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Using neuro-IS/consumer neuroscience tools to study healthy food choices: a review

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Abstract

Dietary choices are one of the main drivers of preventable health issues such as obesity or diabetes. Food choice is a complex behavior that is hard to measure with traditional, paper, and pencil-based methods. Neuro-Information Systems (NeuroIS) research is well suited to examine neurophysiological and psychophysiological processes behind complex food choices. This paper aims to scrutinize the feasibility of applying NeuroIS tools in healthy food research. We argue that the most important food choices are made in extra-laboratory conditions–mostly grocery stores. Thus, mobile EEG and eye-tracking seem to be the most promising research tools in this context. Surprisingly, there are only a few EEG and eye-tracking studies on healthy food choices held in extra-laboratory conditions. We discuss this phenomenon and propose future research directions to fit this gap in the literature.

Keywords: Neuro-Information Systems; neuromarketing; consumer neuroscience; EEG, eye-tracking; food choice behavior

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1. Introduction

Past decades brought a rise in income and standards of living in many parts of the globe. These changes are linked to increased consumption of calorie-dense and unhealthy foods [1]. As a consequence, we observe an increased risk of obesity and other health problems [2]. Customers often do not know that their food behaviors are associated with factors like food convenience, size, and shape of serving containers or background music [3]. Due to these subtle environmental influences, measuring food behaviors explicitly is complicated: people provide answers they consider acceptable; focus on present moment only or are not aware of what drives their actions [4]–[6]. Understanding food behavior decision-making requires an examination of implicit and explicit responses. Stated preferences and actual choice behaviors can differ considerably. Therefore, asking consumers to explain their choices using traditional approaches like surveys and focus groups do not provide a complete picture of health-related consumption behaviors.

Therefore, academics and practitioners show a growing interest in psychophysiological and neuroimaging tools among Information Systems researchers. The resulting subfield of Neuro-Information systems (NeuroIS) uses neuroscience and neurophysiological methods, tools, and theories in Information Systems research [7]. Multiple tools are used in: electroencephalography (EEG), functional magnetic resonance imaging (fMRI), and eye-tracking [7], [8], [9]. There are several reasons why neuroscientific tools have not proliferated in last century: the high cost of equipment and low availability; lack of portable EEG and eye-trackers; lack of software for data analysis; limited theoretical underpinnings to interpret physiological data. For example, the approach-withdrawal model has been popularized only three decades ago [10]. It assumes that higher left frontal brain lobe activation is linked to positive affective states, approach, and goal-directed behavior; higher right frontal lobe activation does the opposite [11]. It is a basic theoretical framework for many neuroscientific studies using EEG, because it can predict purchase intentions [12], [13]. Recent eye-tracking studies show that measuring visual attention can also predict the latter food choices [14]–[16]. In short, only recently, academics and practitioners developed tools that predict food choices from physiological data. At present, these tools are getting cheaper, and therefore, become more accessible to business and academic research [17].

Two cornerstone studies highlight the feasibility of neuroscientific tools to research on food behaviors. In 2004, researchers used an fMRI to understand consumer preferences for the two most popular cola beverages [18]. Their results suggest that when customers are not informed about which beverages they are drinking, the taste of both Coke and Pepsi are similarly evaluated. However, self-reported Coke drinkers showed different patterns of brain activation when they were informed that they were drinking Coke. Using the same technique, Plassmann and colleagues [19] found that the price changes alone alter neural activity associated with the same product. In the presence of pricing information, participants reported a greater liking for the wine with a higher price tag. When the price was unknown, participants liked the same wine equally. Clearly, these methods can provide methodological and empirical insights to research on healthy food choices. However, fMRI results have limitations. In fMRI studies, participants are put into a noisy tube scanning their brain activity. Data are collected in an artificial setting, where participants are asked to lay motionlessly. The reverse inference is commonly used in the discussion of results that have low predicting power [20]. Even EEG and eye-tracking are used primarily in laboratory conditions, where participants are often asked to put their jaw over a chin rest and sit in an artificial position.

Healthy food choice is a complex behavior that is never performed in such environments [21]. Neuroscientific tools are especially useful in research focused on of food industry as it measures complex sensory stimuli [22]. The development of portable EEG and eye-trackers gives consumer neuroscientists physiological data on in-store food preferences. Therefore, we argue that consumer neuroscience is untapped in research on healthy food choices. We focus on an extra-laboratory environment because this is where customers buy the vast majority of their food [23] and in-store consumer behavior is still a relatively unexplored field [24]. Thus, this paper focuses only on mobile EEG and eye-tracking–the only widely used technologies in consumer neuroscience that can be used in the in-store environment. Additionally, many technologies exist in store environments that aid consumer decision-making. This paper answers a research question: how can neuroscientific tools contribute to the understanding and prediction of healthy food choices?

2. Research methodology

We performed a search in PubMed, Web of Science, ProQuest and Google Scholar to review all relevant peer-reviewed studies on healthy food choices with several keywords: "eye track*", "EEG" and "food choice". Studies were split into two categories: eye-tracking-based and EEG-based. In a preliminary literature search, we scanned abstracts, titles, and keywords that resulted in 48 eye-tracking and 26 EEG publications. Thirty-two eye-tracking studies were initially rejected as these did not contain experimental manipulation under choice conditions. Further, seven were rejected due to a lack of choice metric. Sixteen EEG studies were rejected as these did not focus on the chosen metric and/or did not use human subjects. Five studies were removed because they examined disordered eating–this paper focuses on healthy food choices only. Two studies were further removed because of issues with the experimental materials.

Table 1 contains the final list of studies accepted for this review. We divided the experimental set-up into two main categories: laboratory and field. Eye-tracking findings show the relationship between visual and behavioral data. Because the choice of healthy foods is heavily reliant on sensory attributes [25]–[27], EEG results show a correlation between frontal asymmetry and reported pleasantness related to sensory experiences with food (i.e., taste, sight and touch).

3. Findings

Twelve studies have been selected for final analyses: three EEG and one eye-tracking study. Only one EEG and two eye-tracking studies were conducted in field conditions. The final list of eye-tracking studies consists of nine peer-reviewed articles (see Table 1). Only two studies were conducted in field conditions. Five papers focus on different aspects of food package, such as organic logos or health claims [14], [16], [28]–[30]. The rest focus on various health goal priming methods [15], [31], [32] and the relationship between weight, eye-tracking data, and buffet food choices [33].

Three studies employed EEG to experiential food research. Only one of them was conducted in field conditions [34]; the other two were conducted in laboratory settings [35], [36]. Two studies examined the effect of taste on frontal asymmetry [34], [36] and the remaining study examined sight and touch [35].

Table 1. Summary of findings.

Study	What was studied?	Method	Experimental set-up	N	Results
[14]	The effect of food packages potentially misleading elements on food preference and visual attention	ET*	Laboratory–simulated grocery shopping	81	Misleading elements on food packages increase the choices of foods and the amount of visual attention
[34]	The effects of taste on frontal EEG asymmetry	EEG†	Field setting–food consumption in a restaurant	15	The prefrontal asymmetry linked to the pleasantness during food consumption
[28]	The effect of choice logos and traffic light signaling on food choices and attention	ET	Field–in the university canteen	48	Visual attention to health claims on package poorly predicts healthy food choices
[15]	The effects of body primes on choices and attention to low vs. high-calorie foods	ET	Laboratory, computer-based	50	Attention metrics higher for chosen foods
[35]	Multisensory (sight and touch) interaction with food products and its influence on frontal asymmetry	EEG	Laboratory–experiment with real foods	32	Higher approach tendency for sweet foods (chocolate), for visual only and visual and tactile conditions

* ET = eye-tracking
† EEG = electroencephalography

[31]	Whether presenting an overweight woman in a food menu increases visual attention and choices of healthy option	ET	Laboratory–on-screen food choices from the menu	121	More attention to and choices of healthy food options when an overweight woman is presented in the menu
[16]	To find how organic labels can increase attention and choices	ET	Laboratory–a computer-based choice experiment	127	The large and salient organic label captures more attention and is chosen more often
[29]	The effects of nutritional labels on attention and choices of different menu items	ET	Laboratory–on-screen menu presentation and food choices	84	Health logos and color labeling increase fixations on all nutritional information and healthier food choices
[32]	The effect of food goal priming on food choices mediated by changes in visual attention	ET	Laboratory–online shopping	125	Healthy goal priming increases choices and visual dwell time to healthier foods
[30]	The effects of nutritional information on attention and food choices	ET	Laboratory–food choices in front of a computer	309 & 261	Traffic light and health logos trigger more attention and enhance healthy food choices than nutritional tables
[33]	Comparing food choices and visual attention between lean and overweight individuals	ET	Field–buffet	32	Visual fixation in selection task predicts latter choices of savory (healthier) main courses but not desserts
[36]	The difference in frontal EEG activity when tasting regular and tasteless, sugar-free chewing gum	EEG	Laboratory–experiment with real foods	20	More approach tendency during chewing regular gum as compared to the sugar-free and tasteless gum

4. Discussion

This paper examined whether neuroscientific methods can support research on predicting healthy food choices in extra-laboratory settings. It is argued that only portable eye-tracking and EEG systems can serve this purpose. Three studies met our criteria: two eye-tracking [28], [33] and one EEG study [34]. The eye-tracking study on yogurt selection in the university canteen shows that visual attention to health claims on the package does not predict subsequent healthy food choices [28]. Another eye-tracking study, conducted in a canteen shows that visual fixation predicts later healthy food choices only in one of two tasks and only to main courses–in case of savory foods [33]. In the EEG study, the authors found a significant difference between the prefrontal left and right activation associated with the flavor of savory creams when compared to the sweet ones [34]. The sweet flavors produced greater left frontal activation and were correlated with higher pleasantness ratings. However, the results were not verified by the actual choices. In sum–EEG and eye-tracking seem unfeasible to predicting healthy food choices in field settings.

Although food appearance is sufficient to influence implicit responses [35], [37], only laboratory eye-tracking studies showed that various attributes of packaging design and the presentation of nutritional information could influence choices [14]–[16], [29]–[32]. Taste also plays an essential role in healthy food choices [26], [27]. Laboratory EEG studies show approach tendencies for unhealthy, sugary foods (but the actual choice was not measured) [35], [36].

Eye-tracking data are very prone to capturing noise stemming from natural eye movements [38]. The same applies to EEG studies as eye movement, muscular movement, and line noise can introduce artifacts to EEG data [39], [40]. These increase in uncontrolled, field experiments, lowering the quality of data. Perhaps, this is the main reason behind the scarcity of literature on eye-tracking and EEG in field experiments and their lack of choice predicting power.

This literature review suggests that only laboratory studies using eye-tracking have the potential to predict healthy food choices (see Table 1). The same can also be said about EEG studies in other research areas–these can predict purchase intentions [12], [13]. Siegrist and colleagues [41] conducted two experiments comparing eye-tracking results in a real store to results from the 3D virtual reality shopping trip. Interestingly, these results were similar. Hence, conducting field, consumer neuroscience studies seems an unnecessary and inefficient way of gathering data on healthy food choices. It is also possible to take real products to laboratory conditions. For example, Visschers and colleagues [42] conducted a study where participants were choosing cereals for a kindergarten or student cafeteria. They recorded eye-tracking data over the course of this experiment. In this study, real products were used (as opposed to computer simulation); thus, ecological validity was high. To the best of our knowledge, no studies used EEG, where consumers had to choose actual products, even in controlled laboratory settings. Most studies focus on images of products [12], [13], [43], [44]. Therefore, these tools are ideal for studying food choices in online settings.

According to Statista.com, the value of e-commerce will double between 2017 and 2021. Hence, we expect a growth of interest among practitioners and academics in using eye-tracking and EEG in studies on e-commerce. Due to the nature of this shopping environment, such studies should better be held in laboratory conditions for maximum ecological validity. Future research avenues are not limited to using consumer neuroscience in field conditions. For instance, machine learning is a promising field in future consumer neuroscience studies: it can be applied to detect emotions from EEG signal [45]; improve adverts' effectiveness [46]; predict product choices from EEG [47] or fMRI data [48] Combining EEG and eye-tracking can also improve the quality of neurophysiological findings on healthy food choices–it has already been shown beneficial in predicting advertising effectiveness [49], [50].

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