Current Journal of Applied Science and Technology

39(5): 47-54, 2020; Article no.CJAST.54976
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Electroencephalography for Enhanced Understanding of Consumer Preference

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Authors' contributions

This work was carried out in collaboration among all authors. Author BN reviewed journals and wrote the first draft of the manuscript. Author WJS reviewed the literature and finalized the draft. Author BAK helped in managing the literature search and approved the draft. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2020/v39i530545
Editor(s):
(1) Dr. Lesław Juszczak, University of Agriculture in Krakow, Poland.
(2) Dr. Teresa De Pilli, University of Foggia, Italy.
Reviewers:
(1) Sreenivasan Rajamoni Nadar, Walter Reed National Military Medical Center, USA.
(2) Aleksandra Krajnović, University of Zadar, Croatia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/54976

Review Article

Received 05 January 2020
Accepted 10 March 2020
Published 06 April 2020

ABSTRACT

Conventional measurements used to study consumer response to food products may be subject to cognitive bias, as measurement data was consumer's reported thoughts or through questionnaires. Therefore, for an unbiased approach electroencephalography (EEG), an electrophysiological method can provide implicit and extensive data. EEG uses electrical activity of brain to record and explain perceptive, attentive as well as emotional processes of consumer towards foods. The asymmetry of EEG signal between right and left hemispheres of anterior (frontal lobe) or posterior (parietal and occipital lobe) parts of brain can be used to determine acceptability of stimuli in a stimulated person. The accurate measurement through EEG enables marketers to compare consumer response to different marketing stimuli and impact moments associated with particular product or brand for better positioning of product in market.

Keywords: Electroencephalography; EEG; neuromarketing; neuroscientific technique; human brain; encephalography; cortex; postsynaptic and left hemisphere.

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1. INTRODUCTION

Consumer's food choices are often driven by reasons they themselves are not fully aware of. Decision-making about food is influenced by complex set of emotions, feelings, attitudes and values that are not easy to assess simply by asking consumers their opinions. The traditional techniques included self-reports or interviews, measurement of conscious reactions to product or advertising. The understanding of subconscious, physiological and emotional responses to food enables marketers and advertisers to make informed decisions and alter the products and their associated messages most appealing to consumers [1,2]. To enhance this understanding, recently there has been rapidly growing interest in field of "neuromarketing," that takes advantage of neuroscientific techniques to study consumer behaviour.

2. BRIEF HISTORY OF NEURO-MARKETING

The studies in neuromarketing dates back to 1960 when Herbert Krugman, a pioneer in television advertising measured the spontaneous dilated pupils as an indicator of interest in people looking for products. This led to evolvement of eye tracking devices that allowed accurate tracking of eye pupil to reveal certain places that catch the eye of human brain. In 1970, Krugman and Hansen reviewed the processes of right and left hemispheres of human brain through encephalography, which was a huge breakthrough scientifically. However, no one has been able to apply and take advantage of these advances in marketing completely [3].

In 2002, few American companies started to offer neuromarketing research and consulting services, which became an important milestone in the history (Morin, 2011). In 2003, scientists took advantage of fMRI brain imaging techniques to study and understand consumer preferences about popular beverages like Coca-Cola and Pepsi. The study showed how certain areas of subject's brain might be differently activated based on knowing or not knowing the brand name being consumed. When subjects did not know the brand name they were consuming, Pepsi was preferred as the orbitofrontal cortex on left hemisphere was more activated. In contrast, when subjects knew what they were drinking, Coca-Cola was preferred over Pepsi as their dorsolateral prefrontal cortex was more activated [4].

Methods of measuring brain responses: The most widely used neuroscientific techniques for measuring brain responses are:

1) **Functional magnetic resonance imaging (fMRI):** fMRI is a modern method used for functional imaging of brain that measures brain activity by sensing the changes in blood flow based on the fact that cerebral blood flow and neuronal activation are interlinked. It has a superior spatial resolution of the order of mm and poorer temporal resolution of the order of seconds [5,6]. It is widely used by scientific and clinical communities but less often by marketers due to its high acquisition cost [7].
2) **Positron emission tomography (PET):** PET is one of the most expensive functional imaging techniques that uses radioisotopes to label molecules in the brain. PET has a poor temporal and spatial resolution but can detect specific neurotransmitters of interest [8]. Because of high cost and need to inject radioisotopes, there has been little interest in PET for commercial use in neuromarketing [7].
3) **Magnetoencephalography (MEG):** MEG captures the magnetic field caused by the activity of neurons [9]. It has a superior temporal resolution of the order of milliseconds but poor spatial resolution of the order of cm. The reason for its less percentage of usage is high procurement and operational costs [7].
4) **Electroencephalography (EEG):** Most cortical neurons communicate through chemical neurotransmission causing excitatory and inhibitory postsynaptic potentials. These cortical source potentials produce a dipole layer, which can be amplified by EEG [10].

EEG is an electrophysiological monitoring method used to record the electrical activity of the brain that can explain perceptive, attentive and emotional processes of consumer towards food. It measures voltage fluctuations resulting from ionic current in synaptic area of neurons detected by multiple electrodes or with passive or active biosensors connected to few electrodes placed on subject's scalp and forehead [11,12].

Munoz, et al. [13] used single electrode wireless EEG to assess consumer behaviour exposed to

different sales techniques. Similarly, Viejo, et al. [14] used EEG mobile headset to determine acceptability of beers based on subconscious responses.

Although EEG has modest spatial resolution and detects only superficial cortical activity, it is advantageous because of its low cost and is less intrusiveness than other neuroscientific techniques like fMRI with greater spatial resolution. EEG's high temporal resolution of sub-milliseconds allows accurate detection of changes in brain activity due to rapid change in stimuli [15]. Furthermore, EEG has fewer constraints regarding experimental design as the signal can be recorded through portable technologies with usage outside the laboratory [16].

General procedure of EEG in food research application: EEG provides a real-time measurement and used in food research to measure brain waves before, during and after exposure to a certain stimulus [17]. For general procedure, initially electrodes are placed on scalp of participants while they are seated in recliner to minimize body movements. The electrodes are then connected to brain wave amplifier. The participant is exposed to stimuli as food, picture, sound, environment, *etc*. and brain waves are recorded in real-time. The measured brain waves are analysed using specific signal processing method [12].

Relation between EEG waveforms and human emotions: The EEG signal is composed of α, β, Θ and δ brain waves, each characterized by different frequencies and amplitudes reflecting different cognitive states [18]. The effect of wine flavors on emotions in 22 respondents while they were tasting eight different brands of dry white wines was determined. Men and women were positively and equally impressed by the wines with women exhibiting higher emotional excitement than men. Furthermore, the younger consumers reacted more emotionally than older consumers. Higher emotional excitement was caused by Chateau Topolcianky, a wine brand which was popular in Taiwan and their target group was women. These factors could help to analyse the wine consumption patterns and the purchase behaviour of consumers [19].

The asymmetry of EEG signal between right and left hemispheres of anterior (frontal lobe) or posterior (parietal and occipital lobe) parts of brain was used to determine acceptability of stimuli by stimulated person. The EEG index most often used in the field of neuromarketing is the cortical asymmetry in the frontal α–band that operates on lateralization of brain functions, particularly the selective activation of left (right) part of cerebral cortex in response to positive (negative) stimuli [20,21].

Frontal α– asymmetry (FAA) was computed as difference between power in frequency band of left and right frontal hemispheres respectively and positive values of FAA index can be understood as greater activation of left than right hemisphere [22,23].

Yagyu, et al. [24] found a significant difference between prefrontal left and right activation of brain due to flavour of food. The effect of flavoured and flavour free chewing gums on perception of pleasure and cerebral activation using healthy males before and after 5 min of chewing. There was positive frontal α - asymmetry index (approach tendency) after chewing flavoured gum that was not observed for flavour free gum. The results were consistent with self-reported evaluation where subjects felt more refreshed and comfortable after chewing flavoured gum.

Kline, et al. [25] measured anterior EEG asymmetry changes in elderly women in response to different odours like pleasant for vanilla, unpleasant for valerian and neutral for plain. Each odour was presented for 60 sec with an interval of 30 sec. Vanilla aroma induced significantly greater relative left-hemispheric activation compared than other odours. Similar results were reported by Sanders, et al. [26] of greater relative left-frontal EEG activity for lavender or rosemary versus baseline in infants and adults.

Applications of EEG in food research: EEG techniques can be applied in food research with three perspectives:

- Understanding the effect of appearance, flavour and texture of food on the emotional and behavioural responses of the consumer.
- Assessing the consumer preferences and purchase behaviour.
- Study the effects of food consumption on human brain functioning.

Emotional response to appearance, flavour and texture of food: EEG technique can be

used to assess the effect of undesirable food appearance in terms of food quality and safety on implicit and explicit emotional responses measured concurrently with participants aged 18 – 29 years. The video presentations included normal and abnormal foods that included spoilt cereal and milk, poor-quality fruit pancakes due to improper handling and unsafely prepared sausage sandwiches to observe the emotional responses of participants. The results showed increased activation of right hemisphere of brain for evented videos than control ones. These results correlated with results obtained from traditional explicit emotional measurement using Check-All-That-Apply questionnaire where most of the participants felt disgusted after watching evented videos.

Toepel, et al. [27] investigated the effect of meal portion size on brain activity of 21 ideal weight women using EEG for ideal portion selection to be served at prospective lunch intake and expected satiety. Brain activity in cingulate gyrus was negatively associated with cognitive eating restraint when portion sizes were 'too big'. Positive emotional response for ideal portions in middle temporal gyrus was observed where as in superior parietal lobule for both portions and in inferior occipital gyrus for too big portions. There was significant correlation between brain activity sources and food intake attitudes evaluated by three factor eating questionnaire.

Andersen, et al. [28] demonstrated discriminability of perceptually similar and identical tastes using EEG. The response of 22 panel members was recorded in response to equally intense sweet tasting stimuli *viz*. caloric sucrose, low-caloric aspartame and low-caloric mixture of aspartame followed by triangle test to assess participant's perceptual ability. The three taste stimuli were more or less similar in triangle test to participants yet discriminable by brain through EEG analysis. They also found functional relationship between brain response and perception of taste stimuli at individual level.

Consumer preferences and purchasing behaviour: The influence of brand familiarity and price on purchasing decisions was explored by Brown, et al. [29] by computing frontal α–asymmetry when 12 participants tasted drinks of different brands and prices. The results showed greater activation of left frontal lobe due to greater liking for manufacturer labelled brand than private labelled brand due to familiarity of product. In addition, consumers were willing to purchase less expensive brand when quality perceived to be same to more expensive counterpart.

Time-frequency analysis of EEG oscillatory activity performed on 26 healthy subjects during mineral water intake of different brands confirmed that brand processing was associated with the activity of frontocentral reward-related network. β–activity was modulated by experience of pleasure associated with favourite brand whereas Θ–modulation reflects the lack of this experience [30].

The participants were presented 14 different grocery products of private and national brands whose prices increased and decreased as their EEG activity was recorded. The results showed relatively greater left frontal activation during national brand products, high product quality, low price, high perceived need for product and predecision period predicting an affirmative purchase decision proving frontal asymmetry index [31].

Horska and Bercik [32] reported that lighting had significant impact on conscious or subconscious consumer reactions and proved to be an essential marketing tool that positively influenced consumers and increased sales. Fluorescent yellow coloured light influenced the subconscious reactions of respondents mostly.

Van Bochove, et al. [33] found correlation between hedonic score and posterior resting state α and β asymmetry in EEG data from right and left hemispheres of human brain. Activation of left hemisphere was associated with consumers' more positive attitude towards food.

Effect of food consumption on human brain function: Allen, et al. [34] demonstrated that chewing gum improved vigilance due to increase in α and β waves of left frontal and temporal lobes with EEG. Murao, et al. [35] found that smelling green tea especially shaded white tea increased α and β brain wave activity in frontal and occipital regions. The α band is related to semantic information processing for good cognitive performance whereas β–band plays an important role in attention or higher cognitive function. This increase in α and β waves indicates anti-stress effect and relax mood.

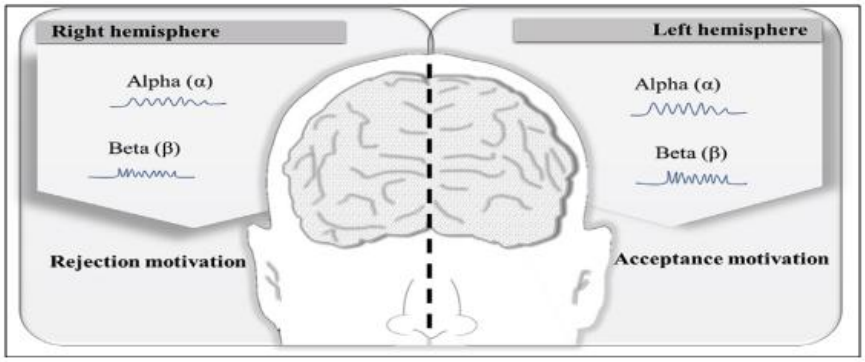
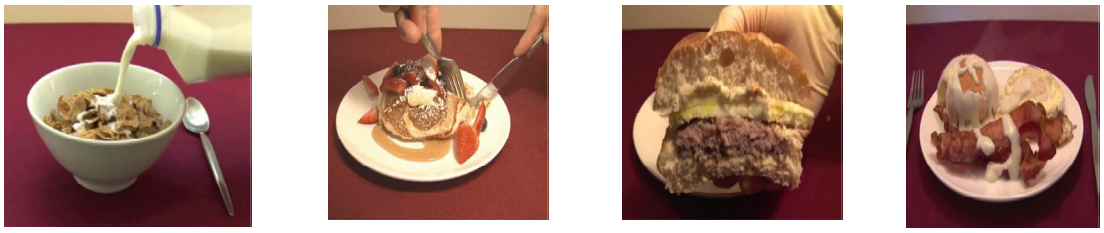


Fig. 1. The asymmetry of EEG signal between right and left hemispheres of anterior [8]



Curdled milk poured onto cereal - spoilage

Pulled hair out of syrup in stack of pancakes and fruit – food handling

Change in colour of raw meat of sausage sandwich – safety

No concerning event - Distractor stimuli

Fig. 2. Emotional response to appearance, flavour and texture of food [36]

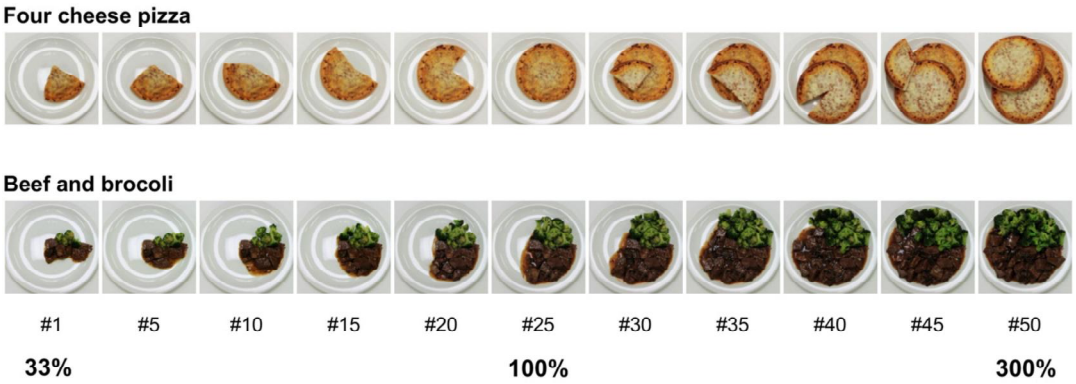


Fig. 3. Triangle test to assess participant's perceptual ability

Labbe, et al. (2011) illustrated the effect of refreshing perception on mental energy using cortical activation and cognitive performance. EEG waveforms obtained immediately before and 15 min after consuming a cooled refreshing drink improved cortical activation in α and β powers involved in neural circuits of attention, working memory and sensory-motor integration.

3. FUTURE PERSPECTIVES

EEG technique is the one of the useful, is expected to be used more frequently in future and will be increasingly applied in various food research areas. It can be used to food product development and services suitable to different consumer needs with greater precision. It can be used to study influence of food product information recognition, advertisement and the environment on consumer behaviour. More excitingly, it can be applied to study effect of functional foods on brain function to develop products with guarantee health benefits in the present scenario of changing life styles.

4. CONCLUSION

Currently, the consumer expectations about the quality of food products is ever growing than before and are trending towards increasing further in the future. Food product and food service providers are striving to meet their expectations. Conventional measurements used to study consumer's emotional responses to food products may be subject to cognitive bias as measurement data was reported as thoughts or through questionnaires. Therefore, for an unbiased approach, EEG can be used to provides accurate data. This precise measurement enables marketers to compare consumer response to different marketing stimuli and impact moments associated with particular product or brand for better positioning of any food product in markets worldwide due to increased travelling.

DISCLAIMER

The products used for this research are commonly used in research. There is absolutely no conflict of interest between the authors and producers of the products because these are not used for revenue generation or advertising but only for advancement of knowledge.

ACKNOWLEDGEMENT

The authors thank honourable Vice Chancellor of Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad for his encouragement.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/54976