh and Whelan, 2011; Kulai and Rashid, 2014). As pointed out by Wu et al. (2015) in a study of a large dataset of food products (n=3213), GF products do not provide additional health benefits, compared with their gluten-containing counterparts by means of the newly established *Health Star* rating in Australia. This finding is in contrast to consumer expectations (consumers without medical need) and purchase motivations to buy GF products indicating health concerns as primary reason for purchase (Dunn et al., 2014; Golley et al., 2015). One important implication recently outlined by Staudacher and Gibson (2015), is that, for individuals without diagnosed celiac disease, following a diet avoiding GF foods may bring some negative consequences:

Table 1. *Identified risks associated with a gluten-free diet in the absence of celiac disease, adapted from Staudacher and Gibson (2015).*

Identified Risk	**Explanation**
monetary cost	higher costs for GF foods compared to gluten-containing counterparts
impaired dietary palatability	reduced palatability of GF foods. Sensory characteristics often not in accordance with gluten-containing counterparts (e.g., bread)
interference with appropriate medical care	self-diagnosed celiac disease and adhering to a GF diet may delay attending proper medical assessment
social consequences	restrictive dieting can lead to difficulties when eating out or in the homes of friends
risk of an eating disorder	restrictive dieting as result or beginning of disordered eating
nutritional inadequacy	restrictive dieting as possible risk for nutritional deficiency

From a nutritional perspective, not all negative consequences outlined above may be of relevance *(Table 1)*. For instance, nutritional deficiency may be far-fetched without knowing the complete dietary history of individuals. While those Individuals without celiac disease may not entirely consume processed GF foods in their diet, but just partially choose GF foods as alternative food choices. However, the concerns outlined by Staudacher and Gibson (2015) are relevant in the sense, that beliefs about the healthfulness of foods or food components are relevant for food choice and ultimately consumption pattern.

Aims of Publication #6

Gluten-free products have become increasingly popular, mainly due to consumers perception of GF being healthier than gluten-containing counterparts. To put GF products into the proper perspective, the aim of this study was to investigate the nutritional quality and product cost for GF foods available in Austrian supermarkets, to i) provide a thorough database for patients with celiac disease and ii) to contribute to the analysis of nutrient content and price range of GF products.

1.4. Thesis concept

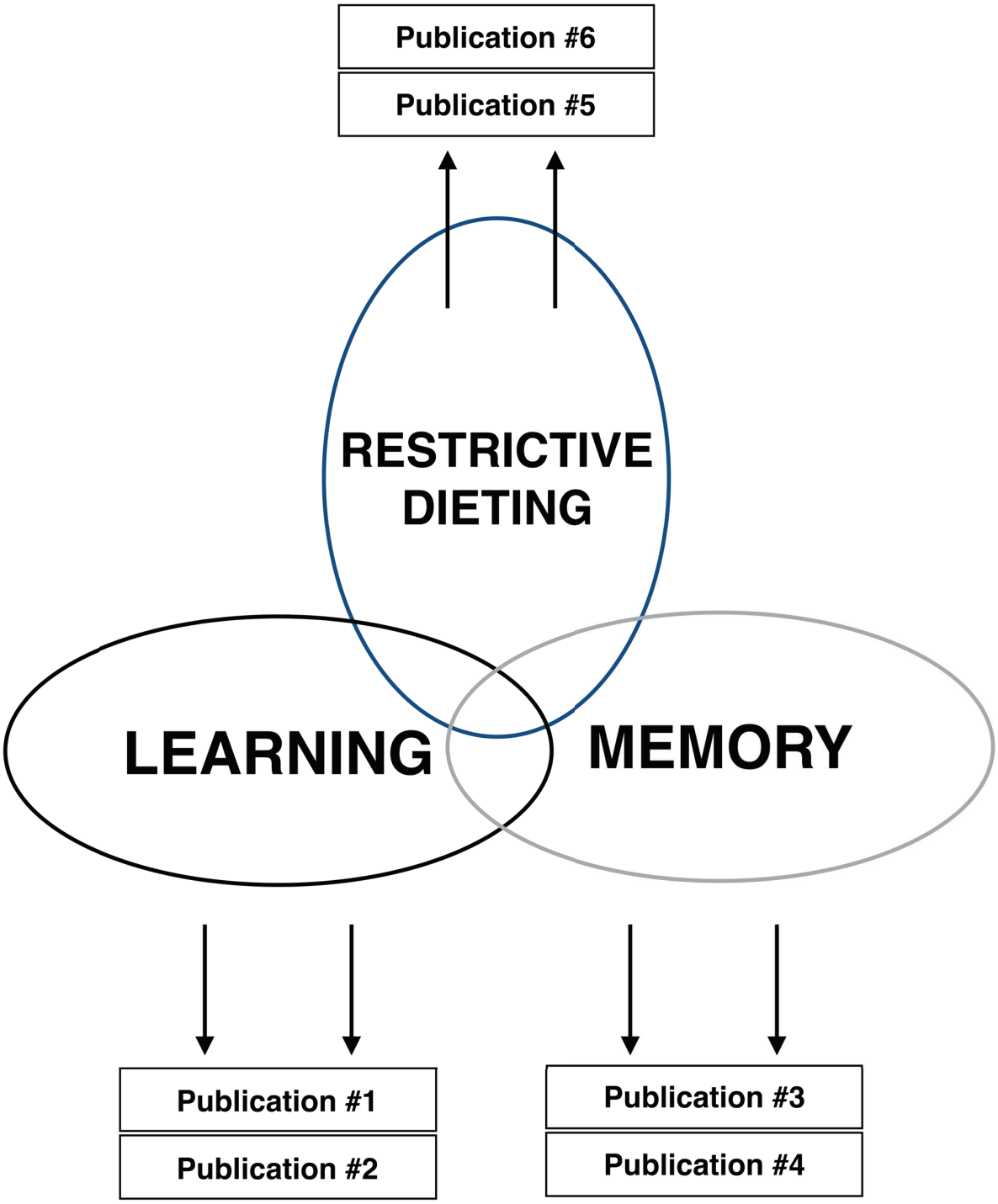

Figure 4. *Schematic concept and overview of the thesis.*

2. RESULTS

The results section represents all articles summarized in the form of the original abstract/ summary, except for *publication #4 (*there is no abstract available, please see Appendix B). For all articles mentioned in the results section the author set the aims, conducted the analyses and wrote the articles as first author in mutual agreement with his supervisor. All articles have been accepted for publication between 10/2014 - 10/2015.

2.1. Publication #1

Title	Inverting the pyramid! Extent and quality of food advertised on Austrian television
Authors	Benjamin Missbach, Adelheid Weber, Elke Huber, Jürgen König
Year	2015
Citation	BMC Public Health 15 (1): 910
DOI	10.1186/s12889-015-2275-3

Abstract

Background: Research showed that food marketing for children frequently contradicts national dietary guidelines. Children, unlike adults, are not able to understand the persuasiveness of the advertisements with its short- and long-term effects on health, thus the common international tenor is to restrict food marketing. In the European Union, marketing restriction based on self-regulation have been initiated (EU Pledge Nutrition Criteria). The study aims contribute to depict the status quo of television advertisement targeted at children before the pledged initiative came into full effect.

Methods: In this study we analyze the quality and displaying frequency of a set of advertisements targeted at children broadcasted on Austrian television. Promoted food products targeted at children or adults were identified. Category-based analysis of the displayed food was performed based on the Austrian Nutrition guidelines (number of displayed food per food category). The children's food content was analyzed according to the newly established nutritional quality criteria for advertised food in the EU to assess the nutritional quality of the depicted food.

Results: In total, 360 h of video material was recorded in February and March 2014. A set of 1919 food advertisements, with 15.1% targeted at children were broadcasted. Of all food

advertisements targeted at children, 92.4% was for fatty, sweet and salty snacks, while no advertisements for vegetables, legumes or fruits were shown. From all food advertisements for children, 65.9% originated from participating companies of the EU Pledge Nutrition Criteria. Further analysis revealed that 95.9% of the advertised food for children showed at least one aspect of nonconformity with the EU Pledge Nutrition Criteria; on the contrary 64.7% of the displayed food advertisement also featured at least one desirable food component (e.g., high fibre content, high protein content).

Conclusions: The present research suggests that the majority of advertised food for children do not conform with the pledged criteria as defined in the EU Pledge Nutrition Criteria and almost all advertisements would be prohibited. We discuss our findings in the context of public health nutrition and present a perspective for future directions in this important field of research.

2.2. Publication #2

Title	Food advertisement and gender stereotypes on Austrian television
Authors	Benjamin Missbach, Siegfried Allemann, Elke Szalai, Jürgen König
Year	2015
Citation	Ernährungs Umschau 62 (4), 59-65
DOI	10.4455/eu.2015.011

Summary (no abstract available)

The goal of this paper is the analysis of food advertisements on Austrian television as to the subject of gender specific stereotypes. Over a two week- period, 45 hours of television footage were recorded, coded, analyzed, and evaluated using seven screening categories. The analysis revealed that men, in comparison to women, are frequently depicted as performing some type of work and are often older (> 50 years), or of middle age (35–50 years of age). Food, such as meat and beer, are more commonly associated with men; milk, coffee and tea rather with women. In addition, women are often portrayed as young (< 35 years of age), in stable relationships and shown while performing housework. As a result, gender manifestations are evident in food advertisements and implications regarding stereotypical role models referring to dietary identities and food communication can be derived.

2.3. Publication #3

Title	Mental imagery interventions reduce subsequent food intake only when self-regulatory resources are available
Authors	Benjamin Missbach, Arnd Florack, Lukas Weissmann, Jürgen König
Year	2014
Citation	Frontiers in Psychology 5: 1391
DOI	10.3389/fpsyg.2014.01391

Abstract

Research has shown that imagining food consumption leads to food-specific habituation effects. In the present research, we replicated these effects and further examined whether the depletion of self-regulatory resources would reduce the habituation effects of imagined food consumption. Since self-regulatory resources have been shown to reduce habituation effects during the perception of emotional stimuli, we expected a reduction in habituation effects from imagined food consumption when self-regulatory resources were depleted. In Study 1, we replicated habituation effects as a response to imagining gummy bear consumption with a high (36) and medium number (18) of repetitions in a camouflaged taste test. Participants imagining gummy bear intake showed decreased food intake compared with participants who imagined putting a coin into a laundry machine. The number of repetitions did not significantly moderate the observed habituation effect. In Study 2, we investigated whether self-regulatory depletion would impede habituation effects evoked by the imagination of walnut consumption. Participants in a depleted state did not show a reduction in food intake after imagining walnut intake compared with participants in a non-depleted state. We discuss directions for future research and processes that might underlie the observed moderating effect of self-regulatory resources.

2.4. Publication #4

Title	Mental imagery and food consumption
Authors	Benjamin Missbach, Arnd Florack, Jürgen König
Year	2015
Citation	Frontiers in Psychology 6: 48
DOI	10.3389/fpsyt.2015.00048

Opinion Article, no abstract available.

2.5. Publication #5

Title	When Eating Right, Is Measured Wrong! A Validation and Critical Examination of the ORTO-15 Questionnaire in German
Authors	Benjamin Missbach, Barbara Hinterbuchinger, Verena Dreiseitl, Silvia Zellhofer, Carina Kurz, Jürgen König
Year	2015
Citation	PLoS ONE 10 (8): e0135772
DOI	10.1371/journal.pone.0135772

Abstract

The characteristic trait of individuals developing a pathological obsession and preoccupation with healthy foods and a restrictive and avoidant eating behavior is described as orthorexia nervosa (ON). For ON, neither universal diagnosis criteria nor valid tools for large-scale epidemiological assessment are available in the literature. The aim of the current study is to analyze the psychometric properties of a translated German version of the ORTO-15 questionnaire. The German version of the ORTO-15, a eating behavior and dieting habits questionnaire were completed by 1029 German-speaking participants (74.6% female) aged between 19 and 70 years (M = 31.21 ± 10.43 years). Our results showed that after confirmatory factor analysis, the best fitting model of the original version is a single-factor structure (9-item shortened version: ORTO-9-GE). The final model showed only moderate internal consistency (Cronbach's alpha = .67), even after omitting 40% of the original question. A total of 69.1% participants showed orthorectic tendencies. Orthorectic tendencies are associated with special eating behavior features (dieting frequency, vegetarian and vegan diet). Education level did not influence ON tendency and nutritional students did not show higher ON tendency compared to students from other disciplines. This study is the first

attempt to translate and to evaluate the psychometric properties of a German version of the ORTO-15 questionnaire. The ORTO-9-GE questionnaire, however, is only a mediocre tool for assessing orthorectic tendencies in individuals and shows moderate reliability and internal consistency. Our research suggests, that future studies are needed to provide more reliable and valid assessment tools to investigate orthorexia nervosa.

2.6. Publication #6

Title	Gluten-free food database: the nutritional quality and cost of packaged gluten-free foods
Authors	Benjamin Missbach, Lukas Schwingshackl, Alina Billmann, Aleksandra Mystek, Melanie Hickelsberger, Gregor Bauer, Jürgen König
Year	2015
Citation	PeerJ 3: e1337
DOI	10.7717/peerj.1337

Abstract

Notwithstanding a growth in popularity and consumption of gluten-free (GF) food products, there is a lack of substantiated analysis of the nutritional quality compared with their gluten-containing counterparts. To put GF foods into proper perspective both for those who need it (patients with celiac disease) and for those who do not, we provide contemporary data about cost and nutritional quality of GF food products. The objective of this study is to develop a food composition database for seven discretionary food categories of packaged GF products. Nutrient composition, nutritional information and cost of foods from 63 GF and 126 gluten-containing counterparts were systematically obtained from 12 different Austrian supermarkets. The nutrition composition (macro and micronutrients) was analyzed by using two nutrient composition databases in a stepwise approximation process. A total of 63 packaged GF foods were included in the analysis representing a broad spectrum of different GF categories (flour/bake mix, bread and bakery products, pasta and cereal-based food, cereals, cookies and cakes, snacks and convenience food). Our results show that the protein content of GF products is > 2 fold lower across 57% of all food categories. In 65% of all GF foods, low sodium content was observed (defined as < 120 mg/100 g). Across all GF

products, 19% can be classified as source high in fiber (defined as > 6g/100 g). On average, GF foods were substantially higher in cost, ranging from +205% (cereals) to +267% (bread and bakery products) compared to similar gluten-containing products. In conclusion, our results indicate that for GF foods no predominant health benefits are indicated; in fact, some critical nutrients must be considered when being on a GF diet. For individuals with celiac disease, the GF database provides a helpful tool to identify the food composition of their medical diet. For healthy consumers, replacing gluten-containing products with GF foods is aligned with substantial cost differences but GF foods do not provide additional health benefits from a nutritional perspective.

3. DISCUSSION

The Discussion section gives a short summary of the main findings of the presented studies. and for each publication, strengths and limitations are reported and discussed within the context of the current literature. At the end of this section, generic limitations are listed.

3.1. Main findings, strengths and limitations (Publication #1)

In *publication #1*, we analyzed television food advertisements targeted at children < 12 years. In detail, we analyzed the quality of advertised food in a large dataset (360h, 1919 food advertisements). From all advertisements, 15.1% were targeted at children, 92.4% was for fatty, sweet and salty snacks, while no advertisements for vegetables, legumes or fruits were shown. The main finding of this study ascertained food advertisements directed at children were in contrast to current dietary recommendations for Austria. Interestingly, fatty, sweet and salty snacks were more frequently displayed for children (17 fold), compared to adults. Secondly, the displayed foods did not conform to proposed guidelines for children's food advertisement of the EU Pledge Nutrition Criteria.

- The main results of the quality of displayed foods are very well in line with other studies investigating food advertisements targeted at children (Chapman et al., 2006; Wilson et al., 2006; Keller and Schulz, 2011; Huang et al., 2012; Gunderson et al., 2013). Additionally, the two-step approach in the presented study added data of how the displayed foods fit into self-regulation guidelines in the EU. Marketing regulation is a highly complex (political) issue; 20 companies are responsible for at least 80% of the television food marketing in the EU's self-regulatory and voluntary initiative which has pledged to implement the suggested guidelines by December 31st, 2014. The study was

conducted prior to its full implementation, therefore a baseline comparison for monitoring the effect of the regulation is provided as a starting point for further studies.

- Initiatives based on self-regulation of food marketing have repeatedly been reported to be only moderately effective. Potvin-Kent et al. (2014) reported data from a preliminary and post-implementation study evaluating the self-regulatory Children's Food and Beverage Advertising Initiative in Canada (2006-2011). The authors concluded that although the volume of aired advertisements for children decreased by -24%, the quality of the advertised food also decreased (foods classified as less healthy +47% for children; +161% for teenagers). However, the applied profiling scheme is of importance. Scarborough et al. (2013) reported, that depending on the applied profiling scheme on a large dataset of television advertisements targeted at food, a range from banning 2.1% (CI: 0.4%; 3.7%) to almost half of the advertisements 47.4% (CI: 42.1%; 52.6%) should have been performed. This finding demonstrates the heterogeneity among the worldwide used profiling schemes. However, the EU Pledge Nutrition Criteria employs a dual strategy to promote healthy components as well, so one important aspect is that foods with positive health components should be encouraged and marketed (e.g., high fiber and protein content). In our study, < 30% of the displayed foods contain components to be encouraged, which points to the fact that current television marketing activity in accordance with the EU Pledge Nutrition Criteria is only of mediocre success (in Austria).
- The EU Pledge Nutrition Criteria was launched in 2007 as part of the EU Platform for Action on Diet, Physical Activity and Health (EU Commission, 2005) resulting in a guideline published in 2012 and updated in July 2015 (EU Pledge Nutrition Criteria, 2015). The most recent self-monitoring report for the EU Pledge Nutrition Criteria implementation concludes that for television advertisements, the overall compliance rate is 98.5% and most websites (97%) are compliant with the pledged criteria. However, this

self-monitoring report is highly opaque and does not align with proper scientific standards (e.g., does not provide detailed methodological approach; does not provide proper statistics; does not provide stratified data on individual food groups; does not provide data or datasets) (EU Pledge Report, 2014). Therefore, additional independent studies to monitor the compliance of companies with the self-administered pledged criteria are needed in the future.

Strengths and Limitations

The presented study holds strengths as well as limitations. First, we did not screen for seasonal differences and the data were assessed in the spring of 2014 (February - March 2014). Secondly, our cross-sectional study design is limited to a mere descriptive level. This approach describes the nutritional quality and the extent of the advertised products, but falls short when explaining the behavioral effects of television advertisement. However, behavioral studies on the effect of television advertisements (especially targeted at children) showed short-term (Halford et al., 2008; Harris et al., 2009), long-term effects on food choice (Aktas Arnas, 2006; Fiates et al., 2008) and ultimately, indicated long-term effects on obesity as well (Boulos et al., 2012). Engagingness of what is being watched (television content) is relevant for short-term effects of energy intake (Chapman et al., 2014; Mathur and Stevenson, 2015) and in addition, cumulative exposure to food advertisement shapes food choice and eating behavior. As reported by Scully (2012), adolescents with frequent advertisement exposure (television viewers; > 2h/day vs. < 2h/day) were more likely to self-report EDNP food consumption. They reported increased odds ratios for fast food (OR 1.31; CI 1.10-1.57) and for sweet snacks (OR 1.91; CI 1.60-2.27).

3.2. Main findings, strengths and limitations (Publication #2)

To gain more insight into the current food environment, we analyzed television food advertisements in a gender context and could show that gender stereotypes are highly prevalent on television *(Publication #2)*. The main finding of this study was that men are more frequently depicted as older (> 50 years) or of middle age (35-50 years of age), while women were more often shown as younger (< 35 years). This finding is accompanied by how women are depicted: women were more frequently shown in stable relationships and while performing some sort of housework. This was contrasted by how men were depicted: men were more often shown in working situations (e.g., as an employee). We analyzed the depicted food items and could show that products like meat and beer were more often displayed for men, while milk, coffee and tea were more frequently shown for women.

- The role of modern media (e.g., television, internet, gaming) as part of nutrition education is increasingly important (Baranowski and Frankel, 2012). Food advertisements convey values and norms. Research investigating gender stereotypes in food advertisements are scarce. However, they paint a similar cross-cultural picture: common gender stereotypes are prevalent in food advertisements (Aronovsky and Furnham, 2008; Furnham and Li, 2008; Espinar Ruiz and González Díaz, 2012). The present finding fits well into the current literature how women and men are depicted in advertisement in the modern media (Holtzman and Sharpe, 2014). In Austria, a societal debate on gender traversed other topics, more prominently (e.g., national anthem re-writing; wage equity for men and women, gender equity for management appointments), but gender and food is of importance from a scientific and marketing perspective.
- Secondly, marketers are responsible for the content of the displayed food. As reported, products like meat and beer are more often shown for men than for women in our dataset.

One very powerful example of stereotyping in food advertisement is the so-called *Pizza-Burger* which is sold as a hybrid food between pizza packed into the form of a Hamburger (Dr. Oetker, 2014). In this spot, two rather childish men are displayed waiting for their meal and observed by their two girlfriends. As the spot continues, the speaker of the advertisement (very low and manly voice) explicitly describes the targeted consumer group: "*for all, for whom salad is only table decoration; for all, for whom water is just for swimming and for all, for whom knife and fork is just kids stuff.*" The speaker continues with the last sentence: "*for you, who do not have appetite, for you who are hungry",* then the two protagonists enjoy the meal on the couch and the salad (arugula) formally displayed as table decoration is thrown away. This exemplifies how several layers of stereotyping are related, but most importantly, it describes men's eating behavior as hedonic, high-caloric and full of pleasure (Beardsworth et al., 2002). Men's eating practices are a construct of socio-cultural articulation of masculinity roles as described in the literature (Newcombe et al., 2012). Marketers may perpetuate classical gender roles transported via the articulation of masculinity in food advertisements.

- Self-perception of individual's gender identity (gender expression) is relevant for health behavior and body weight (Bryn Austin et al., 2016). Media messages transporting masculinity and femininity mold perceptions of gender identity through what is called *gender transformative programming* (Barker, et al. 2007; Barker et al., 2010). The presented study increases the knowledge of how men and women are depicted in food advertisements and transport gender identities that contribute to the perception of gender expressions and ultimately health-related behaviors.

Strengths and Limitations

The presented study holds strengths as well as some limitations. One strength is that the analysis is based on a well-established coding scheme by McArthur and Resko (1975). Additionally, we analyzed the involved characters and displayed foods simultaneously, providing a complete picture of the advertisements. However, we only analyzed a certain set of advertisements within a dedicated timeframe (April-May 2014). Seasonal differences were not taken into account in the presented study and we investigated food advertisements on television exclusively and did not include other media segments (e.g., online marketing, radio marketing and billboard advertisement). Food advertisement on television is only one part of food marketing, but in other media, gender stereotypes have also been identified (Gauntlett, 2008). Although the presented study holds several limitations, the depiction of actors, settings and roles stratified by gender showed that *doing gender* in food commercials on Austrian television perpetuate gender stereotypes.

3.3. Main findings, strengths and limitations (Publications #3 & 4)

In *publication #3*, we found results with important implications for mental imagery research in the eating domain. First, we could show that other items besides M&M's and cheese cubes can be used in this paradigm (in study 1: gummy bears; in study 2: walnuts). Decreased consumption did not differ based on the perceived healthfulness of the target food (e.g., walnuts are generally perceived as healthier than M&M's). Secondly, we could replicate the effect from Morewedge et al. (2010) and observed a reduction in actual food intake, ranging from 20 - 25% from repeatedly visualizing food intake. The number of repetitions (18 vs. 36) did not moderate subsequent food intake (study 1), but depleting self-regulatory resources in participants eradicated the effect and did not decrease subsequent consumption (study 2).

In *publication #4*, we discussed our findings in the context of consumption judgments and eating behavior and its possible clinical relevance (e.g., mindfulness approaches). Research of mental imagery and mindfulness may help understand eating behavior and in a clinical sense, designing personalized interventions targeting problematic eating behaviors.

- Morewedge et al. (2010) reported that simulating food intake can reduce subsequent consumption only when the number of repetitions are relatively high (30 repetitions). With a low number of repetitions (3 repetitions) no effect is visible. However, in our study *(Publication #3, study 1)* we did not find an interaction effect between the number of repetitions (18 vs. 36) and the imagined item (gummy bears vs. coins), $F\ (1, 95) = 0.51$, $p = 0.47$. Currently, there are no other studies investigating the effect using a comparable paradigm. Based on the results of this study, we cannot clearly state the number of repetitions necessary for reducing consumption. Further studies are needed to narrow down the number of repetitions.

- The expected satiating effect of foods influences how individuals perceive satiety for subsequent meal intake (Brunstrom et al., 2011; Brunstrom et al., 2012) and e.g., ghrelin response (Crum et al., 2011). Even more striking is that mental imagery reduced subsequent food intake, although participants' expectations about the effect were in complete contrast with the observed effect. 90% of the participants indicated that imagining gummy bear intake might stimulate their appetite, 8% reasoned that thinking about food intake might decrease their appetite, and 2% assumed that it might have no effect on their appetite. After excluding those participants who reasoned that simulating gummy bear intake would decrease their appetite (8 participants), sensitivity analysis still showed a significant main effect of the imagery task *(Publication #3, study 1)*.
- Food images can influence a variety of physiological and psychological changes. For instance, pre-cephalic salivary release (Wooley and Wooley, 1973; Spence, 2011), anticipatory insulin (Wallner-Liebmann et al., 2010), or total plasma ghrelin (Schüssler et al., 2012) as response to food images. Recently, Spence and colleagues (2015b) speculated that increased exposure to desirable food images (e.g., via digital media) might exacerbate the desire for food, thus leading individuals to eat more. Spence and colleagues (2015b) call this concept *visual hunger*. Exposure to food cues might lead to *visual hunger* induction, which is plausible from an evolutionary perspective (Pinel et al., 2000). However, overstimulation can also induce satiation via voluntary simulation of food intake (Morewedge et al., 2010), or by way of repeated evaluations of food images (Larson et al., 2014). The availability of self-regulatory resources might play a role in this discrepancy.
- Our finding that individuals with depleted self-regulatory resources could not habituate to the imagined food, points to the fact that self-regulatory resources are necessary for food habituation to occur when it comes to mental imagery processing *(Publication #3, study*

2). Assumingly, working memory is a system with limited cognitive capacity (Cowan, 2010), and according to Wagner's SOP Model, depleting self-regulatory resources should not result in a reduction of food consumption because habituation to the food cannot occur. We argue that habituation to a target food occurs only when these resources are available (in this particular mental imagery paradigm). If cognitive resources were intact, reduced consumption (M = 29.62 g, SD = 7.53 g vs. M = 35.49 g, SD = 7.53 g) could be observed F (1, 39) = 6.26, $p < 0.05$, $\eta_{2p} = 0.14$. That is to say, the switch from A1 to the A2 state occurs, and food intake should be reduced *(Publication #3, study 2)*.

- Repetitive thoughts about food consumption are not the only way to reduce the desire to consume a particular food. Of importance is also *how* individuals think about food and eating. In a cross-national study (France; USA), Cornil and Chandon (2015b) could show that multisensory imagery interventions led hungry and non-dieting participants to choose i) smaller food portions; ii) anticipate greater eating enjoyment; and iii) were willing to pay more for their food. In their interventions, participants were asked to vividly imagine eating familiar hedonic foods and focus on the multisensory pleasure the food gives them (e.g., taste, smell, texture). They could show imagery based on multisensory and hedonic experience helps them anticipate greater sensory pleasure from smaller portions (Cornil and Chandon, 2015b). From a food marketing perspective, this finding is interesting, because it puts qualitative above quantity characteristics of foods as determinants for pleasure and consumption. Mental imagery (in this case multisensory imagery) accompanies this effect.
- Mental imagery approaches have been used in clinical settings, especially as an integral part of mindfulness-based cognitive behavioral therapy (MB-CBT) (Kristeller et al., 2006). Research on mindful attention revealed that impulsive tendencies to approach food (Papies et al., 2012) and promoting healthy food choices (Papies et al., 2015) could be

influenced by mindfulness techniques. In addition, mindful attention to thoughts about food consumption were shown to reduce obesity-related eating behaviors (e.g., binge eating, emotional eating and external eating) (O'Reilly et al., 2014). For instance, a systematic review and meta-analysis investigating the effect of mindfulness-based interventions in patients with binge-eating disorder, reported a large (within-group random effects mean Hedges' g = -1.12; 95 % CI -1.67, -0.80; k = 18) or medium-large effect (between-group mean Hedges' g = -0.70; 95 % CI -1.16, -0.24; k = 7) to reduce binge eating symptoms with mindfulness-based interventions (Godfrey et al., 2015). However, our research showed that for mental imagery to be effortfully implemented, self-regulatory resources are necessary, which may also be important when designing effective strategies and new interventions around a cognitive profile towards weight reduction strategies (Jansen et al., 2015).

Strengths and Limitations (publication #3)

The presented study holds several strengths as well as limitations *(publication #3)*. First and most importantly, we cannot rule out the possibility that participants could not properly perform the imagery task after the self-regulatory depletion induction. The ego-depletion paradigm is a well used dual-task paradigm in which the performance of a second self-control task is compromised (Hagger et al., 2010). We did not assess this in our study *(Publication #3, study 2)*, so whether or not the participants were able to perform the mental imagery task properly or were too exhausted to complete, cannot be ruled out. Secondly, in both studies *(Publication #3, study 1 & study 2)* we did not assess physiological measures (e.g., salivation, skin conduction, hormonal response reaction) that would further elucidate the observed effect. Understanding physiological correlates as response to mental imagery, interventions should be addressed in future research in this field. However, compared to other studies using similar

interventions (Larson et al., 2014), we could show a reduction in actual food intake ranging from 20 to 25%, rather than self-reported data in rating scales.

3.4. Main findings, strengths and limitations (Publication #5)

In *publication #5*, we report results from an analysis of a newly described health-directed eating behavior called orthorexia nervosa (ON). We report data from the translated German version of the original ORTO-15 questionnaire. We validated this version with a large online panel (1029 participants). After confirmatory factor analysis (40% of the original questions had to be deleted), the final model of the questionnaire (ORTO-9-GE) was of mediocre quality. Further analysis of the self-reported behavioral and eating behavior questions showed high orthorectic tendencies are associated with special eating behavior features. As such, dieting experience and self-reported food intolerances are associated with higher ON tendencies. Additionally, individuals with current eating disorders score lower on the ORTO-9-GE questionnaire (higher ON tendencies).

- Currently, there are two validated questionnaires available in German to assess ON on a population level. The 10-item questionnaire (DOS: Düsseldorfer Orthorexia Scale (Barthels et al., 2015) and the 9-item ORTO-9-GE. Even though the 10-item DOS shows better internal validity (Cronbach's alpha = .84) compared to the ORTO-9-GE (Cronbach's alpha = .67), there are some major aspects missing in both questionnaires. First, behavioral characteristics overlapping with other eating disorders (e.g., anorexia nervosa, bulimia nervosa) are missing. Behavioral overlapping on a neuropsychiatric level has been demonstrated before (Koven and Senbonmatsu, 2013), but still need to be replicated and may be key to describing ON. Findings from this line of research could be added to already existing assessment tools. Secondly, no information about the quality and quantity of the consumed foods is prompted in both questionnaires. Research in this area is of importance, because to date no studies explicitly report data from e.g., FFQ or other validated measures in individuals with ON. An in-depth analysis of what individuals with

ON actually eat (and avoid) would increase our knowledge about ON. However, this may be influenced by cultural differences, nevertheless, cross-cultural similarities should be prevalent (e.g., low-caloric, low-fat, low-sugar, pure foods, gluten-free).

- Besides the methodological aspect, our data also provide relevant points to be discussed. First, we found that individuals on a vegan or vegetarian diet showed higher ON tendencies, compared to individuals who report a mixed-diet (omnivores). For vegans, some nutrients may be critical in their diet (e.g. iron, calcium, B-vitamins), therefore it is important to know key aspects of some foods to provide adequate nutrients for the body. Therefore, being on a vegan diet requires a fair degree of cognitive processing (e.g., self-discipline, planning, comparing nutritive values of foods). Health aspects have been identified as main motives for a vegetarian and vegan diet (Fox and Ward, 2008). Furthermore, participants who already tried 3-5 diets (or > 6 diets), compared to individuals with no dieting experience, showed increased ON tendencies. Most diets are accompanied by restrictive food intake and represent an important predictor of ON tendencies. This finding is consistent with previous research (Arusoğlu et al., 2008; Varga et al., 2014).

Strengths and Limitations

The presented study *(Publication #5)* holds several strengths, but also some limitations. Dietary patterns influences behavior and health in a reciprocal fashion; therefore the direction of the association may never be fully derived and is inherently buried in the used methodology. This general phenomenon is not something particular in the case of the presented study, but is very common in nutrition research, that have led to a variety of implausible results associating nutrition and health aspects in nutritional epidemiology (Ioannidis, 2013). One additional limitation of the study is that we do not report observational

data, but base our analysis on self-reported data. In some categories self-reporting has been shown to produce biased results; e.g., underreporting weight and height (Elgar et al., 2005). However, studies about ON are rare at this point and research analyzing the quality of commonly used methods is necessary to further our understanding of ON.

3.5. Main findings, strengths and limitations (Publication #6)

In *publication #6*, to provide a comprehensive picture about GF foods, we investigated the quality and cost of gluten-free (GF) products available in Austrian supermarkets. First, we analyzed the nutrient content of a set of GF products from seven different food categories (63 GF products) and compared the data with a set of gluten-containing foods (126 gluten-containing products). Additionally, we collected price data of the analyzed foods. The main findings of the study were twofold. First, we could show that GF products do not provide additional health value from a nutritional perspective. While in most nutrient categories, no differences between GF and gluten-containing products were present, on the contrary, some critical nutrients could be identified (e.g., protein content GF products > 2 fold lower in GF products across 57% of all food categories). The second main finding is that GF foods were substantially higher in cost, ranging from +205% (cereals) to +267% (bread and bakery products), compared to similar gluten-containing products.

- Our study builds on mounting evidence about the nutritional quality of GF foods. Research showed that GF foods contain different critical nutrients (Miranda et al., 2014; Mazzeo et al., 2015; Wu et al., 2015). However, compared to previous research (Matos Segura and Rosell, 2011; Kulai and Rashid, 2014; Miranda et al., 2014) we did not find differences in total fat, saturated fat, PUFA and MUFA. A recent review by Pellegrini and Agostoni (2015) on the nutritional characteristics of GF products identified relevant micro and macronutrients which should be improved (e.g., low content of iron, calcium and B-vitamins). They concluded that several (technological) strategies should be implemented to improve GF products to make them nutritionally more valuable and increase the sensory acceptability for consumers. This is seemingly of great interest for individuals in need (celiac patients) and to companies that produce GF foods.

- Marketing data from the USA suggest that approximately 30% of consumers who buy GF products do so for *good health* (National Purchase Diary Report, 2013), although this may come with a higher price tag. One important implication of this study is that consumers' motivation (perceived healthfulness) to buy GF products (other than patients with celiac disease) is in contrast with the actual nutritional value that can be provided by GF foods. Furthermore, GF products are highly processed food products with special formulation and production processes.
- One important aspect of this study is that restrictive dieting (excluding food products due to perceived health or unhealthfulness; e.g., gluten) may be accompanied by several pitfalls (Staudacher and Gibson, 2015). Besides interference involving appropriate medical care, the risk of exclusion diets may result in the beginning or encourage existing eating disorders. Musolino et al. (2015) reported how a contemporary understanding of *healthism* is embodied in daily eating practices of Australian women with disordered eating (assessed with the Eating Disorder Examination questionnaire). The authors report how 25 women rationalize and accomplish their eating and health regimen (age: 19-52 years, 75% with Eating Disorders Not Otherwise Specified (EDNOS). The authors applied grounded theory principles in mixed-methods ethnographic field work to investigate how participants embody their *health habitus*. The term *health habitus* reflects on how individuals' personified experiences structure their daily lives as to reasonably pursue self-interests for a healthy body. They frame their qualitative research within Bourdieu's concept of *habitus* (Bourdieu, 1998). The concept is central to their analyses, because it explains how symbolic capital (e.g., a healthy thin body; moral virtue), as well as distinction, is acquired through health practices. Musolino and coworkers (2015) found strategies to cover disordered eating behavior employing cultural and normative practices. For instance, one participant reported refraining from dairy and consuming GF products,

although she was neither tested positive for lactose intolerance nor celiac disease. This strategy made her feel *"more healthy now than ever"* (Musolino et al., 2015, Page 22). Another participant reported to use her diagnosed celiac disease to gain control over when and where she eats, especially when not feeling comfortable eating in a restaurant with friends; another participant reported that becoming a vegan freed her of social eating due to the limited food choices in non-vegan restaurants (60% of the participants were either vegetarian or vegan). Additionally, self-proclaimed medical expert status by giving advice was highly prevalent. The strength of this report by Musolino et al. (2015), is to apply a sociological lens on health-directed eating behavior in a sample, showing disordered eating and orthorectic tendencies. In future studies, it is necessary to develop better tools to identify individuals with orthorectic eating behavior hiding behind salient *health habitus*.

- From a public health perspective it may be critical to use functional food to improve long-term health effects for the population. GF foods are absolutely necessary for salutogenesis for those in need (celiac patients), while for those without medical necessity, GF are functional foods. Currently, there is no evidence that consumers health can be improved by recommending GF foods (Catassi et al., 2013; Gibson et al., 2015; De Giorgio et al., 2016). Secondly, there is a discrepancy between rising market shares with an annual growth rate of 10.4% from 2015-2020 (The Business Journals, 2015) and unchanged prevalence of celiac disease diagnosis (Gujral et al., 2012). Besides food safety and some personal drivers (e.g., consuming functional foods for reasons of inner harmony, self-respect or self-confidence), longevity and good health are the main motivators to buy functional foods (Kraus, 2015). Surprisingly, the motivation to consume GF has hardly been investigated. In a small-scale survey by Dunn et al. (2014), 37% of a sample of 97

participants concur that GF foods are healthier than their gluten-containing counterparts. Further research in consumer perceptions of GF foods is necessary.

Strengths and Limitations

The presented study holds strengths and limitations. The study's major limitation is that the analyzed data on the micro and macronutrient content was not assessed directly via chemical analysis, but was estimated through a step-wise approximation process from data in food databases. While direct chemical analysis is more effortful and cost intensive, previous research demonstrated using readily available food databases to estimate nutrient content is an appropriate method (Mazzeo et al., 2015). Secondly, compared to for instance Wu et al. (2015), our sample of 63 GF products is relatively small. However, in Austria this was the first systematic analysis of the nutritive content of GF food. In addition, the study is conceptualized to provide an extended GF food database with the aim of including other researchers and build upon already existing data for the Austrian market (Open Science Framework, collaboration upon registration and request). This conceptual strength is complemented with pricing data for GF food products available in Austrian supermarkets. All in all, it provides a proper perspective for celiac patients as well as for consumers who buy GF products due to other health concerns.

3.6. Generic Limitations

Some additional limitations should be addressed briefly. As this thesis represents a mix of behavioral, observational and cross-sectional studies, different generic limitations should be mentioned.

- First, many findings from behavioral research stem from homogenous study samples representing Western, Educated, Industrialized, Rich, and Democratic populations (WEIRD). Using datasets based on a WEIRD study sample have been criticized for not being representative and thus findings and conclusions should be interpreted with caution (Henrich et al., 2010). In one study of this thesis this population bias is obviously of relevance *(Publication #3)*. However, in all other included articles this is not the case. Conclusions are drawn from observational data *(Publication #1; Publication #2),* data from large datasets within heterogeneous populations *(Publication #5)* or based on the analysis of food databases *(Publication #6)*. The mix of the presented study methods improves the quality of the thesis and makes it less prone to aforementioned potential WEIRD bias.

- Another generic research problem using psychological paradigms is that reproducibility of studies fail or are absent (Bohannon, 2015). Therefore, systematic attempt to replicate 100 prominent psychological paradigms by a large collaborative group (270 psychologists) could show that in 39% of the target paradigms, replication could be accomplished (Open Science Collaboration, 2015). Considering the fragile nature of most investigated paradigms in this study, the number of accomplished replications is acceptable. In the current thesis, one experiment *(Publication #3, study 1)* is a replication of the original study by Morewedge et al. (2010), contributing to the replicability of the original idea.

4. PERSPECTIVES AND FUTURE DIRECTIONS

Understanding eating behavior is a complex endeavor. In the 21st century, understanding this complexity is identified as one of the major challenges for many areas of research important to implement Public Health Nutrition (Allison et al., 2015). The thesis contributes in different areas of research to elucidate aspects of cognitive processing of eating behavior. In the presented studies we could describe important areas of the current food environment (e.g., food advertisements targeted at children and gender food advertisements); replicated and extended how basic memory mechanisms influence food intake (e.g., mental imagery); analyzed a special form of restrictive dieting (orthorexia nervosa) and investigated underlying assumptions of health-directed behaviors (e.g., gluten-free diet from a nutritional perspective). The concept of health is fundamental in nutrition, as is health-directed behavior. First off, health has become a dominant subject in the popular media, e.g., in books *(see Figure 5)*, reflecting the increased interest in health outcomes, both in individuals and on a societal level. Individual nutrition is often identified as key determinant for good health. Not only from books, but also the way people individualize and optimize their diet with the help of technological devices (keywords: quantified self, biohacking) mostly takes place within a health context. As new technological tools emerge to track one's diet, the underlying mechanisms to consume healthy foods stay the same: individuals' expectations for healthful characteristics of certain food products that can lead to consumption or restriction. In some cases however, pathological engagement to eat only healthily could lead to developing disordered eating behavior. However, individuals' attempts for self-regulation of food intake are often prone to be undermined by behaviors and habits stemming from contextual cues and learned associations (e.g., food advertisement for high-caloric foods, gender roles) or are based on incorrect assumptions about the healthfulness of certain food products (e.g., gluten-free).

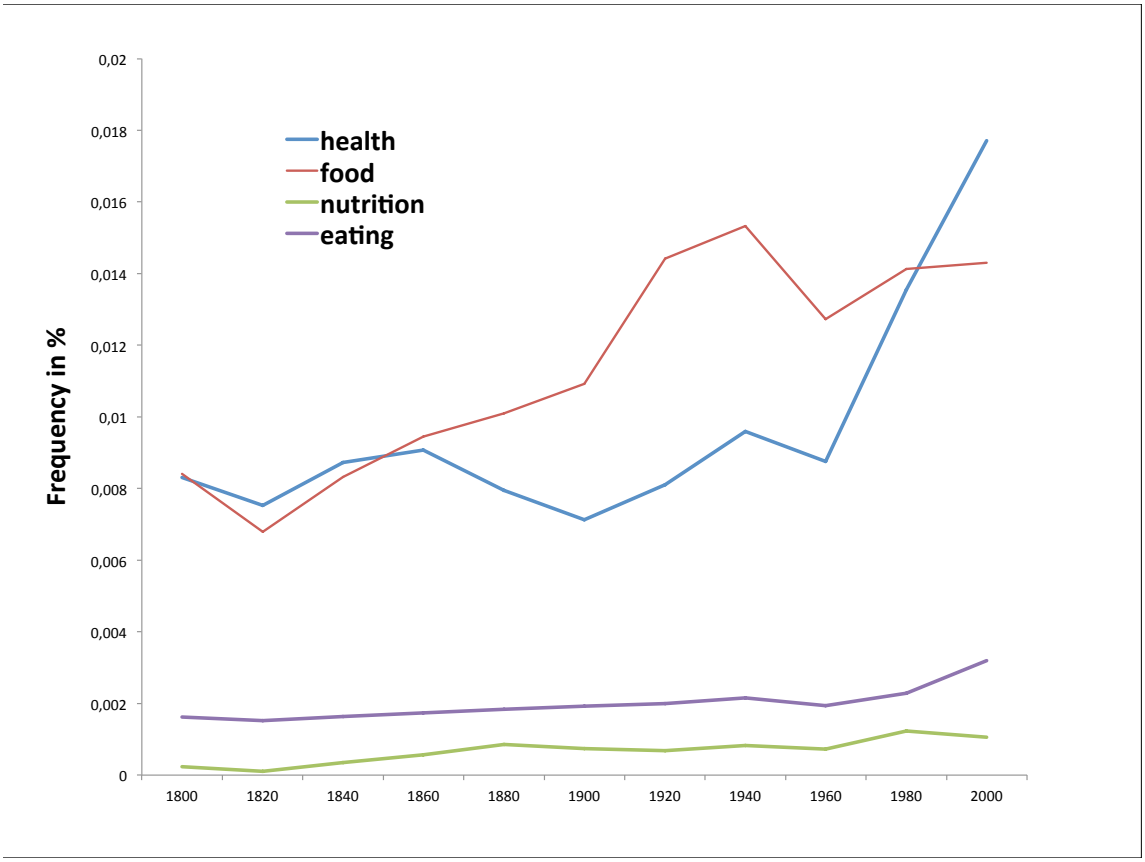

Figure 5. *Google Ngram search of the relative popularity of keywords "health", "food", "nutrition" and "eating". Search was conducted within all the words contained in a large corpus of English books (Michel et al., 2011; Ngram, 2015).*

Secondly, the most conveyed strategy to improve individual health with proper food intake (as propagated by physicians, dietitians and health insurance companies) is to stress the importance of healthier diets and a less sedentary lifestyle, assuming that if people know what they have to do, they will act upon. If people know that eating a well-balanced diet is healthy, they will adapt their behavior. This persistent reasoning is a fallacy, as demonstrated by many failed attempts to maintain weight loss over longer time periods; for obese < 20% succession rate (Mann et al., 2007) and the usually small and short-term BMI changes through dietary programs (Wadden et al., 2014). In a clinical context, to tackle the cognitive profile of obesity (reduce food cue reactivity, strengthen executive skills and retrain attention via bias

modification training) may be a more promising direction for future interventions (Jansen et al., 2015).

As mentioned in the discussion section (Chapter 3.6, point 2), replicating studies are sometimes hard to accomplish especially, but not limited to, the psychological sciences. One striking report by Woods and Begg (2015) points to the fact that replication attempts fail in many animal studies investigating basic physiological processes as response to eating, likewise. They reported, that replicating the key findings within and between laboratories (Seattle, Cincinnati) were highly problematic. Woods and Begg (2015) argued that the complexity of food intake regulation is, as with many other behavioral studies, probabilistic in its nature, because eating behavior is determined by individual experiences and learning processes (Ramsay and Woods, 2014). Therefore, to understand eating behavior in its complexity, prior experiences are important predictors.

In conclusion, to put the thesis in perspective, the often quoted statement on the obesity epidemic by George Bray: *"… the genetic background loads the gun, but the environment pulls the trigger …" (2004, Page 1)*, might need a different reading in the eating behavior context: "*the genetic background loads the gun and determines the physiological and psychological equipment for eating; however cognitive processes mediate environmental interaction and eventually pull the trigger*."

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Appendix A: Curriculum Vitae

BENJAMIN MISSBACH

MASTER OF SCIENCE (MSc)

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RESEARCHGATE
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PERSONAL

DATE OF BIRTH: 01/01/1987

BIRTHPLACE: Traunstein (Germany)

RESEARCH AREAS

Working in the field of nutrition and health. Interested in scientific approaches to study eating behavior. A strong focus on cognitive mechanisms underlying food choice and consumption behavior in following research areas:

Eating Behavior

Health Psychology

Public Health Nutrition

PROFESSIONAL EXPERIENCE

from 03/13 — **PhD position**
University of Vienna, Department of Nutritional Sciences (Prof. Jürgen König)

2009 - 02/2013 — **Leisure education & street work with children and adolescents**
(Wiener Familienbund)

EDUCATION

since 03/2013 — **PhD Nutritional Sciences**
University of Vienna, Department of Nutritional Sciences (Prof. Jürgen König)

2010 - 2012 — **MSc Nutritional Sciences**
University of Vienna, Department of Nutritional Sciences (Public Health)

2007 - 2010 — **BSc Nutritional Sciences**
University of Vienna, Department of Nutritional Sciences

06/2006 — **High School Diploma**
Landschulheim Marquartstein, Bavaria, Germany

JOURNAL ARTICLES

(ALL PEER-REVIEWED)

2015

Missbach B, Hinterbuchinger B, Dreiseitl V, Zellhofer S, Kurz C, and König J. 2015. **When Eating Right, Is Measured Wrong! A Validation and Critical Examination of the ORTO-15 Questionnaire in German**. PLoS ONE 10(8): e0135772. DOI: 10.1371/journal.pone.0135772

Missbach B, Schwingshackl L, Billmann A, Mystek A, Hickelsberger M, Bauer G, König J. **Gluten-free food composition database: The nutritional quality and cost of packaged gluten-free foods.** PeerJ 2015. Volume 3. e1337. DOI: 10.7717/peerj.1337.

Missbach B, Allemann S, Szalai E, König J. **Food advertisement and gender stereotypes on Austrian television**. Ernährungs Umschau 2015; 62(4):59-65. DOI:10.4455/eu.2015.011.

Missbach B, Weber A, Huber E, König J. **Inverting the pyramid! Extent and quality of food advertised on Austrian television**. BMC Public Health. 2015;15(1):910. DOI: 10.1186/s12889-015-2275-3.

Missbach B, Florack A, König J. **Mental imagery and food consumption**. Frontiers in Psychiatry. 2015;6. DOI:10.3389/fpsyt.2015.00048.

Schwingshackl, L., B. Missbach and G. Hoffmann. **An umbrella review of garlic intake and risk of cardiovascular disease**. Phytomedicine ; DOI:10.1016/j.phymed.2015.10.015.

2014

Missbach, B., Florack, A., Weissmann, L., and König, J. (2014). **Mental imagery interventions reduce subsequent food intake only when self-regulatory resources are available**. Frontiers in Psychology 5. DOI: 10.3389/fpsyg.2014.01391.

Schwingshackl, L., Missbach, B., Dias, S., König, J., and Hoffmann, G. (2014). **Impact of different training modalities on glycaemic control and blood lipids in patients with type 2 diabetes: a systematic review and network meta-analysis**. Diabetologia 57, 1789-1797. DOI: 10.1007/s00125-014-3303-z.

Schwingshackl, L., Missbach, B., König, J., and Hoffmann, G. (2014). **Adherence to a Mediterranean diet and risk of diabetes: a systematic review and meta-analysis**. Public Health Nutr, 1-8. DOI: 10.1017/S1368980014001542.

PROFESSIONAL ACTIVITIES

Ad-hoc Reviewer

BMC Public Health, Childhood Obesity, European Journal of Nutrition, Frontiers in Nutrition Frontiers in Psychology, PloS One.

Teaching

- seminar on Nutritional Sciences winter term '13; summer term '14, winter term '14, summer term '15, winter term '15; summer term '16

- practical course (basal metabolic rate measurements): winter term '14, summer term '15, winter term '15, summer term '16

CONFERENCE CONTRIBUTIONS – MEETINGS – ABSTRACTS – TALKS – POSTERS

2015

- Oral presentation: "Inverting the pyramid! Extent and quality of food advertised on Austrian television" Federation of European Nutrition Societies (FENS), October 2015.

2014

- Poster presentation: "Mental Imagery and food intake behavior - cognitive resources as requirement for mental imagery effects on food intake" DGESS, Leipzig March 2014

- Oral Presentation: "Mental Imagery and food intake behavior - illustrated by a gummy bear taste test; cognitive resources as requirement for mental imagery effects on food intake". E3S SNÖ Symposium: Sensory and Consumer Science – Thinking out of the Box; May 2014

2013

- Master Thesis presentation: Alison Douglas Summer School 2013 on satiety regulation (Thought for Food; 14 – 18. Juli 2013)

- Oral Presentation: AG Tagung (Biologie) in St. Pölten; October 2013

OTHER PUBLICATIONS (NOT PEER-REVIEWED)

Missbach, B. (2014). Fruit consumption and risk of type 2 diabetes: results from three prospective longitudinal cohorts, Nutrition – News, Jahrgang 11, Ausgabe 3/14.

Schwingshackl L, Missbach B. (2015). Ernährungsmuster zur Prävention chronischer Erkrankungen, Ernährung Heute, 2_2015.

Missbach B, Beisl J, Grella N, König J. (2015). Die Österreichische Ernährungspyramide. Eine Feldstudie in Wien: Leistbare Gesundheit bei gesunder Leistbarkeit? Die Ernährung, Volume 39: 26-39.

Appendix B: Original Publications (#1 - 6)

Missbach et al. BMC Public Health (2015) 15:910
DOI 10.1186/s12889-015-2275-3

BMC Public Health

RESEARCH ARTICLE Open Access

Inverting the pyramid! Extent and quality of food advertised on Austrian television

Benjamin Missbach*, Adelheid Weber, Elke M. Huber and Jürgen S. König

Abstract

Background: Research showed that food marketing for children frequently contradicts national dietary guidelines. Children, unlike adults, are not able to understand the persuasiveness of the advertisements with its short- and long-term effects on health, thus the common international tenor is to restrict food marketing. In the European Union, marketing restriction based on self-regulation have been initiated (EU Pledge Nutrition Criteria). The study aims contribute to depict the status quo of television advertisement targeted at children before the pledged initiative came into full effect.

Methods: In this study we analyze the quality and displaying frequency of a set of advertisements targeted at children broadcasted on Austrian television. Promoted food products targeted at children or adults were identified. Category-based analysis of the displayed food was performed based on the Austrian Nutrition guidelines (number of displayed food per food category). The children's food content was analyzed according to the newly established nutritional quality criteria for advertised food in the EU to assess the nutritional quality of the depicted food.

Results: In total, 360 h of video material was recorded in February and March 2014. A set of 1919 food advertisements, with 15.1 % targeted at children were broadcasted. Of all food advertisements targeted at children, 92.4 % was for fatty, sweet and salty snacks, while no advertisements for vegetables, legumes or fruits were shown. From all food advertisements for children, 65.9 % originated from participating companies of the EU Pledge Nutrition Criteria. Further analysis revealed that 95.9 % of the advertised food for children showed at least one aspect of nonconformity with the EU Pledge Nutrition Criteria; on the contrary 64.7 % of the displayed food advertisement also featured at least one desirable food component (e.g. high fibre content, high protein content).

Conclusions: The present research suggests that the majority of advertised food for children do not conform with the pledged criteria as defined in the EU Pledge Nutrition Criteria and almost all advertisements would be prohibited. We discuss our findings in the context of public health nutrition and present a perspective for future directions in this important field of research.

Keywords: Advertising, Children, Television, EU Pledge Nutrition Criteria, Food marketing regulation, Nutrition profiling criteria

Background

Food marketing holds double-edged characteristics. Marketing practices, such as the promotion of potentially unhealthy food as well as the promotion of potentially healthy food, can increase consumption both in children and adults [1, 2]. Research on advertisements targeted at children has shown that unhealthy food, respectively energy-dense, high-fat and sugary foods are more often advertised in television (TV) in spite of first marketing restrictions inititiated over a decade ago [3]. This marketing component shapes modern obesogenic environments. Increased accessibility and salience in conjunction with a sedentary lifestyle are important drivers in the global obesity pandemic [4, 5]. In fact, a recent meta-analysis by Chapman et al. [6] showed that one of the three most prominent lifestyle factors for increased short-term effects on food intake is watching TV. The effect of TV on eating habits was shown in both laboratory [7] and epidemiological studies [8, 9].

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Interventions to restrict unhealthy as well as to promote healthy food marketing targeted at children, is a major public health effort to promote eating habits [10]. The most challenging issue however, is to unambigously define what is unhealthy [11], as the establishment of applied models of choice will have considerable influence on the outcome of food marketing regulations [12].

The present study aims to identify the extent of food marketing and the nutritional quality of the advertised food targeted at children on Austrian TV. To assess the current status quo of food advertisements for children, we analyze the food quality based on the suggested guidelines for nutritional criteria in the European Union (EU Pledge Nutrition Criteria). We analyze advertisement data before the guidelines came into force (prior to the 31st of December 2014) to set a starting point for future analysis of the potential impact of the EU Pledge Nutrition Criteria on food advertisement targeted at children.

To date, there is no study analyzing the Austrian TV landscape based on the recently established criteria and only a few international studies describe the status quo before the voluntary commitment for the new criteria came into force.

Food marketing targeted at children

Food marketing is intended to have persuasive effects on children's food preferences, food purchasing behavior and short-term food consumption [13, 14]. For instance, children who watched more TV responded to frequently advertised food items more readily than those who watched less [15, 16]. Even brief exposure to food advertising influenced children's food preferences [17]. As shown by Harris, Bargh and Brownell [1], elementary-school-aged children consumed 45 % more snacks when exposed to food advertisements. In adults, this effect was dissociated of the participants' reported hunger, indicating that this particular snacking behavior is guided by automatic and habitual processes [18]. Repetitive exposure to food products as food primes can enhance the effect on shaping eating habits (mere-exposure effect [19]) through the Pavlovian stimulus–outcome (S-O) conditioning, therefore eliciting short-term food cravings [20].

Children as young as three years old are capable to identify advertisements during TV programs but, unlike adults, are not able to understand the persuasiveness of advertisements and their short- and long-term effects on health [21]. This makes food marketing targeted at children a deceptive way to propose commercial transactions to children and should therefore be restricted [22]. Consquently, international authoritites, including World Health Organization (WHO) member states, called for a general agreement to harmonize food and beverage advertisements within national dietary guidelines of the Global Strategy on Diet, Physical Activity and Health (2004). A systematic review by Galbraith-Emami and Lobstein [23] showed that worldwide initiatives are effective in restricting advertisement on-air time for children, but the effectiveness depends highly on audience definition and nutrient profile criteria. In some countries, limiting advertisement of energy-dense, nutrient-poor food and beverages is implemented in their national action plans on nutrition [24]. Inspite of measures taken, global food marketing, especially unhealthy food for children, appear to be on the rise since first regulatory actions have been initiated [25, 26].

The EU Pledge Nutrition Criteria

In the absence of complete bans of food advertisements, there is a need aimed at a comprehensive and consistent approach across countries to regulate the quantity and quality of the advertised content. International regulatory guidelines have engaged different models, such as nutrient or category-based approaches. In Europe, the EU Pledge Nutrition Criteria are conceptualized to restrict food and beverage advertisements to children younger than 12 years old on TV, print media and on the internet [27]. It is designed as a self-regulatory and voluntary intitative including 20 companies being responsible for at least 80 % of the TV food marketing in the EU. The self-regulatory pledged criteria use a dual strategy to encourage the advertisement of healthy food components (e.g. high fiber and protein content) and simultaneously aim to restrict unhealthy food components (e.g. high amounts of sugar, saturated fatty acids). The voluntary commitment started in 2012 and participating members pledged to implement the suggested guidelines by 31st December 2014.

The EU Pledge Nutrition Criteria use 9 different food categories to arrange food advertisements. In short, food groups, such as soft drinks, or sugar and sugar-based products, are fully restricted for advertisement. Food products that promote a particular food within a certain category have to contain category-specific components per defintion (e.g. for dairy products to contain at least 50 % dairy), otherwise they should not be advertised. Additionally, depending on the presented food category, nutrient-based thresholds are defined for energy (kcal/portion), sodium (mg/100 g or 100 ml), saturated fats (mg/100 g or 100 ml) and total sugars (g/100 g or 100 ml).

Additional to nutrient-based thresholds, certain food components should be encouraged (nutrients and food groups). Desirable food components are qualified as positive and should be encouraged: such as fibre and whole grain in cereal-based products; protein and calcium in milk and dairy products; protein in meat, fishery products; polyunsaturated fatty acids (PUFAs) in vegetable oils, spreads and fats.

The current study

The present study was conducted before the EU Pledge Nutrition Criteria came into full effect (prior to 12/2014) to provide a status quo analysis regarding food advertisements aired on Austrian TV. In detail, we present data from advertisements, displaying frequency and the nutritional quality of the advertised food products. The aim of this study is threefold: we (i) analyze a set of advertisements broadcasted for children on six different TV stations. We split the advertised food into eight food categories based on the Austrian dietary guidelines as defined by the Austrian Food Guide Pyramid [28]; (ii) we provide data regarding the nutritional quality of food advertisements targeted at children by comparing the displayed food with the pledged EU Nutrition Criteria, and (iii) we discuss the results and their implications in a broader context of public health nutrition.

Methods

We used a two-step approach to collect data in this study. First, we recorded and analyzed TV programs. We applied the national dietary guidelines to develop a coding scheme. Two coders identified advertisement orientation (children vs. adults) and target food (displayed food categories). In the second step, the first and second author of the study provided a closeup of the quality of the food advertisements and analyzed the advertised products according to the EU Pledge Nutrition Criteria. As this study did not involve human subjects, *The Code of Ethics of the World Medical Association* for experiments did not apply and the University of Vienna Ethics Committee granted a waiver for ethical approval.

Data collection

Data collection took place in February and March 2014. TV programs were recorded from six seperate TV channels over four days (two non-consecutive weekdays and two independent days on the weekend). TV channels were selected based on media analysis of children's TV habits in Austria, Germany and Switzerland [29], choosing the six most popular TV channels for children (ATV, ORF1, Pro7, RTL, Sat1 and SuperRTL). Recording period for each dedicated day was from 6 am to 9 pm. Recording time was further split into three time periods: morning hours (6 am – 11 am), midday hours (11 am – 4 pm) and evening hours (4 pm – 9 pm).

In total, 360 h of broadcast material was recorded, spread equally over all six TV stations. We recorded full days of TV screening (6 am – 9 pm) to get a complete and consistent dataset of recordings. Previous studies reported segmented recording times (e.g. morning, after-school hours) [30] or solely recorded kids programs [31, 32] which may have led to incomplete datasets for the analysis. In this study, full days from 6 am to 9 pm and all types of programs were recorded to reduce the chance of missing any data. All stations broadcasted their program in German.

Review and coding reliabilty of TV advertisements

First, the content of the TV program was divided into non-programs and programs (e.g. TV shows, news updates). Non-programs included promotion of station programs, station identification, and product advertisements. To identify advertisements, we used a coding protocol established by Thompson et al. [33]. Brief sponsorship messages, such as "this program was brought to you by product X", brand display or buying recommendations, were used to identify advertisements [33]. Hence, product advertisements were divided into food or non-food advertisements. As we only focus on food advertisements in this study, we did not record the percentage of food advertisements compared to non-food advertisements. Food advertisements were considered as such when they promoted the purchase or consumption of food or beverages. In a second step, we identified if food advertisements were targeted at children. This was conducted according to a dichotomous categorization scheme adapted from Chapman et al. [34] (Table 1).

The video material was reviewed by two coders fluent in German (author 2 and 3). Initial coding of the video material was performed by one coder, a second coder was given the same coding form and instructions to code a 10 % sample of the total duration of recordings (36 h). Inter-coder reliability was calculated using the following formula: number of agreements*100 / number of disagreements. This reliability check was only performed for audience orientation and not for the food categorization procedure.

Table 1 Criteria to determine advertisement orientation (target audience) and displayed food categories (target food categories)

Target audience (children)	Target audience (adults)
Animation	Adults or adult celebrities
Children or child celebrities	Adult-oriented music
Pets or animals	Adult-focused voice or dialogue
Identifiable cartoon characters, mascots, promotion of fun	
Child-focused music	
Child-friendly voice or dialogue	
English words and expressions	
Children singing	

Adapted from Chapman et al. 2006 [34]

Inter-coder reliability was 95.8 % in the present study. All discrepancies emerging during the process were discussed within the research team.

Advertised food categories

Initially, to identify food categories depicted in the advertisements, we categorized food according to the national dietary recommendations. The Austrian Food Guide Pyramid is described in seven categories [28]. According to the recommendations, items from each category should be eaten at different frequencies per day (Table 2). In addition, we added one extra category called 'other food not further specified' to complement the categories of the Austrian Food Guide Pyramid. All discrepancies emerging during the categorization process were discussed within the research team and conflicting food categorizations were resolved in consensus. Hence, we analyzed the video material according to following eight food categories:

- Fatty, sweet and salty snacks (e.g. cakes, fast-food products, chips)
- Fats and vegetable oils (e.g. olive oil, nuts, butter)
- Fish, meat, sausages and eggs (e.g. tuna, salami, processed meat)
- Milk and dairy products (e.g. yogurt, cheese, milk)
- Cereal products and potatoes (e.g. bread, granola, rice)
- Vegetables, legumes and fruits (e.g. beans, salad, tomatoes)
- non-alcoholic beverages (e.g. water, tea, coffee)
- other food not further specified (e.g. convenience food, baby food)

We assessed the on-air frequency of the advertisements by counting the total number of advertisements. We interposed this step to analyze the dataset according to the Austrian Food Guide Pyramid to assess how the foods depicted on TV match with the national dietary recommendations.

In a second step, the displayed products were analyzed according to the EU Pledge Nutrition Criteria. This was conducted to assess how the foods depicted on TV match with the EU Pledge Nutrition Criteria. According to the EU Pledge Nutrition Criteria 9 different food categories are defined. For this we re-coded the displayed advertisements accordingly and conducted nutrient profiling analysis with those foods initially passing the category criteria (exclusion criteria: food groups such as soft drinks, sugar and sugar-based products and misleadingly declarated foods; see supplementary material, Additional file 1).

For further analysis, the nutritional information of the food products was obtained directly from the nutrition information on the label of the promoted products during supermarket visits or online. When nutrition information was not readily available, manufacturers were contacted.

Table 2 Categorization code used to determine displayed food categories by means of the Austrian Food Guide Pyramid

Target food category	Consumption recommendation according to the Austrian Food Guide Pyramid
Category 1: Fatty, sweet and salty snacks	Sweets, pastries, fast food products, snacks, munchies and soft drinks are nutritionally less recommended and should be consumed rarely – a maximum of one serving per day. Avoid heavily salted foods e.g. pickled foods, snacks, salted nuts, convenience products
Category 2: Fats and vegetable oils	1–2 tablespoons of vegetable oils, nuts and seeds daily. High quality vegetable oils such as olive oil, canola oil, walnut, soybean, linseed, and nuts, and also seeds contain essential fatty acids an can be consumed daily in a moderate amount (1–2 tablespoons). Other fats such as butter, margarine and l ard and several fatty dairy products (e.g. whipped cream, sour cream and crème fraîche) should be used sparingly.
Category 3: Fish, meat, sausages and eggs	Eat at least 1–2 servings of fish (each approx 150 g) per week and prefer fatty sea fish (mackerel, salmon, tuna and herring) or local cold water fish such as char. Eat a maximum 3 servings of lean meat or low-fat sausages (300–450 g /week) per week. Eat red meat (such as beef, pork and lamb) and sausages rarely. Up to 3 eggs can be consumed per week.
Category 4: Milk and dairy products	Consume 3 servings of milk and dairy products each day. Prefer low fat alternatives. 1 serving equals: milk (200 ml), yogurt (180–250 g) cottage cheese (200 g), curd cheese (200 g), cheese (50–60 g).
Category 5: Cereal products and potatoes	Eat 4 servings of cereals, bread, pasta, rice or potatoes. 1 serving equals: whole wheat bread (50–70 g), buns and bagels (50–70 g), cereals (50–60 g), pasta (uncooked 65–80 g, cooked 200–250 g), rice or corn (uncooked 50–60 g, cooked 150–180 g), potatoes (cooked 200–250 g). Prefer whole grain products.
Category 6: Vegetables, legumes and fruits	Eat 5 servings of vegetables, legumes and fruits per day. 3 servings of vegetables and legumes and 2 servings of fruit would be idea. 1 serving equals: vegetables (cooked 200–300 g, raw 100–200 g), salad (75–100 g), legumes (cooked 150–200 g, raw 70–100 g), vegetable or fruit juice (200 ml).
Category 7: non-alcoholic beverages (e.g. water, tea, coffee)	Drink at least 1.5 l of liquids per day, prefer low-energy beverages (e.g. tap water, mineral water, unsweetened teas and diluted fruit or vegetable juices). A daily moderate consumption of coffee, black tea (3–4 cups) and other caffeinated beverages is acceptable.
Category 8: other food not further specified	miscellaneous e.g. mixed dishes, baby food, convenience products

Adapted form the Austrian Food Guide Pyramid [28]

The data was then compared with the nutrient threshold limits and the food components that should be encouraged as defined by the EU Pledge Nutrition Criteria by the first and second author of this study.

Statistical analysis

Statistical analyses were conducted using IBM SPSS 22. Descriptive statistics were used to explore the frequency of displayed TV food advertisements, while chi-square tests were used to compare the proportion of displayed food categories by target audience and displaying frequency on different times of the day. Results were considered significant at an α level of $p \leq 0.05$.

Results

Overview

A total of 1919 food advertisements were displayed in 360 h of recorded video material. Most food advertisements were shown between 11 am and 4 pm ($n = 734$), compared to evening hours from 4 pm to 9 pm ($n = 719$) and morning hours from 6 am to 11 am ($n = 466$). For the single food advertisement, the average air time was 25.05 s (standard deviation: ± 7.97 s). Within the complete recording period, 290 food advertisements targeted at children were identified (15.1 %) and 1629 advertisements were targeted at adults (84.9 %). For children, there was no difference in advertisement frequency on weekends compared to week days ($\chi^2(1) = 1.08$, $p > .05$). Food advertisement displaying frequency did differ significantly comparing morning, midday and evening blocks, $\chi^2(2) = 10.20$, $p < .05$ (see Fig. 1). In detail, food advertisements for children were less frequent during morning hours compared to midday hours, $\chi^2(1) = 10.13$, $p < .05$ but not compared to evening hours, $\chi^2(1) = 2.62$, $p > .05$. Most advertisements for children were shown during evening hours ($n = 121$).

Advertised food categories

Of all displayed 1919 food advertisements (targeted at children and adults), a total of 161 food products from 72 different companies were aired. In our sample, we identified three main companies that provided food advertisements: Ferrero Inc. (24.1 %), Danone Inc. (9.7 %) and Unilever Inc. (7.9 %). According to the Austrian Food Guide Pyramid, 49.1 % of all the displayed food were for fatty, sweet and salty snacks, 18.8 % for convenience food and 15 % for milk and dairy products. Displaying frequency of vegetables, legumes and fruits and non-alcoholic beverages was 4.5 %, while 4.1 % of the food advertisements were for fats and vegetable oils. Fish, meat, sausages, and eggs were addressed in 2.7 % of the food advertisements and cereal products and potatoes were displayed the least frequent (1.3 %) (Fig. 2).

For children, most commonly advertised food categories were fatty, sweet and salty snacks (92.4 %), convenience food (4.1 %) and milk and dairy products (3.5 %). All other food categories (fats and vegetable oils; fish, meat, sausages and eggs; vegetables, legumes and fruits; cereal products and potatoes and non-alcoholic beverages) were not advertised for children in our sample.

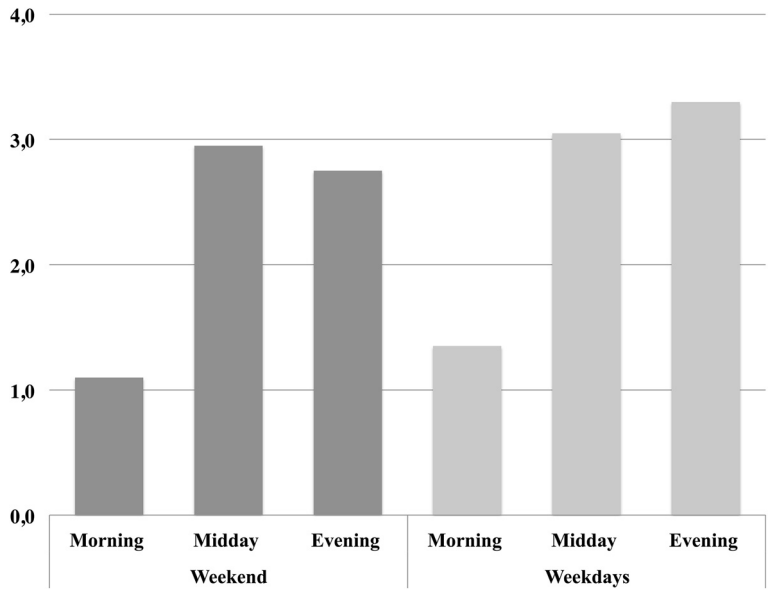

Fig. 1 Displaying frequencies of food advertisements for children (per hour). *Notes*. Advertisements are displayed in displaying frequencies per hour on different times of the day, split into weekends and weekdays. Morning hours (6 am–11 am), midday hours (11 am–4 pm), evening hours (4 pm–9 pm)

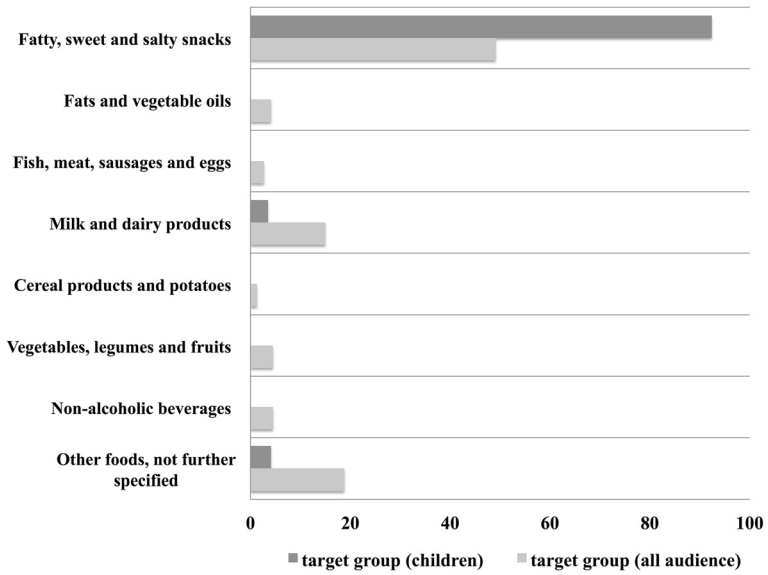

Fig. 2 Displaying frequency of eight food categories divided by target group (in %). *Notes*. Displaying frequency of eight food categories of the Food Guide Pyramid in % of the total displayed food. The displaying frequency is divided along the target group, respectively targeted at children contrasted by all audiences

There was a significant association between the displaying frequency of fatty, sweet and salty snacks and whether advertisement were targeted at children or adults $\chi^2(1) = 255.97$, $p < .001$. Based on the odds ratio, food advertisement for children for fatty, sweet and salty snacks was 17,2 times higher than for adults.

Nutrition quality of the advertised food targeted at children

All 290 food advertisements targeted at children were included for further analysis against the EU Pledge Nutrition Criteria. The displayed advertisements were spread across 20 different products by 11 food companies. Almost 2/3 of the food advertisements for children originated from participating companies of the EU Pledge Nutrition Criteria (65.9 %). Food was shown at different displaying frequencies (ranging from 1 to 48 repetitions) over the recorded time frame.

Based on the category restrictions, 58.9 % of food advertisements did not pass the pledged criteria. In detail, 69 % were excluded, because they were declared as dairy products, but did not fulfill the corresponding criteria (e.g. dairy products must contain at least ≥ 50 % dairy); 15.2 % of the food advertisements promoted soft drinks, 13.5 % represented sugar or sugar-based products and 2.3 % represented combinations of fast food meals (see supplementary material, Additional file 1).

Advertisements passing the criteria for the corresponding category were used for an in-depth nutrient-based threshold analysis (41.1 % of the food advertised for children). Advertisements represented three EU Pledge Nutrition Criteria categories: EU Pledge Category 3: 14.3 % from meat based products; EU Pledge Category 5: 64.7 % from dairy products; EU Pledge Category 6: 21 % from sweet biscuits, fine bakery wares and other cereal based products.

At least one food component that should be encouraged in advertisements for children was identified in 64.7 % of the advertisements. As such, protein >12 E% or > 2 g /100 g or 100 ml was among most advertisements, as well as desirable trace elements (e.g. calcium) and micronutrients (e.g. vitamin D, vitamin B).

On the contrary, from all advertised food targeted at children, in 95.9 % of the adversiements at least one characteristic was identified not in line with the EU Pledge Nutrition Criteria. 97.9 % of the advertised foods by participating companies of the EU Pledge Nutrition Criteria and 91.9 % of non-members failed to pass the criteria (Fig. 3). In total, only 10.1 % of the nutrient analyzed advertisements passed all criteria for nutrient-based threshold (see supplementary material, Additional file 2).

Discussion

The results of this study include two main important findings. First, our data suggest that frequency of food advertising for children on Austrian TV can be attributed to three main food categories: fatty, sweet and salty snacks (92.4 %), convenience food (4.1 %) and dairy and dairy products (3.5 %). This distribution is absolutely in conflict to the present food intake recommendations provided by the Austrian Federal Ministry of Health. The findings of the study are in line with previous

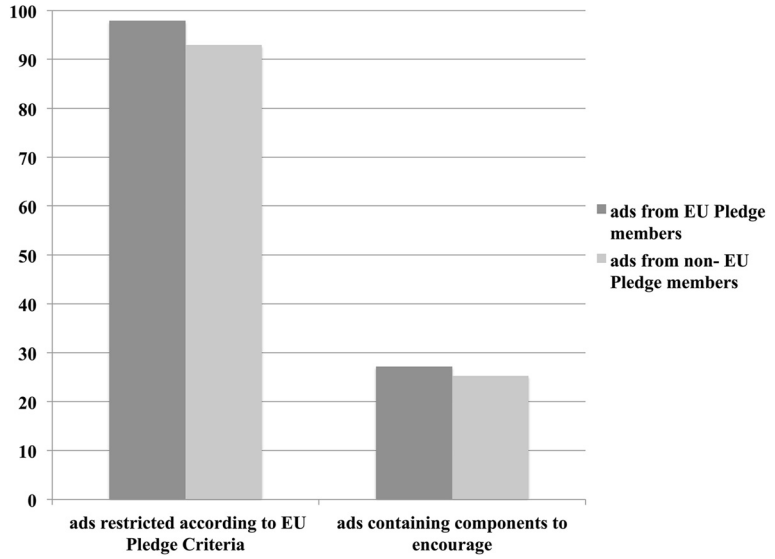

Fig. 3 Food advertisement by member and non-member companies displaying encouraging and restricted foods (in %). *Notes*. Displaying frequency of food advertisements by members and non-members of the EU Nutritition Criteria Pledge split in % of restricted food advertisement and % of food advertisement displaying food components to encourage

studies, showing a similar distortion between intended food recommendation and actual food advertisement patterns [30, 34–36]. For instance, Huang and colleagues (2012) showed that 46 % of food advertisements for children in Singapore were for candy, confectionery and fast food [31]. In contrast, advertisement for food associated with positive health effects (fruits, vegetables, whole grain foods, etc.) are nonexistent in our data.

The second major finding resulted from an in-depth analysis of the food contents marketed to children. Our dataset showed that 95.9 % of food advertisements would be restricted according to the newly established EU Pledge Nutrition Criteria. More than half of the food advertisements (58.9 %) did not pass the marketing criteria based on the category restrictions, and from the remaining 41.1 % only 10.1 % passed the criteria for nutrient threshold. In comparison, Scarborough and colleagues [12] reported that when applying the EU Pledge Nutrition Criteria to 336 food products, only 25.6 % would have been banned. The authors of the study investigated all food displayed during a one year time period [12]. In contrast, in our study we applied the restriction criteria to food especially targeted for children. Our approach may be more straightforward than applying the restriction model to all advertised food and more suitable for this particular research question. In fact, in line with our findings, Gunderson et al. [37] investigated food marketed on different TV stations for children and could show that 92.1 % of the food advertisements targeted at children was food associated with negative health effects.

Notwithstanding the presented data about the displaying frequency of food with negative health effects, our study also showed that 64.7 % of the advertisements targeted at children contain desirable food components according to EU Pledge Nutrition Criteria (e.g. high protein content, calcium, vitamin D, vitamin B). The pledge consortium's reasoning for taking desirable food components into account was to foster innovation, reformulation and competition in the EU. The proclaimed goal of the pledged nutritional criteria is to shift advertising towards improved products [27]. However, by taking a closer look at the food that contain desirable components, almost all of them also contain nutrients to limit. This approach may be an advantage for producers to identify good or problematic formulations of their products. On the other hand, self-regulatory nutrient guidelines were shown to be ineffective in reducing unhealthy food advertisement targeted at children worldwide [38]. As most members of the EU Pledge Nutrition Criteria consortium are mutlinational companies, no pioneering efforts have been made so far [23]. Additionally, the time it takes until a reformulated food compliant with the pledged criteria becomes market-ready, may leave another generation of children watching TV with unhealthy food advertisement. Thus, the finding that 64.7 % of the advertisements targeted at children contain desirable food components according to the pledged nutritional criteria should be interpreted with caution.

Public health perspective

In our study we show that one in seven food advertisement was targeted at children, with 92.4 % displaying

fatty, sweet and salty snacks. In Austria, the average TV viewing time, from the age of three years on, is approximately 158 min per day [39]. TV watching in excess of 120 min and longer is associated with reduced physical and psychosocial health, and a large body of evidence suggests that especially decreasing sedentary time in youth aged 5–17 years leads to reductions in Body-Mass Index and health risks [40]. The reduction of sedentary lifestyles and promotion of early life nutritional education to strengthen overall self-regulatory resources may be key to responsible eating behavior. This has been addressed in a dual-model on a population-based childhood obesity prevention program provided by the WHO [41]. Regulating food marketing for children may be one effective measure to decrease food exposure to children [23]. Our results support the idea that food advertisement seem to distort national dietary recommendations, especially when the recipients of the advertisements are children (e.g. 17 times more likely for fatty, sweet and salty snacks). In Austria, for instance, five servings of fruits or vegetables per day are recommended, none of them were displayed in our study, although the National Action Plan for nutrition explicitly stresses the promotion of healthy food, such as fruits [42].

In the present study we investigated food advertisements by means of their eligibility within the EU Pledge Nutrition Criteria. There is a political alignment accompanied by voluntary codes of conduct by some food companies [43]. A preliminary and post-implementation study evaluating the self-regulatory Children's Food and Beverage Advertising Initiative in Canada (2006–2011) came to the conclusion, that while the volume of aired advertisements for children decreased by 24 %, the advertisement quality decreased likewise. They showed that compared to 2006, food classified as less healthy were increasingly targeted at children (+47 %) and teenagers (+161 %) after implementing the initiative. The authors concluded that, in Canada, the initiated self-regulatory system designed to protect Canadian children from food advertising showed clear weaknesses and advertisement should be regulated more strictly [44]. A recent systematic review of evidence by Ronit and Jensen [45] provides an overview concerning research on industry self-regulation regarding food and beverage marketing and nutrition labeling. The authors conclude, that although methodological heterogenity was prevalent in the 22 reviewed articles, the ineffectiveness of existing self-regulation schemes is univocal, calling for more legislative guidelines. In addition, the use of commonly persuasive techniques, such as premium offers, promotional characters, nutrition and health-related claims, the theme of taste, and the emotional element of fun, are frequently displayed in the endorsement of food for children [46]. Especially promotional characters, like cartoon characters, have shown to influence food preferences in children, but branding has mainly been used for energy-dense and nutrient-poor foods (e.g. cookies, candy or chocolate), as compared to fruits or vegetables [47]. In the EU Pledge Nutrition Criteria, no restrictions for persuasive marketing techniques (mascots, cartoon characters) are implemented. Considering this and the findings of our study, that 65.9 % of the advertised food for children originate from member companies of the EU Pledge Nutrition Criteria and 97.9 % of their advertised foods showed nonconformity aspects, an argument for stricter regulations may be put forward.

As part of a new wave in public health improvements, the promotion of healthy food and nutrient components as proposed by the EU Pledge Nutrition Criteria would fit well into the new'cultural turn' in the field of public health as proposed by Davies et al. [48]. Inarguably, to further minimize influences towards unhealthy behavior, it is necessary to both maximize the value of health and the promotion of healthy choices as default and to minimize factors that create an environment of unhealthy behaviors [49].

Limitations

One major limitation of the present study is that we did not screen for seasonal differences and only presented data from a 2 month time frame (February and March 2014). Nevertheless, our results showed comparable results and displaying frequencies, which have been shown in other studies as well. A second limitation is more general and aimed at criticizing the definition of nutritional criteria. Different nutrient profiling strategies have been developed to ban advertisements targeted at children. Throughout this process, the question what is *healthy food* and what is not, proved to be difficult. To support this argument, Scarborough et al. [12] showed that when using eight different nutrient profile models on a dataset of food advertisements, the percentage of permitted food advertisements varied from 2.1 to 47.4 %. Although the authors used diverging models, the study shows that advertisment restraint highly depends on the applied restriction model. From this point of view, defining nutrient criteria as basis for marketing restrictions have to be grounded on solid scientific findings, taking all available evidence into consideration. In contrast, Lobstein and Davies [11] argued that nutrient profiling as a method to categorize food according to nutritional quality is both feasible and practical and can support a number of public health-related initiatives. A third limitation of the study is that we cannot provide data about causal effects of TV advertisements on food habits and eating behavior. Our study design is therefore limited to a mere descriptive level.

Conclusions

In conclusion, we highlighted several important issues regarding food advertisement targeted at children and showed that in Austria, advertised food is not in accordance with the Austrian dietary guidelines and is mainly nonconfirmatory with the newly established EU-wide nutrition criteria for food advertisement targeted at children. This research provides a good starting point for future monitoring the success of the EU Pledge Nutrition Criteria. Based on our findings, procedures for continous and comprehensive monitoring for self-regulatory pledges in food marketing targeted at children are necessary. This field of research needs further investigation to pinpoint precise tools by which to restrict unhealthy food advertisements, and to promote healthy food in modern media environments.

Additional files

Additional file 1: Identified food products displayed in food advertisement, category and classification according the the EU Pledge Nutrition Criteria. (DOCX 101 kb)

Additional file 2: Identified food products displayed in food advertisement, nutrient-based analysis according to the EU Pledge Nutrition Criteria. (DOCX 36 kb)

Competing interests

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. The authors declare that they have no competing interests

Authors' contributions

BM and AW conceived the study. AW and BM analyzed the data. AW and EMH contributed to the collection and coding of the data. All authors critically reviewed various drafts of the manuscript; all authors approved the final version. JSK is responsible for the integrity of the work as a whole.

Authors' information

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Availability of data and materials

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Food advertisement and gender stereotypes on Austrian television

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Summary

The goal of this paper is the analysis of food advertisements on Austrian television as to the subject of gender specific stereotypes. Over a two-week-period, 45 hours of television footage were recorded, coded, analyzed, and evaluated using seven screening categories. The analysis revealed that men, in comparison to women, are frequently depicted as performing some type of work and are often older (> 50 years), or of middle age (35–50 years of age). Food, such as meat and beer, are more commonly associated with men; milk, coffee and tea rather with women. In addition, women are often portrayed as young (< 35 years of age), in stable relationships and shown while performing housework. As a result, gender manifestations are evident in food advertisements and implications regarding stereotypical role models referring to dietary identities and food communication can be derived.

Keywords: food advertisement, television, gender stereotypes, gender, marketing

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Introduction

Eating habits are formed as a result of diverse societal influences. They develop as a whole throughout one's lifetime and are considered highly complex [1]. Modern television, together with other media (print, radio, internet), plays a major role in data dissemination [2] and contributes to the broad presentation of dietary stereotypes.

Gender as community forming category

Different demands of men and women for products and services have prompted many corporate divisions to conduct research and are incorporating their findings in technology development, marketing and planning. Marketing strategies, and/or product designs are used to reinforce gender stereotypes and consequently manifest societal male/female perceptions of product use and are accordingly applied in their promotion.

The orientation toward these societal norms is evident in product designs, including food products. Numerous studies point out differences in male and female eating behavior [3, 4], but do not elaborate on the influence on diet these standards have in product advertisement and package design. Symbolic gender order reinforces values and therefore clearly influences male and female behavior [5].

Gender hierarchy impacts the depiction of men and women in media and advertising. Media representation of men and women are rather ambivalent: gender-equitable portrayals of various domestic and non-domestic situations are still absent. In media, feminine presentation is still associated with thinness and youth culture [6].

Doing Gender

The terms "sex" and "gender" have been utilized by gender researchers since the 1980s and spotlight that gender differences are not exclusively defined by biology, but by social and societal parameters as well [7].

Gender research's concept of doing gender aims to clarify that gender and the perception of how men and women „are" is a societal construct, can be deconstructed by society, and is therefore not immutable. The concept of „doing gender" can mainly be contributed to Candace West and

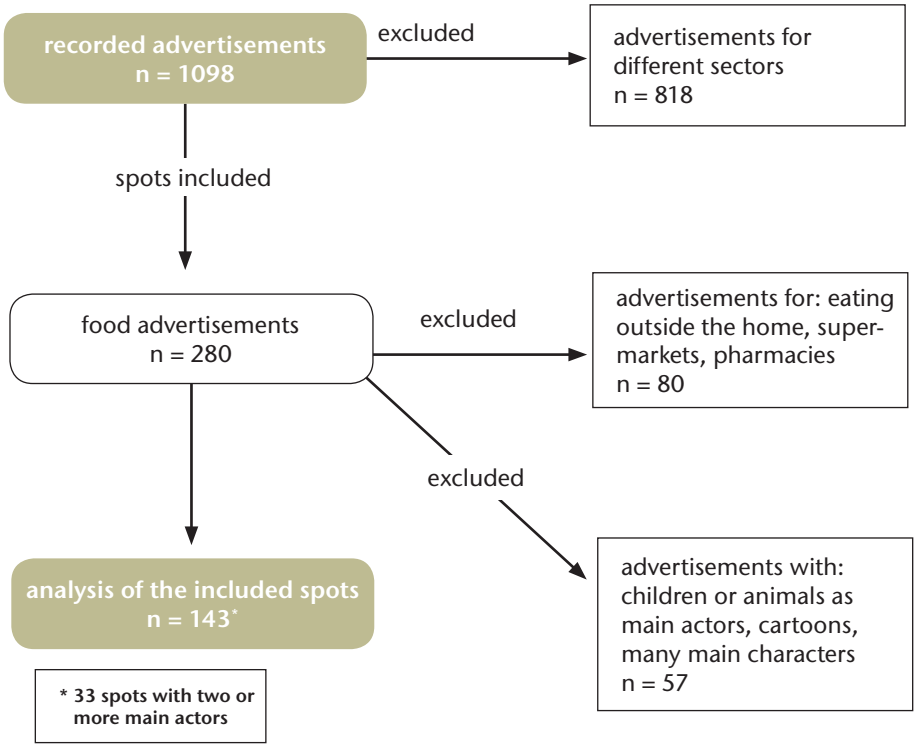

Figure 1: **Selection criteria – flow chart**

Don H. Zimmerman (1987). Both perceive gender as a social construct, an attribute in societal situations, rather than a person's individual trait [8].

Food advertising and gender aspects

Media plays an important role in conveying messages, expectations and images which serve the social construct of gender identity. Television imparts normative, social and cultural information to a broad (heterogenic) audience. While watching food advertisements on television, perceptions how both men and women live and consume food become apparent [9].

While watching food commercials, the reinforced dietary identities become clear rather quickly. Austrians averagely watch 2.5 hours of television a day [10], while Germans approximately watch 3.7 hours [11]. The 1:1 depiction of gender roles can be attributed to television commercials. Flick and Rose assume that precisely this combination of images and individuals are entering into mutual interaction [12]. For example, they show that during commercials, women are commonly depicted in domestic settings, whereas men are more often shown in public. The female environment can also be used exclusively for eating – namely, to fortify health. Again, these images perpetuate numerous male/female dietary habits that have been identified by nutritional science studies on gender: females eat healthier than males [13]. This contributes indirectly to the construction of gender roles which ultimately are reflected in living conditions. Therefore, the connection and influence of food advertisement and gender specific awareness becomes apparent.

On international level, little research exists specifically with reference to gender aspects of food marketing [12]. Next to some English language studies which investigated gender stereotypes in food marketing on private and public television stations [14–16], even fewer research papers focusing on food emerge from German-speaking countries of central Europe [13, 17]. Research of single products in relation to gender context hardly exists [18].

Classic role models of men and women are found in some studies on the topic of television commercials in Europe and the USA. Masculinity is often associated with men as being authoritarian, working outdoors, whereas femininity is frequently attached to domestic settings. Women are more often presented as newlyweds, or housewives depending on men [18].

Gender Marketing – Gender Food

Companies use gender marketing – the intentional targeting of products to men and women in commercials – as a method to boost buyer's motivation and appeal. Gender marketing's sole purpose is to appeal specifically to men or women.

Gender marketing research of food advertisement is especially exciting, since the allocation of food items according to gender really affects male and female buying behavior. Consequently, Austrian men eat 54 % more meat and sausage products. Women, on the other hand, choose more fruit, vegetables and whole grain products [4]. Food producers and advertisers use this direct gender marketing approach in order to achieve increased sales.

Objectives

The main focus of this article is to examine food advertisements on Austrian television regarding potential differences in the portrayal of archetypal masculinity and femininity. Therefore, a categorical analysis of advertisement design and content is utilized.

Methodology

Data collection occurred during two consecutive weeks in April and May of 2014. For five days per week, material was recorded from two television stations, each starting with the preliminary programs at 6 pm and followed by the main shows until 10:30 pm (public station ORF2, market share 21.5 %; premium station PULS 4, market share 3.5 %) [19]). At least one weekend day was recorded. Of the 45 hours of recorded data, an ad hoc sampling of defined selection criteria filtered for food commercials (◆ Figure 1). A total of 143 commercials were categorically analyzed for content. Excluded were: a) commercials for restaurants, supermarkets, pharmaceuticals; b) commercials with more than two actors (compare [16]).

The coding system according to MCARTHUR and RESKO [20] was used for content analysis, comparing the research outcome with international results. The systematic content analysis examined seven different categories:

1) Appearance frequency of leading male or female actors
2) Product category (food and beverages): sweets (chocolate, cookies, etc.), refreshments (sodas, mineral waters, etc.), beer (alcoholic and non-alcoholic), dairy products (yogurt, yogurt drinks, ice cream), processed food (pizza, instant noodles, etc.), functional food (enriched food like probiotic yogurt, fruit juice fortified with vitamins, etc., but no pharmaceutical products!), alcoholic mixed drinks, savory snacks (chips, popcorn, etc.), bread and cereal-based products (breads, cakes, etc.), wine, champagne, spirits, meat and sausage products, baby food (supplementary nutrition, baby food, etc.), coffee and tea (powder and ready-to-consume products), breakfast cereals (muesli, cornflakes, etc.)
3) Voice-over: man, woman, together (both genders)

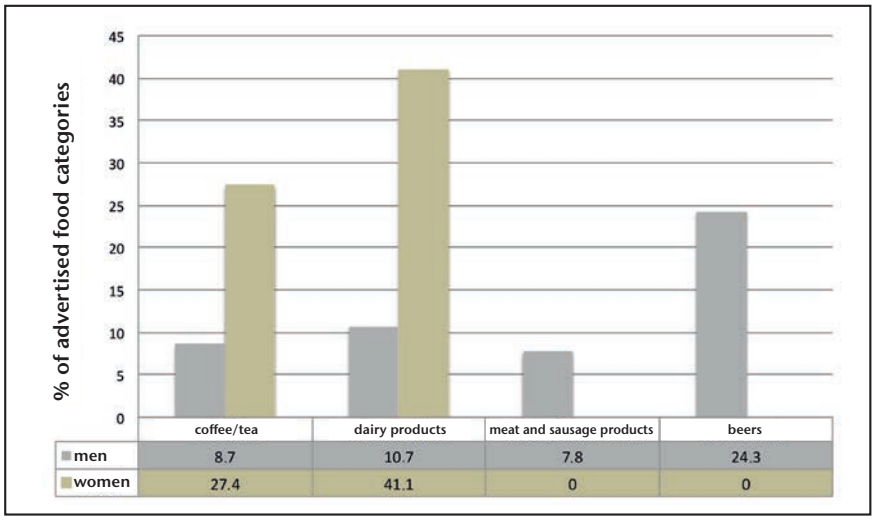

Figure 2: **Differences in the presentation of food categories comparing men to women** (n = 103)

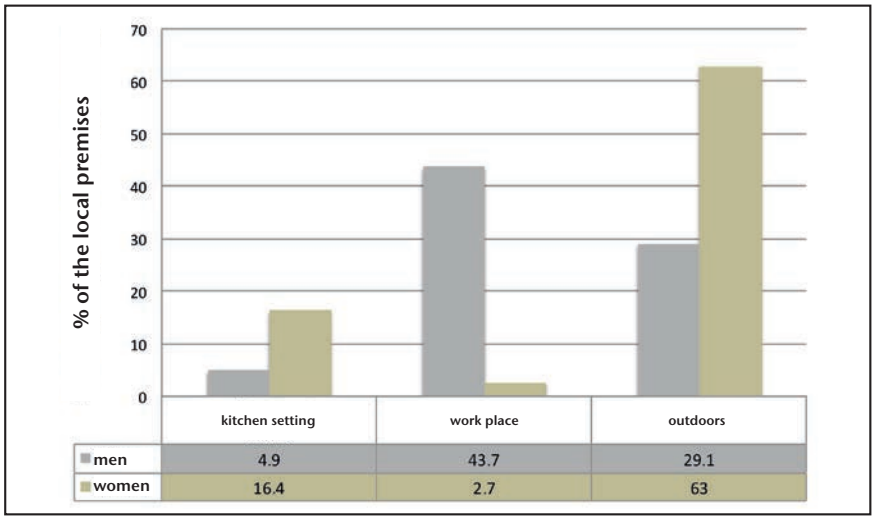

Figure 3: **Differences depicting local premises as compared to men and women** (n = 140)

4) Setting: kitchen, domestic setting except kitchen, work place, outdoors
   Miscellaneous setting (i.e. imaginary setting)
5) Age: < 35 years of age, 35–50 years of age, > 50 years of age
6) Role models: Relationship: (husband/wife/boyfriend/girlfriend), parent, housewife/househusband, employee, interviewer or narrator, product expert, miscellaneous
7) Product argumentation: scientific reason (data + facts), non-scientific reason (opinion, little product knowledge), no reason

Statistical analysis

To analyze the categorical variables, chi-squared tests were used to determine differences in occurrences of single variables (subcategories) between males and females. Level of significance was determined at 5 %.

Findings

In total, more commercials were aired on the premium station PULS4 (n = 640) than on the public station ORF2 (n = 458). Of 22.5 hours of raw material aired on the public sta-

		Authors' research sample N = 143		Espinar-Ruiz and González-Díaz [14] (2012), N= 407		Furnham (2008)[1],
		female	male	female	male	female
Leading Role	n	73	103	216	191	33
	%	**41.5**	**58.5**	53	47	**73**
Voice-over	n	48	88	118	289	26
	%	**34.5**	**63.3**	**29**	**71**	57.6
Age (< 35 years of age)	n	50	6	214	130	16
	%	**68.5**	**5.8**	**52.6**	**32**	36.4
Age (35–50 years of age)	n	23	85	50	22	23
	%	**31.5**	**82.5**	**12.4**	**5.5**	**51.5**
Age (> 50 years of age)	n	0	12	7	7	5
	%	**0**	**11.7**	1.7	1.8	**12.1**
Relationship (spouse/ boyfriend/girlfriend)	n	73	103	–	–	–
	%	**41.5**	**58.5**	–	–	–
Role model: employee	n	48	88	–	–	–
	%	**34.5**	**63.3**	–	–	–
Setting: kitchen	n	12	5	121	77	–
	%	**16.4**	**4.9**	**29.9**	**18.8**	–
Setting: work place	n	2	45	23	26	4
	%	**2.7**	**43.7**	5.7	6.3	9.1
Setting: outdoors	n	46	30	101	140	–
	%	**63**	**29.1**	**24.7**	**34.5**	–

Table 1: **Significant differences of own research sample, compared to three other studies** [14–16]
[1] Recordings from Chinese food advertisements
[2] Recordings from Western food advertisements
[3] Night/evening recordings
[2] Recordings during the day
– = no data
bold = significant differences ($p < 0.05$)

tion, 110 food advertisements (31 % of all aired commercials) were identified. 62 of these complied with the analytical prerequisite. During 22.5 hours, the premium station PULS4 showed 170 food advertisements (36 % of all aired commercials). Of these, 81 commercials met the analytical criteria. A total of 143 food advertisements (ORF2 and PULS4) were considered for further analysis.

Leading actors

In 110 advertisements one actor was cast for the main role, whereas two actors shared the leading role in 33 spots. Therefore, 176 (=110 + 33 x 2) leading actors were identified. Men had significantly more leading roles (58.8 %) compared to women (41.5 %). Men were more often engaged in voice-over roles (63.5 %) than women (34.5 %) (χ^2 [1] = 5.11; $p < 0.05$) (◆ Table 1).

Food

The categories of alcoholic mixed drinks, salty snacks, breads and pastries, wine, sparkling wine, and spirits were not included in the analysis; these products did not appear in the advertisements. Beer was exclusively offered by men (χ^2 [1] = 20.65; $p < 0.01$), along with meat products and sausage products (χ^2 [1] = 5.94; $p < 0.05$). Dairy products, on the other hand (χ^2 [1] = 22.12; $p < 0.01$), as well as coffee and tea (χ^2 [1] = 10.81; $p < 0.05$), were promoted significantly more by women than men (◆ Table 2). When presenting confectionaries, soft drinks, ready-made meals, functional food and baby food, the differences were nominal.

Portrayal of gender stereotypes

In comparison to men, women were portrayed considerably more likely to be in a relationship as wife or girlfriend (χ^2 [1] = 6.09; $p < 0.05$).

and Li [15] N = 45	Furnham and Li [15] (2008)[2], N = 45		Aronovsky and Furnham [16] (2008)[3], N = 97		Aronovsky and Furnham [16] (2008)[4], N = 84	
male	female	male	female	male	female	male
12	29	16	62	35	53	31
27	**64.4**	**35.5**	**64**	**36**	**63**	**37**
30	23	37	64	50	46	54
66.7	**51.7**	**81.3**	66.1	51.4	54.7	64.5
15	12	28	51	3	44	8
33.3	**27.6**	**62.5**	**52.2**	**2.8**	**52.8**	**9.7**
11	29	17	5	55	14	35
25	**65.5**	**37.5**	**4.8**	**57**	**16.7**	**41.9**
19	3	0	–	–	–	–
41.7	6.9	0	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–
4	3	11	–	–	–	–
8.3	**6.9**	**25**	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–

Men were noticeably shown in work situations (39,8 %) compared to women; the examined advertisements showed no women were illustrated working outside the home (χ^2 [1] = 37.88; $p < 0.01$). When portraying men and women as parent, housewife/husband, expert, interviewer or narrator, the differences were insignificant (◆ Table 1). The settings exhibited compelling differences: women were more often depicted in the kitchen (χ^2 [1] = 6.57; $p < 0.05$) and outdoors (χ^2 [1] = 19.99; $p < 0.01$) compared to men. On the other hand, men were seen more frequently at work (χ^2[1] = 36.60; $p < 0.01$; ◆ Figure 3). Other domestic premises, such as the living room or bedroom showed no variations (χ^2 [1] = 0.24; $p > 0.05$). Furthermore, women were often depicted to be younger (< 35 years of age) than men (χ^2 [1] = 77.34; $p < 0.01$). Men were clearly categorized aged 35–50 (χ^2 [1] = 46.90; $p < 0.01$) and older than 50 years of age (χ^2 [1] = 9.13; $p < 0.05$).

Discussion

Our study examined how men and women are portrayed in food commercials on Austrian television and their perpetuation of gender roles. In contrast to other products such as automobiles, technology, hygiene and household products, food advertisement had not been seen as evidently gender specific, but rather as gender neutral [21]. Therefore, food commercials had rarely been subject to gender research [22].

In the last few years, the subject of „gender and diet" has initiated intensive research. Sociologists, nutritional scientists, gender and cultural studies researchers concluded in their studies, that diet and nutrition have to be discussed in the context of gender.

Some food items are associated with feminine, others with masculine characteristics. For example, fruit and vegetables are "peaceful", or "non-dominant", whereas meat for example is associated with masculinity and attributes such as strength, virility and power: meat as the quintessential "male meal" [23].

This is reflected in consumer surveys, which have repeatedly shown that certain food items are more likely to be consumed by either women or men [3]. Food items such as beer and meat have been associated with masculine characteristics [24], and our research confirms that they were mainly promoted by men. Moreover, women were depicted younger (< 35 years of age), men

on the other hand frequently belonged to the age group of > 50 years of age: the so called best-ager group. Best-agers are defined as having desirable characteristics, such as experience, trustworthiness and financial security. The mature, older, and at the same time reliable man is deployed in food advertising to convey these values [25]. Older women, on the other hand, show up less frequently. They appear only rarely in advertising; females are assessed according to their appearance and hereby facilitate the standards of youthfulness and attractiveness [26]. The frequent portrayal of young women matches these ideals; at the same time obscures a further motive which is often connected to women on the issue of nutrition and diet: namely health and vitality.
Furthermore, men were frequently seen at work and women often in domestic settings. This classic gender role definition and the clear attribution of „provider role" to women (household, food supplier) and men (work, money supplier) comes to light, especially in connection with nutrition. This point illustrates how advertisement accepts ritualized male and female behavior and conventionalizes it once again [27, 28].
The gendering of everyday acts (depiction of actors, settings, roles) and things (food promoted by men vs. women) in the commercials examined in this study shows that doing gender in food commercials on Austrian television perpetuates classic gender roles.

Limitations

Due to missing reliability testing, the presented data should be interpreted with caution. Also, seasonal variants of aired commercials have not been gathered [14, 15, 18], and preceding television programs and their influence on subsequent commercials have not been analyzed [29, 30]. Additionally, in this sample, the number of commercials of particular food groups, such as baby food, functional food, ready-made meals and soft drinks were very small (≤ 5). Due to limited numbers, it can therefore not be ruled out that potential differences between groups were undiscovered.

Conclusion

Food commercials on Austrian television convey classic male and female role models and transmit stereotypical gender associations vis-à-vis certain food items. This rather conservative characterization of male and female roles on the subject of nutrition seems to ignore the important societal and domestic progress made in the last decades, but contributes to the viewers' solidification of traditional gender roles, which ultimately shape once more nutritional habits and everyday living.

Conflict of Interest
The authors declare no conflict of interest according to the guidelines of the International Committee of Medical Journal Editors.

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Mental imagery interventions reduce subsequent food intake only when self-regulatory resources are available

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Research has shown that imagining food consumption leads to food-specific habituation effects. In the present research, we replicated these effects and further examined whether the depletion of self-regulatory resources would reduce the habituation effects of imagined food consumption. Since self-regulatory resources have been shown to reduce habituation effects during the perception of emotional stimuli, we expected a reduction in habituation effects from imagined food consumption when self-regulatory resources were depleted. In Study 1, we replicated habituation effects as a response to imagining gummy bear consumption with a high (36) and medium number (18) of repetitions in a camouflaged taste test. Participants imagining gummy bear intake showed decreased food intake compared with participants who imagined putting a coin into a laundry machine. The number of repetitions did not significantly moderate the observed habituation effect. In Study 2, we investigated whether self-regulatory depletion would impede habituation effects evoked by the imagination of walnut consumption. Participants in a depleted state did not show a reduction in food intake after imagining walnut intake compared with participants in a non-depleted state. We discuss directions for future research and processes that might underlie the observed moderating effect of self-regulatory resources.

Keywords: mental imagery, self-regulation, satiation, habituation, depletion, regulation of food intake

INTRODUCTION

Food intake is important for survival but also has negative consequences such as overweight and obesity, which are accompanied by massive societal and financial burdens (Reilly and Kelly, 2011). Thus, understanding the fundamental underlying mechanisms of food intake is pivotal. A fact challenging individuals' self-regulation is the presence of food cues in their environments (Swinburn et al., 1999). Indeed, a common view is that cues leading individuals to imagine the consumption of food (e.g., cues from sensory marketing) powerfully increase appetite and the likelihood of food consumption through perceptual modulation (Barsalou, 2008; Elder and Krishna, 2010). However, although this might be true in many cases, researchers have shown that mechanisms of habituation can help individuals cope with these challenges (Papies et al., 2012). Research on sensory-specific satiety, for instance, has shown that individuals habituate to specific foods while consuming such foods (Rolls et al., 1981; Hetherington, 1996) in a modality-specific way (Havermans and Mallach, 2014). Even more interesting, recent research has also found that individuals habituate while imagining the consumption of specific food (Morewedge et al., 2010). Since research on the habituation effects of imagined food consumption is rare, the objective of the present research was to examine whether these kinds of habituation effects could be replicated across different kinds of food items, different amounts of repetitions and most importantly whether similar limiting circumstances would hold for imagined food consumption as they do for other kinds of habituation. In particular, we studied whether habituation effects would decrease when self-regulatory resources were depleted compared with when they were not depleted. This latter point is of major relevance because the depletion of self-regulatory resources usually increases impulsive behavior such as the consumption of palatable food (Vohs and Heatherton, 2000; Hagger et al., 2010; Heatherton and Wagner, 2011), and it would be of interest to determine whether reduced habituation effects contribute to such phenomena.

Repeatedly imagining oneself eating a certain food was shown to decrease subsequent consumption of the same food (Morewedge et al., 2010). To further contribute to the understanding of such habituation effects, we investigated whether the effects would increase with the number of repetitions, whether they would occur for different food items, and whether they would be reduced when self-regulatory resources were depleted.

THEORETICAL BACKGROUND

Perception and food cognitions involve perceptual simulations and mental images (Bensafi et al., 2007; Barsalou, 2008). Thinking about a desired food increases a person's motivation to consume that food (elaboration intrusion theory of desire) and is defined as an interplay between associative and elaborative cognitive processes (Kavanagh et al., 2005). External food cues trigger the activation of anticipatory signaling of the autonomous nervous system in preprandial phases. For example, external food cues increase the production of gastric juices and saliva and activate hormonal release to prepare the body for impending food intake (Rodin, 1985). At the same time, the desire to eat increases (Dadds et al., 1997). Spontaneous mental images can

lead to similar responses (May et al., 2012). Such images are involved in the development of cravings for alcohol (Statham et al., 2011) and food (Tiggemann et al., 2010; Kemps et al., 2012; Meule et al., 2012; Bullins et al., 2013; Rodriguez-Martin et al., 2013).

Whereas it is evident that thoughts about food can enhance appetite, recent research also suggests that repeatedly imagining food consumption upon being instructed to do so by an experimenter may lead to different effects than thoughts about food without multiple repetitions. In a landmark study Morewedge et al. (2010) showed that 30 repetitions of imagining the consumption of a specific food (e.g., M&M's; cheese cubes) resulted in decreased consumption of the food afterward compared with three repetitions. Hence, imagining food intake does not always lead to increases in food intake. Morewedge et al. (2010) speculated that habituation processes are involved in these effects. Indeed, habituation effects for food consumption have been found for the actual consumption of food before (Epstein et al., 2009a,b; Carr and Epstein, 2011).

According to the memory-based associative conditioning theory, habituation occurs when the presentation of new stimuli is no longer surprising. The presentation of stimuli that already represent information that is stored in short-term memory leads to a reduction in stimulus response (Wagner et al., 1981; Epstein et al., 2009b). A core principle of the standard operating procedure (SOP) model is that when a stimulus is presented, the stimulus is represented in the form of a memory node, which is then activated to a high state of activity (maximally active; the A1 state). Over time, the activity decays, leading to a lower level of activation (processing is more peripheral; the A2 state), and after further decay, such activity becomes inactive (the I state). Information flow is unidirectional from the A1 to A2 to I states; thus, processing in the other direction (from A2 to A1) cannot occur. During food intake, a switch between a state of maximum activity (A1) to a less active and more peripheral processing state (A2) occurs. Sensory-specific satiety, a decrease in the ability to derive pleasure from a certain food after repeatedly being exposed to it, is therefore defined as a habituation process (Rolls et al., 1981; Swithers and Hall, 1994). Repeatedly thinking about consuming a certain food can be seen as a simulation of real food intake without being physically exposed to the food. The experience is similar to an exposure to internally stored memories about the sensory, contextual, and emotional characteristics of an experience (Pylyshyn, 2002; Kosslyn, 2003). When objects are visualized, neural regions are activated in a way that is similar to the actual process of seeing the objects (Ganis et al., 2004), although qualitative differences in the neural dynamics can be observed (Lee et al., 2012; Johnson and Johnson, 2014). Hence, simulating food intake appears to evoke regulating mechanisms that are similar to those evoked from actual food intake.

Interestingly, the SOP model implies (Wagner et al., 1981), that memory processes are the basis for habituation processes and that habituation should be reduced when these memory processes are blocked. In line with this assumption, research has found that distraction is able to reduce habituation effects. For example, individuals were less likely to habituate to the consumption of popcorn when being distracted by actively watching a movie (Epstein et al., 2009b; Harris et al., 2009). Also, results of a recent meta-analysis supported the assumption that distraction leads to an increase in the amount of food consumed (Robinson et al., 2013). A different line of research has shown that the depletion of self-regulatory resources blocks inhibition in eating behavior (Vohs and Heatherton, 2000; Kahan et al., 2003). This research did not study habituation effects directly, but it showed that individuals with reduced self-regulatory resources were less likely to limit their food intake. Self-regulation and executive functioning are proposed to share the same resources. Depleting these resources was associated with reduced inhibitory effects (Kaplan and Berman, 2010). Direct evidence for habituation-reducing effects of the depletion of self-regulatory resources comes from research on the perception of emotional stimuli. Wagner and Heatherton (2013) asked participants in one condition to complete a task that demanded self-regulatory control. In this task, participants had to watch a 7-min nature documentary and inhibit their reading of words presented at the bottom of the screen. They found that this task resulted in a reduction in habituation as a response to emotional pictures observed in the amygdala compared with a control task (Wagner and Heatherton, 2013). Since habituation needs cognitive resources to occur, and since self-regulatory depletion already impedes habituation on the level of very basic brain processes, we posit that habituation while imagining food intake should decrease when individuals' self-regulatory resources are depleted.

THE PRESENT STUDY

The main objectives of the present study were first to replicate the habituation effects after the repeated imagination of food consumption with different food items and different numbers of repetitions and second to test whether the effects would be moderated by self-regulatory depletion. To replicate (Morewedge et al., 2010) findings, we used gummy bears in Study 1 and walnuts in Study 2. To examine the moderating effect of self-regulatory depletion, we varied whether participants had to complete a depleting task in advance in Study 2.

According to the SOP model, increasing the number of repetitions should result in an even more pronounced effect on behavior – thus leading to a larger reduction in food intake. Therefore, we hypothesized that in conditions with a larger number of repetitions, the reduction in food intake due to habituation would be higher than in conditions with a smaller number of repetitions. Therefore, we varied the number of repetitions in Study 1 and tested for habituation in the different conditions.

We furthermore posit that the effects of repeatedly imagining food consumption are based on very general mechanisms and are not linked to a specific kind of food. Therefore, we introduce two new foods into the experimental paradigm to broaden the food spectrum. Morewedge et al. (2010) used foods containing large amounts of fat (cheese cubes: ∼20–30% fat content) and sugar (M&M's: ∼66% sugar) with specific sensory and health characteristics. In the present research, we examined whether habituation would occur after participants imagined themselves consuming gummy bears (Study 1) and walnuts (Study 2). We used gummy bears to study whether the effect could be replicated with a food

that is relatively easy to imagine (mignon design in the form of bears). We expected to observe habituation effects after participants repeatedly imagined the consumption of gummy bears. In Study 2, we used walnuts because they are only marginally processed foods and do not include added micro or macronutrients. Although walnuts contain a high amount of fat (∼63%), generally walnuts are regarded as healthy and natural foods. In contrast, M&M's, cheese, and gummy bears are highly processed foods. Again, we argue that habituation is defined as a very general mechanism that occurs independently from the imagined food. We expected to observe habituation effects after participants imagined walnut consumption.

Finally, we argue that habituation to the target food should occur only when cognitive resources are available. If cognitive resources are intact, it should be possible to induce the habituation effect. That is, the switch from the A1 to the A2 state will occur, and food intake should be reduced. On the other hand, if cognitive resources are depleted, no habituation effect should occur, and food intake should not be reduced. Therefore, we hypothesized that when a person is in a state of self-regulatory depletion, cognitive resources are not available for habituation to occur. Thus, performing mental imagery with foods in this condition does not lead to habituation and no decrease in food intake in a subsequent taste test was expected (Study 2).

STUDY 1

The main objectives of Study 1 were to replicate the habituation effect after participants imagined food consumption and to test this effect with a large and medium number of repetitions. To examine these objectives, we applied a 2 (*number of repetitions*: 18 vs. 36) × 2 (*imagery item*: gummy bears vs. coins) between-subjects design. Participants were asked to imagine consuming gummy bears or inserting a coin into a laundry machine. We expected a habituation effect after the imagined consumption of the gummy bears and that the habituation effect would be stronger for 36 compared with 18 repetitions.

MATERIAL AND METHODS

Participants

A sample of 101 undergraduate students from the University of Vienna participated in the study on a voluntary basis. Participants were recruited via Internet forums, social media, and flyer postings on the campus of the University. They were asked to refrain from eating 3 h before the experiment and were blinded to the true intentions of the study. They believed they were taking part in a taste and rating test of gummy bears. All ranges of BMI and age were included in the sample. Six participants were excluded from the statistical analyses because they indicated that they did not imagine food consumption as they were asked to. This resulted in a total sample of 95 participants (77 female and 18 male) with a mean age of 24.01 years (SD = 5.1) and a mean BMI of 22.02 kg/m^2 (SD = 2.7) across both sexes. Ten participants (four male, six female) were classified as overweight (BMI ≥ 25 kg/m^2) and one male participant as obese (BMI ≥ 30 kg/m^2), whereas all other participants displayed a BMI between 18.5 and 24.99 kg/m^2 and were therefore considered to have a normal weight.

Study design

The study was designed as a camouflaged taste test of gummy bears presented immediately after a repetitive mental imagery paradigm. This intervention involved repeatedly imagining the consumption of gummy bears or, as a control, visualizing oneself putting coins into a laundry machine with a given number of repetitions of either 18 or 36. Participants were randomly assigned to the 2 (*number of repetitions*: 18 vs. 36) × 2 (*imagery item*: gummy bears vs. coins) between-subjects design using urn randomization (Wei and Lachin, 1988). Unbeknownst to the participants, the qualitative results of the subsequent taste test were not analyzed further, whereas in fact, the amount of gummy bears consumed was the main variable of interest in this study.

Procedure

After arriving at the laboratory, all participants stated their age, sex, body weight, and height and completed questionnaires on current hunger, fullness, overall liking of gummy bears, and restrained eating. Subsequently, participants were asked to perform the mental imagery paradigm, which was explained as a "test of mental visualization skills."

Participants in the gummy bear condition received detailed instructions on how to imagine the consumption of gummy bears either 18 or 36 times. Participants in the control condition were told to imagine putting a 50¢ coin into a laundry machine (motor control task) with an equivalent number of repetitions. The control task was designed to involve imagined motor behaviors that were similar to those from the imagined consumption task. The numbers of 18 and 36 repetitions were chosen to balance between applied practicability and to avoid demanding too much or too little from the participants. A standard package of gummy bears available in an Austrian supermarket contains 72 gummy bears. Thus, 36 repetitions represents half of a standard package available at Austrian supermarkets. Followed by a short introduction from the experimenter, participants were seated in one of the eight separated booths of our sensory lab. They were given detailed written instructions on the mental imagery task procedure (see Table S1). In the description of the task, we stressed a precise wording and asked the participants in the consumption imagery group to focus on sensory and textural characteristics of the imagined food item and on the eating experience of the imagined food itself. In the control group, participants were asked to focus on the sensory and textural characteristics of the imagined coin item and on the action (motoric) experience of throwing the coin in the laundry machine. To keep track of each repetition, we asked the participants to count each repetition on a checklist using pen and paper. We verified the checklists at the end of the experiment. Additionally, we encouraged the participants to spend at least 15 s for every repetition, but did not measure the cumulative time spent for the complete mental imagery task.

After the imagination task, participants were asked to engage in a taste test of different colored gummy bears. Each bowl contained 83 g of gummy bears. Participants were told to eat *ad libitum* from the bowl. The bowls were weighed before and after the taste test to assess the amount of gummy bears eaten. Also, participants rated their hunger, fullness, and liking of the gummy bears once more,

completed questionnaires to assess the vividness of their mental imagery, and answered the manipulation check question about whether or not they performed this task. Finally, participants were informed that the experiment was over, were debriefed, thanked for their cooperation, and dismissed.

MEASURES

Manipulation check

To examine whether participants really performed the required mental imagery task, they were asked to indicate whether they had conducted the task or not ("Did you really perform the task we asked you to?").

Hunger status and liking of the product

Visual analog scales (VASs) were used to measure appetite sensations (Stubbs et al., 2000). We used a 120 mm horizontal line with the extremes of the sensations *hunger* and *fullness* at the ends of the line. Participants had to quantify their subjective feeling by placing a mark across the line. We asked participants "how hungry do you feel?" and "how full do you feel?" with the anchor points "0 = not hungry" and "120 = very hungry" and "0 = not full" and "120 = very full," respectively. To measure how much they liked the product, we used a VAS with three anchor points ("not at all," "neither. . .nor," "very much").

Visual imagery

To assess visual imagery, participants were asked to visualize visual images and rated four different scenes on the vividness of four different aspects of these scenes on a 5-point Likert scale (1 = *no picture at all; you merely know that you are thinking about the object*; 5 = *perfectly clear; as vivid as normal vision*) using the Vividness of Visual Imagery Questionnaire (Marks, 1973). An everyday preference for using visual mental images was assessed via the Individual Difference Questionnaire consisting of 13 statements. Participants rated their agreement with each statement on the 5-point Likert scale (1 = *complete agreement*; 5 = *complete disagreement*). Adapted German versions of both questionnaires were used (Hirschfeld et al., 2012) with an internal consistency in the current study of α (Vividness of Visual Imagery Questionnaire) = 0.93 and α (Individual Difference Questionnaire) = 0.72.

Restrained eating

An adapted German version of the 10-item Restraint Scale (Dinkel et al., 2005) was used to assess concern for dieting and weight fluctuation among participants. Concern for dieting was assessed with questions about dieting frequency (0 = *never;* 4 = *always*), weight fluctuation affecting the participants' lives (0 = *not at all*; 3 = *very much*), sensible eating in front of others (0 = *never*; 3 = *always*), thinking about food all the time (0 = *never;* 3 = *always*), feeling guilty after overeating (0 = *never*; 3 = *always*), and mindfulness of one's own eating behavior (0 = *not at all*; 3 = *extremely*). Dieting frequency was assessed with questions regarding their maximum amount of weight gain in kilograms within 1 month (0 = *0–2.5 kg*; 1 = *2.5–5 kg*; 2 = *5–7.5 kg*; 3 = *7.5–10 kg*; 4 = > 10 kg), their maximum amount of weight gain in kilograms within 1 week (0 = *0–0.5 kg*; 1 = *0.5–1 kg*; 2 = *1–1.5 kg*; 3 = *1.5–2.5 kg*; 4 = > 2.5 kg), their typical weight fluctuation within 1 week (0 = *0–2.5 kg*; 1 = *2.5–5 kg*; 2 = *5–7.5 kg*; 3 = *7.5–10 kg*; 4 = > 10 kg), and their maximum weight in kilograms above their desired weight in kilograms (0 = *0–0.5 kg*; 1 = *0.5–3 kg*; 2 = *3–5 kg*; 3 = *5–10 kg*; 4 = > 10 kg). The scale values were averaged across the items. High values indicated restrained eating. Internal consistency in the current study was α (Restraint Scale) = 0.67.

Eating behavior

The amount of gummy bears consumed served as the primary dependent variable. We weighed the bowl of gummy bears before and after the experiment with a standard scale to three decimals places. At the end of the experiment, we assessed participants' reasoning about the possible effect of imagining food intake on their hunger status.

Ethics statement

The experimental procedure was reviewed and approved by the University of Vienna Ethics Committee (*reference number*: 00065), and written informed consent was obtained from all participants before data collection. Participants were informed that they could withdraw their participation at any time during the experiment.

Statistical analysis

Results were considered significant at an α level of $p \leq 0.05$. Results marked *ns* refer to *p*-values > 0.05 (for a summary of the data, see Table S2).

RESULTS AND DISCUSSION

Eating behavior

We hypothesized that participants would eat a smaller amount of gummy bears when they repeatedly imagined eating gummy bears compared with putting coins into a laundry machine. Furthermore, we expected this effect to be more pronounced for 36 compared with 18 repetitions. To test the hypotheses, a 2 (*repetition number*: 18 vs. 36) × 2 (*imagery item*: gummy bears vs. coins) between-subjects ANOVA with gummy bear intake as the dependent variable was computed. As expected, participants consumed a smaller amount of gummy bears when they repeatedly imagined eating gummy bears ($M = 24.63$ g, SD = 11.02 g) compared with when they repeatedly imagined putting coins into a laundry machine ($M = 32.94$ g, SD = 16.94 g) [$F_{(3,95)} = 8.61$, $p = 0.004$, $\eta_p^2 = 0.09$] (see **Figure 1**). In contrast to our hypothesis, the interaction between repetition number and imagery item was not significant [$F_{(1,95)} = 0.51$, $p = 0.47$].

As expected, liking gummy bears had a pronounced effect on gummy bear consumption [$F_{(1,95)} = 13.8$, $p = 0.04$, $\eta_p^2 = 0.13$]. Liking gummy bears did not change significantly from before ($M = 80.17$, SD = 23.58) to after the experiment was conducted ($M = 77.55$, SD = 26.99) [$F_{(1,95)} = 0.12$, $p = 0.29$]. None of the following parameters had effects on the amount of gummy bears consumed: (i) hunger assessed before the experiment [$F_{(1,95)} = 0.36$, $p = 0.55$]; (ii) fullness before the experiment [$F_{(1,95)} = 0.11$, $p = 0.78$]; (iii) time of last meal intake [$F_{(1,95)} = 0.14$, $p = 0.71$]; (iv) restrained eating scores [$F_{(1,95)} = 1.26$, $p = 0.27$]; (v) BMI scores, [$F_{(1,95)} = 0.39$, $p = 0.53$]; (vi) gender [$F_{(1,95)} = 2.80$, $p = 0.09$]; (vii) Vividness of Visual Imagery Questionnaire scores

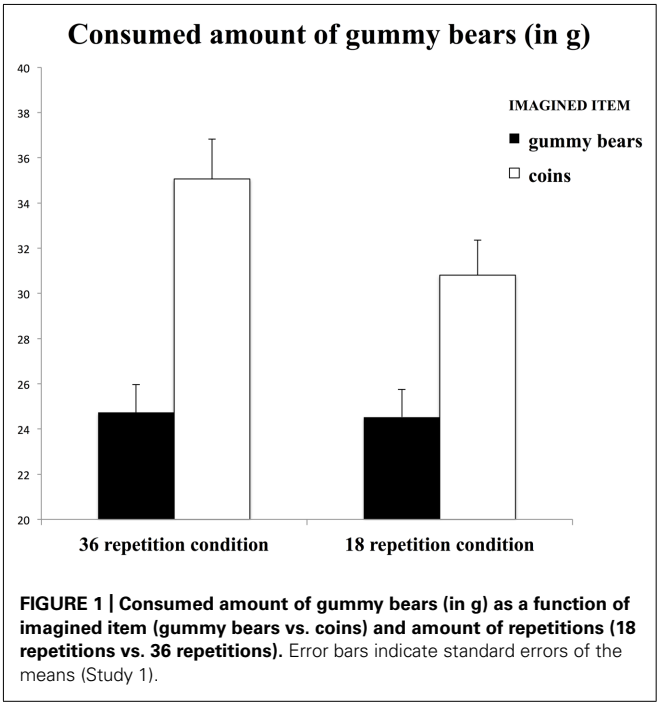

FIGURE 1 | Consumed amount of gummy bears (in g) as a function of imagined item (gummy bears vs. coins) and amount of repetitions (18 repetitions vs. 36 repetitions). Error bars indicate standard errors of the means (Study 1).

$[F_{(1,95)} = 0.08, p = 0.78]$; or Individual Difference Questionnaire scores $[F_{(1,95)} = 0.29, p = 0.59]$. In an analysis of covariance, the inclusion of the above variables did not affect the reported habituation effect $[F_{(1,95)} = 4.32, p = 0.04, \eta_p^2 = 0.05]$.

No changes in fullness from before ($M = 49.32$, SD $= 26.91$) to after the mental imagery task ($M = 58.26$, SD $= 25.89$), $[F_{(1,94)} = 1.27, p = 0.29]$ or in hunger from before ($M = 33.26$, SD $= 24.41$) to after the mental imagery task ($M = 28.99$, SD $= 23.69$), $[F_{(1,94)} = 0.81, p = 0.48]$, were observed.

Participants' expectations

To examine whether the reported habituation effect could be evoked by participants' expectations, we also analyzed these expectations. Importantly, most participants did not expect a habituation effect. 90% of the participants inferred that imagining gummy bear intake might stimulate their appetite, 8% reasoned that thinking about food intake might decrease their appetite, and 2% assumed that it might have no effect on their appetite. When we excluded participants who expected a decrease in their appetite (eight participants), a between-subjects ANOVA still showed a significant main effect of the imagery task $[F_{(3,87)} = 7.51, p = 0.007, \eta_p^2 = 0.08]$, indicating a lower consumption of gummy bears among participants who repeatedly imagined eating gummy bears ($M = 25.00$ g, SD $= 11.27$ g) compared with those who repeatedly imagined putting coins into a laundry machine ($M = 33.31$ g, SD $= 16.13$ g).

To sum up, in Study 1, we replicated the habituation effect after imagining food consumption. Importantly, the participants' expectations could not account for this effect.

Morewedge et al. (2010) found no habituation effect for three compared with 30 repetitions. Hence, at least more than three repetitions are necessary to produce the effect. In Study 1, the number of repetitions (18 vs. 36) did not significantly moderate the effect. We expected that a larger number of repetitions would be necessary for the habituation effect to occur. The present data did not confirm this hypothesis but reflected the strength of the habituation effect. In Study 2, we examined whether self-regulatory depletion would impede habituation effects while participants imagined food consumption.

STUDY 2

The main objective of Study 2 was to test the hypothesis that a depletion of self-regulatory resources would decrease the habituation of imagined food consumption. We formulated this hypothesis because self-regulatory depletion has been shown to reduce habituation in other contexts (Wagner and Heatherton, 2013). We applied a 2 (depletion vs. non-depletion of self-regulatory resources) × 2 (*imagery item*: walnuts vs. coins) between-subjects design. We varied whether participants completed a task that depleted or did not deplete their self-regulatory resources. Furthermore, we asked participants to imagine either consuming food or putting a coin into a laundry machine. As the target food, we used walnuts in Study 2.

MATERIAL AND METHODS

Participants

For Study 2, we recruited exclusively female participants via online forums, social networks, and message boards at the University of Vienna. We decided to include only women in the present study because the probability of observing an effect with a small sample size would be higher in a homogenous sample. In Study 1, men tended to eat more than women. Therefore, in Study 2, 90 females participated in the experiment. Four participants had to be excluded from the study because they failed the manipulation check. Four participants were excluded from the statistical analyses to preserve data homogeneity (cut-off > 2.5 SD of mean walnut consumption). Hence, data from 82 female participants were included in the statistical analyses. These participants had a mean age of 24.52 years (SD $= 3.19$) and a mean BMI of 21.38 kg/m^2 (SD $= 2.70$). 11 were classified as overweight (BMI $\geq$ 25 kg/m^2), one as obese (BMI $\geq$ 30 kg/m^2), whereas all other participants displayed a normal BMI between 18.5 and 24.99 kg/m^2. Most of the participants were undergraduate students in the nutritional sciences who volunteered to take part in the experiment.

Similar to Study 1, participants were deprived of food for 3 h and blind to the true purposes of the study, believing that they were participating in a taste test of different brands of walnuts. As compensation, every participant received a lottery ticket. As in Study 1, all ranges of BMI and age were included in the sample.

Study design

Study 2 was designed as a camouflaged taste test of walnuts, but in contrast to Study 1, the taste test was preceded by two interventions. First, a counting task with two different variations of difficulty was applied in order to induce a state of high and low self-regulatory depletion (Webb and Sheeran, 2003; Hagger and Chatzisarantis, 2013). Subsequently, the mental imagery paradigm was performed as the second task in the dual-task procedure either by asking participants to imagine that they were eating walnuts or, as a control, to imagine putting a 50¢ coin into a laundry machine

with a given number of 18 repetitions. Participants were randomly assigned to a 2 (depletion vs. non-depletion of self-regulatory resources) × 2 (*imagery item*: walnuts vs. coins) between-subjects design using an online randomizer tool (Urbaniak and Plous, 2008). The amount of walnuts consumed was the main dependent variable in this experiment, and the questionnaire results of the taste tests were not analyzed further.

Procedure

Participants completed questionnaires with regard to their current hunger and overall liking of walnuts and stated their age, height, and body weight. Next a "test of mathematical abilities" was introduced, but it was in fact a counting task that was based on a test for assessing automatization difficulties in patients with dyslexia (Fawcett et al., 1996; Webb and Sheeran, 2003). The test was used to manipulate self-regulatory depletion in the present study. Participants in the high self-regulatory depletion condition were told to count backward from one thousand in multiples of seven while standing on only one leg. This procedure has been shown to evoke self-regulatory depletion in the past because participants need to resist the desire to quit this exercise due to their struggle to try not to lose their balance while engaging in a complicated counting task (Hagger and Chatzisarantis, 2013). Participants in the low self-regulatory depletion condition were instructed to count backward from 500 in multiples of five while standing on both legs, a task that was expected to require no self-control. After that, participants completed three manipulation check items to assess effort, difficulty, and fatigue (Webb and Sheeran, 2003) and rated their current mood by completing the short German version of the profile of mood states (Dalbert, 1992). Afterward, participants were seated in one of the classrooms of our facilities. We ensured that participants were not distracted in any way and seated them in an empty classroom. They were given detailed written instructions on the mental imagery task procedure (see Table S1). As in Study 1, we asked the participants to focus on sensory and textural characteristics of the imagined food item and on the eating experience. Participants in the control group were asked to focus on the sensory and textural characteristics of the imagined coin item and on the action (motoric) experience of throwing the coin in the laundry machine. To keep track of each repetition, we asked the participants to count each repetition on a checklist using pen and paper. We verified the checklists at the end of the experiment. Additionally, we encouraged the participants to spend at least 15 s for every repetition, but did not measure the cumulative time spent for the complete mental imagery task and therefore could not assess how much time each individual spent for the task.

Subsequently, participants engaged *ad libitum* in a taste test of different brands of walnuts, which were weighed before and after the experiment unbeknownst to the participants. Each participant was presented a total of 120 g of walnuts equally distributed in four identical bowls. Then participants completed the mental imagery manipulation check and the sub-scale for restrained eating from the Dutch Eating Behavior Questionnaire and the short version of the Barratt Impulsiveness Scale. Finally, participants were debriefed, thanked, and dismissed after receiving a lottery ticket as compensation.

MEASURES

Manipulation check

To examine whether participants really performed the required mental imagery task, they were asked to indicate whether they conducted the task in the instructed way or not ("Did you really perform the task we asked you to?").

Mood

Positive and negative mood states were examined. The short German version of the profile of mood states was used (Dalbert, 1992). After an initial question "How do you feel right at this moment?" participants rated 19 different items including grief ($n = 3$), desperation ($n = 3$), rage ($n = 3$), fatigue ($n = 4$), and positive mood ($n = 6$) on seven-point Likert scales ranging from 1 (*not at all*) to 7 (*very much*). Internal consistencies were α (*grief*) = 0.86, α (*rage*) = 0.77, α (*desperation*) = 0.81, α (*fatigue*) = 0.91, and α (*positive mood*) = 0.89.

Hunger status

To measure hunger before and after the experiment, a VAS with a length of 100 mm was used with four anchor points consisting of "not hungry at all," "hungry," "very hungry," and "extremely hungry" (Stubbs et al., 2000). Liking of walnuts was assessed using the same VAS with three anchor points used in Study 1 for the gummy bears.

Task perceptions

We also measured whether self-regulatory depletion was successfully induced by the manipulation. Participants were instructed to rate the counting task on seven-point Likert scales ranging from 1 (*not at all*) to 7 (*very much*) according to whether the task was fatiguing, difficult, and required effort. The internal consistency in the current study was α (difficult, fatiguing, effortful) = 0.87 (Webb and Sheeran, 2003). High values indicate a strong self-regulatory depletion.

Trait impulsiveness

The short German version of the Barratt Impulsiveness Scale-15 was used to assess trait impulsiveness (Meule et al., 2011). This measure is commonly used to measure impulsive behavior as a trait. The Barratt Impulsiveness Scale-15 consists of three factors, which are non-planning, motor, and attentional impulsivity. Each factor consists of five items, which were rated on a 4-point scale ranging from 1 (*never*) to 4 (*always*). Statements for non-planning include "I plan tasks carefully"; for attention impulsivity, "I am restless during lectures or talks"; and for motor impulsivity, "I say things without thinking" (Spinella, 2007). The items were averaged into an overall impulsivity measure. High values indicate high trait impulsivity. Internal consistency in the present study was α (Barratt Impulsiveness Scale-15) = 0.78.

Restrained eating

The German translation of the sub-scale for restrained eating of the Dutch Eating Behavior Questionnaire was used (Van Strien et al., 1986). This scale consists of 10 items that target restrained eating with questions such as "When you have put on weight, do you eat less than you usually do?" or "Do you deliberately eat less in order to avoid becoming heavier?" These questions were answered

on a 5-point Likert scale ranging from 1 (*never*) to 5 (*very often*). Internal consistency in the present study was α (*Dutch Eating Behavior Questionnaire*) = 0.91. High values indicate restrained eating.

Eating behavior

The amount of walnuts consumed as assessed by weighing the walnuts before and after the experiment with a standard scale to three decimals places served as the primary dependent variable.

Ethics statement

The experimental procedure was reviewed and approved by the University of Vienna Ethics Committee (*reference number*: 00065), and written informed consent was obtained from all participants before data collection. Participants were informed that they could withdraw their participation at any time during the experiment.

Statistical analysis

Results were considered significant at an α level of $p \leq 0.05$ (results marked *ns* refer to *p*-values > 0.05).

RESULTS AND DISCUSSION

Self-regulatory depletion induction

Independent *t*-tests revealed significant differences in perceived difficulty, effort, and fatigue between the two ego-depletion conditions. In the depleted self-regulatory condition, participants rated the counting task as significantly more difficult, $t(80) = 11.65$, $p < 0.001$; effortful, $t(80) = 7.87$, $p < 0.001$; and fatiguing, $t(80) = 12.50$, $p < 0.001$, than participants in the non-depleted self-regulatory condition (**Figure 2**). This indicates a successful induction of self-regulatory depletion (Hagger and Chatzisarantis, 2013; Hagger et al., 2013). The self-regulatory depletion manipulation did not affect positive mood [$F_{(1,80)} = -1.41$, *ns*], grief [$F_{(1,80)} = 0.85$, *ns*], desperation [$F_{(1,80)} = 0.24$, *ns*], rage [$F_{(1,80)} = 0.71$, *ns*], or overall fatigue [$F_{(1,80)} = 1.19$, *ns*].

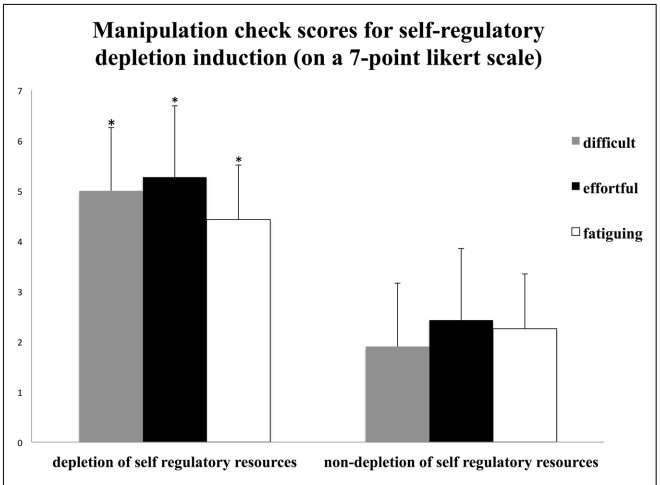

FIGURE 2 | Manipulation check scores for self-regulatory depletion induction (on 7-point Likert scale) displaying difficulty, effort and fatiguing as a function of resource depletion (depletion vs. non-depletion of self-regulatory resources). Asterisk indicates $p < 0.05$.

Eating behavior

We hypothesized that participants would eat a smaller amount of walnuts when they repeatedly imagined eating walnuts compared with imagining putting coins into a laundry machine. Furthermore, we expected this effect to be less prevalent in a state with depleted self-regulatory resources compared with a state with non-depleted resources. To test the hypotheses, we computed a 2 (depletion vs. non-depletion of self-regulatory resources) by 2 (imagery item: walnuts vs. coins) between-subjects ANOVA with walnut consumption as the dependent variable.

The results are depicted in **Figure 3**. In line with our hypothesis, participants in the non-depletion condition ate a smaller amount of walnuts when they imagined eating walnuts ($M = 29.62$ g, SD = 7.53 g) compared with when they imagined putting coins into a laundry machine ($M = 35.49$ g, SD = 7.53 g) [$F_{(1,39)} = 6.26$, $p = 0.02$, $\eta_p^2 = 0.14$]. By contrast, participants in the depletion condition did not differ in their intake of walnuts when they imagined eating walnuts ($M = 36.29$ g, SD = 9.77 g) compared with when they imagined putting coins into a laundry machine ($M = 35.63$ g, SD = 8.14 g), [$F_{(1,39)} = 0.06$, $p = 0.82$]. The interaction between self-regulatory depletion and the imaginary item was only marginally significant but had a medium effect size [$F_{(3,80)} = 3.18$, $p = 0.08$, $\eta_p^2 = 0.04$; see **Figure 3**]. The main effect of repeatedly imagining eating walnuts ($M = 32.95$ g, SD = 8.91 g) compared with repeatedly imagining putting coins into a laundry machine ($M = 35.27$ g, SD = 7.74 g) on the amount of walnuts consumed was not significant [$F_{(3,80)} = 2.03$, $p = 0.16$, $\eta_p^2 = 0.03$]. The main effect of the self-regulatory depletion manipulation on the amount of walnuts consumed was marginally significant. Participants ate more walnuts when self-regulatory resources were depleted ($M = 37.89$ g, SD = 11.26 g) compared with when

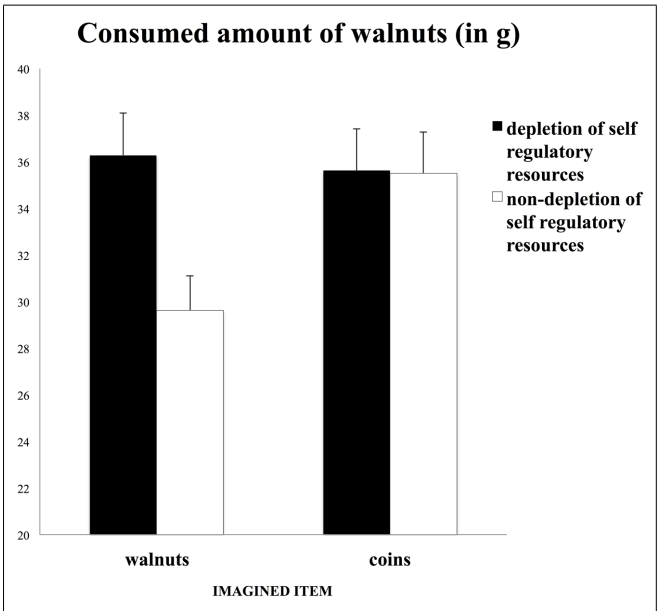

FIGURE 3 | Consumed amount of walnuts (in g) as a function of imagined item (walnuts vs. coins) and state of self-regulatory resources (depletion vs. non-depletion of self-regulatory resources). Error bars indicate standard errors of the means (Study 2).

they were not depleted ($M = 33.26$, SD $= 9.36$), [$F_{(3,80)} = 3.43$, $p = 0.07$, $\eta_p^2 = 0.04$].

A one-way analysis of covariance revealed that none of the following parameters showed effects on the amount of walnuts consumed: (i) BMI scores [$F_{(1,80)} = 0.01$, $p = 0.93$]; (ii) hunger prior to the experiment [$F_{(1,80)} = 0.10$, $p = 0.92$]; (iii) impulsivity scores [$F_{(1,80)} = 0.03$, $p = 0.86$]; (iv) restrained eating scores [$F_{(1,80)} = 0.16$, $p = 0.69$]; and (v) liking walnuts [$F_{(1,80)} = 0.24$, $p = 0.63$]. Liking walnuts did not change significantly from before ($M = 82.61$, SD $= 24.65$) to after the experiment was conducted ($M = 84.38$, SD $= 23.70$) [$F_{(1,80)} = 1.91$, $p = 0.17$]. There were no changes in hunger from before ($M = 41.13$, SD $= 20.92$) to after the mental imagery task ($M = 27.03$, SD $= 20.51$) across intervention groups [$F_{(1,82)} = 0.15$, $p = 0.93$].

To sum up, in Study 2, we found initial evidence that self-regulatory depletion can reduce habituation effects on the intake of food after imagining the consumption of the food.

GENERAL DISCUSSION

Recent research has provided initial evidence that imagining the consumption of food leads to habituation effects that are similar to those that occur with the actual consumption of food (Morewedge et al., 2010). The objective of the present research was to replicate this effect with different kinds of foods and to test the hypothesis that self-regulatory depletion reduces habituation effects from the imagined consumption of food. The main reasoning for the latter was that habituation effects are basically memory effects that require cognitive resources. Therefore, the depletion of cognitive resources should reduce habituation effects that occur from imagining the consumption of food. The results of two studies showed that the habituation effect from food consumption is a stable phenomenon that occurs for different kinds of foods. Study 1 provided a replication of the initial habituation effects induced by mental imagery by Morewedge et al. (2010) and generalized these over another kind of food (gummy bears) as well as over different (smaller and larger) amount of imagery repetitions. In addition, the results of Study 2 provided initial evidence that the depletion of self-regulatory resources impedes habituation effects from imagining the consumption of food.

We replicated the findings of previous experiments using mental imagery (Morewedge et al., 2010) with two different food items (gummy bears and walnuts) with different optical and perceived health characteristics. The finding that habituation occurred with both types of food is in line with the assumption that habituation effects are independent of food characteristics (Epstein et al., 2009b). Furthermore, 18 and 36 repetitions showed similar effects on food intake (Study 1), indicating that 18 repetitions of mental imagery are enough to induce the habituation effect. Study 1 provided a replication of the initial habituation effects induced by mental imagery by Morewedge et al. (2010) and generalized these over another kind of food (gummy bears) as well as over different (smaller and larger) amount of imagery repetitions. We know from previous studies that three repetitions are not sufficient (Morewedge et al., 2010). Hence, the habituation-inducing threshold lies between 3 and 18 repetitions. This finding has implications for future research, because high numbers of repetitions can have side effects such as depletion or even impatience of participants and can lead to infeasibility of the mental imagery task. The finding that habituation effects occur on lower levels shows that it is possible to study the phenomenon with a decreased amount of repetitions. This implies that the phenomenon of habituation is limited in the extent, and that more repetitions do not necessarily lead to stronger habituation effects. Conducting 18 repetitions can be a time consuming task, thus future research should try to narrow down the threshold in which habituation to imagined foods occurs, using lower amounts of repetitions. A lower number of repetitions might lead to a more practicable approach using mental imagery and consequent habituation to reduce food intake.

At this point, we can only speculate why the different amount of imagery repetitions yielded a habituation effect of the same strength. Assumingly, the central process of imagery and habituation in the working memory might offer the answer. The working memory is a system with limited cognitive capacity (Cowan, 2004), and it is therefore possible that performing a vivid mental imagery task more than 18 times (36) might be overly taxing for the working memory (image vividness is related to capacity of cognitive resources (Bywaters et al., 2004)) in that the retrieval, maintenance, and refreshment of a repeated vivid mental imagery might have used all the available (working memory) resources (Kosslyn, 1996; Gunter and Bodner, 2008). As habituation also needs memory capacity to take place, we could assume that when the memory resources reached a capacity limit after a certain number of repetitions of the vivid mental imagery (we encouraged the participants to vividly imagine the food consumption), there were no more resources which could be used to strengthen the habituation effects even more over the next couple of repetitions.

To date, habituation effects of imagined food consumption have been found with M&M's, cheese cubes (Morewedge et al., 2010), gummy bears (Study 1), and walnuts (Study 2). Similar to the studies by Morewedge et al. (2010), the results of the present studies showed that imagining the consumption of food does not reduce hunger or lead to a feeling of fullness.

Habituation effects after imagining food consumption do not represent demand effects because they deviate from the common expectation that thinking about food consumption increases appetite and hunger. In Study 1, we asked participants about their expectations and found that most of them expected an increase in consumption after imagining food consumption.

An interesting question is whether habituation effects from imagining food consumption follow the same rules as other habituation effects. Previous research has shown that habituation effects for example, those related to the perception of pictures or the consumption of food are reduced when individuals are distracted (Epstein et al., 2009b; Harris et al., 2009) or when their self-regulatory resources are depleted (Wagner and Heatherton, 2013). The finding from Study 2 that habituation was reduced when individuals' self-regulatory resources were depleted implies that the habituation effects from visualization are based on processes that are similar to those involved in other forms of habituation.

It is difficult to explain the observed finding that the depletion of self-regulatory resources reduces the effects of imagined food consumption by reducing impulse control after self-regulatory

depletion alone (Baumeister et al., 1998; Epstein et al., 2009b). First, walnuts are not a product that is related to strong impulses as chocolate and sweets are. Second, if there were strong impulses to eat walnuts, and if individuals needed self-regulatory resources to limit themselves when eating walnuts, the depletion of self-regulatory resources should have increased food intake in both imagination conditions (walnuts and coins) and not only in the condition in which walnut consumption was imagined.

From a different theoretical perspective, other promising studies have also examined the effects of thoughts on food, satiety, and how much such foods are liked (Papies et al., 2012; Redden and Galak, 2013; Larson et al., 2014). Papies et al. (2012) argue, for example, that spontaneous mental images can lead to a more abstract representation of food with a reduced focus on eating; this in turn reduces appetite, liking, and automatic approach responses to food. We cannot rule out the possibility that repetition effects also lead to a different representation of food. However, the mentioned stream of research did not study repetition effects as we did in the current study, and they did not predict differences between a single instance of imagining and the repeated imagination of food consumption.

A strength of the current research is that we measured actual food intake. Indeed, we observed a reduction in actual food intake ranging from 20 to 25% from repeatedly imagining food intake.

LIMITATIONS

Although findings from both presented studies are intriguing, we want to mention that the interpretation of the results should be cautious because the interaction between self-regulatory depletion manipulation and the imaginary item was only marginally significant. The hypothesis that self-regulatory depletion reduces habituation effects after imagining the consumption of food is in line with models proposing that cognitive resources are needed for habituation effects to occur (Epstein et al., 2009b). Indeed, we suppose that the self-regulatory depletion task we applied in Study 2 slowed down the memory processes that are involved in habituation effects. However, at present, we cannot rule out the possibility that the self-regulatory depletion task reduced engagement in the imagination task or impeded attention allocation for the task (Friese et al., 2012; Inzlicht et al., 2014). Self-regulatory depletion might make it difficult for participants to imagine food consumption vividly, and one might speculate that a vivid imagination is a necessary precondition for habituation effects. In addition, it is possible that self-regulatory depletion amplifies processing at a lower level of brain processes but does not affect the memory processes that underlie habituation. Hence, on the basis of the present studies, we can conclude that self-regulatory depletion reduces the habituation effects of imagined food consumption.

But we can only speculate about the underlying processes. We would assume that the self-regulatory depletion decreased habituation effects in Study 2 by impeding the process of habituation. We assume that the self-regulatory task depleted cognitive resources (mainly memory) essential for habituation to take place and therefore habituation itself did not occur as a consequence. Apart from that, however, one might speculate that habituation is not only influenced by memory processes but also by other components of self-regulation leading to a reduced intake in participants with depleted self-regulatory resources. Beyond working memory, presumably disrupting self-regulation leads to a disruption of willpower resources, as well. Nevertheless, there is evidence that habituation enfolds slower in people who are allegedly weaker in self-regulation, such as people with obesity (Temple et al., 2007; Epstein et al., 2011), although cognitive resources are intact. Therefore, self-regulatory processes might influence habituation effects beyond just cognitive resources by additionally influencing resources of willpower. In fact, the depletion task used in Study 2 involved a component of extra self-control (balancing on one leg), which might have led to induce depletion of extra self-regulatory resources and thus those were responsible for reduced habituation. Future research might focus in more detail on the processes that underlie habituation effects after the imagination of food consumption and help to show which memory and brain processes are involved in such effects.

CONCLUSION

The findings of this paper further elucidate how cognitive processes interfere with and shape eating behaviors. The results suggest that habituation after the repeated imagination of food consumption is a stable phenomenon that needs self-regulatory resources to occur.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://www.frontiersin.org/journal/10.3389/fpsyg.2014.01391/abstract

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Mental imagery and food consumption

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INTRODUCTION

One enigmatic capacity of human experience is the ability to travel back and forth in time by using mental simulations. By imagining shapes, forms, and scenes, humans can relive the past and visualize future events (1, 2). Historically, this memory-based mechanism has been discussed in scientific and non-scientific fields. As described by Marcel Proust in his epic work, In Search of Lost Time (3), the sensory experience of gustatory cues, in this case, a sponge-cake called Madeleine, seems to be powerful enough to trigger a cascade of vivid intrusions associated with a particular set of memories (4). Besides anecdotal references, visual mental images are of great interest in the domain of eating behavior because research has shown that (involuntary) mental simulations of intrusions and (voluntary) repetitive mental imagery influence eating behavior. Unraveling the basic mechanisms that underlie mental imagery in the food domain has the potential to provide new insights into the perception and consumption of food.

In this opinion article, we briefly report on the role of mental imagery simulations in eating behavior and its associated pathologies and illustrate how research on mental imaginary has contributed to the current understanding of the cognitive aspects of food intake regulation and satiation processes. Furthermore, we discuss whether guided mental imagery intervention strategies can be integrated into the successful self-regulation of eating behavior and provide a perspective for future research on mental imagery.

MENTAL SIMULATION OF FOOD CONSUMPTION AND EFFECTS ON JUDGMENTS AND BEHAVIOR

Many individuals in modern society live in environments that promote excessive weight gain because of the omnipresence of food (5). The exposure to food automatically prepares individuals for food intake and often evokes thoughts about food, a simulation of food intake, and a strong motivation to consume food (6). Indeed, even the exposure to words related to tempting food can activate a cascade of associations with food (7) and the simulation or reenactment of prior eating occasions (8). Although internal cues of hunger or craving are relevant to the formation of such intrusive thoughts to a large degree, it is clear that thoughts about food consumption are also triggered by consumption-related cues in the environment. Shop design and product presentation in marketing have tapped into these mechanisms by using sensory, textural, and emotional triggers to evoke intrusions, facilitate the simulation of consumption, and increase actual purchases and consumption (9, 10). Recently, research has shown that such marketing practices are not just a creative idea put forth by marketing managers but are supported by concrete evidence for the link between mental simulations and behavior. Elder and Krishna (11) presented participants with a picture of smooth vanilla yogurt in a bowl. They varied whether a spoon was on the right or left side of the bowl. In support of the hypothesis that participants simulate their eating of the yogurt prior to their actual intake in order to forecast the taste of the yogurt, the researchers found that right-handed participants indicated higher purchase intentions when the spoon was on the right side of the bowl compared with when it was on the left side. Hence, the characteristics of the presentation that facilitated the simulation of eating increased the motivation to eat the yogurt. The facilitation effect is not limited to visual perception. For instance, Mitchell and Kahn (12) reported that the ambient odor of a room had a considerable effect on the extent to which individuals thought about the presented products. When the odor was congruent with a product (e.g., chocolate), consumers were more likely to process information about the product. Similarly, Seo and Roidl (13) found that congruent odor enhanced visual attention to odor-congruent food items. In their study, 60 participants were presented with four odors (orange, lavender, coffee, and licorice) prior to and during the presentation of foods via photographic slides. Participants who received olfactory cues looked more frequently and for longer at the corresponding foods than participants in a control condition with no odor presentation. The presentation of food also has an effect on taste assessments. For example, subtle changes of the natural color of an orange juice drink (darker orange hue) decreases liking scores substantially (14). In accordance, manipulating expected brand pronunciation (incongruent brand labeling) was shown to reduce hedonic liking of yoghurts (15). Taken as a whole, the results of the above-mentioned studies correspond with the assumption that conditions that facilitate the simulation of the consumption of attractive food increase interest in the food (e.g., visual attention or processing of information

about the food) and the desire for food consumption.

Researchers have recently referred to theories on grounded cognition (16, 17) to explain the effects of perceptions on thoughts and behavior (10). The basic idea of these theories is that the cognitive representation of concepts is grounded in related modal systems. Previous theories on cognition had supposed that cognitions were amodal and, for example, not based on modal representations of motor behavior. These theories had implied that individuals can think about eating in the same way whether or not they can move their mouth and tongue at the current moment. By contrast, the more recent approaches of grounded cognition suppose that thinking about an object is related to perception and motor behavior. This means that humans cannot think about food without simultaneously activating related perceptions and that they simultaneously simulate motor behavior that is related to the stimulus. Hence, the mode of thinking is supposed to be strongly related to the mode of perception and the mode of action. According to the grounded cognition approach, thinking about food or just reading food-related words should evoke mental simulations of eating (7). Recently, such assumptions have received support from neuroscience research. Researchers found that solely the perception of pictures of palatable food led to activations in brain areas associated with gustatory experiences (18) and elevated ghrelin levels (orexigenic hormone) in healthy volunteers (19). Like food cues, ghrelin is one major mediator of food anticipation (20) and recruits the same neuronal circuitry in the dorsomedial and ventromedial hypothalamus (21).

An example of a particularly strong influence of thoughts on behavior is food craving. Food craving is regarded as a strong motivational state that urges individuals to seek and consume a particular kind of food (22), often containing high amounts of sugar or fat (23). When individuals crave food, their thoughts about food are often so intrusive that they have trouble pursuing other goals or focusing on different thoughts. For craving, the causal direction of the influence is bidirectional in the sense that craving has an influence on thought and vice versa. However, it is important to take into account that the mental simulation of food consumption triggered by external cues as described above can result in craving.

REPEATED MENTAL SIMULATION AND MINDFULNESS

EFFECTS OF REPEATED MENTAL SIMULATION ON FOOD CONSUMPTION

An interesting aspect of mental simulations during food perception is that mental simulations do not necessarily lead to increased consumption, but rather, under certain circumstances, they can lead to decreased consumption. Interestingly, repeatedly thinking about food consumption can lead to habituation and a reduced motivation to consume a specific food, just like real consumption (24). Habituation to food is understood as a process that leads to a decrease in both the physiological and behavioral responses to an eating episode and a drop in enjoyment with repeated consumption (24). Several studies (25–27) have found evidence that habituation can take place when individuals repetitively judge food or imagine eating food. For instance, Morewedge et al. (26) asked participants to think either 3 or 30 times about eating M&M's. Later, participants were allowed to eat M&M's. Participants who thought about eating the candy 30 times ate less of the product than those who thought about it 3 times and those in a control condition (who imagined throwing coins into a laundry machine). Like other habituation effects, this effect was shown to be sensory-specific and was only present when the imagined food was congruent with the consumed food. The effect did not show when the imagined food (e.g., M&M's) was not the same as the consumed food (e.g., cheese cubes) [(26); Experiment 4]. Similar sensory-specific characteristics between imagined and consumed foods are therefore fundamental for food habituation to occur. In our recent study, we found that habituation after imagined eating needs mental resources as habituation during actual eating does (28). Several studies have indicated that habituation is based on a memory process that needs cognitive capacity to occur. Hence, when individuals are distracted during eating, for example, when they watch TV during eating (29, 30), they habituate less to food and eat more. We found that a depleting task had a similar effect on habituation after imagined food consumption. In our study, we used a mathematical counting task (31) to deplete participants prior to simulating the eating of 18 walnuts in one condition. We showed that participants in this depletion condition did not habituate to the mental simulation, and habituation was blocked, whereas they habituated in a condition without depletion.

EFFECTS OF MINDFULNESS ON FOOD CHOICE

As reported above, repeatedly imagining food consumption can reduce the desire to consume the food (26). But repetitive thoughts about food consumption are not the only way to reduce the desire to consume a particular kind of food. Also important is *how* individuals think about the food. While a single vivid image of the consumption increases the influence of impulsive responses on food choice, the influence of impulsive responses on food choice decreases when consumers think about the reasons for their food choice (32). Similarly, mindful attention to thoughts about food consumption can reduce choices for unhealthy food items that are impulsively preferred by consumers. For example, Papies and colleagues (6) instructed participants to regard their thoughts from a metacognitive perspective as temporary constructions that appear and disappear. When this mindful attention was applied to food consumption, it reduced impulsive tendencies to approach food (6) and also promoted choices of healthy food (33).

REPEATED MENTAL SIMULATION AND MINDFULNESS AS INTERVENTIONS

It is important to note that the effects of mindfulness are conceptually different from effects of repeated mental simulation. First, repeated mental simulation, but not mindfulness, needs repetition to show effects. Second, repeated mental simulation shows specific effects on a particular kind of food (26) but this is not the case for mindful attention (6). At present, it can be assumed that the habituation effects of repeated mental simulation reflect a memory process that leads to inhibition after some length of imagining exposure to food, whereas mindfulness might be more likely to block the tempting simulation of food consumption. Both processes are of interest for practice. Mindfulness could be

used as a method for reducing unhealthy food intake. By contrast, repeatedly imagining food consumption might reduce food intake when consumption has already begun. For example, to increase habituation to a particular kind of food, individuals could think about consuming an unhealthy food that they usually prefer to eat (e.g., chocolate) repeatedly across consecutive days. However, while such long-term effects were demonstrated with exposure to real food (34), it is still a task for future research to study the long-term effects of imagined food consumption. But there is no doubt that the relevance of habituation processes is obvious if we consider recent research that has shown that overweight children habituate more slowly during consumption than non-overweight children (35). Against this background, research on repeated mental simulations could provide a promising starting point from which to advance interventions in food consumption.

CONCLUSION

Current research on food intake behavior regulation is driven by a vital need to understand the successful and unsuccessful self-regulation of food consumption. Integrating the cognitive mechanisms of mental imagery and mindfulness that guide eating behaviors may be one important milestone for enhancing current models of food intake regulation. As proposed by Redden (36), a general model should include reflective (memory recall inferences, metacognitions) and perceptual (adaptation, habituation) components of satiation. He argues that satiation is partially constructed in the moment on the basis of external cues that interact with each other in a specific eating situation. Research on mental imagery and mindfulness can help us understand eating behavior and to design individual-level interventions. It can also help us understand why some individuals are more successful self-regulators than others (37).

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RESEARCH ARTICLE

When Eating Right, Is Measured Wrong! A Validation and Critical Examination of the ORTO-15 Questionnaire in German

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Abstract

The characteristic trait of individuals developing a pathological obsession and preoccupation with healthy foods and a restrictive and avoidant eating behavior is described as orthorexia nervosa (ON). For ON, neither universal diagnosis criteria nor valid tools for large-scale epidemiologic assessment are available in the literature. The aim of the current study is to analyze the psychometric properties of a translated German version of the ORTO-15 questionnaire. The German version of the ORTO-15, a eating behavior and dieting habits questionnaire were completed by 1029 German-speaking participants (74.6% female) aged between 19 and 70 years (M = 31.21 ± 10.43 years). Our results showed that after confirmatory factor analysis, the best fitting model of the original version is a single-factor structure (9-item shortened version: ORTO-9-GE). The final model showed only moderate internal consistency (Cronbach's alpha = .67), even after omitting 40% of the original question. A total of 69.1% participants showed orthorectic tendencies. Orthorectic tendencies are associated with special eating behavior features (dieting frequency, vegetarian and vegan diet). Education level did not influence ON tendency and nutritional students did not show higher ON tendency compared to students from other disciplines. This study is the first attempt to translate and to evaluate the psychometric properties of a German version of the ORTO-15 questionnaire. The ORTO-9-GE questionnaire, however, is only a mediocre tool for assessing orthorectic tendencies in individuals and shows moderate reliability and internal consistency. Our research suggests, that future studies are needed to provide more reliable and valid assessment tools to investigate orthorexia nervosa.

Introduction

There is a thin line between eating right and healthy and a pathological preoccupation with healthy foods. This appears paradox at first, because public health nutrition policies' primary strategy is to promote healthy dietary choices and eating right to decrease diet-related

pathologies like overweight and obesity [1]. In contrast, there are mounting reports from eating disorder professionals who find themselves confronted with individuals who are pathologically preoccupied with healthy eating: a condition called orthorexia nervosa (ON) [2]. ON was first framed by Bratman and Knight [3] in the late 90's, describing eating behavior associated with behavioral and psychiatric traits. Individuals with ON are typically concerned about food quality rather than food quantity. Nevertheless, there is still a lack of valid instruments for ON [4]. The aim of this study is to provide a validated measurement tool for ON in German language, based on the original (English) ORTO-15 questionnaire [5] and further contribute to our understanding of mediators for orthorectic eating and the identification of groups at risk to develop ON.

Orthorexia Nervosa Symptoms and Diagnostics

ON is an eating-related condition with obsessive eating directed at healthy foods. The healthfulness of foods can vary depending on individual's preferences. ON can, in extreme cases, lead to a pathological preoccupation with pure and unprocessed foods and stringent eating plans, combined with significant psychopathological overlappings with anorexia nervosa (AN) and obsessive-compulsive disorders (OCD) [6]. Transgressing self-imposed dietary rules often lead to intense feelings of anxiety, guilt and shame followed by more stringent dietary restriction leading to a vicious cycle [7].

Different from common eating-related disorders, individuals with ON do not fear to gain weight and have clear, rationalized rules related to food intake [4]. Additionally, eating according to a fixed schedule and spending a lot of time to prepare meals [8–10], and unrealistic food beliefs are very prominent among individuals with ON [10]. Social isolation as a consequence of a constant daily domination of healthy eating and reduced stress by eating good and proper foods accompanied by spiritual feelings about foods have been reported [8].

At present, ON is not classified as a formal eating disorder neither by DSM-5 [11], nor by ICD-10 criteria [12]. Grading of ON is still a matter of debate and under current DSM-5 criteria, individuals with ON characteristics may best be classified in the broad category of Avoidant/Restrictive Food Intake Disorder (ARFID) [11]. Several medical consequences are described, which are very similar to other known eating disorders. For instance a shortage of essential nutrients, malnutrition, starvation and weight loss have been reported [13, 14].

Assessment, Epidemiology and Moderators for Orthorexia Nervosa

To monitor the prevalence of ON and to investigate various subtypes of the condition, thorough assessment tools are needed. Previous investigations report several inconsistencies about the validity and internal reliability of commonly used questionnaires [15]. To date, two instruments were developed to identify individuals with ON: the 10-Item Bratman Scale [3] and the ORTO-15 questionnaire [5]. While the 10-Item Bratman Scale was widely disregarded by the scientific community, several language and item adaptations of the ORTO-15 questionnaires were developed (Polish, Hungarian, Turkish). The only adapted version showing good internal reliability is the Hungarian adaptation (11 items), Cronbach's alpha = .82. The Polish version (9 items) and the Turkish adaptation (11 items) showed only weak internal reliability of Cronbach's alpha = .64, respectively Cronbach's alpha = .62, while in the original work by Donini, Marsili [5], no Cronbach's alpha was reported. All translated versions of the original ORTO-15 questionnaire deleted various items to increase validity and internal reliability of the original questionnaire [10, 16, 17]. There is no valid instrument to measure ON in German language.

Due to the weakness in assessing ON, there is only limited epidemiological data available on the prevalence of ON and no data from cross-sectional surveys on representative community

samples. Donini, Marsili [5] reported a prevalence of 6.9% within different population groups, but these rates should be interpreted with caution because they are not based on a representative study sample.

There are many gaps in the literature concerning potential moderators and risk factors for ON [4]. To fully understand ON, it is important to assess and understand possible moderators for this condition. Hence, there are conflicting results for moderators of ON reported in the literature. As such, high orthorectic tendencies are reported for different population groups (e.g. health professionals [18] and performance artists [16]). Conflicting results are reported whether men or women are more susceptible for ON [5, 13, 19, 20] and if education level mediates ON tendencies [16, 21]. It is also argued that a cultural adaptation for ON is necessary because symptoms of ON may vary across different countries and population groups [10].

Study Aims

The aims of the current study are threefold. First, we describe the adaptation process of the original ORTO-15 into a German version of the questionnaire; (ii) we investigate the psychometric properties of the translated version via Confirmatory Factor Analysis by applying the instrument on a large and heterogeneous study sample and (iii) we analyse the relationship between socioeconomic, eating and dieting behavior with orthorectic eating tendencies in our study sample.

Materials and Methods

Sample

In total, 1538 participants commenced the online survey, while 323 failed to complete the whole questionnaire battery (78.9% completion rate), leaving 1215 participants. 140 participants were excluded because they failed to complete the ORTO-15 questionnaire. Participants with diagnosed diet-related diseases (diabetes mellitus type I and II, Crohn's disease, celiac disease, gastritis) in which eating behavior has to be adapted for medical reasons were excluded (46 participants) (see S1 Fig for flow chart).

In total, 1029 questionnaires were eligible for further data analysis. To get a more homogenous sample for the descriptive analysis, cut-off thresholds were applied for variables age and BMI (cut-off < 99.9 of the CI). Our study sample consists of 768 women and 261 men (74.6% vs. 25.4%). The mean age of the respondents was 31.21 ± 10.43 years (34.32 ± 11.64 for males; 30.16 ± 9.78 for females). BMI (based on self reported body weight and height) ranged between 15.24 kg/m^2 and 54.21 kg/m^2, with a mean weight of 23.33 kg/m^2 ± 4.37 kg/m^2. Most participants were students (N = 377, 36.6%), with more than half of the students enrolled in courses in nutritional sciences or dietetics (N = 208, 20.2%), other health-related courses (e.g. medicine, aging-management, nursery; N = 12, 1.2%), and from other fields (e.g. marketing, business, food sciences; N = 157, 15.3%). Employed participants included following professions: business office jobs (N = 157, 15.3%), health professionals (N = 106, 10.3%), social work (N = 80, 7.8%), tourism (N = 72, 6.9%), flight attendants (N = 69, 6.7%), food sector (N = 69, 6.7%), other professions (e.g. informatics, architecture, law; N = 263, 25.6%).

Procedure

Participants were recruited via online advertisement (social media, email distribution lists) and we collected data online. Participants received the link to a survey called 'Eating Behavior and Health Aspects' and as an incentive, four prices were raffled among four participants who completed the entire set of questions (total value 200€). Participants completed an informed

consent form, entered sociodemographic information, completed a German translation of the ORTO-15 questionnaire and an additional questionnaire battery. The questionnaire battery consisted of questions about lifestyle and eating behavior habits, the ORTO-15 questionnaire and additional ON related questions. The study protocol was approved by the University of Vienna Ethics Committee (reference number: 00115). Participants were informed that they could withdraw their participation at any time during the online questionnaire.

Measures

Orthorexia Nervosa: ORTO-15. The ORTO-15 questionnaire is a self-report 15-item measure with a 4-point Likert scale (Table 1). It is originally constructed based on a combination of the Minnesota Multiphasic Inventory [22] and the Bratman test [3] to measure the interrelationship between cognitive-rational (items 1, 5, 6, 11, 12, 14), clinical (items 3,7, 8, 9, 15) and emotional aspects (items 2, 4, 10, 13) of eating behavior [5]. The ORTO-15 questionnaire assesses beliefs about attitudes covering food selection (item 4), the extent to which food concerns influence daily life (item 7), the perceived effects of eating healthy food (item 12) and habits of food consumption (item 15). Lower overall scores refer to more ON components (increased ON tendency). Donini, Marsili [5] report sensitivity, specificity, and predictive validity values for the ORTO-15 using an original cut-off < 40 (maximum score = 60) in an Italian adult sample. Other studies used e.g. median split to define individuals with or without ON tendencies [19].

We developed a German version of the ORTO-15 questionnaire by using a multistep translation method as suggested by Sousa and Rojjanasrirat [23]. Briefly, two professional translators (no health care background) translated the ORTO-15 questionnaire into German without adding words or introducing new expressions. Both translations were merged in accordance with the authors (BM; VD; SZ, CK). One clinical psychologist and Author 2 (BH) created the final version of the questionnaire. Afterwards, this version was again back translated into English language by a professional translator and the last version was compared to the final German version within the project team (BM; VD; SZ, CK). At this stage of process, we checked for possible differences in meaning of both versions, all remarks were integrated into the final version of the questionnaire.

To check for clarity or spelling issues, we used a sample of 25 students to evaluate the final version of the questionnaire. Again, we included all final remarks from this evaluation into the final version of the questionnaire.

Self-reported eating behavior questions. We assessed self-reported dieting behavior and questions regarding weight changes. We asked participants about food intolerances, dieting frequency, dieting styles (vegan, vegetarian, mixed diet), prevalent eating disorders, prevalent mental disorders and lifetime weight changes (for detailed listing, see S1 Table).

Statistical analyses

For statistical analyses we used several approaches. First, to determine the factor structure of the translated version of the ORTO-15, we used Confirmatory Factor Analyses (CFA). To evaluate validity and reliability check for all models, additional to Cronbach's alpha, we applied Composite Reliability (CR), Average Variance Extracted (AVE), Maximum Shared Variance (MSV), and Average Shared Variance (ASV) [24].

In a second step, we analyzed the relationship between the mean scores for the best fitting model. Normal distribution of the continuous variables was tested by Shapiro-Wilk test. For normally distributed continuous variables, we used parametric methods (Spearman), nonparametric methods were used for non-normally distributed data (Kruskal-Wallis; Mann-Whitney).

Table 1. ORTO-15 full text in English and the translated German version.

Item	German Translation	English original
1	*Achten Sie beim Essen auf den Kaloriengehalt der Lebensmittel*?	*When eating, do you pay attention to the calories of the food*?
2	*Fühlen Sie sich beim Lebensmitteleinkauf überfordert*?	*When you go in a food shop do you feel confused*?
3	Haben Sie sich in den letzten 3 Monaten beim Gedanken an LM Sorgen gemacht?	In the last 3 months, did the thought of food worry you?
4	Bestimmt die Sorge um Ihren Gesundheitszustand Ihre Essensauswahl?	Are your eating choices conditioned by your worry about your health status?
5	Ist Ihnen der Geschmack wichtiger als der gesundheitliche Aspekt von Lebensmitteln?	Is the taste of food more important than the quality when you evaluate food?
6	Sind Sie bereit mehr Geld für gesünderes Essen auszugeben?	Are you willing to spend more money to have healthier food?
7	Sorgt Sie der Gedanke an Ihre Ernährung mehr als 3 Stunden täglich?	Does the thought about food worry you for more than three hours a day?
8	*Erlauben Sie sich gegen Ihre Essprinzipien zu verstoßen*?	*Do you allow yourself any eating transgressions*?
9	*Glauben Sie, dass Ihre Stimmung Ihr Essverhalten beeinflusst*?	*Do you think your mood affects your eating behavior*?
10	Glauben Sie, dass die Überzeugung ausschließlich gesunde Lebensmittel zu essen, das Selbstwertgefühl steigert?	Do you think that the conviction to eat only healthy food increases self-esteem?
11	Glauben Sie, dass gesund zu essen Ihren Lebensstil verändert? (Häufigkeit von Restaurantbesuchen, Freizeitaktivitäten, usw.)	Do you think that eating healthy food changes your lifestyle (frequency of eating out, friends, . . .)?
12	Glauben Sie, dass gesundes Essen Ihr Aussehen verbessern könnte?	Do you think that consuming healthy food may improve your appearance?
13	*Fühlen Sie sich schuldig, wenn Sie gegen Ihre Essprinzipien verstoßen*?	*Do you feel guilty when transgressing*?
14	*Glauben Sie, dass es auch ungesunde Lebensmittel im Handel gibt*?	*Do you think that on the market there is also unhealthy food*?
15	Sind Sie während Ihrer Mahlzeiten alleine?	At present, are you alone when having meals?

Scoring grid for ORTO-15 test and item responses (Answer categories: Always-Often-Sometimes-Never). Scoring grid for items: 3/4/6/7/10/11/12/14/15: 1-2-3-4. Scoring grid for items 1/13: 2-4-3-1. Scoring grid for items 2/5/8/9: 4-3-2-1; items in italic were removed after statistical analysis, leaving the German version (ORTO-9-GE).

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Jockheere's test was used to test for an ordered pattern between group differences in non-normally distributed data. The Bonferroni post-hoc test was used to correct for multiple comparisons.

Besides CFA, were we used IBM SPSS 22 AMOS, all statistical analyses were carried out using IBM SPSS 22 software package.

Results

Confirmatory factor analysis (CFA)

In total, we analyzed four different models. Model I is based on the original three-factor structure of the ORTO-15 questionnaire (cognitive-rational, clinical, emotional). Model II is a single-factor model. Models III and IV are shortened versions of the questionnaire after omitting six items with low-item correlations and factor loadings during a model fitting process. The established ORTO-9-GE version was again evaluated without (model III) and with inter-item covariation suggested by modification indices (model IV).

Modeling the ORTO-15 (Model I and Model II). The first model tested if our data fit well with the original structure postulating a three-factor model as proposed by Donini, Marsili [5]. The CFA revealed that the three-factor solution had to be rejected due to poor model fit ($\chi 2 = 466.38$; $p < .001$; CMIN/DF = 5.361; CFI = .78; TLI = .74; RMSEA = .065; PCLOSE < .001; see Fig 1). Internal consistency was unacceptably low (Cronbach's alpha = 0.303).

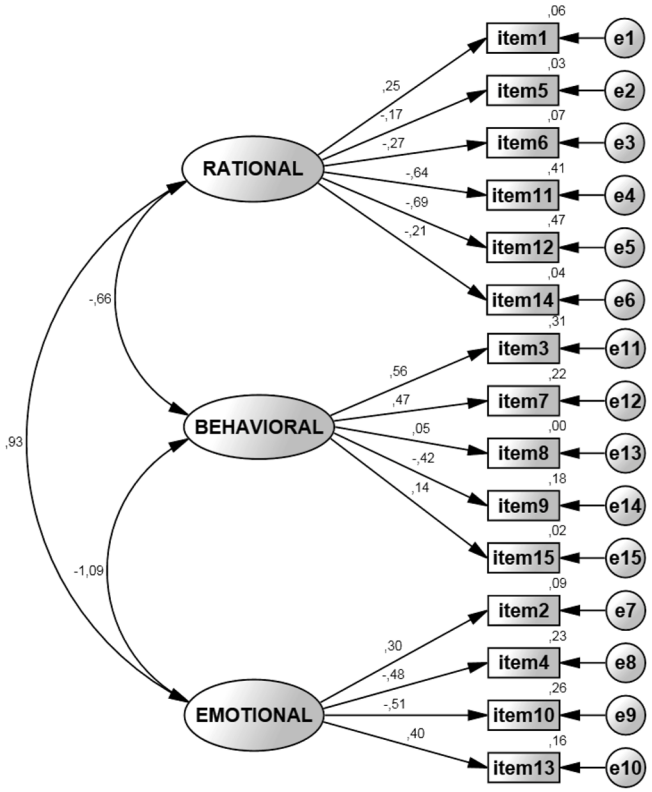

Fig 1. ORTO-15 as originally hypothesized by Donini and colleagues (3-factor structure). The displayed values are unstandardized regression weights from the study sample in the original 3-factor structure. Squares represent items, oval circles represent factors, squares represent questionnaire items and small circles represent error terms.

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We tested a single-factor Model (Model II), which was rejected due to poor model fit, likewise ($\chi 2 = 540.509$; $p < .001$; CMIN/DF = 6.006; CFI = .74; TLI = .69; RMSEA = .070; PCLOSE < .001; see S2 Fig).

Modeling the ORTO-15 (Model III and Model IV). Model I and Model II had very poor fit indices, thus we conducted an item analysis to evaluate the appropriateness of each item and improve overall model fitness. We omitted six items with low item-total correlations and low factor loadings (items: 14, 13, 9, 8, 2, 1), to improve the goodness of fit in our model (see Table 2). After item omission, CFA was conducted, but the indicators for Model III still remained inadequate ($\chi 2 = 225.604$; $p < .001$; CMIN/DF = 8.356; CFI = .821; TLI = .761; RMSEA = .085; PCLOSE < .001, see S3 Fig).

To improve the model, variances of the error terms were analyzed through modification indices. Following the cut-off criteria of modification indices equal to or higher than 40, two error terms were correlated: 3/4 (91.712) and 5/6 (40.197). The error-term correlations were incorporated into Model IV generating a new single-factor structure with acceptable goodness of fit indices ($\chi 2 = 83.865$; $p < .001$; CMIN/DF = 3.355; CFI = .947; TLI = .92; RMSEA = .048; PCLOSE = .602, see Fig 2).

Internal consistency of the shortened 9-item version of the questionnaire was still low, but overall acceptable (Cronbach's alpha = .67). The full text of the original ORTO-15 and its German version, ORTO-9-GE can be found in Table 1.

Table 2. Item analysis of the ORTO-15 questionnaire (Model 2 and Model 4).

			Original (15-item version, Model 2)			Final (9-item version, Model 4)		
	M	SD	Corrected item-total correlation	Standardized factor loadings in Model 2	Cronbach's alpha if item deleted	Corrected item-total correlation	Standardized factor loadings in Model 4	Cronbach's alpha if item deleted
Item 1 (reversed)	2.74	1.05	.11	.07	.38	-	-	-
Item 2 (reversed)	1.42	.63	.12	.08	.34	-	-	-
Item 3	3.17	.82	.15	.22	.27	.35	.34	.64
Item 4	3.00	.84	.24	.24	.24	.42	.39	.62
Item 5	2.24	.72	.19	.02	.26	.16	.15	.67
Item 6	1.97	.75	.25	.05	.24	.23	.26	.66
Item 7	3.62	.73	.16	.19	.26	.33	.37	.64
Item 8	2.35	.66	.10	.00	.29	-	-	-
Item 9 (reversed)	2.57	.83	.17	.16	.38	-	-	-
Item 10	2.74	.94	.32	.32	.19	.46	.62	.61
Item 11	2.40	.94	.32	.36	.19	.47	.67	.60
Item 12	2.03	.92	.29	.38	.20	.49	.66	.60
Item 13 (reversed)	2.41	1.08	.20	.18	.42	-	-	-
Item 14	1.33	.63	.10	.03	.29	-	-	-
item 15 (reversed)	2.83	.59	.01	.02	.31	.08	.11	.68

All 15 items of the ORTO-15 displayed with M = mean and SD = standard deviation. For model 2 and model 4, corrected item-total correlations, standardized factor loadings and reached Cronbach's alpha values when the according item would be deleted.

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Descriptive statistics and ON tendencies among different populations

The mean score of the ORTO-9-GE questionnaire was 24.52 (SD = 3.58), ranging from 13 to 36 points with 69.1% of the participants showing ON tendencies (cut-off <26.7). Male (24.96 ± 3.56) compared to female participants (24.36 ± 3.58) differ significantly in their ON tendencies, U = 91575, z = -2.09, $p < .05$, r = -.06. Weak positive correlations between ORTO-9-GE scores and age (r = .13; $p < .01$) and a weak negative correlation with BMI (r = -.09; $p < .01$). ORTO-9-GE scores did not differ significantly within education levels (compulsory school, secondary school, academic, other school), H (3) = 2.83, p = .42 and the current housing situation (living alone, with parents, in a flat share, with children other living situations) did not influence ORTO-9-GE scores, H (4) = 7.93, p = .09.

Additionally, we examined different population groups in our study sample. Our data showed that students (24.10 ± 3.39) compared to non-students (24.75 ± 3.67) had significantly lower ORTO-9-GE scores, U = 111545, z = -2.48, $p < .05$, r = -.07, but there was no difference between nutritional students (24.09 ± 3.26) students from other disciplines (24.12 ± 3.55), H (1) = .41, p = .52. Flight attendants (24.98 ± 3.38) compared to other professions (24.48 ± 3.59) did not differ in ORTO-9-GE, U = 30230, z = -1.21, p = .22, r = -.006 and there were no differences between health professionals (24.67 ± 3.40) and individuals without health profession background (24.49 ± 3.62) in orthorectic tendencies, U = 66966, z = -.64, p = .52, r = -.01 (see S2 Table).

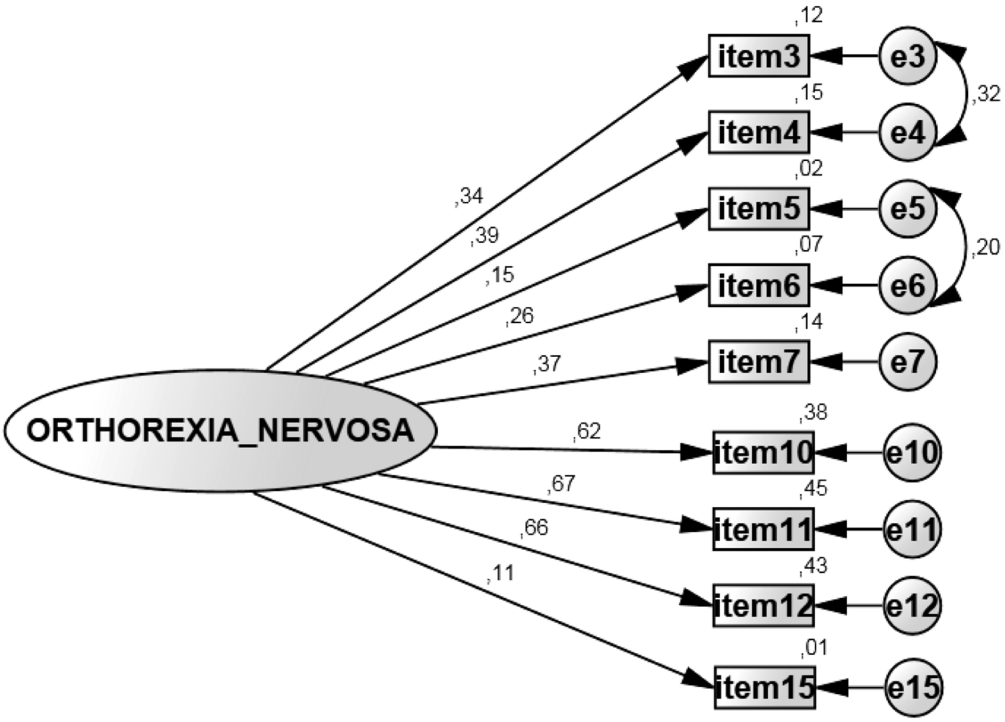

Fig 2. ORTO-9-GE factor structure after item omission and model fit (1-factor structure). The displayed values are unstandardized regression weights from the study sample after model fit and correlation of error terms: 3/4, 5/6. Squares represent items, oval circles represent factors, squares represent questionnaire items and small circles represent error terms.

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Self-reported eating behavior and ON tendencies. Individuals who report to follow a very strict eating schedule (23.65 ± 3.71) compared to those who report not to follow a strict eating schedule (24.62 ± 3.50) showed lower ORTO-9-GE scores, U = 50664, z = -2.97, $p < .01$, r = -.09. Individuals who are convinced to exclusively eat healthy foods (23.37 ± 4.26) compared to those who do not agree with this statement (24.63 ± 3.40) showed significantly lower ORTO-9-GE scores, U = 41581, z = -3.58, $p < .01$, r = -.11. In addition, individuals who report to spend a large amount of time with the preparation of meals (23.85 ± 3.56) compared to those who not spend a large amount of time for meal preparation (25.18 ± 3.40) showed significantly lower ORTO-9-GE scores, U = 91477, z = -5.48, $p < .01$, r = -.17. ORTO-9-GE scores in individuals who report to be reluctant to eat food that is prepared by others (22.00 ± 3.97) compared to those who do not agree with this statement (24.79 ± 3.36), differed significantly, U = 27631, z = -7.03, $p < .01$, r = -.23 (see Table 3).

Self-reported intolerances also influenced ON scores. Individuals who indicate to have 2 or more food intolerances (22.11 ± 1.96) compared to those who report one or no self-reported food intolerances (24.54 ± 3.59) showed siginificantly higher ON tendencies, U = 2471, z = -2.39, $p < .05$, r = -.07. Individual dieting style is also associated with ON scores. Individuals who are on a vegetarian (23.47 ± 3.64) or a vegan diet (22.6 ± 3.82) show higher ON tendencies than individuals on a mixed diet (24.72 ± 3.47), H (1) = 22.16, $p < .01$ (see Fig 3).

Dieting experience affects ORTO-9-GE scores. Higher ON tendencies are found among individuals with profound dieting experience; individuals with no dieting experience showed increased ORTO-9-GE scores (25.25 ± 3.31) compared to individuals with 1–2 diets

Table 3. Associatons between self-reported health and eating behaviors and ORTO-9-GE scores.

	Agreement	Diasagreement	Statistics	Significance
I don't like to eat foods prepared by others.	22.00 ± 3.97	24.79 ± 3.36	z = -7.025	< 0.001
I consume only healthy foods.	23.37 ± 4.25	24.63 ± 3.41	z = -3.588	< 0.001
I always eat according to my eating schedule.	23.65 ± 3.71	24.62 ± 3.50	z = -2.970	< 0.05
	Frequency	**ORTO-9-GE scores (M ± SD)**	**Statistics**	**Significance**
Food intolerance	≤ 1 food intolerances	24.54 ± 3.59	z = -2.395	< 0.05
	> 2 intolerances	22.11 ± 1.96		
Eating disorder	current	19.95 ± 3.29	z = -5.39	< 0.001
	no eating disorder	24.62 ± 3.53		
Mental disorders (obsessive-compulsive disorder, depression, anxiety disorder)	current	22.67 ± 4.39	z = -2.66	< 0.001
	no mental disorder	24.59 ± 3.54		

Self-reported eating and health behaviors and ORTO-9-GE scores. M = mean; SD = standard deviation; test statistic for non-parametric tests (z-scores and p-values indicated).

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(23.09 ± 3.71), 3–5 diets (22.87 ± 3.55) and more than 6 diets (21.20 ± 3.56), H (1) = 57.78, $p < .01$ (see Fig 4).

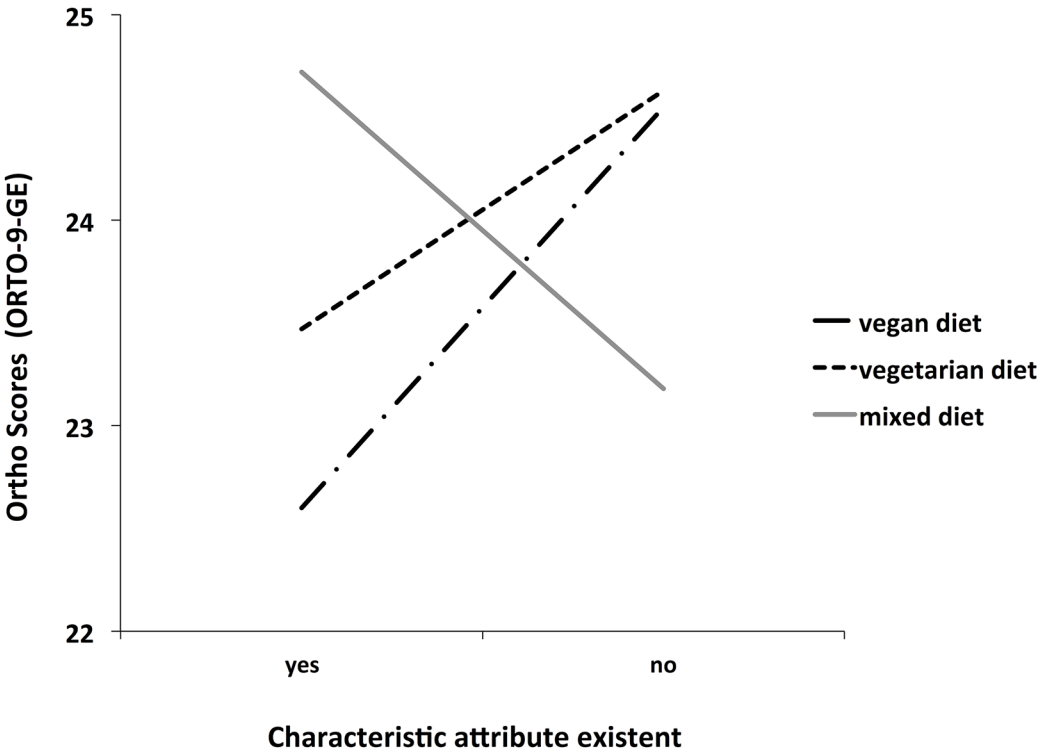

Fig 3. ORTO-9-GE scores associated with dieting style. ORTO-9-GE scores as a function of dieting style. Participants dieting style defined as either vegan, vegetarian or having a mixed diet. Lower ORTO-9-GE scores indicate higher orthorectic tendencies.

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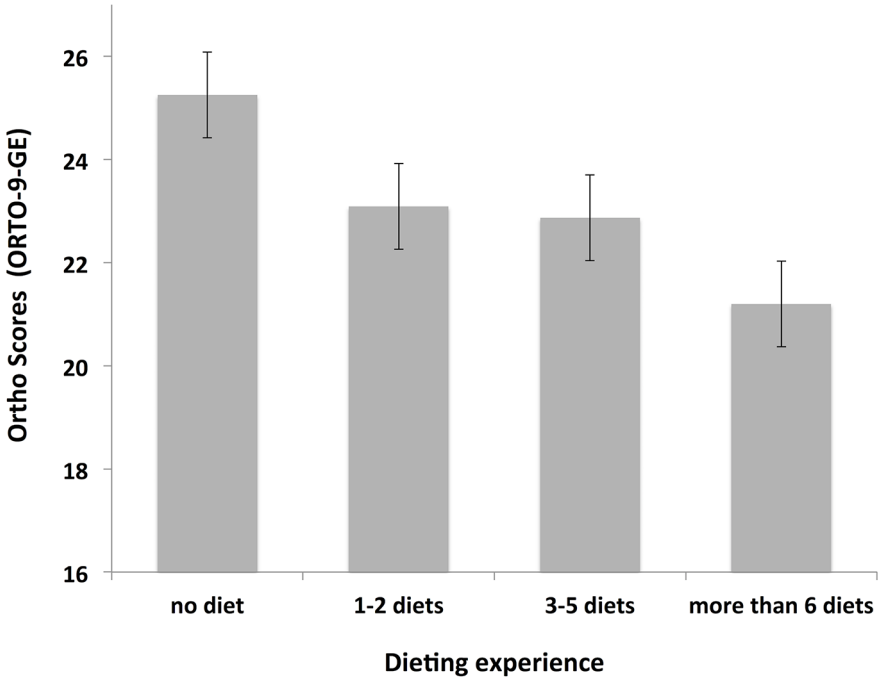

Fig 4. ORTO-9-GE scores associated with dieting experience. ORTO-9-GE scores as a function of dieting experience (range: no dieting experience to > 6 diets). Lower ORTO-9-GE scores indicate higher orthorectic tendencies. Error bars indicate standard errors of the means.

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Self-reported eating, mental disorders and weight change and ON tendencies. Current self-reported eating disorders also influenced ORTO-9-GE scores: individuals who report a current eating disorder showed higher ON tendencies (19.95 ± 3.28) compared to those not reporting an eating disorder (24.61 ± 3.52), $U = 3668$, $z = -5.39$, $p < .01$, $r = -.16$. Hence, individuals who indicate a current mental disorder (obsessive-compulsive disorder, depression, anxiety disorders) showed lower ORTO-9-GE scores (22.67 ± 4.39) compared to those without any of these conditions (24.59 ± 3.54), $U = 13227$, $z = -2.63$, $p < .01$, $r = -.08$.

Our data showed that past weight changes influenced ON tendency. Individuals who report major lifetime weight changes (>40 kg), showed significantly lower ORTO-9-GE scores (21.77 ± 3.55) compared to individuals who report only minor weight changes (5-10kg; 24.63 ± 3.46), $H(1) = 19.68$, $p < .01$. Jockheere's test revealed a significant trend in the data: as self-reported weight change increased, ORTO-9-GE scores decreased, $J = 4071$, $z = -4.43$, $p < .01$, $r = .14$ (see Fig 5).

Discussion

The present study aimed to investigate the psychometric properties of a translated German version of the ORTO-15 instrument among a heterogeneous population sample. So far only a few studies have investigated the psychometric properties of the ORTO-15 questionnaire. This study was the first attempt to validate the original version translated into German language. Our data showed conflicting as well as overlapping results compared with results from previous studies.

We found that eating behavior traits which deviate from eating behavior considered as normal, such as strict eating schedules and the reluctance to eat food prepared by others are associated with higher ON tendencies. This finding is at the core of ON and in accordance with

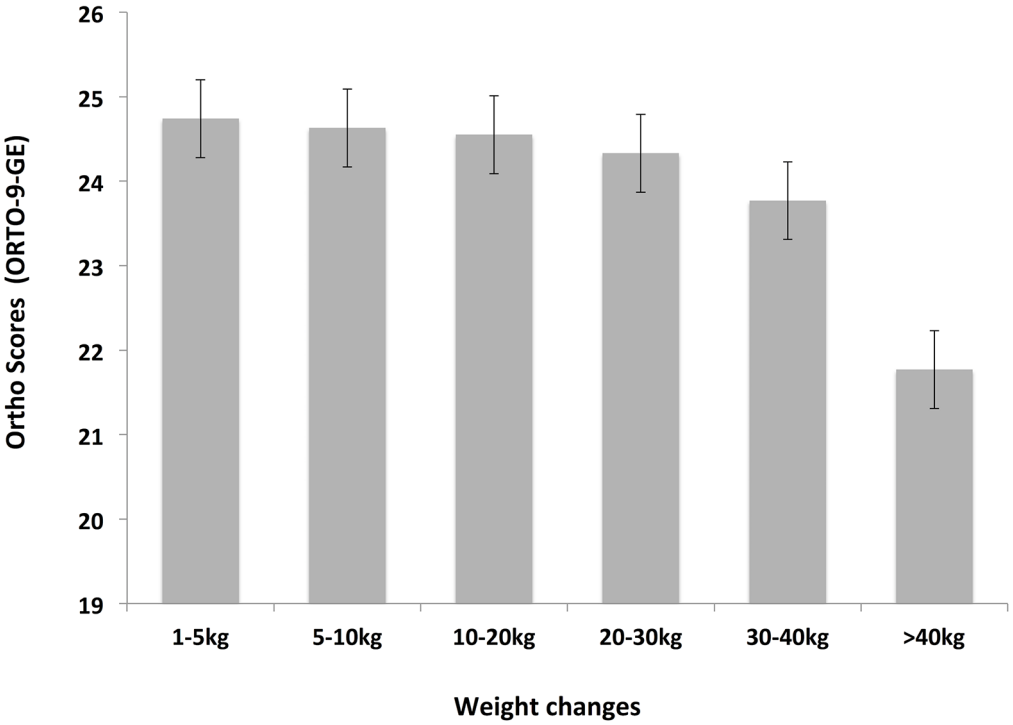

Fig 5. ORTO-9-GE scores associated with lifetime weight changes. ORTO-9-GE scores as a function of lifetime weight changes (range from 1-5kg to > 40kg lifetime weight change). Lower ORTO-9-GE scores indicate higher orthorectic tendencies. Error bars indicate standard errors of the means.

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previous studies [10]. To our knowledge, this is the first study to demonstrate that individuals with ON tendencies are more likely to be on a vegetarian or vegan diet. This is only moderately surprising, because being on a vegetarian diet requires a fair degree of self-discipline, planning and cognitive processing related to eating behavior. Besides ethical considerations, health aspects have been identified as the main motive for becoming vegan or vegetarian [25]. However, a recent study by Burkert, Muckenhuber [26] could show that poorer overall health condition (e.g. allergies, mental health disorders), a higher need for health care and poorer quality of life is associated with a vegetarian diet. Albeit only reported anecdotally, ON is associated with a shortage of essential nutrients and malnutrition due to an unbalanced diet [4, 19]. In our study, individuals who reported $\geq$ 2 food intolerances showed higher ON tendencies. Together, the results of this study can be seen as a reference that preceding ON tendencies in individuals on a vegetarian or vegan diet may be a behavioral manifestation and a possible explanation for having poorer overall health condition.

Additionally, our data support the idea that more frequent dieting experiences increase ON tendencies reflecting previous research results [10, 18, 21, 27]. Nutrition students did not differ in their ON tendencies compared to students from other disciplines. This finding is intriguing regarding the assumption that nutritional students are more prone for dieting behavior than their counterparts from other disciplines. Another pivotal outcome from this study is, that major lifetime weight changes ($>$ 40 kg) and those individuals with currently diagnosed eating disorders showed an increased tendency for ON. Past or recent eating disorders are mostly accompanied by major weight fluctuations [28] and in either direction of weight change (under/overweight), an adaptation of eating behavior may be relevant for treatment. Therefore, an explanation for decreased ON scores may be given.

Limitations and generic problems with the ORTO-15 measure

Some limitations of the present study should be taken into account. The presented data analyses rely on self-reported data via online assessemt. Self-reported weight and height is highly biased as shown by previous studies (e.g. underreporting) [29]. Recall bias can not be excluded in the present study. Secondly, behavioral data on eating behavior was measured indirectly and is not based on experimental or observational data. Interpretation of self-reported behavior (e. g having a strict eating schedule) should be cautious.

Generic problems of the ORTO-15 measure

Our findings show that after a thorough translation process of the original version of the ORTO-15 questionnaire, an instrument with only mediocre validity could be constructed (ORTO-9-GE). After CFA, the best fitting model showed weak psychometric properties and it was necessary to omit six items from the original 15-item questionnaire (omitting 40%) to reach moderately acceptable construct validity. Sufficient, but still only moderate internal reliability points to the fact that the original questionnaire may be flawed from scratch. This finding is not newly established, since even Donini who is the author of the original questionnaire admitted the psychometric flaws of the original version of the ORTO-15 [5]. This fact has been widely ignored by the scientific community and rather than developing new and better tools, no alternatives for the ORTO-15 have been constructed so far. For instance, item 1 of the ORTO-15 seems to be problematic: *When eating, do you pay attention to the calories of the food*? The scoring grid for this question is ambiguous (always and never score low, often and sometimes score high) as well as the intention of the question. Besides calories, eating exclusively healthy food is not always associated with calories-only, but other beliefs about foods are present. As such, in a case study Moroze, Dunn [7] reported that almost mystic beliefs about magical properties of broccoli or a conviction about healthy properties of certain micronutrients are present in individuals with ON.

Our present findings may explain the incongruent and often contradictive findings from studies using the ORTO-15 instrument and adapted versions. Our study suggests that the internal validity of the original ORTO-15, without undergoing an extensive adaptation process and model fit, would be of insufficient internal reliability (Cronbach's alpha = .30). Large-scale investigations of ON are mainly based on the ORTO-15 measure, but in most studies validity and reliability (Cronbach's alpha) was of poor construct validity [19, 21, 30, 31] or were not reported [5, 16, 32, 33]. Only few studies reported acceptable construct validity [10, 34]. On the other hand it has been argued that the usage of Cronbach's alpha is not a reliable tool for assessing the validity of an instrument [35]. Still, to reach acceptable validity with incremental fit indices [36], we had to delete almost half of the original items. Varga, Thege [10] argue that the inconsistency of the assessment may be partly due to cultural differences between countries. This argument may be very speculative and is not supported by data from relevant studies. Our research conflicts with this cultural-differences argument and indicates that cultural differences may be less of a problem, but rather the original construction of the ORTO-15 being the more fundamental problem. First, Austria is a heterogeneous country with heterogeneous cultural backgrounds among citizens (similar to Germany and Switzerland). A general definition of an instrument to measure behavioral traits should measure reliably across different population groups, not solely provide valid data among participants from e.g. Western, Educated, Industrialized, Rich, and Democratic (WEIRD) study samples [37]. Using different instruments depending on cultural or religious backgrounds may be unrewarding on the one and not applicable on the other hand. Second, a solid measure should take basal mechanisms describing the pathology of ON into account. When omitting 40% of the instrument, important information

of the original instrument may get lost and results ultimately become vague. As shown in our study, to increase the reliability of the questionnaire, we had to omit relevant questions regarding ON pathology (items: 14, 13, 9, 8, 2, 1); for instance, the information whether or not individuals feel guilty when transgressing their food habits (item 13) is of particular importance for ON. The statistical necessity to omit this item can hardly be argued with cultural differences, but rather is a result of the overall construction problem of the original ORTO-15 questionnaire. This should be considered in futures studies investigating ON.

Conclusion

In conclusion, ON is framed by a variety of factors due to its complex nature. Our research shows that several eating and dieting behaviors influence ON tendencies. Most importantly, this study indicates that the ORTO-15 measurement entails some basic psychometric flaws and its usage should be rethought from scratch.

Supporting Information

S1 Fig. Flow Chart of the study.
(PDF)

S2 Fig. ORTO-15 factor structure (1-factor structure). The displayed values are unstandardized regression weights from the study sample in a 1-factor structure. Squares represent items, oval circles represent factors, squares represent questionnaire items and small circles represent error terms.
(TIFF)

S3 Fig. ORTO-9-GE factor structure after item omission (1-factor structure). The displayed values are unstandardized regression weights from the study sample in a 1-factor structure after omitting item: 1/2/8/9/13/14. Squares represent items, oval circles represent factors, squares represent questionnaire items and small circles represent error terms.
(TIFF)

S1 Table. Lifestyle and eating behavior questions.
(DOCX)

S2 Table. Associations between ORTO-9-GE scores and descriptives of the study population. The table shows descriptives of the study sample and according ORTO-9-GE scores. M = mean; SD = standard deviation.
(DOCX)

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Author Contributions

Conceived and designed the experiments: BM BH JK. Performed the experiments: BM VD SZ CK. Analyzed the data: BM VD. Contributed reagents/materials/analysis tools: BM JK. Wrote the paper: BM BH JK.

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Gluten-free food database: the nutritional quality and cost of packaged gluten-free foods

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ABSTRACT

Notwithstanding a growth in popularity and consumption of gluten-free (GF) food products, there is a lack of substantiated analysis of the nutritional quality compared with their gluten-containing counterparts. To put GF foods into proper perspective both for those who need it (patients with celiac disease) and for those who do not, we provide contemporary data about cost and nutritional quality of GF food products. The objective of this study is to develop a food composition database for seven discretionary food categories of packaged GF products. Nutrient composition, nutritional information and cost of foods from 63 GF and 126 gluten-containing counterparts were systematically obtained from 12 different Austrian supermarkets. The nutrition composition (macro and micronutrients) was analyzed by using two nutrient composition databases in a stepwise approximation process. A total of 63 packaged GF foods were included in the analysis representing a broad spectrum of different GF categories (flour/bake mix, bread and bakery products, pasta and cereal-based food, cereals, cookies and cakes, snacks and convenience food). Our results show that the protein content of GF products is >2 fold lower across 57% of all food categories. In 65% of all GF foods, low sodium content was observed (defined as <120 mg/100 g). Across all GF products, 19% can be classified as source high in fiber (defined as >6g/100 g). On average, GF foods were substantially higher in cost, ranging from +205% (cereals) to +267% (bread and bakery products) compared to similar gluten-containing products. In conclusion, our results indicate that for GF foods no predominant health benefits are indicated; in fact, some critical nutrients must be considered when being on a GF diet. For individuals with celiac disease, the GF database provides a helpful tool to identify the food composition of their medical diet. For healthy consumers, replacing gluten-containing products with GF foods is aligned with substantial cost differences but GF foods do not provide additional health benefits from a nutritional perspective.

Subjects Food Science and Technology, Nutrition, Public Health
Keywords Gluten-free diet, Celiac disease, Gluten-free products, Food composition database, Cost of gluten-free products

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INTRODUCTION

Individuals with celiac disease (CD) show high levels of intestinal inflammation when exposed to gluten-containing foods (*Ludvigsson et al., 2013*; *Rubio-Tapia et al., 2013*). In western countries, the prevalence for CD is estimated at approximately 1% (*Golley et al., 2015*; *Gujral, Freeman & Thomson, 2012*). Clinically, as direct response to gluten and related prolamines in a diet, immunological processes damage intestinal mucosa and lead to villous atrophy, crypt hyperplasia and nutrient malabsorption (*Dickson, Streutker & Chetty, 2006*; *Husby et al., 2012*). To get full remission of the symptoms, excluding gluten-containing cereals (e.g. wheat, rye, barley) in a strict lifelong gluten-free (GF) diet is indicated (*El-Chammas & Danner, 2011*; *Green, 2009*). The nutritional quality of GF products that replace cereal-based foods is pivotal for patients with CD. Previous research showed that GF food products differ in their nutrient content compared to gluten-containing counterparts (*Mazzeo et al., 2015*; *Miranda et al., 2014*). In addition, a recent evaluation of more than 600 GF foods in Australian supermarkets showed that it is unlikely that GF foods have health benefits for individuals without CD, in particular due to the reported lower protein content in GF compared to non-GF products (*Wu et al., 2015*). However, contemporary data reporting the nutritional quality is scarce (*Staudacher & Gibson, 2015*), although the popularity of GF food products is increasing among consumers (*Marketsandmarkets.com, 2013*). To the best of our knowledge, no database with respect to nutritional quality for packaged GF food is available in German-speaking countries.

For CD patients, adhering to a restrictive GF diet can be challenging for several reasons. First, food choices are essentially limited because cereal products are staple foods in western countries and play a predominant role in a regular diet (e.g., bread or pasta). Second, a wide range of processed foods contain gluten-based products as additional ingredients. Prior to consumption of these foods, a detailed examination of the ingredient list has to be performed to avoid being exposed to gluten. This requires fundamental nutritional knowledge and a high level of self-discipline (*Mulder et al., 2015*). Third, 20–38% of patients with CD have some nutritional deficiencies due to their medical condition (*Kinsey, Burden & Bannerman, 2008*; *Saturni, Ferretti & Bacchetti, 2010*); e.g iron deficiency, deficiency in B vitamins (B_6, B_{12}) and trace minerals (e.g., zinc) (*Harris et al., 2012*; *Theethira & Dennis, 2015*). In a nutshell, patients with CD are need to structure their diet in a strict manner to maintain a positive long-term health outcome. Therefore, GF products have been developed as alternatives to cereal-based formulations. A wide range of products based on teff, amaranth, buckwheat or quinoa are now available for consumers exploring different alternatives to enhance sensory properties and shelf-life (*Gallagher, Gormley & Arendt, 2004*; *Pellegrini & Agostoni, 2015*).

Likewise, GF products are very popular among consumers without CD, which has led to almost exponential rise in sales for GF products over the last decade (*Marketsandmarkets.com, 2013*; *Strom, 2014*). *Mardini, Westgate & Grigorian (2015)* report updated US data from the National Health and Nutrition Examination Survey (NHANES) from 2009–2012. From all study participants (14.701 participants), 0.9% adhered to a GF diet, even though

85% of this group was never diagnosed with CD and 99% had negative serological markers for CD. For the majority of consumers, GF products are perceived as healthier than conventional products (*Marcason, 2011*). While evidence for this assumption is not based on solid data (*De Giorgio, Volta & Gibson, 2015*; *Gaesser & Angadi, 2012*), food companies continue to market GF foods as healthier and charge premium prices for their products (*Singh & Whelan, 2011*; *Stevens & Rashid, 2008*). Still, there is no solid data putting GF products into proper perspective about nutritional quality and product costs.

To provide better consumer information, the present work is the first attempt to build a nutrient composition database for packaged GF products available in one German-speaking country (Austria). The aim of the current study is to present data from GF foods representing the main sources of cereal-based food and analyze their nutrient content and cost.

MATERIALS & METHODS

We used a matched food sample procedure to analyze the nutrient content of packaged GF foods available on the Austrian Market. We grouped packaged GF foods with matching gluten-containing foods from two nutrition databases, estimated their nutrient content by using a step-by-step estimation process and compared the nutritional quality. We defined primary (macronutrient and energy content) and secondary outcome parameter (micronutrients and cost of the products) for further analysis.

Food products included

Between fall 2014 and spring 2015, packaged GF foods from 19 brands were obtained from three main supermarket chains in Austria in 12 different branches across Vienna. We selected 162 packaged GF foods from seven different food categories representing the majority of consumed processed foods that are originally based on cereal formulations for celiac patients (*Martin et al., 2013*). We only analyzed packaged GF foods marked with the European gluten-free label (*Commission of the European Communities, 2009*), excluded foods with non-verified gluten-free labels and excluded foods from categories that are not gluten-based in their original formulation. Following food categories were analyzed: flour/bake mix, bread and bakery products, pasta and cereal-based food, cereals, cookies and cakes, snacks and convenience food (for detailed listing, see Table S1). Additionally, we assessed the cost for each product.

Both food quality as well as cost ranged widely within individual food products. To minimize this within-product range and provide more homogenous data in both target variables (nutritional quality; product cost), we matched two gluten-containing foods differing in cost range (one budget and one pricier product) for each GF food. From originally 162 identified packaged GF foods, we excluded duplicates (86) and foods with incomplete nutrient information (13 foods) (see flow diagram and detailed list of exclusion in Supplemental Information 1). Our final sample consists of 63 GF and 126 similar gluten-containing foods for subsequent nutrient content matching procedure.

Step-by-step estimation process for nutrient content

The selected GF foods were matched with two similar gluten-containing foods available in two different databases used in the Austrian Nutrition Surveys (BLS 3.02 Max Rubner Institute, Germany; Austrian Nutrient Database: ÖNWT, dato denkwerkzeuge, Vienna, Austria). We used a Microsoft Excel worksheet to compile the composition in macro- and micronutrients of the GF foods per 100 g in its raw form. We imputed the quantity for each ingredient in a descending order. In a second step, we estimated the quantity of each ingredient for every product based on the percentage of the final recipe and its rank order reported on the label (theoretical nutrient composition). Furthermore we compared the theoretical macronutrient composition of the food with the given information on the food label. The process was reiterated by adjusting the percentage of the different ingredients until the final results reflected the values of energy content reported on the food label. To assess the precision of this procedure, we calculated the estimation precision (theoretical nutrient content/nutrient content on the food label in %). The precision for the estimation of all macronutrients was very good and within an overall variation range of 7% (for detailed listing, see Supplemental Information 2).

As a result of this process, we could estimate the amount of ingredients available in the GF products and extrapolate the nutritional components for following ingredients and nutrients: water (g/100 g), sugar (g/100 g), energy content (in kcal/100 g), macronutrients (carbohydrates, proteins, total fat, saturated fatty acids, monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), fibre; all in g/100 g), cholesterol (mg/100 g), minerals (i.e., Iron, Calcium, Sodium, Potassium, Phosphorous and Zinc; all in mg/100 g) and vitamins (Vitamin E, Thiamin, Riboflavin, Niacin, and Vitamin C; all in mg/100 g; Vitamin D, Retinol, β-carotene equivalents in µg/100 g).

Statistical analyses and availability of the database

Statistical analyses were conducted using IBM SPSS Statistics 22. Unpaired t-test was used to compare means; bivariate comparisons were tested by χ^2 test. The Bonferroni post-hoc test was used to correct for multiple comparisons; p-values < 0.05 were classified as significant. Post-hoc power analysis was calculated by the difference between two independent means with G*Power 3.1.9 (*Erdfelder et al., 2009*).

The Gluten-Free Food Database (Austria) can be accessed via the science collaboration platform: Open Science Framework. Contributions to the dataset can be made upon request and registration via the online platform (*Open Science Framework*).

RESULTS

The database provides quantitative information of macro- and micronutrients of the GF product. It contains nutrient data present in the traditional databases of gluten-containing foods (see Tables 1 and 2).

Primary outcome parameter: macronutrient and energy content

Across all food categories, energy content ranged between 270.5 ± 13.5 kcal/100 g (category: bread and bakery products) to 398.8 ± 25.4 kcal/100 g (category: snacks).

Table 1 Macronutrient composition of gluten-free products in Austria.

	Energy (kcal)	Protein (g)	Carbohydrates (g)	Sugar (g)	Total fat (g)	Saturated fatty acids (g)	MUFA (mg)	PUFA (mg)	Fiber (g)
Flour/bake mix									
Flour[a]	345.5	3.7	77.6	1.0	1.7	0.2	0.3	1.0	3.8
Bake mix white (cake)	338.4	3.2	77.5	17.8	1.2	0.3	0.5	0.5	2.3
Bake mix brown (cake)	394.7	2.6	82.9	52.5	5.4	3.1	1.8	0.4	2.8
Bake mix (Pizza)[a]	322.7	5.9	70.3	1.5	1.9	0.4	0.8	0.7	3.9
Breadcrumbs[a]	350.8	5.9	70.1	0.4	4.8	1.3	1.9	1.2	6.0
Bread/Bakery products									
Rustic bread	238.4	3.7	51.0	0.7	1.9	0.3	0.8	0.6	1.4
Whole-grain bread	263.6	8.5	40.8	5.1	7.2	1.0	2.2	3.9	8.4
Toast[a]	224.8	4.8	39.0	2.1	5.3	1.4	2.0	1.5	6.3
Bun	259.2	1.4	48.7	5.2	6.2	3.0	1.6	1.2	1.6
Ciabatta	213.4	3.3	44.9	2.9	2.0	0.3	2.3	0.7	8.3
Raisin bread	261.0	4.0	49.1	18.6	4.2	1.5	0.8	0.8	1.6
Scone	293.2	3.7	52.2	13.8	7.5	2.2	1.4	1.1	2.7
Baguette	270.1	4.5	56.7	6.4	2.5	0.4	1.9	3.0	5.3
Lye Pretzel	343.8	4.8	59.2	7.8	9.4	4.7	1.0	0.9	2.2
Rusk	343.9	0.3	82.5	0.8	0.9	0.3	3.2	0.7	0.7
Crispbread	351.6	6.9	77.8	6.0	0.9	0.2	0.4	0.2	2.9
Wraps	228.7	3.1	38.8	0.4	7.5	2.2	0.3	0.4	2.8
Pasta and cereal-based products									
Fusilli	335.9	8.2	69.9	1.0	2.2	0.3	0.7	1.1	7.2
Spaghetti	329.0	8.7	66.3	1.3	2.8	0.4	0.9	1.4	9.4
Penne	338.4	6.9	72.4	4.3	1.9	0.3	0.5	0.9	4.9
Lasagne sheets	373.0	7.0	76.3	0.8	4.0	1.1	1.6	0.8	2.4
Vermicelli	371.2	12.5	71.6	2.0	3.4	0.4	1.0	1.7	13.5
Tagliatelli	370.9	12.1	72.0	1.9	3.3	0.4	1.0	1.7	13.1
Cous Cous	345.0	8.8	73.8	1.5	1.1	0.1	0.4	0.4	5.0
Cereals									
Granola (chocolate)	392.3	5.5	72.6	34.0	8.5	4.7	3.1	0.6	4.6
Granola (nuts)	478.0	7.1	64.9	16.7	21.0	7.7	10.3	2.5	4.8
Cornflakes	322.4	8.5	62.9	1.4	3.7	0.6	1.1	1.6	7.6
Cookie and Cakes									
Shortbread	385.3	3.3	73.6	13.8	8.3	2.7	3.9	1.5	1.2
Neapolitan wafers (original)	236.0	2.5	22.9	18.1	15.0	8.3	5.2	1.1	3.3
Cookie (chocolate)	479.2	2.0	64.3	5.7	23.8	11.9	8.5	2.5	2.3
Mignon wafers (hazelnut)	507.9	5.0	54.0	41.7	30.4	13.9	11.9	3.7	5.6
Marble cake	403.7	5.4	48.1	20.7	22.6	3.8	10.2	7.4	0.8
Ladyfinger	356.9	5.7	74.6	33.1	3.5	1.0	1.4	0.6	2.5
Cookie (whole-grain)	471.1	4.6	71.8	21.1	18.2	7.8	6.8	2.8	3.6
Granola bar	400.8	7.2	59.2	25.0	14.8	7.0	5.3	1.7	12.9
Cookie (orange)[a]	433.0	6.2	60.2	49.7	18.3	10.5	5.5	1.4	2.6
Apple strudel	270.9	4.2	43.2	18.1	8.7	3.4	2.9	2.2	1.6
Muffin	371.6	5.2	55.8	30.0	14.6	4.1	3.4	2.2	3.5

(*continued on next page*)

Table 1 (*continued*)

	Energy (kcal)	Protein (g)	Carbohydrates (g)	Sugar (g)	Total fat (g)	Saturated fatty acids (g)	MUFA (mg)	PUFA (mg)	Fiber (g)
Snacks									
Cracker	340.8	10.1	43.5	0.0	13.8	9.3	3.3	0.4	0.3
Brezels	449.7	0.5	65.5	0.8	20.6	9.8	7.5	2.4	0.8
Grissini	392.5	2.0	67.4	2.6	12.6	3.9	6.1	2.4	0.7
Saltsticks	480.9	0.6	72.0	1.5	21.1	10.3	7.8	2.2	0.8
Wafers (plain)	329.7	8.6	63.8	1.4	4.1	0.6	1.2	1.8	7.7
Convenience foods									
Pizza (salami)	235.1	8.0	24.8	2.8	11.5	4.8	4.1	1.9	1.5
Pizza (margherita)	209.1	6.3	27.6	3.5	8.0	3.8	2.5	1.3	2.0
Lasagne	170.4	7.4	16.4	2.2	8.3	3.8	3.2	0.8	1.1
Chicken nuggets	251.2	15.3	22.5	0.5	11.0	1.5	4.2	4.8	3.0
Fish sticks	216.0	9.2	28.1	4.0	7.3	0.8	1.8	3.8	1.9
Tortellini (pork)	285.3	7.7	48.1	1.3	6.6	2.5	2.5	1.0	1.7
Soup (potato and leek)	355.9	16.2	47.7	7.9	10.4	2.2	4.3	2.6	8.3
Soup (mushrooms)	431.4	15.5	43.4	13.7	21.7	2.1	10.2	5.7	1.6
Wafer-cone (icecream filling)	278.0	5.2	27.8	24.2	16.2	5.9	7.0	2.9	3.5
Pudding (semolina)	362.5	6.2	82.0	14.8	0.6	0.1	0.2	0.2	1.8
Baked pastry case	483.9	4.3	43.3	21.6	32.9	15.7	12.0	3.6	4.4
Wafer (Oblate)	329.2	1.1	79.1	0.2	0.4	0.1	0.1	0.2	1.2
Rice drink (natural)	56.9	1.1	11.0	0.2	0.9	0.1	0.4	0.3	0.4
Flaky pastry	389.5	1.4	31.6	2.05	29.0	8.1	7.3	12.3	5.3
Frozen cake (almond, chocolate)	405.2	7.0	25.1	24.4	31.1	10.9	13.1	4.3	2.0

Notes.

Data displayed as mean values.

[a] Mean values of two very similar products were pooled.

Across all food categories, energy content, carbohydrate, total fat, saturated fatty acids, fiber and sugar did not differ between GF and products gluten-containing products ($F < 1; p > 0.05$).

Protein content was significantly lower in GF foods (5.8 ± 3.7 g/100 g) than gluten-containing foods (8.6 ± 2.9 g/100 g); $F = 31.9; p < 0.01$ (see Fig. 1). Lower protein content was present in 4 out of 7 food categories (flour/bake mix, bread and bakery products, pasta and cereal-based products and snacks). In flour/bake mix products, the average protein content was 4.6 ± 3.4 g/100 g for GF and 9.9 ± 2 g/100 g for their gluten-containing counterparts (see Table 3).

Secondary outcome parameter: micronutrients and product cost

Overall, sodium content in gluten-containing foods (448.9 ± 704.6 mg/100 g) did not differ compared to GF foods (373.5 ± 569.2 mg/100 g; $F < 1, p > 0.05$). In one category (cereal products), sodium content was higher in GF foods. Across all three analyzed GF cereal products, sodium content was 491.3 ± 91.6 mg/100 g while in gluten-containing foods, sodium content was 160.7 ± 139.3 mg/100 g ($F = 13.4; p < 0.01$). For bread and bakery products, sodium content was lower in GF products (388.4 ± 206.4 mg/100 g) compared to gluten-containing foods (581.9 ± 290.3 mg/100 g; $F = 4.5; p < 0.05$).

Table 2 Micronutrient composition of gluten-free products in Austria.

	Sodium (mg)	Cholestorol (mg)	Iron (mg)	Calcium (mg)	Potassium (mg)	Zinc (mg)	Phosphor (mg)	Vitamin C (mg)	Vitamin D (µg)	Vitamin E (mg)	Retinol (µg)	ß-Carotin (µg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)
Flour/bake mix															
Flour[a]	3.02	0.00	1.42	32.16	147.84	0.99	78.76	0.00	0.00	0.11	0.00	0.02	0.08	0.03	0.29
Bake mix white (cake)	39.67	0.00	1.17	54.73	240.21	1.08	204.11	0.12	0.00	0.04	0.00	0.00	0.03	0.02	0.29
Bake mix brown (cake)	41.71	9.47	1.23	17.52	252.71	0.79	118.76	0.32	0.00	0.06	0.00	0.00	0.02	0.02	0.29
Bake mix (Pizza)[a]	783.75	0.00	1.49	89.31	347.84	1.64	720.85	0.39	0.00	0.08	0.00	0.00	0.06	0.05	1.14
Breadcrumbs[a]	196.33	0.04	2.25	31.67	182.99	1.88	183.23	0.00	0.00	1.02	0.00	4.51	0.25	0.04	0.31
Bread/bakery products															
Rustic bread	120.53	0.00	0.38	10.58	75.45	0.48	35.90	0.00	0.00	1.01	0.00	0.00	0.06	0.02	0.48
Whole-grain bread	685.79	0.00	2.41	96.43	304.10	1.70	208.75	0.01	0.00	0.23	0.00	0.01	0.21	0.10	1.33
Toast[a]	394.29	0.02	1.58	34.01	273.02	1.24	135.35	0.03	0.00	2.05	0.00	0.37	0.17	0.11	1.92
Bun	402.11	4.02	0.60	17.67	52.68	0.39	36.52	0.00	0.00	0.48	0.00	1.28	0.03	0.06	0.48
Ciabatta	355.74	0.00	1.03	17.15	117.38	0.86	91.38	1.20	0.00	1.05	0.00	0.08	0.14	0.09	0.97
Raisin bread	299.48	0.37	1.01	59.31	157.72	0.73	80.86	0.43	0.00	0.08	0.02	0.04	0.07	0.09	0.51
Scone	314.90	32.64	0.82	30.76	91.38	0.50	73.71	0.01	0.00	0.19	0.06	0.05	0.07	0.14	1.09
Baguette	336.38	0.00	0.66	13.96	120.93	0.41	48.25	0.84	0.00	1.41	0.00	0.01	0.07	0.06	0.62
Lye Pretzel	790.76	7.06	0.40	124.30	137.68	0.57	78.43	13.10	0.00	0.49	0.02	1.29	0.04	0.15	0.15
Rusk	5.52	0.01	1.06	21.34	11.95	0.40	20.24	0.00	0.00	0.08	0.00	1.00	0.00	0.01	0.09
Crispbread	547.20	0.00	0.67	11.61	99.13	0.67	109.04	0.00	0.00	0.24	0.00	0.04	0.11	0.04	1.38
Wraps	402.35	0.63	0.21	18.09	83.57	0.19	39.96	0.25	0.23	0.07	0.05	0.06	0.03	0.01	0.58
Pasta and cereal-based products															
Fusilli	1.88	0.00	1.80	14.67	114.68	1.87	205.75	0.00	0.00	0.81	0.00	0.21	0.33	0.10	1.76
Spaghetti	1.00	0.00	2.40	18.00	120.00	2.50	256.00	0.00	0.00	1.11	0.00	0.30	0.44	0.13	1.93
Penne	1.90	0.00	3.15	22.73	198.37	1.43	211.40	0.00	0.00	0.48	0.00	0.12	0.28	0.12	1.61
Lasagne sheets	55.98	146.52	1.37	30.53	91.97	1.32	144.47	0.00	0.00	0.89	0.10	0.04	0.10	0.18	0.52
Vermicelli	6.71	0.00	3.81	45.15	297.12	3.05	327.38	0.93	0.00	1.68	0.00	0.31	0.51	0.16	2.14
Tagliatelli	5.94	0.00	3.65	41.70	274.68	3.02	321.78	0.80	0.00	1.62	0.00	0.32	0.51	0.16	2.14
Cous Cous	1.00	0.00	1.00	4.00	80.00	0.41	73.00	0.00	0.00	0.52	0.00	0.26	0.13	0.04	1.20
Cereals															
Granola (chocolate)	504.01	15.77	1.51	17.98	265.98	0.52	73.86	0.13	0.00	0.25	0.00	0.51	0.05	0.06	0.96
Granola (nuts)	393.96	0.16	1.72	44.88	314.76	1.60	174.62	0.11	0.00	3.54	0.00	1.78	0.20	0.09	1.40
Cornflakes	575.88	0.00	1.52	8.61	265.44	1.45	208.76	0.00	0.00	1.47	0.00	0.90	0.35	0.20	1.47
Cookie and cakes															
Shortbread	408.14	17.31	0.66	33.19	79.97	0.59	72.93	0.22	0.00	0.84	0.02	9.02	0.05	0.10	0.73
Neapolitan wafers (original)	16.20	21.70	0.71	8.86	259.18	0.59	61.06	0.01	0.00	0.12	0.00	0.01	0.03	0.03	0.37
Cookie (chocolate)	199.30	3.37	0.82	13.20	91.10	0.73	57.96	0.00	0.00	1.66	0.00	4.50	0.05	0.02	0.26
Mignon wafers (hazelnut)	417.91	28.84	2.70	28.12	476.92	1.16	124.82	0.02	0.00	1.31	0.00	0.03	0.09	0.06	0.68
Marble cake	54.88	138.60	1.32	22.11	103.26	0.76	98.91	0.00	0.00	12.54	0.10	0.02	0.05	0.15	0.24
Ladyfinger	98.46	141.37	1.00	37.26	79.88	0.80	100.96	0.00	0.00	0.72	0.10	0.00	0.05	0.15	0.28
Cookie (whole-grain)	295.19	5.16	1.17	15.24	68.83	0.78	89.30	0.13	0.00	0.37	0.00	0.12	0.14	0.05	0.87
Granola bar	237.91	4.24	2.14	96.16	292.51	1.37	170.55	0.45	0.00	1.00	0.01	0.16	0.19	0.19	1.23
Cookie (orange)[a]	190.66	23.28	1.74	103.46	389.10	0.83	120.50	4.78	0.00	0.39	0.06	0.27	0.08	0.13	0.45
Apple strudel	102.98	1.83	1.13	177.03	240.82	0.68	128.36	4.75	0.00	0.16	0.05	0.08	0.07	0.27	0.25
Muffin	247.84	79.20	2.66	29.50	219.98	0.74	102.31	0.00	0.00	3.54	0.06	0.01	0.06	0.11	0.30

(*continued on next page*)

Table 2 (*continued*)

	Sodium (mg)	Cholestorol (mg)	Iron (mg)	Calcium (mg)	Potassium (mg)	Zinc (mg)	Phosphor (mg)	Vitamin C (mg)	Vitamin D (µg)	Vitamin E (mg)	Retinol (µg)	ß-Carotin (µg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)
Snacks															
Cracker	2416.36	47.71	1.40	434.99	83.08	2.05	305.78	0.43	0.00	0.41	0.13	0.06	0.03	0.12	0.48
Brezels	554.28	0.20	0.67	11.72	17.23	0.45	26.93	0.00	0.00	1.48	0.00	4.26	0.01	0.03	0.21
Grissini	226.87	20.01	0.63	52.59	64.73	0.62	62.82	0.06	0.00	1.31	0.03	15.02	0.02	0.09	0.07
Saltsticks	1007.36	0.21	0.93	15.82	25.22	0.47	30.69	0.00	0.00	1.56	0.00	4.47	0.02	0.04	0.34
Wafers (plain)	119.98	0.01	1.50	8.15	268.55	1.47	211.73	0.02	0.00	1.61	0.00	0.92	0.36	0.20	1.49
Convenience foods															
Pizza (salami)	614.15	22.66	0.97	103.75	275.57	1.13	115.28	7.43	0.00	3.23	0.04	0.24	0.11	0.11	1.68
Pizza (margherita)	437.51	14.95	0.68	110.73	266.87	0.85	106.10	6.97	0.00	2.97	0.05	0.26	0.05	0.10	1.02
Lasagne	450.21	38.88	0.79	56.08	211.47	1.38	99.60	5.51	0.02	1.14	0.04	0.24	0.11	0.13	1.51
Nuggets	396.19	35.00	1.34	16.80	158.47	1.37	179.53	0.05	0.00	5.46	0.00	0.16	0.14	0.09	4.71
Fish sticks	378.34	23.54	1.19	24.87	128.33	0.49	142.50	0.24	0.00	4.04	0.00	0.11	0.12	0.22	1.62
Tortellini (pork)	628.05	72.33	1.49	51.06	118.68	1.64	122.19	1.06	0.01	0.75	0.04	0.04	0.24	0.12	1.38
Soup (potato and leek)	3801.76	1.03	2.53	80.57	1014.25	0.88	260.47	11.70	0.00	1.61	0.00	0.42	0.17	0.28	4.63
Soup (mushrooms)	472.57	0.43	0.89	17.52	104.01	0.22	34.90	0.95	0.00	3.82	0.00	0.68	0.04	0.07	0.91
Wafer-cone (icecream filling)	101.42	22.61	1.39	97.43	358.09	0.78	127.37	0.81	0.12	3.66	0.02	0.04	0.04	0.16	0.37
Pudding (semolina)	117.48	0.00	0.54	9.64	91.27	0.50	79.69	0.10	0.00	0.09	0.00	0.00	0.06	0.02	1.18
Baked pastry case	108.30	0.32	1.61	30.08	138.24	1.30	202.23	0.70	0.00	2.87	0.00	6.82	0.18	0.09	1.91
Wafer (Oblate)	6.98	0.00	1.80	31.88	26.15	0.43	35.54	0.00	0.00	0.12	0.00	0.03	0.05	0.02	0.33
Rice drink (natural)	52.58	0.00	0.23	12.47	17.01	0.20	15.55	0.00	0.00	0.51	0.00	0.00	0.01	0.00	0.19
Flaky pastry	412.00	2.35	0.22	49.65	47.07	0.20	24.56	0.13	0.03	2.10	0.00	0.17	0.24	0.01	0.22
Frozen cake (almond, chocolate)	120.14	170.20	1.69	39.44	219.39	0.90	126.96	0.21	0.13	4.26	0.15	2.19	0.06	0.16	0.38

Notes.

Data displayed as mean values.

[a] Mean values of two very similar products were pooled.

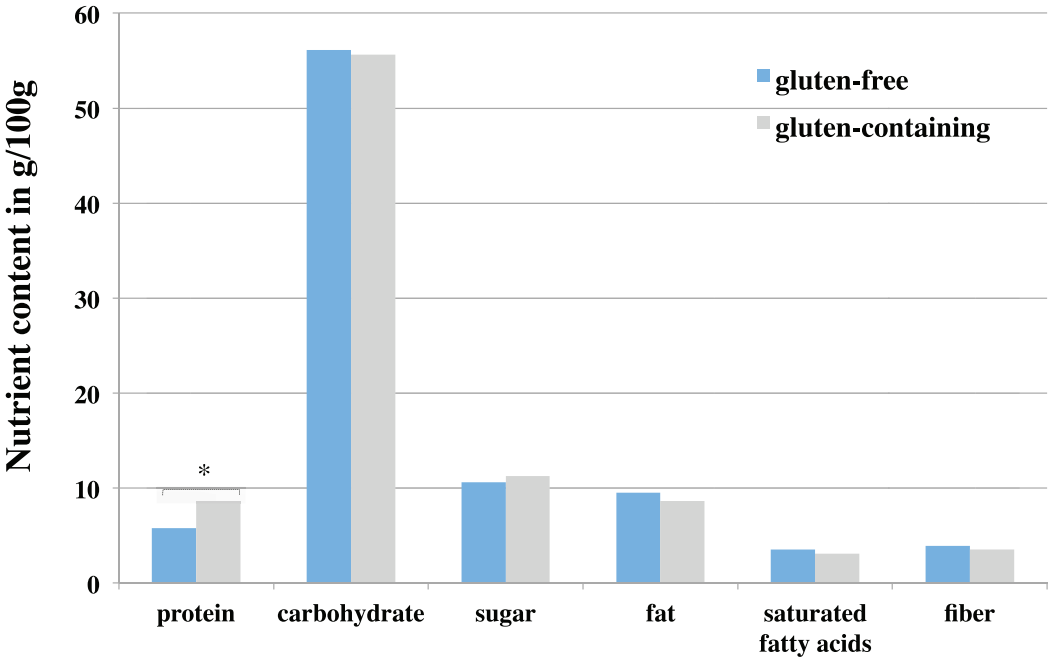

Figure 1 Nutrient content in g/100 g between gluten-free and gluten-containing foods across seven different food categories. Notes. Data displayed as mean values. * Significant differences ($p < 0.05$) between gluten-free and gluten containing foods.

Across all other categories, sodium content did not differ significantly. 27% of all products showed high sodium content (defined as >500 mg/100 g, *Commission of the European Communities (2006)*), this did not differ between GF and gluten-containing foods (χ^2 [1] = 1.94; $p > 0.05$). In contrast, 65% of GF and 61% of gluten-containing foods showed low sodium content (defined as <120 mg/100 g, *Commission of the European Communities (2006)*).

Potassium content was significantly lower in GF products (190.4 ± 160 mg/100 g) than in products containing gluten (247.5 ± 130 mg/100 g; $F = 6.9$; $p < 0.05$). This difference was present in 2 out of 7 food categories (pasta and cereal-based products; snacks), while all other categories did no show significant differences. Moreover, zinc content was significantly lower in GF pasta products (1.9 ± 0.9 mg/100 g vs. 4.6 ± 0.4 mg/100 g; $F = 82.1$; $p < 0.01$). GF Pasta products showed higher fiber content (7.9 ± 4.2 g/100 g) when compared to gluten-containing products (3.7 ± 0.7 g/100 g; $F = 13.6$; $p < 0.01$). Across all GF products, 19% can be classified as source high in fiber (defined as >6 g/100 g, *Commission of the European Communities (2006)*).

Substantial cost disparities were present between GF products and gluten-containing products. On average, the cost for GF products ranged from 2.95€ (white flour) to 80.80€ per kg (Wafer, Oblaten) and was significantly higher in GF products (11.58 ± 11.43€) compared to gluten-containing products (6.62 ± 5.36€; $F = 53.1$; $p < 0.01$) across all product categories. Within bread and bakery products, GF food were +267% more

Table 3 Comparison between micro-and macronutrient composition of gluten-free and matched gluten-containing foods among categories.

		Flour/bake mix	Bread/bakery products	Pasta and cereal-based products	Cereals	Cookie and cakes	Snacks	Convenience foods
Energy (kcal)	**Gluten free**	346.4 ± 35.5	270.5 ± 46.7	351.9 ± 17.7	397.5 ± 63.6	395.8 ± 84.4	398.7 ± 59.2	297.3 ± 108.5
	Gluten-containing	335.0 ± 23.0	280.9 ± 49.8	346.5 ± 10.9	397.4 ± 56.3	416.3 ± 78.1	371.6 ± 45.3	298.2 ± 102.0
	P†	0.373	0.543	0.426	0.997	0.488	0.376	0.978
Protein (g)	**Gluten Free**	4.6 ± 3.2	4.1 ± 2.2	9.2 ± 2.1	7.0 ± 1.2	4.8 ± 1.6	4.3 ± 4.1	7.4 ± 4.8
	Gluten-containing	10.0 ± 2.0	8.3 ± 1.0	11.9 ± 0.9	9.2 ± 2.4	5.8 ± 1.9	10.5 ± 1.4	8.2 ± 3.9
	P†	<0.01	<0.01	<0.05	0.245	0.105	<0.01	0.605
Carbohydrates (g)	**Gluten Free**	74.4	52.3	71.7	66.7	57.3	62.4	37.2
	Gluten-containing	67.8	52.7	69.4	57.6	59.9	61.4	39.5
	P†	<0.05	0.912	<0.05	0.101	0.561	0.860	0.733
Sugar (g)	**Gluten Free**	9.5 ± 17.2	5.5 ± 5.2	1.8 ± 1.1	17.4 ± 13.3	27.2 ± 14.6	1.3 ± 0.8	8.2 ± 8.8
	Gluten-containing	6.0 ± 9.1	4.4 ± 5.4	0.8 ± 0.2	14.5 ± 6.4	33.7 ± 12.6	1.0 ± 0.2	9.8 ± 12.2
	P†	0.543	0.912	<0.05	0.714	0.188	<0.860	0.655
Total fat (g)	**Gluten Free**	2.9 ± 2.2	4.7 ± 2.7	2.7 ± 0.9	11.1 ± 7.3	16.4 ± 8.4	14.4 ± 6.2	13.1 ± 10.5
	Gluten-containing	2.2 ± 2.3	3.8 ± 2.8	1.9 ± 1.0	14.3 ± 8.0	17.0 ± 8.4	9.0 ± 8.0	11.6 ± 9.0
	P†	0.481	0.349	0.133	0.621	0.852	0.238	0.630
Saturated fatty acids (g)	**Gluten Free**	0.9 ± 1.1	1.4 ± 1.3	0.4 ± 0.3	4.3 ± 2.9	7.1 ± 5.1	6.8 ± 3.8	4.1 ± 4.3
	Gluten-containing	0.7 ± 1.2	0.9 ± 1.0	0.4 ± 0.3	4.4 ± 3.4	6.8 ± 4.5	4.2 ± 5.3	4.0 ± 4.1
	P†	0.716	0.183	0.818	0.986	0.868	0.384	0.917
MUFA (mg)	**Gluten Free**	1.0 ± 1.1	1.5 ± 0.8	0.9 ± 0.4	4.8 ± 4.0	5.9 ± 3.2	5.2 ± 2.6	4.8 ± 4.1
	Gluten-containing	0.5 ± 0.9	1.3 ± 1.2	0.4 ± 0.4	6.4 ± 4.1	6.7 ± 3.6	2.7 ± 2.4	4.5 ± 3.7
	P†	0.236	0.614	<0.05	0.627	0.509	0.117	0.783
PUFA (mg)	**Gluten Free**	0.8 ± 0.6	1.4 ± 1.1	1.1 ± 0.4	1.5 ± 0.8	2.4 ± 1.7	1.8 ± 0.7	3.0 ± 3.0
	Gluten-containing	0.6 ± 0.4	1.0 ± 0.8	0.8 ± 0.3	3.2 ± 0.9	2.6 ± 1.8	1.4 ± 1.0	1.9 ± 1.4
	P†	0.220	0.195	0.100	0.055	0.723	0.412	0.101
Fiber (g)	**Gluten Free**	4.1 ± 2.9	3.9 ± 2.7	7.9 ± 4.0	5.6 ± 1.4	3.5 ± 3.1	2.0 ± 2.8	2.6 ± 2.0
	Gluten-containing	4.0 ± 2.3	3.3 ± 1.7	3.7 ± 0.7	7.4 ± 1.9	3.5 ± 3.8	4.6 ± 3.2	2.4 ± 2.0
	P†	0.944	0.429	<0.05	0.247	0.979	0.188	0.669
Sodium (mg)	**Gluten Free**	255.9 ± 326.9	388.4 ± 198.3	10.6 ± 18.6	491.3 ± 74.8	205.0 ± 122.6	856.0 ± 835.0	539.8 ± 894.2
	Gluten-containing	281.6 ± 294.6	581.9 ± 284.6	15.8 ± 18.0	160.7 ± 127.2	247.8 ± 394.0	832.1 ± 626.7	715.8 ± 1186.1
	P†	0.855	0.039	0.564	<0.05	0.724	0.938	0.623
Cholestorol (mg)	**Gluten Free**	1.2 ± 3.1	3.4 ± 8.7	20.9 ± 51.3	5.3 ± 7.4	40.7 ± 49.0	13.6 ± 18.7	27.0 ± 43.1
	Gluten-containing	2.6 ± 7.0	5.5 ± 12.1	21.5 ± 42.2	1.4 ± 2.0	32.4 ± 38.4	1.5 ± 2.6	28.5 ± 41.5
	P†	0.617	0.602	0.980	0.318	0.595	0.083	0.908
Iron (mg)	**Gluten Free**	1.6 ± 0.8	1.0 ± 0.7	2.5 ± 1.0	1.6 ± 0.1	1.5 ± 0.7	1.0 ± 0.4	1.2 ± 0.6
	Gluten-containing	1.6 ± 1.1	1.2 ± 0.6	2.5 ± 0.3	6.1 ± 7.3	1.6 ± 1.3	2.2 ± 1.8	1.4 ± 1.3
	P†	0.964	0.216	0.944	0.375	0.840	0.188	0.496
Calcium (mg)	**Gluten Free**	47.3 ± 27.2	37.6 ± 33.9	25.3 ± 13.7	23.8 ± 15.4	55.6 ± 55.0	104.7 ± 165.9	48.8 ± 33.1
	Gluten-containing	24.3 ± 19.1	18.9 ± 10.8	33.6 ± 7.6	75.4 ± 117.0	37.2 ± 27.5	50.3 ± 45.1	46.4 ± 40.0

(*continued on next page*)

Table 3 (*continued*)

		Flour/bake mix	Bread/bakery products	Pasta and cereal-based products	Cereals	Cookie and cakes	Snacks	Convenience foods
	P†	<0.05	<0.05	0.105	0.524	0.202	0.384	0.842
Potassium (mg)	**Gluten Free**	231.3 ± 127.5	138.3 ± 118.9	168.1 ± 82.5	282.1 ± 23.1	224.2 ± 136.7	91.8 ± 91.7	211.7 ± 234.1
	Gluten-containing	222.3 ± 86.8	201.3 ± 61.0	295.4 ± 121.2	378.3 ± 152.7	235.1 ± 124.3	309.7 ± 179.8	241.8 ± 145.4
	P†	0.848	<0.05	<0.05	0.370	0.818	0.352	0.607
Zinc (mg)	**Gluten Free**	1.4 ± 0.8	0.7 ± 0.5	1.9 ± 0.9	1.2 ± 0.5	0.8 ± 0.2	1.0 ± 0.6	0.8 ± 0.5
	Gluten-containing	1.2 ± 1.1	0.8 ± 0.4	4.6 ± 0.4	2.6 ± 1.0	0.8 ± 0.6	1.6 ± 1.1	1.0 ± 0.8
	P†	0.734	0.766	<0.01	0.078	0.930	0.370	0.346
Phosphor (mg)	**Gluten Free**	286.1 ± 267.0	84.1 ± 61.3	220.0 ± 85.2	152.4 ± 57.3	104.0 ± 33.5	127.6 ± 111.8	111.5 ± 66.4
	Gluten-containing	194.7 ± 177.1	104.9 ± 49.2	301.3 ± 178.4	321.0 ± 222.1	109.2 ± 73.7	207.2 ± 152.4	130.7 ± 84.6
	P†	0.350	0.247	0.290	0.292	0.823	0.352	0.456
Vitamin C (mg)	**Gluten Free**	0.2 ± 0.2	1.2 ± 3.4	0.2 ± 0.4	0.1 ± 0.1	1.3 ± 2.4	0.1 ± 0.2	2.4 ± 3.5
	Gluten-containing	0.0 ± 0.0	1.6 ± 7.6	1.0 ± 3.5	22.4 ± 49.9	2.0 ± 3.4	0.0 ± 0.1	16.7 ± 56.1
	P†	<0.05	0.885	0.612	0.516	0.512	0.404	0.341
Vitamin E (mg)	**Gluten Free**	0.3 ± 0.4	0.7 ± 0.8	1.0 ± 0.4	1.8 ± 1.4	1.9 ± 3.3	1.3 ± 0.4	2.4 ± 1.6
	Gluten-containing	0.3 ± 0.4	0.8 ± 1.0	1.0 ± 0.2	2.1 ± 1.2	2.3 ± 3.2	0.9 ± 0.5	1.7 ± 1.1
	P†	0.952	0.841	0.972	0.728	0.724	0.178	0.065
ß-Carotin (mg)	**Gluten Free**	1.1 ± 3.0	0.4 ± 0.5	0.2 ± 0.1	1.1 ± 0.5	1.2 ± 2.7	4.9 ± 5.3	0.8 ± 1.7
	Gluten-containing	0.0 ± 0.0	0.2 ± 0.5	0.1 ± 0.3	1.2 ± 1.2	1.1 ± 1.6	0.4 ± 0.7	0.9 ± 1.5
	P†	0.160	0.347	0.320	0.838	0.887	<0.05	0.786
Niacin (mg)	**Gluten Free**	0.6 ± 0.4	0.9 ± 0.7	1.6 ± 0.5	1.3 ± 0.2	0.5 ± 0.3	0.5 ± 0.5	1.5 ± 1.4
	Gluten-containing	1.5 ± 1.6	1.6 ± 0.8	3.6 ± 2.7	11.0 ± 22.0	0.7 ± 0.8	3.3 ± 3.1	1.8 ± 1.6
	P†	0.128	<0.05	0.077	0.523	0.552	0.084	0.488

Notes.

Data displayed as mean values per unit/100 g ± standard deviation.

P† Differences in mean nutrient content between GF and non-GF products were assessed by unpaired *t*-test.

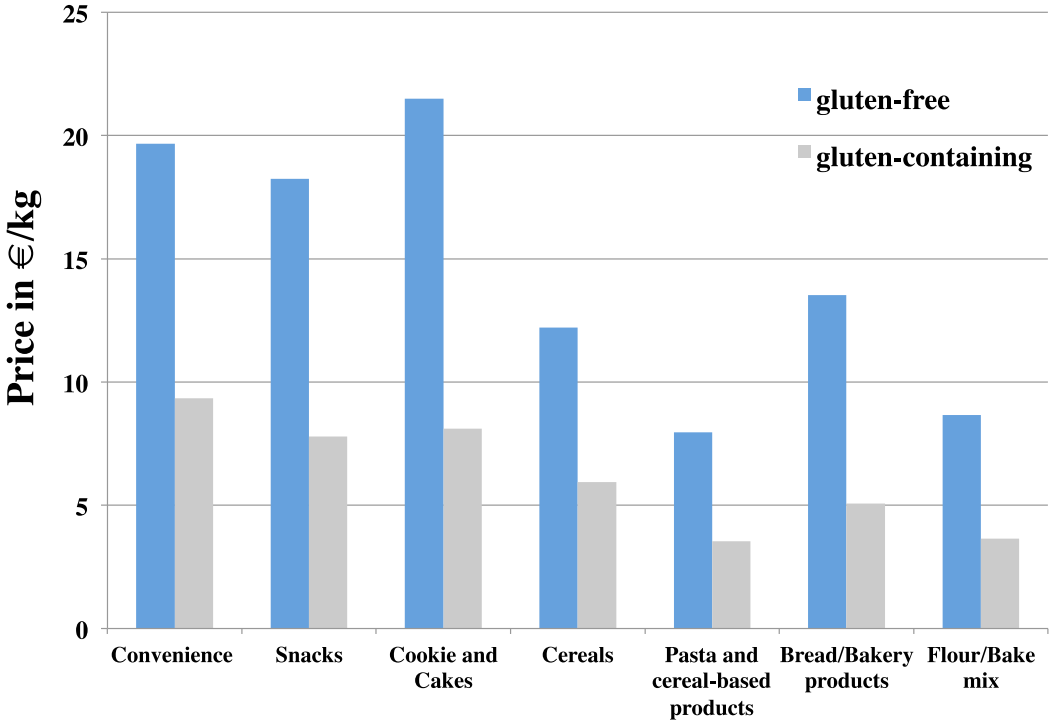

Figure 2 Cost in €/kg between gluten-free and gluten-containing foods across seven different food categories. Notes. Data displayed as mean values. Within all food categories differences in mean cost between GF and and gluten-containing foods were significant ($p < 0.05$).

expensive than similar gluten-containing products. The lowest cost disparity (+205% higher cost for GF products) was observed for cereal products (Fig. 2).

DISCUSSION

The present study is the first attempt to present a large dataset comparing GF foods and gluten-containing products available in one German-speaking country (Austria). The data showed that there is great variability between GF foods and gluten-containing products for specific nutrients.

One key finding of this study is that protein content was significantly lower in GF foods across all staple foods. In flour/bake mix products, the average protein content was >2 fold lower compared to their gluten-containing counterparts. This finding is in line with previous findings (*Wu et al., 2015*), except that we did not observe significant differences in total fat, saturated fat, PUFA and MUFA in our products (*Kulai & Rashid, 2014*; *Matos Segura & Rosell, 2011*; *Miranda et al., 2014*). Only in pasta and cereal-based products was MUFA content significantly higher in GF foods. The low amount of proteins in GF foods can be explained by their formulation. In GF formulations, carbohydrate-rich but protein-poor ingredients are used, such as white rice flour, tapioca or potato starch (*Mezaize et al., 2009*). This can lead to lower protein content in GF foods, which may be a reasonable explanation for the observed differences in our data.

Reports about protein intake and its clinical relevance for celiac patients is conflicting. In a prospective study comparing dietary intake from 88 celiac patients (7-day dietary

record) with data from non-celiac individuals from the German National Diet and Nutrition Survey (NVS II), no differences in protein intake for males or females were observed (*Martin et al., 2013*). On the other hand, *Miranda et al. (2014)* analyzed 58 adults with CD and showed that protein intake was lower in women who were on a GF diet compared to a diet containing gluten. In this study, the protein content of breads was almost one third lower than their equivalent foods with gluten. In our dataset, GF breads contained half of the proteins compared to regular breads with gluten. Addtionally, in a cross-sectional study, *Van Hees et al. (2015)* compared dietary intake of amino acids in 77 CD patients. Compared to 33 healthy controls, celiac patients with good adherence to a GF diet showed significantly lower amino acid concentrations in blood (tyrosine, phenylalanine and tryptophan). The authors argue that both, a reduced intake of vegetable protein and malabsorption as a results of CD may be responsible for this result. The findings of our study suggest that reduced protein content in GF products may facilitate problematic protein intake in CD patients and should be considered in dietary counseling.

In 65% of all analyzed GF foods, low sodium content (defined as <120 mg/100 g, *Commission of the European Communities (2006)*) was observed. Interestingly, in bread and bakery products, sodium content was lower compared to gluten-containing foods. The lower amount of sodium in GF bread may be accounted for the joint initiative "Weniger Salz is g'sünder" with the aim to reduce salt in bread and bakery products by 15% by 2015 initiated by the *Austrian Ministry of Health (2011)* and the Industrial Bakers of Austria (*Lloyd-Williams et al., 2014*). Foods from the datasets used in this study contained nutrient information that were assessed prior to this initiative (started 2011), which may be a possible explanation for this discrepancy.

LIMITATIONS

Some limitations of the present study should be taken into account. First, we did not analyze the nutritional composition of GF foods through direct chemical analysis, but only estimated the data from nutrient content by deriving data from two nutrient databases. Direct chemical analysis is the gold standard to estimate the nutrient composition of food. Nevertheless, previous studies have shown that estimating the nutrient composition of GF food via indirect analysis is a valid method, likewise (*Mazzeo et al., 2015*; *Miranda et al., 2014*; *Wu et al., 2015*). Additionally, nutrient data shown on food labels provided by the food industry are commonly based on estimation of nutrient content of the ingredients rather than direct chemical analysis of the food products (*Pennington, 2008*).

A second limitiation of the study is the small sample size of the analyzed products. Due to the rigorous exclusion steps applied in this study, we only analyzed 63 from originally 162 identified GF foods. We analyzed foods that are originally based on cereal formulations. In some categories, low numbers of GF foods were included (e.g., category cereals only three items; category flour/bake mix only five items). Hence, post-hoc power analysis revealed that in the case of e.g protein content in GF and gluten-containing food groups in flour/bake mix products, statistical power (1-β) was still high at 95.7%. Nevertheless, this is only the first step to build a database for GF products in Austria,

and we will be extending the database for future investigations. Therefore, the provided number of foods is a solid starting point for further analysis.

Finally, it should be noted that we only included data from products sold in one German-speaking country (Austria), while a majority of GF products are well distributed across European countries, translating our findings to other countries should be interpreted conservatively. Nevertheless, this study improves our knowledge about the nutritional quality of GF foods and secondly, the applied methodological strategy holds a great potential to consolidate data from other countries to form a transnational database on GF products.

Implications of the present research

To put our findings into perspective about the ongoing discussion if choosing GF foods holds potential nutritional advantages or disadvantages for consumers, it is important to note that GF products are very popular among consumers without CD. In fact, GF foods are increasingly purchased by individuals without CD (*Silvester et al., 2015*). A report by *Dunn, House & Shelnutt (2014)* showed that only 57% consume GF foods for medical reasons, while for almost half of the consumers other factors e.g., lifestyle and positive health association are important for purchasing GF foods. This trend is reflected in worldwide sales numbers as well. Between 2004 and 2011 the market for GF products grew at an annual growth rate of 28% (*Sapone et al., 2012*). The global GF product market is projected to reach a value of $6,206 million, growing at a compounded annual growth rate of 10.2% by 2018 (*Marketsandmarkets.com, 2013*). This implies that the GF product market represents a very prosperous market in food and beverages. In addition, there is an ongoing discussion about the prevalence of nonceliac gluten sensitivity (NCGS) in the general population. For individuals suffering from NCGS, adhering to a GF diet could also be beneficial in the remission of their symptoms (*El-Chammas & Danner, 2011*). Nevertheless, the majority of clinical evidence for NCGS remain inconsistent and rather controversial (*Biesiekierski, Muir & Gibson, 2013*). From a public health perspective, there is no need to adhere to a GF diet for consumers without diagnosed CD (*Catassi et al., 2013*; *De Giorgio, Volta & Gibson, 2015*; *Molina-Infante et al., 2015*).

Still, the question why GF products are perceived as healthier for consumers without CD is of relevance (*Dunn, House & Shelnutt, 2014*). On a behavioral level, the increased perceived healthfulness may be explained by the 'health halo' effect, which states that products that are labelled as 'healthier' (e.g. low-fat label) can mislead consumers about other important nutritional elements, e.g., energy content and portion sizes (*Faulkner et al., 2014*). The 'health halo' effect can also lead to some undesired behavioral effects such as increased consumption and poor caloric estimates (*Ebneter, Latner & Nigg, 2013*).

Marketers tap into the perceived healthfullness which reflects, besides the increased production cost of GF products, in the overall higher cost of GF products. In our dataset, the cost for all analyzed GF products was 205–267% higher than for conventional foods. This finding is in line with previous findings (*Kulai & Rashid, 2014*; *Lee et al., 2007*; *Singh &*

Whelan, 2011; *Stevens & Rashid, 2008*). In fact, *Singh & Whelan (2011)* report even higher cost disparities for GF foods ranging from 70–510%.

CONCLUSIONS

In conclusion, this study presents the first findings for a thorough analysis of GF products in a German-speaking country. There are some marked differences between GF and gluten-containing foods. Based on the nutrient composition of GF foods, our results indicate that GF foods are not aligned with particular health benefits, but rather show critical nutrients which should be considered in future formulations. The findings of our study indicate that re-thinking the health aspects ascribed to GF products, at least based on nutrient content of GF foods, should be considered and publicly communicated. Especially in the face of a growing market share, common health misconceptions should be kept in mind when discussing GF products.

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Competing Interests

The authors declare there are no competing interests.

Author Contributions

- Benjamin Missbach conceived and designed the experiments, performed the experiments, analyzed the data, contributed reagents/materials/analysis tools, wrote the paper, prepared figures and/or tables, reviewed drafts of the paper.
- Lukas Schwingshackl and Jürgen König conceived and designed the experiments, contributed reagents/materials/analysis tools, reviewed drafts of the paper.
- Alina Billmann, Aleksandra Mystek and Melanie Hickelsberger performed the experiments, reviewed drafts of the paper.
- Gregor Bauer conceived and designed the experiments, reviewed drafts of the paper.

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