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A practical evaluation of biometric measures for understanding the consumer experience during direct product evaluation: current and future perspectives

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Companies need a good understanding of consumer experiences to develop successful in-market products. To aid this goal, there has been a move toward using implicit measures alongside explicit measures to gain insight into different levels of processing important for consumer decision-making. This has involved biometric tools such as those capturing facial behaviour, electroencephalography, eye-tracking, and those capturing autonomic nervous system measures, such as electrodermal activity. Here, current literature involving direct product evaluation and adopting biometric measures in sensory and consumer studies is reviewed. Findings show that technological advances make biometric tools a more practical choice in consumer studies than previously. Further, a trend is observed in studies synchronising the capture of multiple biometric measures alongside explicit measures, offering a deeper understanding of these measures and the information they provide. However, for biometric tools to be of real value in direct product evaluation, there is a need to enhance knowledge on result interpretation.

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Introduction

Sensory and consumer research plays an important part in the food industry by investigating consumer responses to products, including sensory perception, affective response, hedonic evaluation and product conceptualisations [1]. By understanding the consumer experience, companies aim to predict consumer food-choice behaviour and develop products that will be successful in the market; a difficult goal to achieve [2].

Consumer researchers have turned their attention to capturing temporally dynamic data using implicit measures in their studies, a trend that took off in the early 2000s [3] and continues. These implicit measures require no conscious consideration by the consumer. This is important, as both conscious and subconscious processes are involved in decision-making and, if only traditional self-reporting methods are adopted, the researcher may fail to capture a complete picture of the consumer experience [4].

Biometric tools measure changes in body signals, providing an insight into the consumer experience and include eye-tracking, electroencephalography (EEG), tools to capture autonomic nervous system (ANS) measures, and those that capture changes in facial activity, including Automated Facial Expression Analysis (AFEA) and facial electromyography (EMG). This short review sets out to help researchers in the field make decisions around using biometric tools in sensory and consumer studies by 1) signposting key review literature outside this paper's scope but of potential interest to researchers, 2) synthesising and practically evaluating the findings from a selection of empirical studies from the last five years and 3) considering the challenges and future perspectives of using biometric tools.

Navigating the literature

The continued interest in adopting biometric tools to better understand the consumer is apparent in the number of existing review and perspective articles related to the subject. Table 1 details a selection of papers to assist readers in navigating this expanding field of research. However, there is often an urge to adopt popular methods in research for fear of being left behind. By synthesising and evaluating the current research on the topic, the current review aims to help researchers understand the considerations of adopting these measurement tools from a practical standpoint. The current review is less concerned with the mechanics of using these methods and the systems available, as this is already covered in existing reviews (e.g. [7,14]).

Table 1

A selection of review and perspective papers from 2020 to 2024 related to the use of biometric measures in consumer research.

Author	Year	Title	Main area of focus	Of particular interest to
Kessler, Jiang, Hurley [5]	2020	The State of Automated Facial Expression Analysis (AFEA) in Evaluating Consumer Packaged Beverages	A systematic review (2009–2019) of studies adopting automated facial expression analysis for product development of food and beverages.	Researchers interested in using AFEA as a new tool in their sensory and consumer studies, this review provides information on key considerations to be made when deciding to use AFEA and when designing experiments.
de Wijk, Noldus [6]	2021	Using implicit rather than explicit measures of emotions	A narrative perspective on the use of implicit tools, including biometric tools, in consumer and sensory research.	Researchers wanting an introduction to the benefits of combining explicit and implicit measures and a broader understanding of such methods that can be adopted in sensory and consumer science.
Fuentes, Tongson, Viejo [7]	2021	Novel digital technologies implemented in sensory science and consumer perception	Review includes digital technologies adopted in sensory science or being developed for this purpose. The review covers how new technologies can be used and has a section on biometrics.	Researchers looking for information on the development of remote sensing methods used for the measurement of biometric signals.
Motoki, Saito, Onuma [8]	2021	Eye-tracking research on sensory and consumer science: A review, pitfalls and future directions	Review including studies that have investigated food-related behaviour using eye-tracking.	Researchers looking to get an overview of attention and eye-tracking parameters that can, and have been, adopted in food studies.
Torrico, Mehta, Borssato [9]	2023	New methods to assess sensory responses: a brief review of innovative techniques in sensory evaluation	Overview of methods used in sensory studies, includes section on biometric methods, virtual environments, and artificial senses.	Researchers looking to get a good introduction to the wide range of new tools being added to the toolbox of sensory and consumer research.
Low, Janin, Traill, Hort [4]	2022	The who, what, where, when, why and how of measuring emotional response to food. A systematic review	A systematic review on measures of emotional response to food (1997 - 2021).	Researchers looking for an understanding of implicit and explicit measures of emotion and how these can be used in combination.
Adhikari [10]	2023	Application of selected neuroscientific methods in consumer sensory analysis: A review	Use of neuroscientific techniques within consumer research studies related to food, with a focus on EEG and eye-tracking.	Researchers with an interest in eye-tracking and EEG who are looking for a general, select overview of how these tools can be used for research related to food.
Khondakar [11]	2024	A systematic review on EEG-based neuromarketing: recent trends and analyzing techniques	Engineering-focused systematic review (2017 – 2023) of EEG-based neuromarketing methods.	Researchers looking to understand important considerations when carrying out EEG-based consumer studies and require more detail on the technical aspects of the use of EEG. Not related directly to sensory and consumer science.
Panteli, Kalaitzi, Fidas [12]	2024	A review on the use of EEG for the investigation of the factors that affect Consumer's behaviour	EEG-based neuromarketing systematic review (2000 – 2023) that considers the factors involved in the complex process of decision-making, including external stimuli and how these interact.	Researchers looking to consider the general factors that may affect consumer decision-making when designing an EEG-based experiment. Not related directly to sensory and consumer science.
Rodrigues, Dias, Teixeira [13]	2024	Emerging Methods for the Evaluation of Sensory Quality of Food: Technology at Service	Current overview of the technology used in sensory research to better understand consumer responses to food. Includes a wide range of emerging methods and a section on biometric measures is included.	Researchers with a desire to keep up to date with changes in sensory and consumer science and the technologies for analysing the sensory characteristics of food that allow for a better insight into human perception of food.
Zhao et al.[14]	2024	An advance in novel intelligent sensory technologies: From an implicit-tracking perspective of food perception	A review of facial technologies and neuroimaging tools used in sensory and consumer science studies. A particular emphasis is given to detailing literature adopting eye-tracking (2020–2024) and EEG (2019–2024) in consumer sensory research.	Researchers looking for a detailed introduction to implicit methods falling into the facial analysis (including eye-tracking) and neuroimaging categories, particular focus is placed on eye-tracking and EEG. The review also covers less practical methods, such as MEG and fMRI.

Instead, our focus is on whether the results of current studies are interpretable and beneficial for use in direct product evaluation studies that primarily seek to better understand a product's intrinsic sensory characteristics, as are often adopted in consumer and sensory research.

With the food industry's growing focus on predicting consumer behaviour using data captured during consumer affective testing, there is a need to consider the efficacy of biometric tools and their ability to help the industry develop more successful food products. Direct product evaluation studies often require a unique approach. For instance, such studies often involve the consumption of subtly different food samples, are often conducted in blind testing conditions, and their findings are used to inform product development. Therefore, for a tool to be effective, it needs to be sensitive enough to capture changes in the consumer that arise from small variations in stimuli, be practical for use during eating or drinking and enable the measurement of reliable data.

Biometric tools

Facial activity

To capture emotion-related responses during product evaluation, measures of facial response have emerged as the common tool of choice. This is driven by the idea that facial activity is linked to emotion [4]. Both facial EMG, which measures action potentials during muscle contraction and can capture activity below visual detection [15] and AFEA, which automatically measures visible facial behaviour by use of a camera, have been adopted in consumer product evaluation studies [16]. The former links activity of specific muscles, but often independently rather than in combination, to affective response, such as activity of the zygomaticus major (used in smiling) with positive affect, while the latter technology is generally driven by the idea that experienced basic emotions, including happiness, surprise, fear, sadness, anger and disgust, have distinct signature patterns of facial activity [17]; a notion that has been heavily contested in recent years [18]. However, some AFEA systems may extend their categorisations, for instance, to include affective dimensions. Both methods also have practical drawbacks, such as facial EMG using sensors applied to the face, which may feel unnatural for a consumer, and AFEA requiring stringent lighting conditions and a clear camera shot to obtain, extract and categorise displays of emotion, meaning facial hair or glasses can hinder data capture [19].

Despite current evidence showing that individuals display limited expression to palatable food stimuli [20,21] and that it is often negative expressions that give insight to disliked samples [22,23], AFEA has been adopted in many sensory and consumer studies. For instance, facial behaviour research has provided industry with additional insights regarding the emotional responses of specific consumer groups, including providing a better understanding of the visual appeal of foods for seniors [24] and children [26], which can aid the development of products specific to these consumer groups. Further research has investigated consumers from different cultural backgrounds [25] and the effect of consumption environment on the consumer experience, showing that facial expressions are sensitive to context effects and add value to self-reported food-evoked emotions [27].

There have been many important advances to aid in the ease of adopting and analysing facial behaviour measures. Such applications have been tested in studies, including for the prediction of liking of beers [28], yoghurt [29], and to offer insight into consumer acceptability of unfermented and fermented coffee samples [30]. Although many of the cited studies support the idea that biometric measures can aid product development by giving a more holistic insight into the consumer experience, taken together, the results of current research still highlight the complexity of interpreting facial behaviours, which may be product-specific [23], limited in variation from neutral [21,23], explain less variation within the data than explicit measures (e.g. [23]) and are impacted by other factors, such as product familiarity [31]. A further hindrance to synthesising results from studies is that different labs may use different software for facial expression analysis, and work is still required to understand the impact this has on study outcomes [16]. Furthermore, the datasets used to train classifiers generally do not consider spontaneous food-related responses. Literature exploring the use of facial analysis tools in consumer research suggests that a focus on naturalistic spontaneous expression may be more insightful to understanding consumer behaviour than posed expressions [16]. Recent research is trying to move away from the reliance on basic facial expressions and is aiming to better understand facial behaviour related to food and beverages linked to hedonics [32].

However, one of the key benefits of using biometric measures is the fact they can capture temporally dynamic responses rather than static responses, but there is still a lack of clarity on the time that is most insightful for capturing facial activity for predicting future behaviour, which is likely to be product-specific (potentially individual-specific). Therefore, the complexity of the data analysis often means that explicit measures are still the most effective option. For instance, the need for training, including interpretation, has been highlighted as a drawback of using facial expression analysis by those working in sensory or product development [33]. However, with continued development, AFEA may have more to offer sensory and consumer scientists in the future.

Current research has also tested facial EMG, and notable are studies testing it for use with the consumption of

solid food. Findings have shown hedonic liking to be related to facial behaviour during evaluations of chocolate [34] and gel-type solid food [35]. Notably, in these studies, the muscle that appears the most consistently promising for consumer experience insight is the corrugator supercilii (involved in frowning), which may be due to muscles, such as the zygomaticus major, being affected by the movement linked to eating. Research adopting surface EMG has sought to develop a method for the recognition of the intensity of basic tastes using facial muscle activity, with findings showing that bitter, sour and salty could be recognised, but results were impacted by subject diversity; sweet and umami could not and the sample size was very small [36].

It is still often the case that explicit measures better discriminate samples than implicit facial behaviour measures [22]. This should not be a reason to disregard its use in product evaluation situations, but instead prompt research that gives information into fundamental knowledge of facial behaviour in response to food. It is also likely that we have not yet seen the tool tested fully in situations that may be more appropriate for its use, such as outside the lab, and current evidence gives some indication that, for studies requiring an understanding of how consumers respond to changes to existing products based on production or ingredients, facial behaviour measures are insightful (e.g. [30,37]).

Electroencephalography

EEG is not the only neuroimaging technique that can be used with consumers; however, it is the focus here due to its practicality and low cost in comparison to other methods. It is however acknowledged that important information on brain mechanisms related to human perception may be gained from the use of other techniques, such as functional magnetic resonance imaging (fMRI).

Nonetheless, the use of EEG has afforded an insight into brain activity, in terms of the role expertise plays in the link between implicit and explicit measures when evaluating beer [38] and the frequency and temporal dynamics related to basic tastes [39]. Findings revealed that EEG could not discriminate between intensity categories of all basic tastes, such as low and medium bitter and salty stimuli, and results suggested sensitivity to taste signals is better with high-intensity taste stimuli [39]. Further findings indicated that activity may relate to specific compounds rather than basic taste [39]. This type of research is valuable for the industry, as it offers a depth of knowledge on what researchers might expect. However, further research is required if taste and other sensory properties related to complex foods are to be understood.

A study using trained panellists has tested the feasibility of biometric measures for insight into the emotional response of expert panels, finding that they can work on a practical level in these situations [40]. A further consumer study showed a model including EEG (frontal asymmetry) managed to perform well for categorising vinegar or regular drinks; however, other measures such as sip size and ECG had higher discriminative power [41]. The trained panellists study showed theta band power to be related to olfactory intensity, and that data from cardiovascular measures and electrodermal activity were complementary to obtain insight into the panellist experience [40].

Taken together, the results of current studies suggest that EEG data can offer additional insight for understanding the consumer experience when used alongside other biometric and explicit measures; however, knowing how to action findings in terms of product development may still prove challenging for consumer and sensory professionals.

Autonomic nervous system measures

For the evaluation of subconscious responses, direct product evaluation studies have typically included measures related to electrodermal activity, such as skin conductance responses or those related to the cardiovascular system, such as heart rate. Current research has included the development and testing of applications that measure facial behaviour, cardiovascular measures and skin temperature in a synchronised fashion, using a noncontact method and adopting algorithms and machine-learning models [42]. This is a welcome development for sensory and consumer research as it makes the tools less intrusive to the consumer, which can help ensure consumers act naturally during testing, and it allows for a better understanding of how the measures are related and how they link with explicit measures. For instance, heart rate and facial expressions, during beef patty evaluation with older and younger adult consumers, were found to be linked, and differences were found between the age groups in the variations in these measures brought about by the samples [21]. Body temperature was negatively associated with foam height liking and positively associated with the disgust facial expression during beer evaluation [28]. Heart rate was found to be associated with arousal ratings during evaluation of regular drinks [41], and heart rate and head orientation (yaw) linked to the firmness and overall liking during yoghurt evaluation in a study that also measured physiochemical properties of the products [29]. However, these studies also highlight the potential difficulty in interpreting results, for instance, with inconsistencies in findings of heart rate [21] and body temperature [28] across different studies.

Importantly, inconsistency may be partly driven by results from direct food evaluation studies being compared with nonfood studies, which may evoke different

responses; however, there is also the fundamental issue that patterns of ANS activity do not link easily to a specific category of emotion [18]. These challenges are compounded by the fact that food-related responses are still under-studied, and product variations can increase the complexity of interpretation. For instance, heart rate was found to add to a predictive model for discriminating a vinegar solution from regular drinks [41], whereas sucrose concentration in chocolate pudding affected heart rate at the third level of intensity when compared with the first and fourth levels on the first day, and when compared with the first and second levels on the second, with findings potentially giving insight to the optimal sucrose level; notably, in this study, galvanic skin response did not offer insight into the sucrose concentration levels [43].

In summary, current research has found ANS measures to offer additional information in direct product evaluation studies. From a practical perspective, there are inconsistent findings, meaning there is arguably not yet a clear benefit of utilising such measures over and above explicit measures, especially when the aim is to test differences between a range of pleasant samples of the same product category during blind testing conditions, which is often the case in sensory and consumer research.

Eye-tracking

Measures of visual attention have been captured using eye-tracking in many consumer studies, and developments have been made to the technology to make it easier to use in naturalistic settings. Currently, it is adopted predominantly in studies that look to investigate indirect product evaluation or those that involve extrinsic elements of the product, such as products in the supermarket, food pictures, advertising, labelling information or changes in packaging (e.g. [44]). However, eye-tracking can be utilised alongside other remote sensing biometric measures (see [45]). Furthermore, where differences in visual aspects of food or beverages, or changes to the environment in which they are presented, are under investigation for their subsequent effect on the evaluations of food, this approach may prove useful when used alongside other implicit and explicit measures [46]. Moreover, eye-tracking has also been used to better understand consumer interaction with explicit measures used in sensory and consumer studies, including rate-all-that-apply (RATA) [47]. Therefore, it is a tool that can be used to improve knowledge of existing sensory measures, as well as offer complementary information on the consumer experience.

Challenges and future perspectives

Collectively, the results of recent studies suggest that biometric measures provide additional information to traditional explicit approaches. However, to gain further value, there is a need for a greater depth of knowledge of changes to the body that accompany food evaluation. Biometric tools can help to better understand food response from a physiological and psychological perspective; however, considering individual differences and cultural variation appears to be key, as evidence suggests that the stimulus itself may not be the only factor influencing variations in biometric responses [21,25]. Furthermore, by integrating study results clearly with existing literature in discussions and placing a greater focus on the interpretation of results in terms of what this means and how it can be actioned from a consumer sensory point of view, researchers would greatly help the discipline understand the full value of these measures. It is our opinion that the added value these tools offer cannot be shown with new statistical approaches or technologies alone, as clarity is also required if the full practical benefit is to be gained from adopting biometric tools in sensory and consumer science. Therefore, when considering direct product sensory evaluation studies that often compare similar products during blind tasting, the research community's attention to biometric tools should not be at the expense of improving explicit measures.

Technological developments mean biometric measures are becoming more practical for use in direct product evaluation studies that focus on intrinsic product characteristics, and as sensory and consumer researchers move toward utilising more realistic study designs in terms of context, repeated exposure and realistic serving sizes, these measures will offer further value [48]. Furthermore, with the development of applications that measure different biometric signals nonintrusively and in combination, a better understanding will be gained of how these signals are associated with one another in the context of food evaluation. Nonetheless, it is still the case that most current studies seek to link biometrics with liking or a proxy measure of behaviour, such as purchase intent or willingness to pay (e.g. [21,34,49,50]). When tested for their association with consumer behaviour in the real world, biometric measures may be a much more important tool of choice for consumer sensory researchers.

Conclusion

Studies using combined biometric measures alongside explicit measures have started to offer the research community a deeper understanding of what individual biometric measures capture and what to expect in food-related studies. These studies indicate that biometric measures do give additional information to explicit measures. However, the research community would benefit from more food-related studies, ideally including consumption of food, carried out in disciplines such as psychology, physiology and neuroscience, or with

consumer sensory teams with these skills, to fully understand the nature and value of this additional information. This will help to turn insight into action in terms of product development and help achieve the goal of greater product success.

CRediT authorship contribution statement

Jennifer Wagner: Conceptualization, Methodology, Investigation, Data curation, Writing – original draft, Project administration. **Joanne Hort:** Conceptualization, Methodology, Writing – original draft, Supervision.

Data Availability

No data were used for the research described in the article.

Declaration of Competing Interest

Both authors, J Wagner and J Hort, declare no conflicts of interest.

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