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BOUABID ICHOU

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Hungarian University of Agriculture and Life Sciences

Buda Campus

Institute of Food Science and Technology

MSc THESIS

The effect of virtual reality sensory testing in different environments.

Insider consultant: Attila Gere
Co-consultant: Abdul Hannan Bin Zulkarnain
Insider consultant's Institute/department: Department of Postharvest, Supply Chain, Commerce and Sensory Science
Created by: Bouabid Ichou

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1. Introduction and objectives

1.1. Introduction

The Consumption of food comes among one of the vital and memorable functions of our daily life. It is a process that is both sensory and interactive and it integrates the brain and the five senses. That the chillum presents us with an escape from our lives is indisputably true. In effect, it is the environment that creates your sensory judgment. The setting, the music, the light … or even the people one may be surrounded with or simply see around has the power to affect our feelings. During this time virtual reality has made its way to being a new haven for sensory test practices, changing the way the researchers can proceed with the sensory attributes inventories. For virtual reality technology is not just about replicating the appearance of reality but concurrently developing the technology that will help in creating sensory environment that are even more immersive than the traditional ones. With regard to sensory literature, the results of sensory evaluations of VR have been very optimistic especially when simulating different eating environment in reality and trying to find out a consumer's perceptions and impressions of a certain food product (Yu *et al.*, 2023).

The nature of our research is the evaluation of two different virtual reality environments (food court and park) on the perception of samples. Setting the virtual sensory unit in those events for product tasting and sensory valuation in the virtual world, and then observing a connection with the usual sensory tank at the same time. The study comprised of 40 participants filled after VR questionnaire to ascertain how the respondents of the questionnaire reacted after the VR. Virtual reality is more than just a social immersion as we usually see in training and the new age of technology scientists and the public are able to use it as a useful tool. Also, according to the impact studies, the level of enjoyment among sensory researchers, in the food industry, should be investigated as a part of the significance of this field in our lives.

1.2. Background

Having known the background of this project, going through the available information and secondary research, we have identified a few key important points. Virtual reality is a computer technology used to create a simulated environment. Nowadays, virtual reality sensory testing is a real developing industry as an alternative to traditional sensory testing. Sensory testing mostly focuses on measuring consumers' acceptance and preferences of products. It is a technique that contributes to understanding how consumers perceive product perceptions. Sensory testing is used for product investigation, development, and quality. Traditionally, sensory testing took place in controlled sensory environment. The process can be quite time and money-consuming due to preparations to invite a group of people to test products. This study's primary goal is to offer a more affordable option for sensory testing so that data gathering may be done more simply and accurately.

1.3.Aim of the Study

This study aims to evaluate the relative efficacy of virtual reality sensory testing as opposed to conventional approaches in the field of food science. In particular, the study details the experiences of virtual reality sensory testing while applying it to several specific sensory analysis techniques and situations to properly evaluate the sensory characteristics of foods in a real-world context(figure1). This study seeks to evaluate whether or not virtual reality sensory testing can induce truly authentic sensory reactions from test subjects, with the main objective following, to determine the applicability of a wide variety of sensory analysis techniques including Just-About-Right and Check-All-That-Apply, to the application of virtual reality. This study also seeks to determine the nature of the effects that various virtual reality settings, such as sensory environment, food court, and parks, have on sensory perception. The intended method of this study would primarily seek to integrate current trends in food science with current advances in virtual reality technology to determine how sensory testing can be improved through virtual reality and how food science processes can gain unique insights into consumer behavior and preferences through virtual reality. Objectives of the Study,

- To assess the effectiveness of virtual sensory testing in different environments using VR technology.
- To compare the outcomes of sensory analysis methods conducted in VR environments with virtual sensory booth testing.
- To investigate the impact of VR technology on sensory perception, engagement, and consumer responses.
- To widen the potential applications of VR technologies in sensory science and consumer research.
- To contribute to a deeper understanding of how VR technology can enhance sensory evaluation processes and improve data collection in sensory science.

1.4.Scope of the Study

The project will focus on discovering if sensory methods can work in VR for measuring consumer perception of a product. Consider for instance, the summary of the research gathered that virtual reality can be used as an option in sensory testing. This particular study did not get the entire scope, since along with virtual reality another sensory evaluation factor was untouched its reliability and precision. One thing to keep in mind is that the purpose of sensory evaluation is to bring out the opinion of the consumer towards a given product and most times you are required to uncover what the consumer is perceiving and why he or she has that opinion. This data should be used to get consumers’ feedback on product development, comparison of products from the competitors or requirement for products acceptance. This, in turn, allows virtual reality to capture and measure what a consumer is aware of theirs likes and dislikes in the first place, giving it ability to evaluate the same data which is now gathered by consumers while using interior design products and preference mapping a method that charts their taste in or preference of items of interior design (Smith Elder, 2011).

Figure 1: Virtual replica of Mate sensory laboratory

2. Literature Review

2.1.Introduction to Sensory Analysis

One of the key processes for evaluating food products' quality is sensory analysis. It is used in various spheres, such as manufacturing, trade, and public catering, and examines psychophysiological aspects of human senses during a food tasting procedure. Generally, such tasting commissions are oriented on expert sensory analysis and implemented to a certain standardized approach. Tasting methods that are applied in the process, including Check-All-That-Apply(Kim, Heo and Sub Kwak, 2023) and Just-About-Right,(Plaehn, 2013) are aimed at identifying some specific sensory attributes. Moreover, such technological phenomenon as virtual reality is becoming more and more of an asset, helping to include additional means for sensory testing using new ways to create diverse eating environments to simulate. The article has adopting the new trend in the field of education would be helpful to the students studying in food biotechnology, product design, trade business, commodity science, and related areas. This document provides also priceless guideline and masterpiece to the professionals that meant to verify the quality and foods safety, allowing them to keep the critical sensory standards during the whole food production cycle. The Impact of Trained and Consumer Panels in Sensory Analysis While the latter two panels are quite prominent, the main purpose is to target both trained and consumer panels for their significance in the evaluation of the sensory aspects that appeal to the customers or consumers. Sensory analysis not only provides knowledge of sensory aspects of food products but also becomes an important factor in the market analysis section including trained and consumer panels. Thus from this perspective, the sensory analysis adopted a combined approach which includes sensory perspective and the products' progression in the market *Padmavathi, D. (2018).* (Ares and Varela, 2017) .

2.2.The Role of Trained and Consumer Panels in Sensory Analysis

2.2.1. Trained sensory panel

Trained sensory panels, composed of experts extending from different areas, often are valuable in sensory testing, as they employ individuals who have received multidisciplinary training to judge sensory components of goods and services. The expert reflects the experience more than meaning and therefore they are able to recognize small sensory details which low trained people might be unable to notice. Their training can be anything from a few weeks to a couple of months and they learn how to recognize, quantify and describe various sensory traits by use of color, flavor or fragrance vocabulary that is specific. This involves Memoration of degree and

in particular each attribute's intensity and quality.
Training the panels is usually done to provide instruction on handling about 5 to 30 samples per session. This depends on the proposed study chances and the ability of the panelists to make the right comparisons. They employ metrics of the type 1 and 5 to many-wheel going from primary as like and dislike hedonic scales to multiple point scales where there is say, 15 of them that reflect specific qualities such as sweetness and bitterness. This specific check-up enables the balanced results and integrity of sensory reports.
A key thing is to tune out and follow the adviser's instructions and a constant quality control and efficiency analysis of the panelists' judgments over time. The sensory environment is narrowed down on additionally by elimination of external elements such as lighting, temperature, and smell that can influence the results.
This group of experts is the pulse of the product quality and development process, offering a necessary guiding support to establish standards and groups that satisfy industry, as well as, consumers expectations. The activities they perform contribute to the evaluation and monitoring of products. They verify that products go through a fair and rigorous testing process, thus being an important milestone in the product development journey and for the quality control of industries which will always rely on sensory evaluation (Ares and Varela, 2017).

2.2.2. Consumer Sensory panel

Sensory evaluation takes advantage of consumer panels, which represent a different point of view through incorporating the opinion of real consumers. Typically, these are ordinary people who assess a product with respect to their personal liking and experience. They emphasize hedonic testing and assess consumer acceptance and total satisfaction. In contrast to the amount of training required for assessors, panelists receive minimal instructive training, just focusing on their natural perceptions and spontaneous reactions. Typically, 5 to 10 samples are evaluated to ensure a wide range of feedback without overwhelming the participants. Questions are straightforward and most often use a hedonic scale from dislike extremely to like extremely to capture general preference. Thus, holistic evaluation with consumer panels is an imperative for the understanding of market preferences and product acceptability that will help understand a product's market appeal on aspects such as taste, texture, and appearance. Consumer panels' contributions are recognized for their contribution to market-driven product development and improvement, where the significance of using consumer panels becomes more recognized with the development in sensory science (Ares and Varela, 2017).

2.3.Virtual Reality

Virtual Reality (VR) is a technological cornerstone, which fully immerses users into various environments that exceed physical restraints. This is one of the most highly influential technologies in the history of creating digital experiences and has far-reaching applications in sectors of one's choice. In the Mixed Reality (MR) collaborative setting(figure2), VR emerges as a transformational tool that becomes a bedrock of Augmented Reality (AR) and translates it in developing seamless remote interactions. A remarkable collaborative MR platform has been developed due to its blend with VR and AR: CoVAR. The CoVAR system introduces an extraordinary shared virtual environment that allows users to work within the interaction between AR and AV (Augmented Virtuality) within the same environment in a shared spatial setting. Here, VR contributes to bridging the span of physical space, wherein it enables participants to experience immersive experiences that almost mimic real-world interaction in the midst of geographical separations. Thanks to the innovative use of room-scale 3D reconstruction, VR not only augments the sensory richness of the collaborative space but also significantly raises the ecological validity of remote collaboration. This new approach literally illustrates how VR bridges the gap between virtual presence and collaborative efficiency, offering a new era in applying VR technologies across various landscapes that include education, emergency response, and remote maintenance (Piumsomboon *et al.*, 2017).

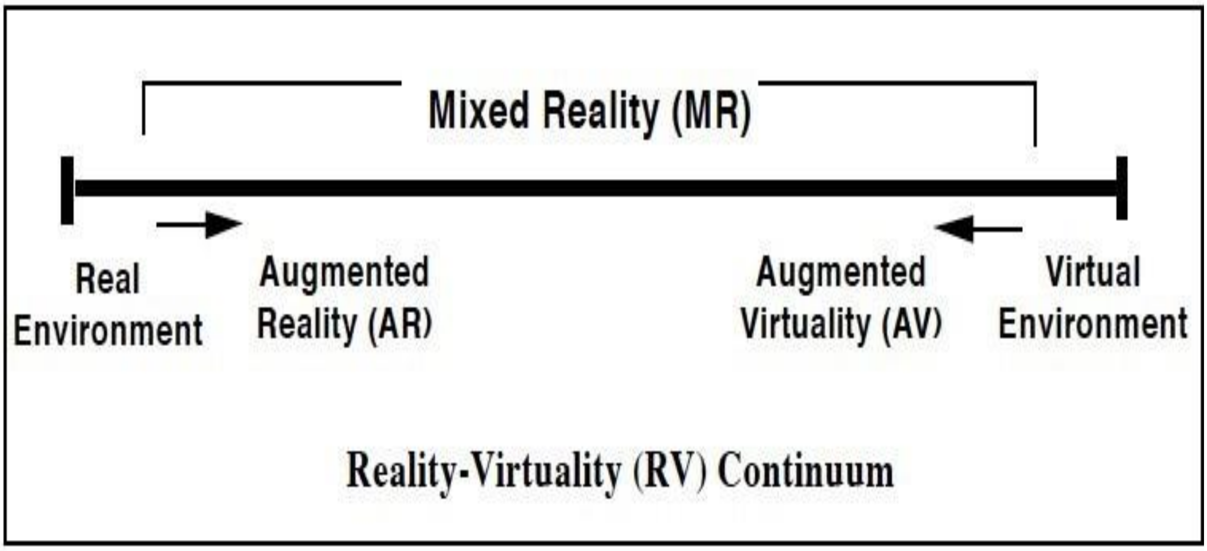

Figure 2 : Milgram and Kishino's Mixed Reality on the Reality-Virtuality Continuum.[Milgram and Kishino 1994]

2.4.Role of Virtual Reality in Food Sensory Evaluation

Virtual Reality technology is bringing about the greatest sensory revolution in the dawn of a new era by supporting the development of immersive environments which serve for the evaluation of sensory perception and emotional responses to the stimulus especially in the context of food products. VR sensory environment employ an innovative method of (evaluation), which does improve user engagement and ecological validity beyond the conventional ones. Conducive to VR's ability, the concept of sensory evaluation in the immersive environment has been tested and proven to be better engagement and perception of food commodities in comparison to conventional sensation analysis. Researchers have investigated VR to analyze the qualities of alcoholic beverages, including taste assessments and connoisseur consults, red meat steaks, chocolates, tea, and cola. These studies are based on testing fundamentals such as food can be looked and eaten to analyze how people's sensory perception of food is changed through VR. Which is primarily consists of two key components: one that consist of the hardware as well as the software. The hardware is in conjunction with headsets, input devices, and more often motion tracking technology, which is the software that includes the VR content and applications to create immersive worlds for the users to interact. Thus in unison these components construct what is truly a three dimensional simulation of the virtual world that is interacted with and explored just as the real one in real time.

The potential applications of VR and augmented reality (AR) technologies in sensory science are vast, offering new possibilities for collecting and processing sensory and consumer information. VR has also been utilized in educational settings to enhance learning experiences and provide immersive environments for students. The use of VR in sensory science opens up avenues for studying sensory immersion's impact on perception and engagement. By creating realistic and immersive sensory experiences, researchers can explore how various factors influence sensory perception (Xu, Siegrist and Hartmann, 2021).

2.5. The Evolution of Sensory Evaluation in the Food Industry: Understanding Its Foundations and Practices

Sensory evaluation is a scientific discipline that analyses and measures human responses to the composition of food and drink, e.g. appearance, touch, odor, texture, temperature, and taste. In schools, it provides an ideal opportunity for students to evaluate and give feedback on their dishes, test products, and experimental designs. The precise way in which sensory evaluation is conducted, along with the different tests and sensory language used, needs to be taught.

This will help students to understand the process and develop their sensory vocabulary. It also means that students will record and generate evaluative feedback to support their work (Mihafu, Issa and Kamiyango, 2020).

The development of virtual Sensory environment (SE) using VR technology provides a foundation for the creation of VR applications focused on different methods of sensory analysis across various product samples. These virtual SEs aim to supplement traditional sensory analysis methods by offering a more engaging and interactive platform for evaluating sensory attributes. The integration of VR technology with sensory analysis not only enhances the evaluation process but also broadens accessibility, allowing researchers to explore diverse environments that may be challenging or costly to recreate physically (Zulkarnain, Kókai and Gere, 2024).

The evolution of sensory evaluation methods in the food industry has a rich history dating back to the mid-20th century when universities like the University of California at Davis began offering courses on sensory evaluation, stimulating research and development in this field ('Sensory Evaluation Practices 3rd Edn Introduction to Sensory Evaluation', 2004).

Over time, sensory evaluation has become crucial in assessing food quality, with traditional methods relying on human senses, which can be subjective and time-consuming(Rodrigues, Dias and Teixeira,2021).Recent scientific articles highlight the emergence of innovative methodologies aiming to enhance objectivity and reliability in sensory analysis, supplementing or supplanting human assessment with modern tools that mimic human senses like smell, taste, and vision (Rodrigues, Dias and Teixeira,2021).

These advancements in sensory evaluation not only improve efficiency but also contribute to enhancing food quality, consistency, and safety in the industry (Rodrigues, Dias and Teixeira, 2021).

The historical background of sensory evaluation reveals its roots in the food and beverage sectors, where interest in sensory evaluation grew, leading to the development of methodologies like the "Flavour Profile Method" and "Hedonic Index" in the 1930s.The application of sensory testing methods, particularly in Europe and the United States during World War II, played a significant role in ensuring the quality of food products and addressing the need for reliable food assessment.The continuous evolution of sensory evaluation methods reflects a blend of traditional sensory analysis techniques and modern technological advancements, shaping the way food quality is assessed and ensuring consumer satisfaction in the food industry (Sensory Evaluation Of Food – Guires Food Research Lab, 2024).

2.5.1. Why use sensory evaluation?

In the fast-paced world of the food industry, sensory evaluation appears as a flexible and wonderful instrument, highlighting the vivid diversity of product development and control quality. Additionally, it allows exploring the peculiarities of dishes and products to determine similarities and differences. We carefully test the usual food items to determine their quality level through the prism of sensory evaluation, and investigate the samples to uncover specific areas for improvement and their unique features and characteristics. Sensory evaluation measures the appropriateness of dishes and products for use and identifies any weaknesses by testing their response. Furthermore, it delves deeply into the unique characteristics of the samples and ingredients utilized. Furthermore, sensory evaluation plays a crucial role in ensuring the final food item is precisely as intended, balancing subjective perceptions with objective values. This way, it allows managers to succeed (Sidel, Stone and Bloomquist, 1981).

2.6.Traditional Sensory Testing Methods: Review commonly used sensory analysis methods

When it comes to the sensory analysis methods, techniques can be grouped into two main categories according to the type of panel with regard to its members. While they involve more elaborate and sophisticated analysis of the product, these categories bring different aspects and outlooks into evaluation. The outlined categorization elucidates the strong connection between aperitif capability with consumer perception, hence the need for improvement of the field of the sensory evaluation.

2.6.1. Methods with Trained Sensory Panel Members

2.6.1.1.Sensory profiling

This technique is a specific method applied for focusing on bringing the panelists who are expert in making an explicit and thorough examination of a product's sensory properties. Sensory profiling carries out a detailed and well-organized annotation of the product sensory features among the educated panelists. Now visualize a group of skilled panelists slightly spreading out and starting to de-layer the smart pack, thus exposing the lovely ingredients carefully placed within, as they ponder about how to best describe the sensory profiling of that product which evokes the product’s essence through their word of mouth in a snap. This technique is essential for product distinctions and characterization in a very strong market competition, implying making products capable of meeting customer expectations if they work synergistically (Rapid Sensory Profiling Techniques and Related Methods: Applications in New Product Development and Consumer Research 2022).

2.6.1.2.Ranking test

While in the world of sensory analysis ranking tests is one of the most important tools which make it possible to assess every sensory parameters differences in various products. Picture an experienced group of judges attentively assigning rank attributes to a brief of products, enjoying the innateness of every masterwork as artists do. These are the kind of tests that show the finer details of the product by giving way to all refinement strategies so that best quality will be kept in mind to truly be loved by consumers and meet standard setting (Cleaver, 2017).

2.6.1.3.Discrimination test

Sensory evaluation takes you to the magic world where you put yourself into the front of a trained panelist, and tests like triangle test help you to understand the minute details between products. Picture this: The semi-cylindrical panels, relying on their substantial smell and taste senses, are ought to cope with the task of isolating the out-of-place sample from among the three samples. Amidst the fine tact between the products' quality and the nuances in the samples, they try to strike it right. What Triangle Test does, a bedrock in this sensory realm analysis, is act as a detective to explain any sensory change because an ingredient is changed or a processing method is employed. Figure 1: The three samples in prepared portions color-coded for substances detection are set out for the panelists' hand-on work in closed, methodical, controlled conditions where every detail is scrutinized. This technique not only ensures fairness during the assessments but it is also based on sophisticated statistical methods to distinguish meaningful sensory differences. The Ballet dancers are no different from this as they present a well-coordinated step-by-step movement which comes close to a masterfully orchestrated dance. the other tests such as Paired Comparison, Duo-Trio Tests are sifted into sensory music sustaining the methodological way for the tests to be efficient in identifying and comparing sensory attributes therefore keeping the quality line heedful of sensory analysis standards (Sensory Evaluation Practices 3rd Edn Introduction to Sensory Evaluation. (2004). Sensory triangle testing, discrimination test at Campden BRI. (n.d.). Retrieved March 29, 2024 .

2.6.2. Methods with Consumers

2.6.2.1 JAR just about right Scaling

Just-About-Right scaling is a scales-sensory attributes of a product based on sensory that evaluates the product to match the prefect values from consumer's perspective. Employees are given a set of features which characterize the sensory characteristics of the product what you describe (e.g. sweetness, tastiness, texture) and are asked to rate each attribute how well in line with what you want (e.g. "too sweet," "about right," "not sweet enough"). This technique will enable a product developer to most closely finalize formulations and match consumer target expectations.

2.6.2.2 CATA check all that apply method

This is a short form of the CATA method that is widely used to rapidly capture sensory attributes perceived by consumers from a product. The sample of the product is presented to participants, after that a list of sensory attributes is given, and participants are asked to identify all sensory attributes that they perceive in that sample. It can help identify the most important sensory attributes associated with the product and get useful information in the optimization and differentiation of the product.

2.6.2.3 Hedonic test

Hedonic Tests play a vital role in unraveling consumer acceptance and preference. Imagine a scenario where these tests act as a compass, gauging the likability or dislikability of a product's sensory attributes by consumers. Through preference rating scales, they capture the essence of consumer reactions, providing valuable insights to tailor products to meet consumer expectations and elevate their appeal in the competitive market landscape (Rapid Sensory Profiling Techniques and Related Methods: Applications in New Product Development and Consumer Research 2022).

2.7. Traditional vs. Virtual Reality Testing

Traditional consumer testing methods such as CATA and JAR conducted in isolated booth environments have limitations in providing a truly immersive and engaging experience for participants. These traditional methods cannot often simulate real-world scenarios accurately, leading to a disconnect between the testing environment and actual consumer experiences. Furthermore, the controlled nature of traditional sensory environment may not fully capture the complexities of consumer responses in dynamic and varied settings. This limitation can impact the validity and reliability of sensory analysis results obtained through traditional methods (Stelick *et al.*, 2018).

On the other hand, Virtual Reality (VR) technology offers a promising avenue for research by addressing these limitations. VR provides a more immersive and engaging experience for participants by creating realistic and interactive sensory environments. By leveraging VR technology, researchers can design controlled yet immersive environments that closely mimic real-world scenarios, allowing for a more holistic understanding of consumer responses to sensory stimuli. This enhanced level of immersion enables researchers to explore disparities in consumer responses more effectively and analyze sensory experiences more comprehensively (Wang *et al.*, 2021).

The benefits of VR in creating a controlled yet immersive environment for sensory analysis are significant. VR technology allows researchers to manipulate sensory stimuli and environmental factors with precision, providing a platform to study how different variables influence sensory perception. By immersing participants in virtual environments, researchers can observe and analyze sensory responses more naturally and engagingly. This approach not only enhances the accuracy of sensory analysis but also opens up new possibilities for studying consumer behavior and preferences more dynamically and interactively. Overall, VR technology offers a transformative tool for sensory science, enabling researchers to conduct more insightful and impactful studies on sensory perception and consumer responses (Ammann, Stucki and Siegrist, 2020).

2.8.Previous Studies on Virtual Reality in Sensory Testing

What has already been known and what has been done in the field of Virtual Reality in sensory testing? Earlier studies of Virtual Reality in sensory science investigated the application of VR technology in sensory evaluation and perception research(table1). These findings could indicate the potential of VR in sensory analysis and the possibility of providing more immersive experiences to participants. More recent research has shown that sensory evaluation performed in an immersive VR condition such as in the case of this study may lead to better engagement and perceptual efficacy of the food product. The impact of VR has been tested in various studies concerning sensory perception related to alcoholic beverages, wine tasting experience, beef steaks, chocolate, tea, and cola. VR technology has also been used in the environment of an education experience to provide learners with a more immersive learning environment (Xu, Siegrist and Hartmann, 2021).

Table 1 : Virtual Reality application in sensory analysis practices.

	Findings	References
Dynamic Context Sensory Testing-A Proof of Concept Study Bringing Virtual Reality to the Sensory	The Dynamic Context Sensory Testing study's purpose was to present the proof of concept with the use of Virtual Reality technology to manipulate the sensory properties of the food by manipulating the consumption	(Stelick *et al.*, 2018)

	Booth: Virtual reality in the sensory booth	environment. The study was aimed to change the context in which the food takes place while Virtual Reality is used, and such changes can influence the sensory experience of the food testing. The present essay will investigate the impact of VR technology on sensory experiences and perception during sensory testing.	
		The results of this study illustrate that VR technology could very well change how food is consumed in terms of the environment in which it is tasted; environmental factors do indeed change the sensory properties and experiences of food. VR was used to create dynamic contexts for testing, thus showing how environmental changes result in sensory perceptions, and they highlighted the potential of VR in enhancing sensory evaluation processes and in providing new insights into how surroundings affect sensory experiences during food consumption.	(Stelick *et al.*, 2018)
	Getting started with virtual reality for sensory and consumer science: Current practices and future perspectives	The research is into the usage of Virtual Reality (VR) in sensory and consumer science, emphasizing the very fundamental factors of immersion and presence that should be considered while designing studies with VR. Researchers underline the significance of these factors toward increasing the impact of VR studies within sensory and consumer science domains. This article provides insights on diverse options available in terms of hardware, software, and response mechanisms for conducting VR studies specifically designed for sensory analysis.	(Janice Wang *et al.*, 2021)

	Sensory and consumer scientists will find this study very useful when they embark on VR technology since they have been enriched with immersion and presence theories, which are virtually orientation guiding them in that whole process. Software, hardware, and response measurement processes being explored by the researcher give an easy way to comprehend the fundamentals in conducting research using sensory analysis with VR technology. This study sets the stage for future developments in VR usage within the sensory and consumer sciences, generally steering researchers towards innovative ways of selecting products and food evaluation using VR technology.	(Janice Wang *et al.*, 2021)
Exploring the Effects of Immersive Virtual Reality Environments on Sensory Perception of Beef Steaks and Chocolate.	The study examined the impacts of a virtual reality (VR) environment on sensory perception to beef steaks and chocolate. Two independent studies were conducted: one for beef and one for chocolate. For beef, participants rated the beef significantly higher in liking for all sensory attributes when consumed within the VR restaurant compared to the traditional sensory booths. For chocolate, the VR countryside context brought about significantly higher hedonic scores for both flavor and overall liking compared to the sensory booth. This study illustrated that in the case of food products, specific contextual settings, in this case VR environments, can cause the sensory response of the participants to differ from traditional sensory laboratory conditions.	(Crofton, Murray and Botinestean, 2021a)

2.9. Applications of Sensory Analysis Methods in Virtual Reality Environments

Latest advancements in sensory science, particularly in predicting food product success, involve the integration of virtual reality (VR) and technology. This innovation offers immersive and interactive ways to understand human sensory experiences and enhance sensory evaluation. VR technology has the potential to revolutionize sensory science across various domains, including consumption context, biometrics, food structure and texture, and sensory marketing. Their integration promises to significantly impact the food industry by improving the predictive validity of newly launched products within the marketplace and contributing to the design and development of new products with optimized consumer benefits (Crofton *et al.*, 2019).

As the technology for virtual reality (VR) is redefined, it creates new possibilities for sensory science thus being able to distinguish the influence of the environment on a consumer's food response in different situations. VR engrosses a person into the artificial world which alters towards affective and hedonic views of food. Studies involving VR have only started to appear in the past. They concentrate mainly on such things as scents in identifying, emotional aspect and cognitive processes. Virtual reality technology makes up sensory testing so it could be possible to explore the complex natural environment that stimulates the experimental subjects(Crofton, Murray and Botinestean, 2021).

One key aspect is the impact of VR on sensory perception and emotional responses to food products. VR allows for the creation of ecologically valid consumer experiences, offering insights into product preferences and purchasing decisions. The application of VR in sensory science helps bridge the gap between theoretical knowledge and practical application, enhancing skill development and understanding consumer behavior in virtual environments.

The integration of VR technology in sensory analysis presents a novel methodological approach to studying sensory perception, where the visual representation of food products influences scent perception and cognitive resources. By simulating real-world scenarios, VR technology revolutionizes data collection and processing in sensory science, paving the way for innovative research methodologies and applications in diverse fields (Hannan, A., Zulkarnain, B., Kókai, Z., & Gere, A. (2024)) (Kong, Y., Sharma, C., Kanala, M., Thakur, M., Li, L., Xu, D., Harrison, R., & Torrico, D. (2020)).

2.10. Novel Sensory Technologies: Biometric and Virtual Innovations in Sensory Assessment

The developments in the sensory field have extended the scientific instruments for measuring the sensory responses. The new innovations have been established to generate a critically objective note on the perception of items such as foods and beverages, among other sensory stimuli. The sensory evaluation has embraced technological innovations from other scientific fields to consider physiological aspects that are unconscious. There is also an intensive study on stimuli perception developed in virtual environments. The already existing sensory techniques such as discrimination, descriptive, and affective methods have several limitations accompanied by conventional biases, especially in assessing the participants. Sensory evaluation practices have, therefore, explored new methods that offer a reduced scope of biasness and a full account of the sensory mechanisms (Torrico et al., 2023).

2.11. Theoretical Frameworks in Food Perception and Preference

Theoretical frameworks in food perception and preference provide structured models that researchers utilize to comprehend the intricate processes underlying how individuals perceive, evaluate, and select foods. These frameworks integrate insights from diverse fields such as psychology, sensory science, consumer behavior, and marketing to elucidate the multifaceted nature of decision-making in the realm of food. Key theoretical frameworks include Sensory Evaluation Theory, which focuses on how sensory attributes like taste, aroma, texture, and appearance influence individuals' food perception and preference. Hedonic and Affective Theory emphasizes the role of emotions and pleasure in shaping food preferences. Expectation-Confirmation Theory posits that individuals' expectations about food attributes influence their subsequent evaluation and satisfaction. Cognitive Models of Decision-Making delve into the cognitive processes guiding food choice, including attention, memory, learning, and decision heuristics. Consumer Behavior Models draw from consumer behavior theory to explore the broader social, cultural, economic, and environmental factors influencing food preferences and choices. These frameworks collectively enhance our understanding of the psychological, sensory, and sociocultural dimensions of food perception and preference, providing a comprehensive lens through which to analyze consumer behavior in the food domain (Wwjmrd, 2017) (Vabø and Hansen, 2014).

3. Materials and Method

3.1. Research and design

In the project we conducted showed the sessions of tradition and innovation which involved the setting up of a virtual sensory environment (SE) that we created with Virtual Reality (VR) technology. It was our long-term mission aiming to introduce novel technology took over from the online world into the offline sensory analysis methods, making it popular among researchers in general. We started in a different way by designing a digital process which mimics the tradition proper sensory environment to a large extent, not leaving a lot of things out as the sights and the detailed sensory stimuli. Utilizing Unity software and Oculus VR technology, and adhering to the ISO 8589: In VR environment of 2007 standards, we set up for affairs having two different scenes: park and lively food court, known as Sensory Environment 1 and Sensory Environment 2. Thus, our evaluation was based on these environments that shaped the evaluation process. The booths of virtual were like station for people to interact with animate stimuli in innovative ways and the new things in a more dynamic environment. This was not just the copy past of the sensory stuff but the addition of something greater: immersion facilitated by the virtual reality. Results from these two environments were compared to results coming from a virtual sensory booth, which was not part of the current thesis. The solution that emerged was a novel design that revolutionized the product evaluation, being so complex that it challenges ordinary techniques and therefore it is setting the limits for what is known as the sensory science. Notably, the key purpose of our project consisted of evaluating the two different virtual reality environments on the perception of samples using the highly-developed technology, leading to a deeper insight into sensory science.

3.2. Participants

In our path to virtual discovery, we were accompanied by 40 students of MATE, including 9 males and 31 females, during our journey to this project experiment took place in a living lab was a joint effort- we tasked people with different ages and backgrounds(figure3), to assist us with the various stages of the virtual reality experience development process. This was the first time some of them had ever booted up a VR device. As such, it still felt new and fresh as they experienced it with boys, also girls who seem to have been doing it for quite some time. Such a mixture provided a great number of different points of view to our investigation; thus, making the researching process more interesting and boosting it with various meaningful insights. Those students, who range from basic to some VR knowledge, undoubtedly added a new dimension to the sense of exploring the unknown while each one of them necessarily contributed to the study. Not only did their involvement bring along further research but also opened the door for the start of their journey into the virtual environments realm to understand and discover through them.

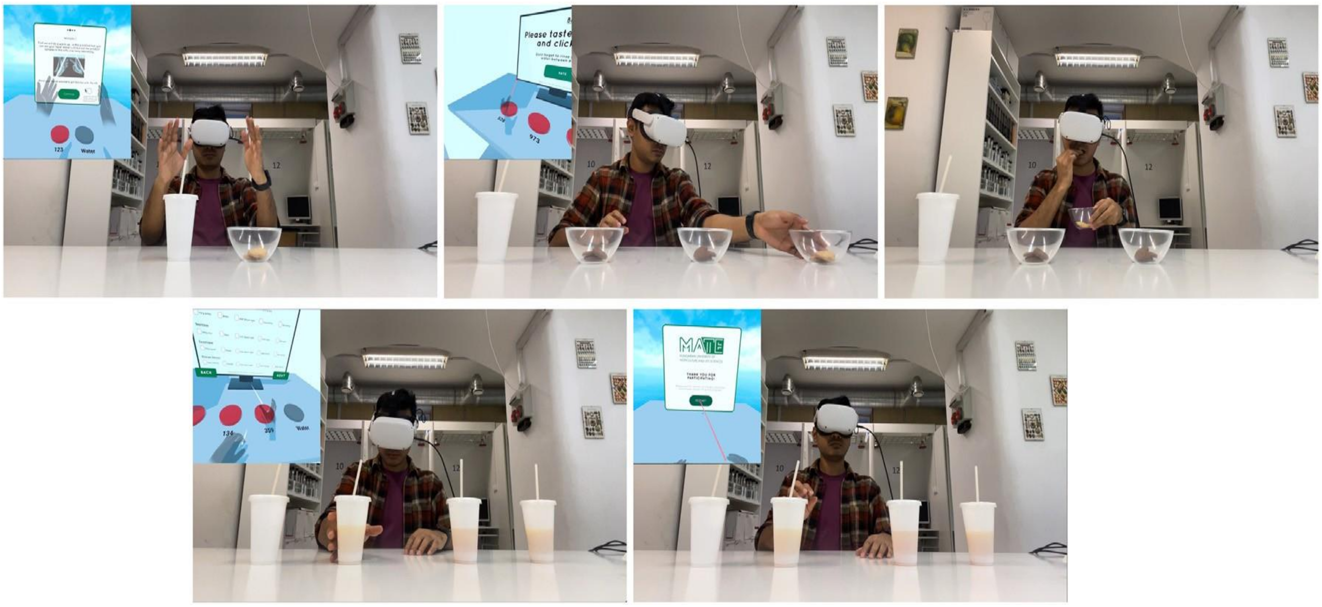

Figure 3 : Point of view of participant and real time game play VR mode sensory

3.3.Virtual Environment (Food court and park)

The study further continued beyond the Virtual Sensory environment to include two distinct virtual environments: Food Court and Park, which were recorded in video by insta360 camera, referred to as Sensory Environment 1 and Sensory Environment 2(figure 4,5), respectively. These environments had been designed to investigate the contextual influences on sensory perception, giving participants a choice for sensory evaluation. Both environments were provided with the capability of conducting sensory tests, the JAR and CATA methods, over some selected food products randomly numbered. The structured layout facilitated an immersive exploration of how varied settings differ as much in sensory perceptions; each booth followed a consistent procedure for giving instructions, processing the sensory test, and expressing preferences. This is a way of exemplifying how VR can provide a realistic and varied sensory assessment to enhance sensory science research and studies into the consumer.

Figure 4 : 360 Video of food court

Figure 5 : 360 Video of park

3.4. Virtual Sensory booth

We developed and used a Virtual Reality (VR) Sensory Booth to innovate the traditional sensory evaluation process. It was built by taking an approach of sound engineering through Unity software, and with respect to the Oculus Quest 2(figure 6,7), the selected device was taken to be, in an effort to draw the participants to the VR Sensory Booth. Encompassing all ISO 8589:2007 standards, the virtual environment was constructed with due consideration given to the color, lighting (6500 K)(Zulkarnain, Kókai and Gere, 2024), and ventilation necessary for a well-established sensory laboratory. Within this virtual space, the participants engaged in sensory evaluations on two specific types of food samples: biscuits and orange juice, using the Just-About-Right (JAR) and Check-All-That-Apply (CATA) methods. The procedures and sensory attributes were tailored to each product for detailed analysis of the sensory perceptions of the participants. This innovative approach not only aimed to enhance sensory analysis but also to explore the general application of VR technology in sensory science, especially within the food industry, indicating the usability and flexibility of this system in replicating and testing real-world sensory experiences. Results from the two virtual environments were compared to results coming from this virtual sensory booth study, which was not part of the current thesis.

3.5. System and Software Technologically

The development of our VR sensory environments began with an infusion of intricate software and state-of-the-art hardware required to create this research tool. The unity version 2022.1, a game engine developed by Unity Technologies, powered the heart of our tech stack known for its robust and versatile development environment. This feature allowed the creation and simulation of the designs in the virtual sensory environment to their exact likeness, ultra-realistic and interactive. The Oculus Meta Quest 2 VR headset added its prowess on Unity's powerful tools through the Meta Quest Software bringing the sensory environment we created rigorously to life(figure7). The similitude in architectural design between our setup and the SE in the Hungarian University of Agriculture and Life Sciences conformed to the ISO 8589:2007 standards through the minimalistic design used with white or light grey colors, proper natural lighting at 6500 K, and excellent ventilation. This created a simulated setting life-like for comparison and evaluation as it allowed various foods to be presented randomly. The technological steps in creating the VR sensory environment explained above form the basis of the methodology that follows and is a significant step in the use of VR in sensory science and a new frontier in how food science can be taught and performed (Zulkarnain, Kókai and Gere, 2024).

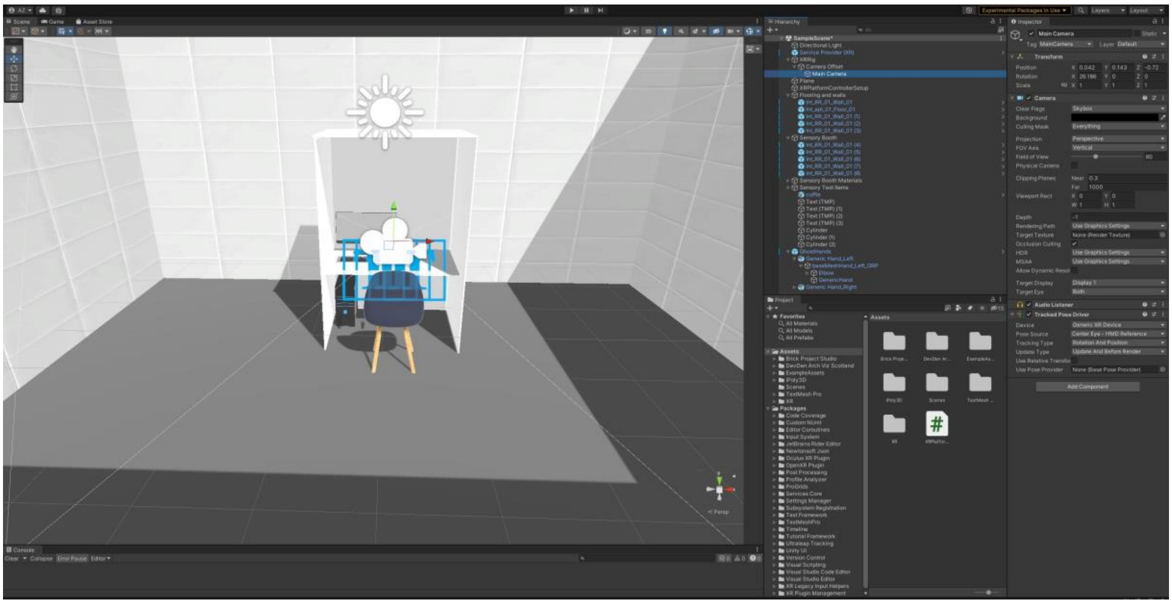

Figure 6 : Unity version 2022.1 software owned by Unity Technologies

Figure 7 : Oculus Meta Quest 2 VR headset operated by Meta Quest Software.

3.6. Procedure and Sensory Method

3.6.1. Selection of Samples:

For the sensory evaluation, we utilized two actual product samples, one in each environment:

biscuits in Table 2 (park environment) and orange juice in Table 3 (food court environment). The two samples were chosen due to their unique sensory attributes, which made them a comprehensive reference sample for the evaluation of the VR SE's efficiency. Importantly, the samples were selected not solely due to their properties but also due to their exposure to the particular environment of the food court or park, which strength the overall context transfer. The exposure to the two samples occurred in a random order to minimize the sequence effects and self-evaluation bias. The same samples were evaluated in the virtual sensory booth study to make the results comparable.

Table 2 : Different biscuit sample

Name of company	**Cacao**	**Cacao with Whole Grain**	**Chocolate Chips**
Picture of product			
Number of sample	973	231	528

Table 3 : Orange juice sample

Name of company	**Sio**	**Tesco**	**Hapy Day**

Picture of product			
Number of sample	932	134	359

3.6.2. Sample preparation

The standardization of samples is among the important steps in the sensory evaluation setup that ensures the reliability of the results. This implies the similarity of sample preparation in identical conditions, and tends to make the atmosphere for conducting similar sensory tests. The purpose is to eliminate substitutions that can create any sensory disturbances which may not be associated with 360 degrees' view only but other real world factors that VR technology cannot erase. In particular, this study was same in offering the models that are based on biscuits and orange juice while preparing all the tests. The standardization thus becomes one of the musts to ensure that the sensory evaluation results are true and reliable, no matter which VR environment they are done in. Thus, making the samples in this manner puts the accent on the influences of VR world on sensory perception, rather than on the differences between the samples that might arise. Orange juice was served in plastic cups with lid and straw, while biscuits were served in glass bowls. Randomization of samples was also completed samples were coded with 3-digit random numbers (figure3).

3.7. Evaluation Methods:

3.7.1. Overview to the experiment

Upon arrival at the laboratory, the participants were briefed about the study's aims and procedures. During this session, the researcher acquired their informed consent. Additionally, this phase encompassed the completion of a demographic questionnaire designed to capture critical background information. Subsequently, the participants were immersed into the virtual environments through a VR headset. For sensory evaluation, we employed Just-About-Right and Check-All-That-Apply methods, complemented by preference testing. These methods were preferred for their flexibility, making their incorporation feasible in both conventional and virtual sensory analysis paradigms. The participants interacted with the virtual samples through a user interface in the VR environment, making sensory assessments and preferences. The same process flow applies for both the environment and sensory booth regarding the rating of JAR, CATA and preference test based on their preferences (Figure 8).

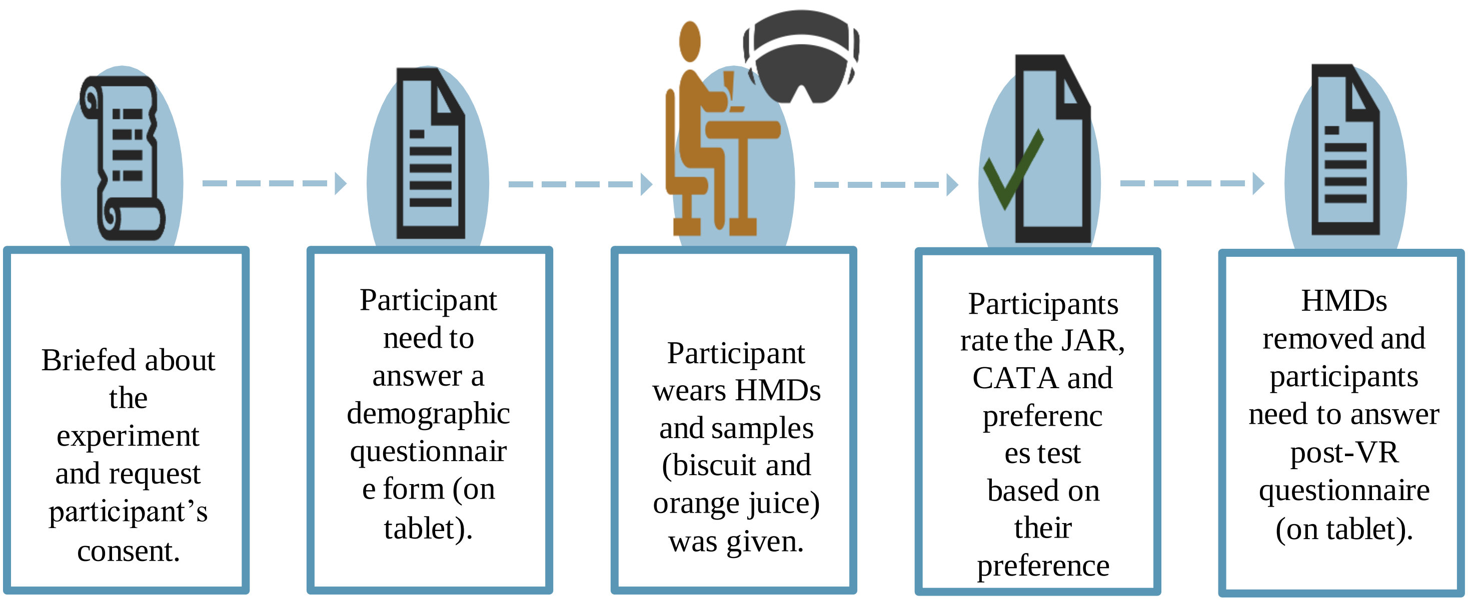

Figure 8 : Experiment process VR sensory testing.

3.7.2. VR Questionnaire:

3.7.2.1. JAR

The JAR scale used in this research study is very important in explaining the relationship between virtual reality and participants' perceptions of the product attributes in different simulated environments. By looking at the sensory attributes of biscuits and orange juice across scales from not enough to too much with just-about-right option in the middle. We hope to uncover how this may make differences in sensory balance due to VR settings like a virtual food court or park and how these differences may be perceived by consumers.

This questionnaire should be repeated for all samples biscuit/orange juice.

The questionnaire is set up to assess four key attributes of the biscuits: Crunches, Chewy, Sweet, and Chocolate intensity. Every single element is considered and evaluated by a scale of 1-5 according to people preferences: from 1 (not enough) to 5 (too much) with 3 being the just-about-right or Just Right. The total scale for each attribute is formed by five response check boxes indicated by a different color to show both In this technique, panelists take a journey of discovering the various types of qualities that the designers assumes ought to be incorporated into an innovative product and how their services compare to what consumers desire and also pointing out areas that need adjustment to match the consumer's preference for such characteristics. Orange juice sample.

Same applies for the JAR scale questionnaire for evaluating how the participants likes the orange juice. This questionnaire assesses four distinct attributes: Bitterness, Sourness, Sugary, and Orange Flavor. Attribute scores range from one point to five points using a JAR scale.

3.7.2.2. CATA

Our CATA section thus goes ahead to give a full round of descriptions of the sensory associated with each product in VR environments (Tables 4 and 5). This way, we capture multiple sensory impressions, ranging from taste to texture, in the sense that different virtual settings may highlight or diminish certain sensory qualities when applied to biscuits and orange juice.

This questionnaire should be repeated for all samples biscuit/orange juice.

Table 4 : CATA Scale questionnaire for Biscuits (Samples 394, 570, 453)

Descriptors	**Applicable**
Hard	☐
Granular	☐
Citrus Flavor	☐
Pasty	☐
Bitter Taste	☐
Soft	☐
Intense	☐
Vanilla Flavor	☐
Crumbly	☐
Crunchy	☐
Salty Taste	☐
Dry	☐

Descriptors	**Applicable**
Nutty Flavor	☐
Grainy Flavor	☐
Sweet Taste	☐
Chocolate Flavor	☐
Long Lasting Taste	☐

Table 5 : CATA Scale questionnaire for Orange Juice (Samples 683, 531, 717).

Descriptors	**Applicable**
Refreshing	☐
Sweet	☐
Long Lasting Taste	☐
Intense	☐
Irritating	☐
Bitter	☐
Sour	☐
Off-flavour	☐
Natural Taste	☐
Astringent	☐
Pulpy	☐
Thick	☐
Orange	☐
Artificial Taste	☐
Lemon	☐

In this way, these tables list out all the descriptors for each product type, with checkboxes (☐) for participants to indicate applicability, providing a straightforward way to compile sensory profiles from the evaluations.

3.7.2.3Preference test

Preference testing directly interrogate the participants' preference or liking towards our product in the virtual-reality-induced environment. This section is essential to our assessment of the overall appeal to consumers of our products and samples in varied VR scenarios, so we know in which environmental settings enjoyment of biscuits and orange juice is enhanced or diminished (Tables 6). The question used was “How much do you like the sample?

Table 6 : Questionnaire Preference for Biscuit Samples

Sample Number	1: Dislike Very Much	2: Dislike	3: Neutral	4: Like	5: Like Very Much
Sample 394	☐	☐	☐	☐	☐
Sample 570	☐	☐	☐	☐	☐
Sample 453	☐	☐	☐	☐	☐

This questionnaire should be repeated for all samples of the orange juice. (Samples 683, 531, 717).

3.7.2.4. Stimulator Sickness Questionnaire (SSQ)

With this in mind, as a safeguarding measure, a discomfort checklist applies the SSQ while experiencing VR technology (Table 7). Under the 'General Discomfort' to 'Burping,' we can identify symptoms and conduct sensory research to ensure that any negative effect of particular VR environments can be identified without compromising participants' well-being during the study process.

Table 7 : Stimulator Sickness Questionnaire (SSQ).

Symptoms	Severe	Moderate	Slight	None
General Discomfort	☐	☐	☐	☐
Fatigue	☐	☐	☐	☐
Headache	☐	☐	☐	☐
Eye Strain	☐	☐	☐	☐
Difficulty Focusing	☐	☐	☐	☐
Salivation Increasing	☐	☐	☐	☐
Sweating	☐	☐	☐	☐
Nausea	☐	☐	☐	☐
Difficulty Concentrating	☐	☐	☐	☐
"Fullness of Head"	☐	☐	☐	☐
Blurred Vision	☐	☐	☐	☐
Dizziness with Eyes Open	☐	☐	☐	☐
Dizziness with Eyes Closed	☐	☐	☐	☐

Symptoms	Severe	Moderate	Slight	None
Vertigo	☐	☐	☐	☐
Stomach Awareness	☐	☐	☐	☐
Burping	☐	☐	☐	☐

3.7.2.4.1. SSQ Calculations

Based on Table 8, the SSQ score is considered negligible when it is lower than 5. A minimal score falls between 5 and 10, signifying a minor level of discomfort. A score of 10 to 15 is considered significant, indicating a notable level of discomfort. A score of 15 to 20 is regarded as concerning. Lastly, a score exceeding 20 is classified as severe (Kennedy *et al.*, 1993).

Table 8 : Determinations of the Simulator Sickness Questionnaire (SSQ) symptoms belonging to categories (nausea, oculomotor, and disorientation).

Simulator Sickness Questionnaire (SSQ) Symptoms	Categories		
	Nausea	Oculomotor	Disorientation
General discomfort Fatigue	1	1	
Headache		1	
Eyestrain		1	
Difficulty focusing		1	
Increased salivation		1	1
Sweating	1		
Nausea	1		
Difficulty concentrating	1		1
Fullness of head	1	1	
Blurred vision			1
Dizzy (eyes open)		1	1
Dizzy (eyes closed)			1
Vertigo			1
Stomach awareness			1
Burping	1		
	1		
Total	[1]	[2]	[3]

- Score Calculation:
- Nausea = [1] x 9.54
- Oculomotor = [2] x 7.58
- Disorientation = [3] x 13.92
- Total Score = ([1] + [2] + [3]) x 3.74

3.7.5. Post-VR

Post-VR, therefore, emerges as the tool par excellence for the extraction of this in-depth feedback after participants are engaged with the sensory evaluations within varied virtual environments, such as a Food Court and a Park. This tool scrutinizes participants' overall impressions of the VR environments, immersion levels, and the realism and quality of VR graphics; interaction with virtual items; and their general perception of the VR technology employed. Such an examination reveals that for the sensory evaluation experiences, they have been brought out to emphasize the fact that some settings may foster more precise or consistent evaluations, as feedback from participants would have noted such environments that enhance sensory testing to be more immersive and real. Besides, the analysis further extends to dealing with discomfort or symptoms of simulator sickness in the Post-VR questionnaire and pointing towards future VR applications within the balance provided by the VR immersive experience alongside the comfort of the participants. Feedback on the technological facets of the VR sensory environment, such as graphics quality and interaction fluidity, also helps in checking the effective use of VR in sensory testing.

3.8.Data analysis

Through the XLSTAT software, with a concentration on computations like mean, standard deviation, minimum, and maximum, the statistical analysis brings in a complete description of the virtual SB's variance impact. This storyline becomes integrated with the purpose, implementation, and statistical insights derived from the Post-VR feedback to understand how VR can be used to augment sensory evaluation practices. In XLSTAT, JAR (Just-About-Right) and CATA (Check-All-That-Apply) analyses really brighten up by getting to the heart of what people find and think about different products. JAR looks into whether people feel a product's features hit the sweet spot, while CATA is like gathering a crowd’s first impressions on what stands out about a product. These tools help us change products to better fit your likes and dislikes, especially as we explore how virtual reality can change the game in sensory tests.

4. Results and Discussion

4.1.Software development

Configuration and calibration (introductory) layer:

The presentation of the samples was achieved by exposing the participants to the virtual representations of the samples which very closely mimicked the physical representation of the real samples. The interaction of participants with the samples was conducted by a user interface in VR that allowed users to look and feel samples and evaluate these based on the users' choice of parameters at a level of detail that may have been impossible if real samples had been used. All the controls to interact with the VR environment are very intuitive.

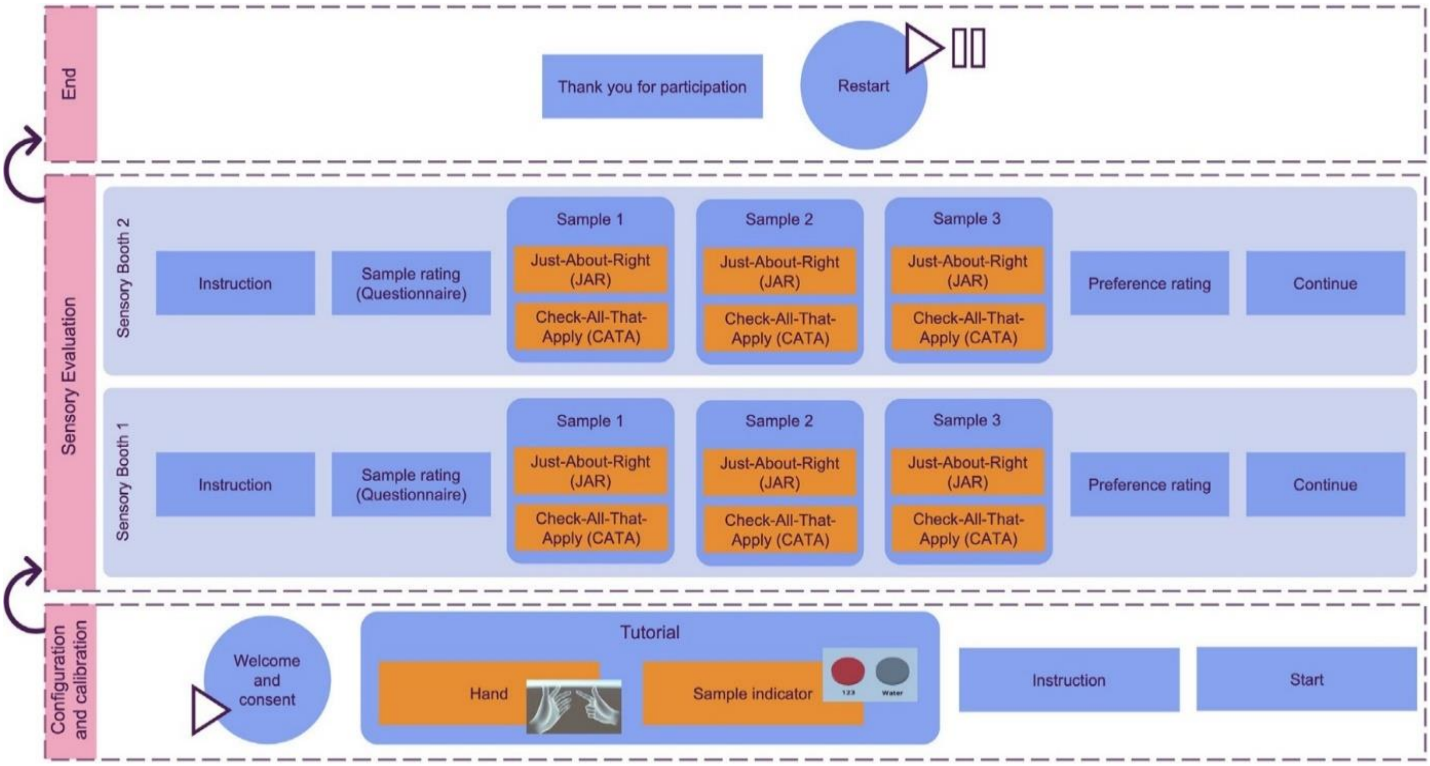

Figure 9 : Multi-layer scenes architecture for the development of virtual sensory booth (SB) application. The application consists of three main layers:

The first scene is the configuration and calibration scene. Its purpose is to calibrate the virtual sensory booth to meet the specific requirements of the participants. This includes setting the height, the distance of the sample and ensuring that the scene is sufficiently clear to be observed by the participant, given that some participants wear glasses. It also serves to calibrate the distance of the scene to the participant solely to ensure that the eye projector images line up. These tasks are required to be performed once per participant. The scene includes clear instructions and tutorials for each of the tasks. It is also the scene in which the hand interaction tutorial would start. This is particularly important as the ability to interact with the virtual SB is crucial for the participant to complete their tasks successfully. The same architecture was used as presented on Figure 9, with a difference of using virtual sensory environments instead of sensory booths.

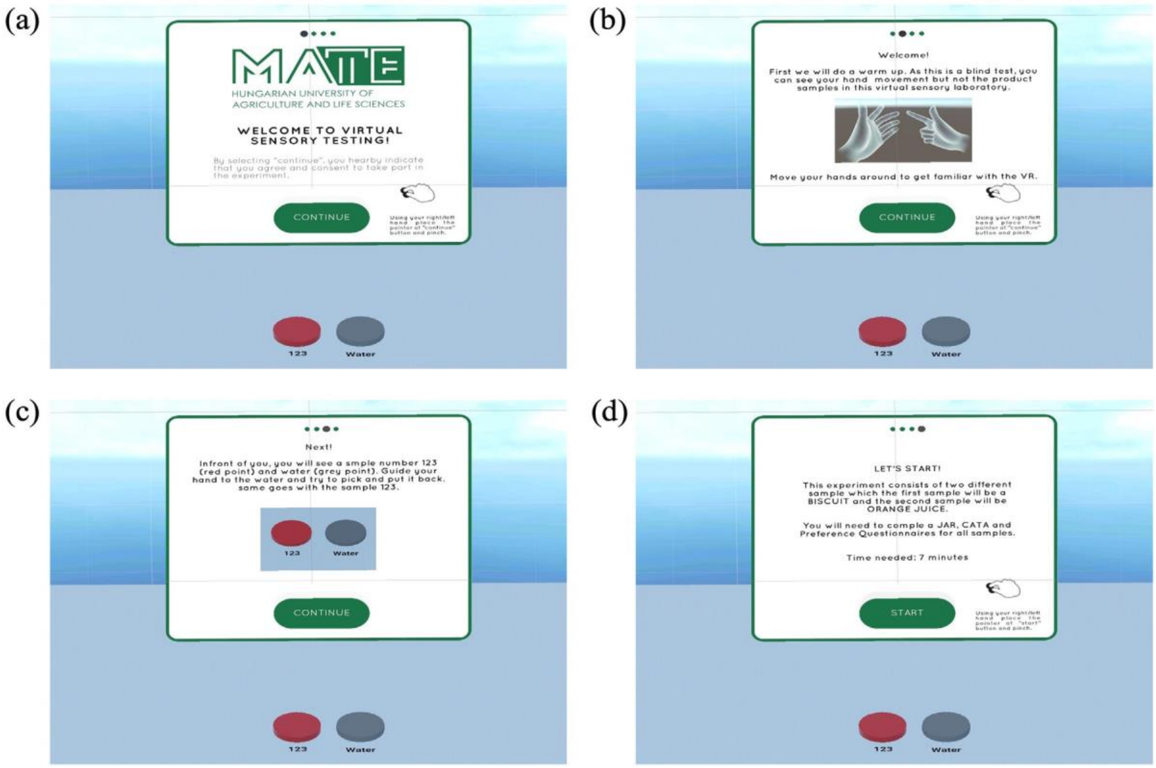

Figure 10 : Configuration and calibration (introductory) scene steps; (a) Welcome note and consent, (b) Tutorial on hand tracking, (c) Tutorial on sample indicator, (d) Sensory instruction on methods and products, and starting point.

Fig. 10 shows the scene that consists of several steps. Step 1 is ready to give a welcome note and ask for participant's consent to make sure that they understand the tasks of the experiment. Participants should click the 'Continue' button, and the following scenes will appear. Steps 2 to 4 are a part of a tutorial that is a warming-up session. It can be especially important for participants who do not have any previous experience with VR technology. Step 2 is devoted to the hand tracking. Participants need to use their hands to perform the tasks and are encouraged to follow the instructions of two animated hands that help them explore how they can interact with the environment. The Quest 2 VR headset tracks the pinching motion using two front cameras, meaning that the clicking should be done using fingers and thumb. Step 3 introduces the participants to the sample indicator. He or she can practice taking the food samples and putting them back. Such an exercise would allow the lab assistant to correctly coordinate the position of the food samples regarding the appropriate indicator. The fourth step is the final step where the instruction page appears. It provides the information about the product sample category, a method to evaluate the sensory properties, and the estimated time for the testing period. If click ‘Start’, the next scene will be displayed to the participant. It is essential to mention that the information that is displayed, as well as the images and the samples of the products, can be adjusted by the researcher using Unity software.

4.2.Sensory evaluation layer

The next layer is the sensory evaluation layer, which is the heart of the application, responsible for the two types of product sensory testing and answering the sensory questionnaire and can be seen below. In this application, both Just-About-Right JAR and Check-All-That-Apply CATA tests for each sample are provided, enabling interaction with the virtual SE. Step scenes for the product. The flow for both SE 1 and 2 is the same, and only the sample product and its attributes vary, as seen in Fig. 1. In SE 1 and 2, (figure12,13) step 1 is an instruction page Fig. 1 a regarding the type of product, pressing the “Rate” button will take the participants to the latter steps. The table shows random three-digit numbers, which indicates a different sample number on the table that is used for testing. The steps 2 Fig. 3 b and 3 Fig. 3 c in the scene SE 1 and 2 repeat alternately, where JAR questionnaire comes first and CATA questionnaire come next, which repeated for three times each of the sample number indicated in the table. Step 4 rating odour can be seen in Fig. 3 d is where preference and liking of each sample is rated using a 5-scale Likert scale to allow for differentiation of the most preferred product. Finally, in step 5, participants are being informed that the product sensory test is finished and can proceed to the next product or the end scene.

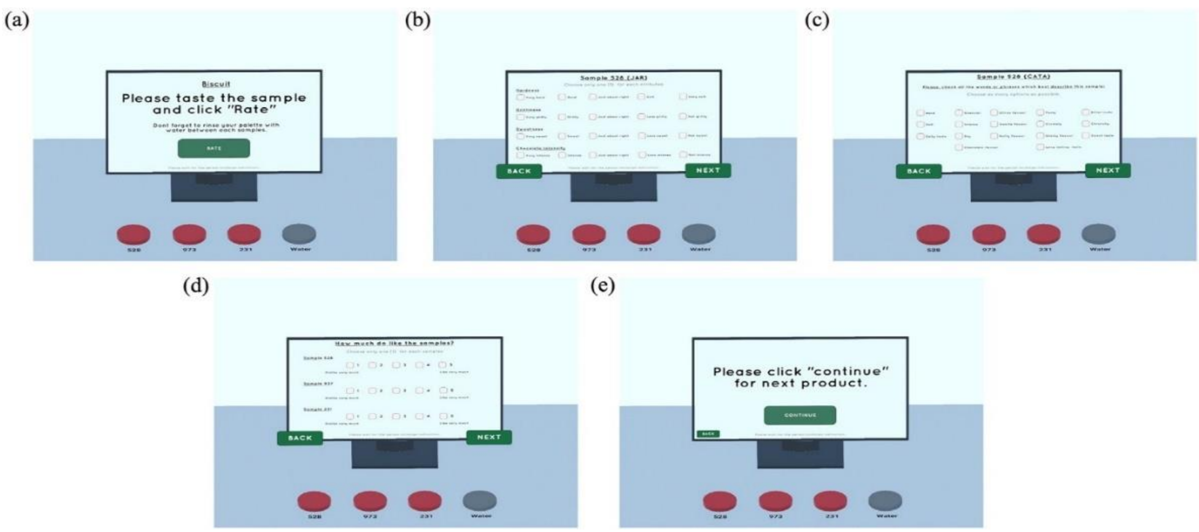

Figure 11 : Sensory evaluation booth 1 scene steps; (a) Instruction page with product sample, (b) JAR for samples (will be repeated 3 times with 3 different samples), (c) CATA for samples (will be repeated 3 times with 3 samples), (d) Preference on each

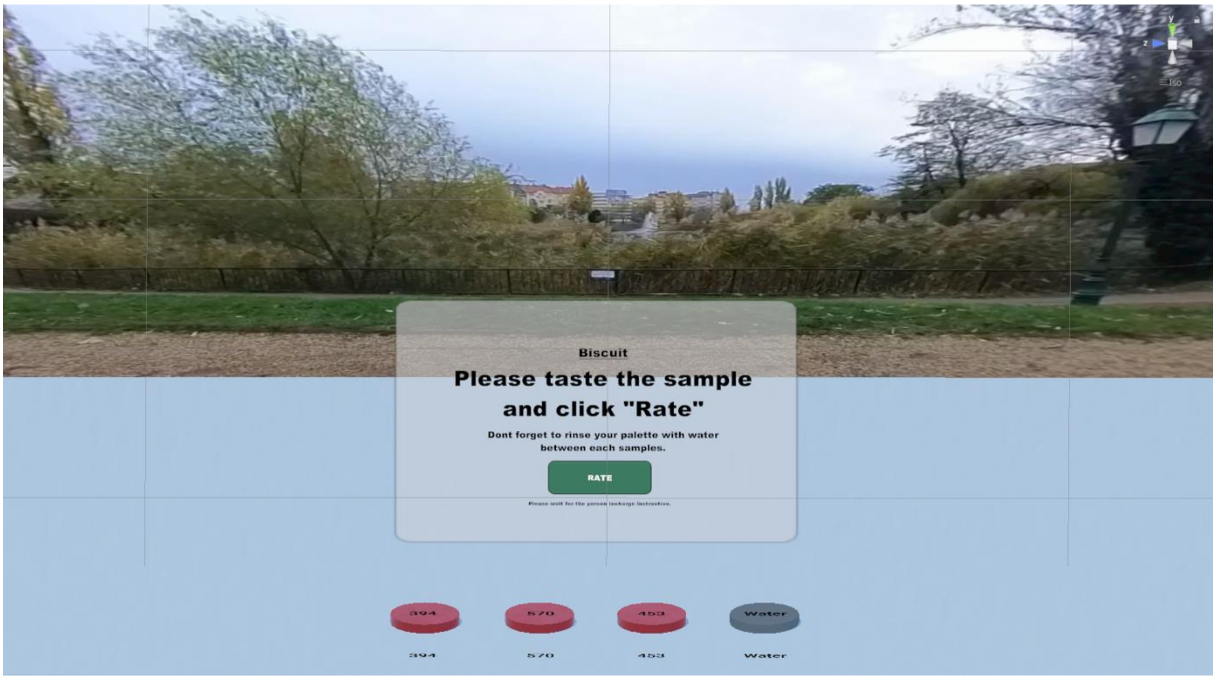

Figure 12 : Sensory evaluation environment(park) for JAR ,CATA and preference (will be repeated 3 times with 3 samples)

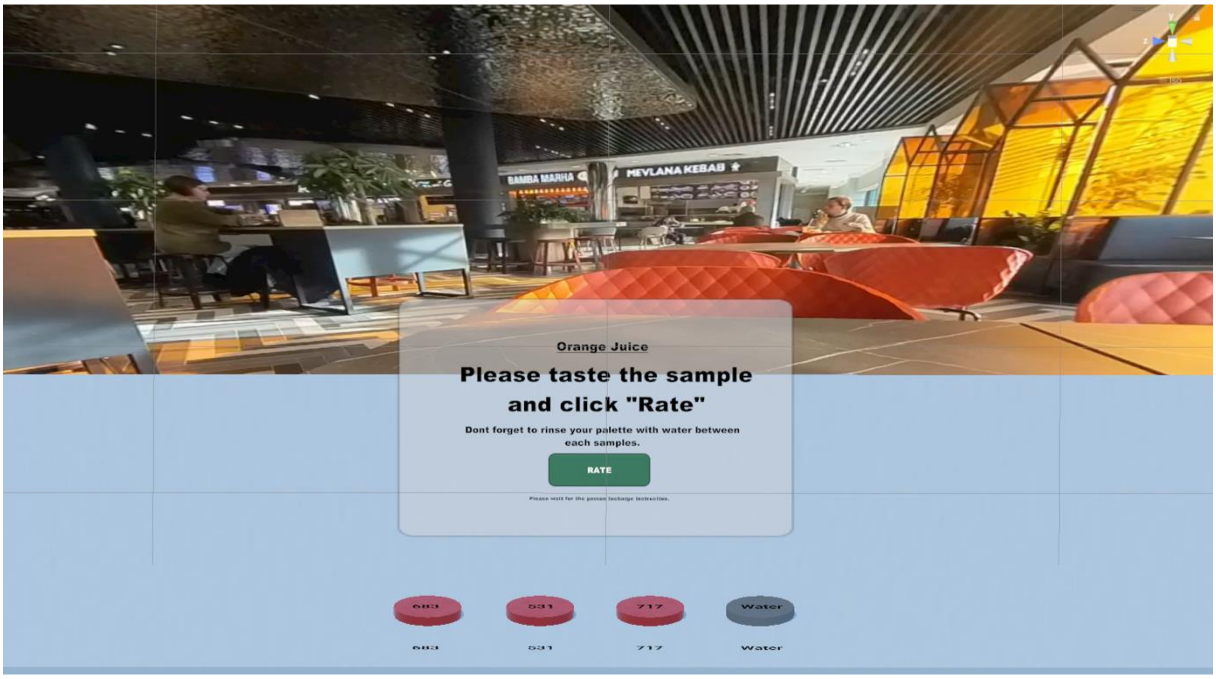

Figure 13 : Sensory evaluation environment (food court) for JAR, CATA and preference (will be repeated 3 times with 3 samples)

4.3.End layer

The fifth end scene is indicating to participants that the experiment is second and it can be started again. There are written thanks for the validation again: then we have to validate (figure 14). Clicking in button RESTART can click any employees in the laboratory and the process starts over from the beginning. It is evident that the user can modify any instructions, and may change picture in the Unity software.

Figure 14 : End scene with a restart button.

4.4.Participants

Our study included 40 participants, with 9 males (22.5%) and 31 females (77.5%), and was characterized by gender diversity in representation(table9). With the average age of the group as 25.58 years and a standard deviation of 2.15 years, the age range was largely homogenous. The group of males was older on average 26.44 years, with an age range extending from 20 to 40 years, which reveals a significantly higher degree of age diversity; the standard deviation is 6.16 years. The females had a slightly lower mean age of 24.71 years, with an age range from 21 to 34 years, and a standard deviation of 3.11 years, which reflects a narrower age range among females. Basically, VR has been experienced in the majority of 22 participants (including 5 males and 17 females), while 18 participants (4 males and 14 females) represented a relatively high proportion who were new to VR technology. Thus, the composition of our sample and the level of experience with VR technology can present a detailed picture of sensory evaluation carried out in a virtual setting to analyze how different variables, including gender, age, and prior VR experience, may modulate sensory evaluations.

Table 9 : Participants gender, age and virtual reality (VR) experience.

Gender	Number of participants	Percentage (%)	Age	VR experience

	(*n*)		Mean ± SD			Min	Max	Yes	No
Male	9	22.5	26.44	±	6.16	20	40	5	4
Female	31	77.5	24.71	±	3.11	21	34	17	14
Total	40	100	25.58	±	2.15	21	33	22	18

4.5.Comparison of JAR (Sensory Environment SE and Sensory Booth SB) Biscuit

4.5.1. sample 528 Biscuit-chocolate chip

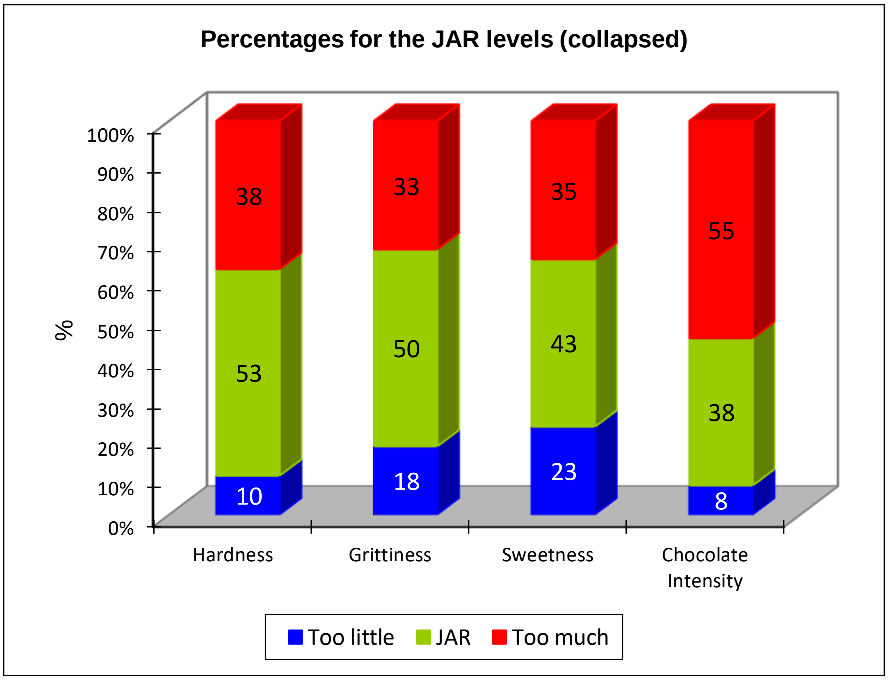

Figure 15 : Sample 394 environment

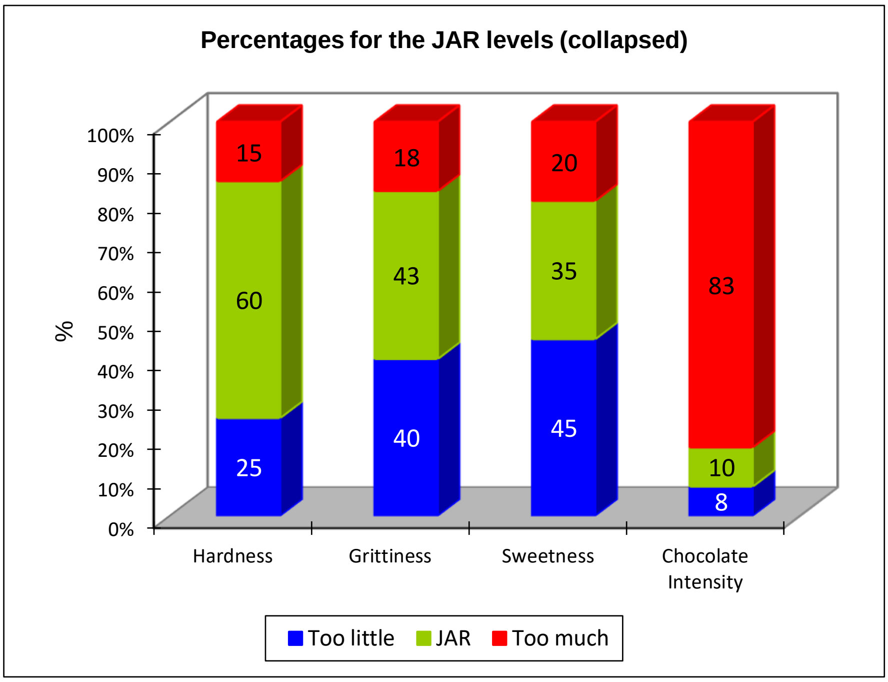

Figure 16 : Sample 528 SB

Based on both figure 15 and 16 here is its interpretation:

Hardness: Sample was given a 60% JAR rating for hardness within the controlled sensory booth, indicating that majority of the participants found it ideal. In comparison, Sample in the environmental setting received a 53% JAR rating. Almost the same but there is a slight difference here could be attributed to environmental factors that might affect the participant's tactile perception.

Grittiness: For Sample in the sensory booth, JAR ratings for grittiness came in at 43%, meaning there was less agreement on the ideal texture compared to hardness. In the environmental setting, Sample received a rise in JAR rating to 50%, which might suggest that the context may have influenced a more favorable perception of the biscuit's grittiness.

Sweetness: Ratings of sweetness for Sample in the sensory booth were JAR, as rated by 35% of participants. Sample in the environmental setting exhibited an elevated sweetness perception in the JAR rating of 43%, implying that this could have been influenced by sensory experiences that taste brings about.

Chocolate Intensity: Substantially, the chocolate intensity was rated in different ways in both samples. Only 10% of the sample was rated for Sample's chocolate intensity as JAR within the sensory booth, an astonishingly low rating. But with Sample in the environmental method getting a higher JAR rating of 38%, a significant rise in environmental setting. This large increase in the environmental setting suggests that the experience of flavor might be greatly enhanced outside the sensory booth, probably due to a more relaxed atmosphere or other sensory stimuli present within the environment.

4.5.2. sample 973 Biscuit- cacao

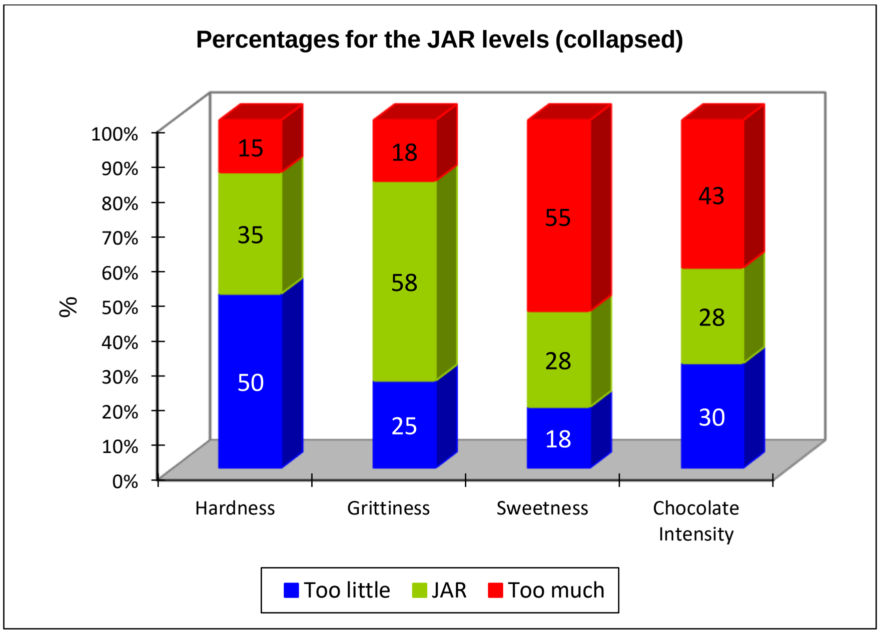

Figure 17 : Sample 973 SB

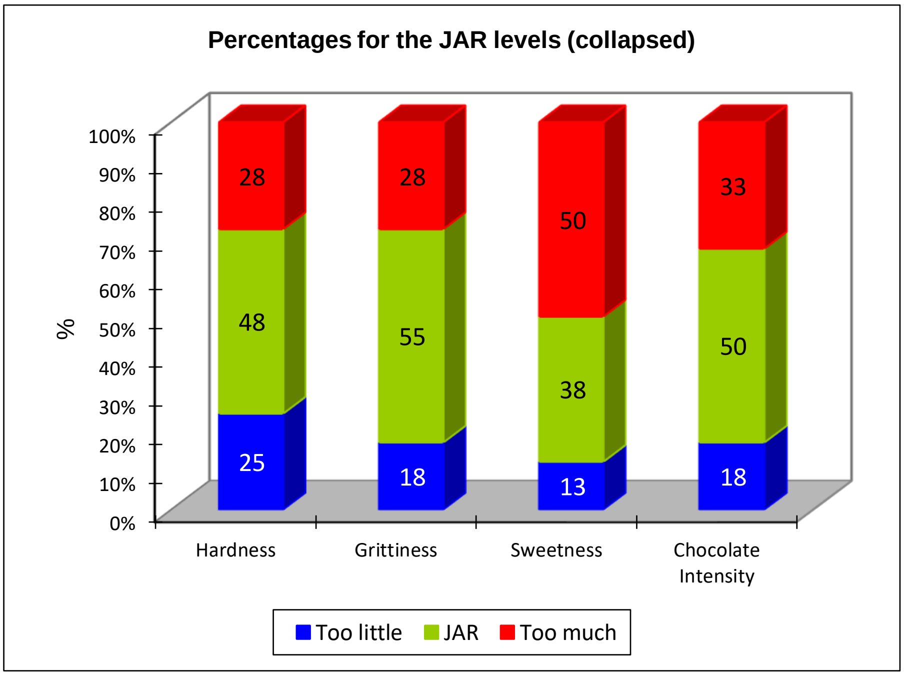

Figure 18 : Sample 570 environment

Hardness:Sample in the Sensory Booth had a JAR rating of 35% for hardness, which means a majority of the taste testers found that it wasn't just right. However, the ratings became better in the environment for Sample as it has a JAR rating of 48% by the Cacao biscuit environmental method, confirming the good acceptance of texture of the biscuit in the environment.

Grittiness: The Sensory Booth's Sample has a higher JAR rating for grittiness at 58%, which indicates a stronger agreement amongst participants that this textural attribute is ideal. Conversely, the environmental Sample showed a slight reduction in consensus with a JAR rating of 55%, indicating that even though the environment didn't dramatically impact the perception of grittiness, it minimally affected it.

Sweetness:Sample in the Sensory Booth, had a very low JAR rating at 28% for sweetness, which is really low. On the other hand, sample of the Environmental method was elevated to JAR at 38%. Perhaps an increase in JAR is being witnessed because of the effect from environmental influences on sweetness, where the increased sensory perception gets supported by environmental elements.

Chocolate Intensity: It was observed to differ remarkably in chocolate intensity, with Sample in the Sensory Booth, being JAR-rated only by 28% of participants. This, in comparison, resulted in the bright JAR increase of Sample in the Environment to 50%. Such a big difference in the environment suggests that the environmental elements add to the perception of a chocolate flavor but increase significantly to the perception of a sensory experience. These comparative percentages are reflected below and do show an influence of environmental factors. Most of the attributes appear to be held pretty stable across different environments with the exception of attributes on which the intensity will have been rated. For instance, sweetness and chocolate intensity are the two most vulnerable attributes to enhancement in the environmental setting relative to the sensory booth because of our senses possibly being heightened due to sensory exposure in the environmental setting or perhaps the environment being more relaxed so as to enhance taste(figure 17,18).

4.5.3. sample 231 Biscuit-cacao and whole grain

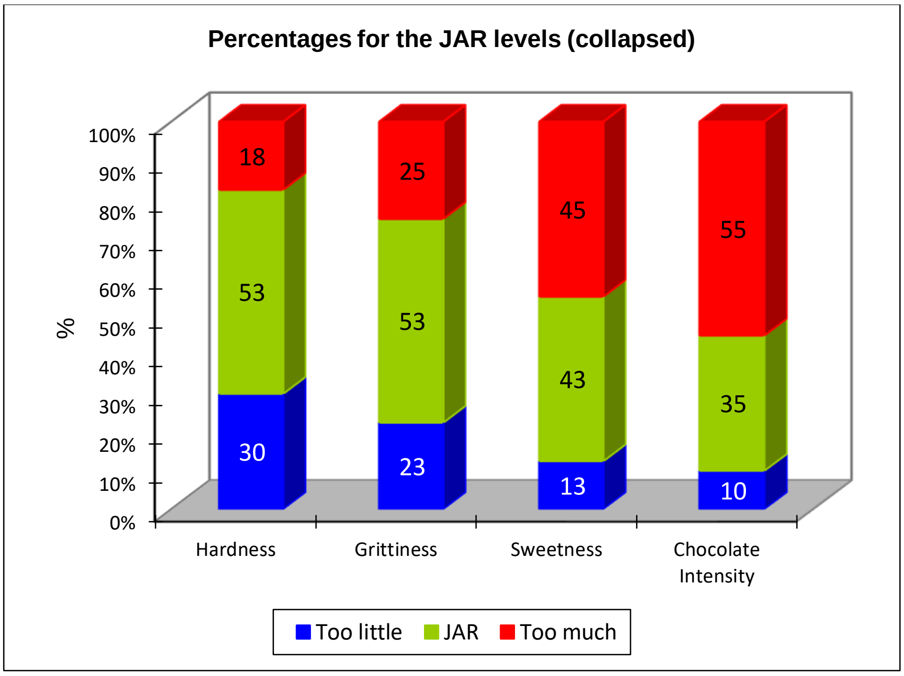

Figure 19 : Sample 453 environment

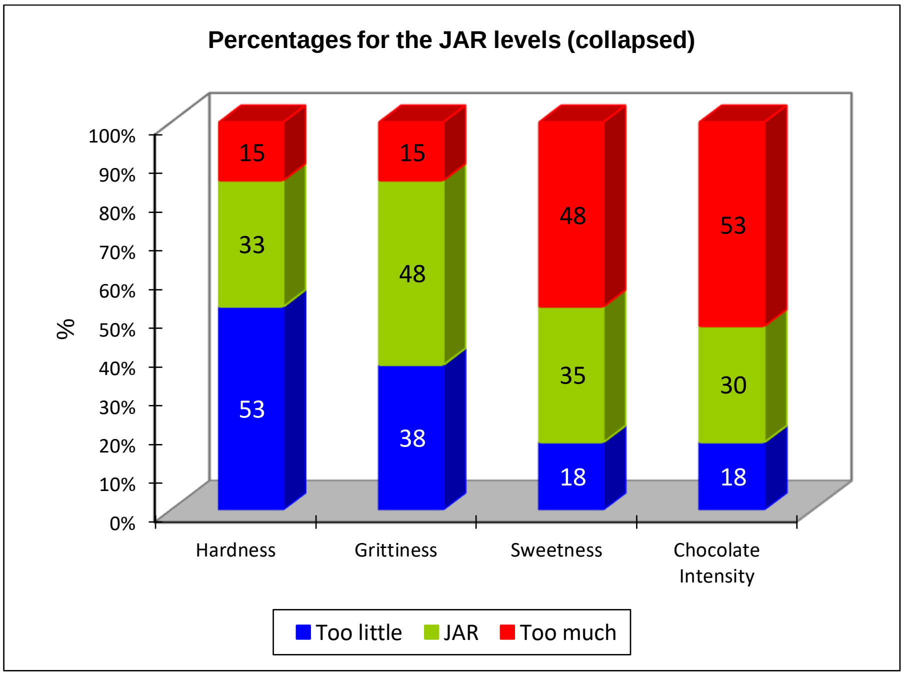

Figure 20 : Sample 231 SB

Hardness: had a JAR rating of 33% for the sensory booth, where the majority of participants did not deem the hardness optimal. There was a noticeable jump in the JAR rating of Sample from 53%, with the ambient surroundings suggesting that possibly, the environmental conditions are favorable in perception of hardness, hence the biscuit is perceived as even tastier.
Grittiness: For Sample the grittiness level had a JAR rating of 48% within the sensory booth, showing a relatively balanced perception of this texture attribute. In the environment, there was the same sort of JAR rating of 53% for Sample as they could as well consider it slightly high from a perception viewpoint towards the level of grittiness desirability.
Sweetness: For Sample 35% of participants rated sweetness as JAR in the sensory booth, with less than half of the participants saying that sweetness could have been better. In the environment, the JAR rating went from 35% to 43%, indicating that the place might have influenced the perception a little bit, bringing it to match expectations better.
Chocolate Intensity: For Sample in the sensory booth, chocolate intensity was considered JAR by 30% of the participants, a rate that implies there is room for improvement. For Sample in the environmental method, there was a slight increase in the JAR rating for chocolate intensity to 35%, an indicator that the environmental factors, not drastically changing perceptions of chocolate intensity, can make a slight difference in its perception.
Overall, the sensory evaluation of cacao and whole wheat biscuits shows the positive effect the environmental method can have on sensory attributes. This tends to increase in the JAR rating of hardness, grittiness, and sweetness moving from the sensory booth to an environment. The reason this might happen is that ambiance, some other sensory stimuli around, and the relaxed environment can bring changes or enhancements into the sensory perception of the products. Grittiness was not affected by the variations of environment, as the consistency in environmental setting shows in both the environments, while grittiness was affected by sensory attributes most significantly. While sensorial attributes such as grittiness, sweetness, and chocolate intensity are changed by environmental factors, the durability that they inherit is a feature of the environment (figure 19,20).

4.6.Comparison of CATA (Sensory Environment SE and Sensory Booth SB)– Biscuit

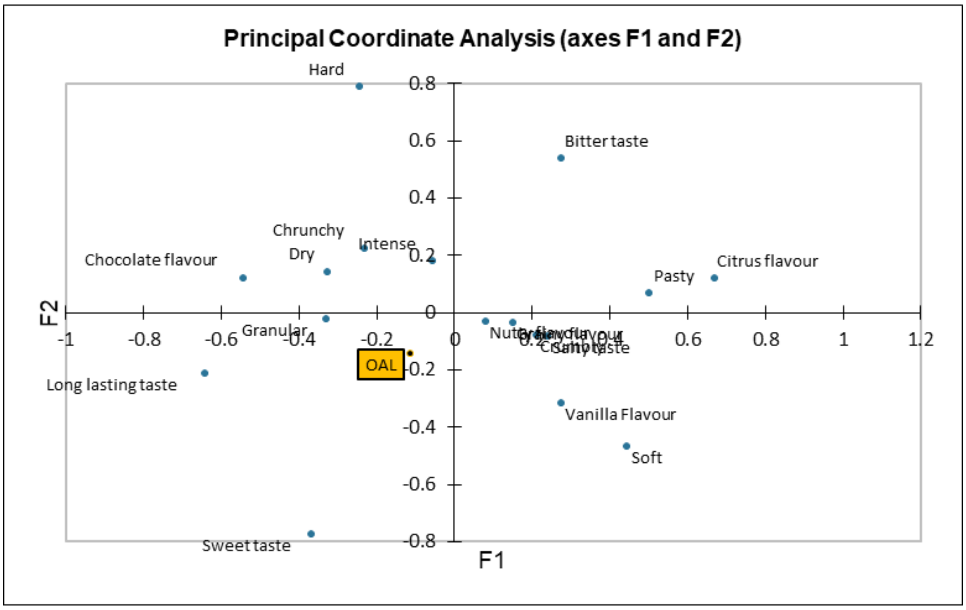

Figure 21 : CATA result for biscuit (environment)

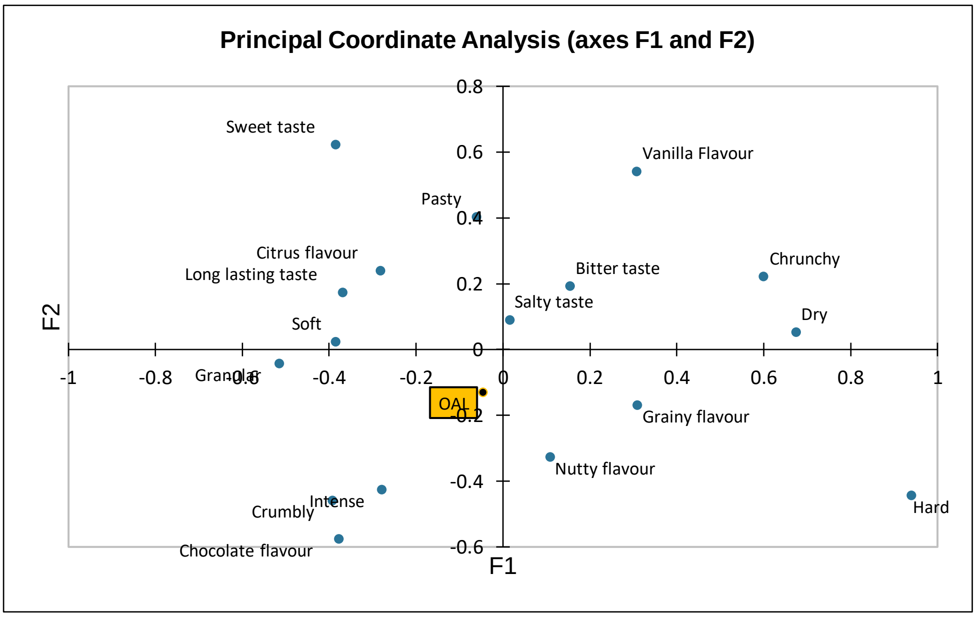

Figure 22 : CATA result for biscuit (sensory booth)

Environment Method: Hard: The negative value of F1 shows a general disfavor, but the high positive value of F2 suggests a complexity of perception. granular: The strongly positive value of F1 indicate a clear preference for the granular in the environment. Long lasting taste: Both factors point to the positive values, indicating a recognition and acceptance of bitterness. Soft: Positive on F1 but negative on F2 means the reaction was mixed regarding softness. Sweet Taste: The strongly negative values on both factors indicate that there is a general disfavor towards sweetness in the environment. Chocolate Flavor: The negative F1 with a slight positive F2 might indicate a nuanced perception, perhaps less favorable overall. Overall liking: Both values are negative, showing a less overall acceptance in the environmental setting. Sensory Booth: Hard: The very high positive value of F1 suggests that hardness is more perceived in a positive sense in the sensory booth. Vanilla Flavor: F1 and F2 both indicate a favorable perception of the vanilla flavor. Crunchy: The high positive value of F1 indicates a definite liking for crunchiness in the booth. Dry: A score as high as this indicates that dryness is significantly taken into consideration in the sensory booth. Sweet Taste: High negative values show a low acceptance for sweetness in the sensory booth. Chocolate Flavor: F1 and F2 values both point to a general disfavor of chocolate flavor in the sensory booth. OAL: The overall sensory pleasure of the biscuit in a sensory booth was found to be less accepted. Comparison and Interpretation: In comparison, the different contrast in OAL depicts that, overall, there may be lower acceptance in both the environmental setting and the sensory booth. However, the properties of citrus and crunchiness are more favored in the environmental setting and the sensory booth, respectively. These inconsistencies may be, at the very least, linked with different sensory stimuli present in each setting, which can change the way that attributes, such as texture or flavor, are perceived. The sweetness and chocolate flavor show complex perceptions in both settings, clearly indicating that these attributes have been influenced in a particular way by environmental and contextual conditions. This may indicate that products with sweetness and chocolate flavor are most susceptible to the influence of the environment and context. These results highlight the complexity in the contextual influences on sensory perception, at the same time hinting at the consideration in sensory evaluation design for certain product attributes (figure 21,22).

4.7. Comparison of JAR (Sensory Environment SE and Sensory Booth SB) orange juice

4.7.1. Sio - sample 932

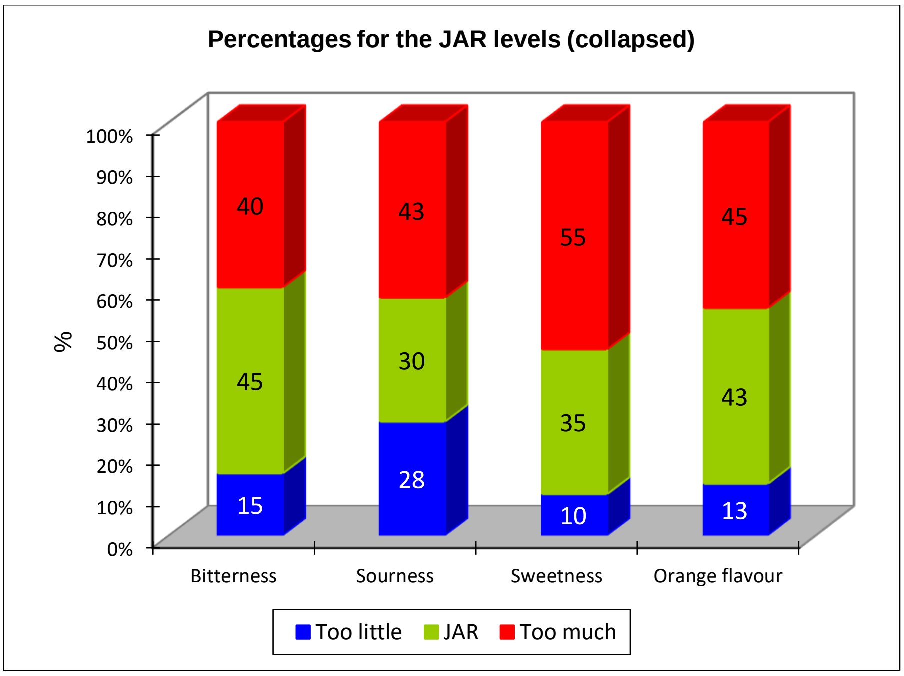

Figure 23 : Sample 683 environment

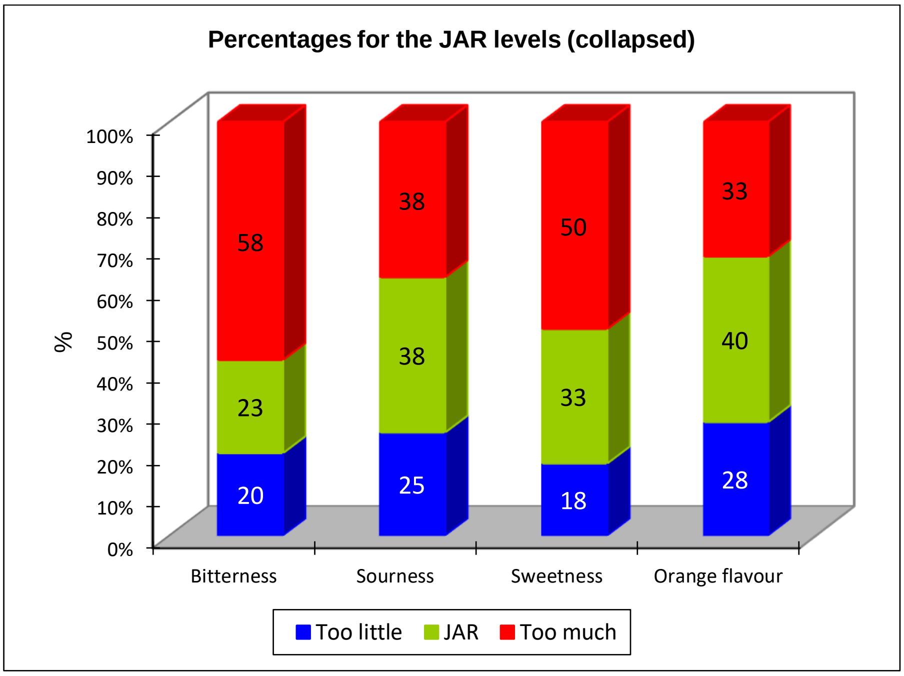

Figure 24 : Sample 932 SB

Bitterness: The Sensory Booth sample, was judged to be JAR-fied at 23% regarding the bitterness aspect. This, therefore, suggests that participants were less likely to consider the bitterness aspect as ideal. In contrast, the higher JAR rating, 45%, for the sample was in the environment. It shows that the bitterness level is acceptable, probably influenced by the ambiance of the place that may temper the perception of bitterness.

Sourness: Sample had a JAR rating for sourness in the Sensory Booth at 38%. The Environmental method decreases this to 30%, which shows that last one may have heightened the perception of sourness, though a lesser negative was given.

Sweetness: Sample had JAR ratings of sourness in the Sensory Booth at 33%. This increases when considered in the Environmental method by 35%, suggesting that the natural or ambient setting can boost the perception of sweetness, and for some participants, the orange juice will taste sweeter.

Orange Flavour Intensity: The JAR rating of sample for the taste component of orange juice was rated at 40% in the Sensory Booth. The rating increased slightly to 43% for sample in the environmental method, signifying that the surroundings may have influenced the sensory experience of the flavor, giving a more intense and enjoyably tasting orange flavor.

Conclusion: The comparison of the JAR ratings of orange juice from the sensory booth and the environmental method points out that the environment in which sensory evaluations take place can very much affect sensory perception. Bitterness and orange flavor intensity were rated more favorably in the environmental method, whereas sourness decreased, as would be suggested a possible effect on the sensory evaluations of liquid food products like orange juice. The environment seems to create a setting that enhances certain flavor perceptions, possibly due to a more relaxed and natural tasting environment compared to the more controlled and perhaps clinical environment of the sensory booth (figue 23,24).

4.7.2. Tesco - sample 134

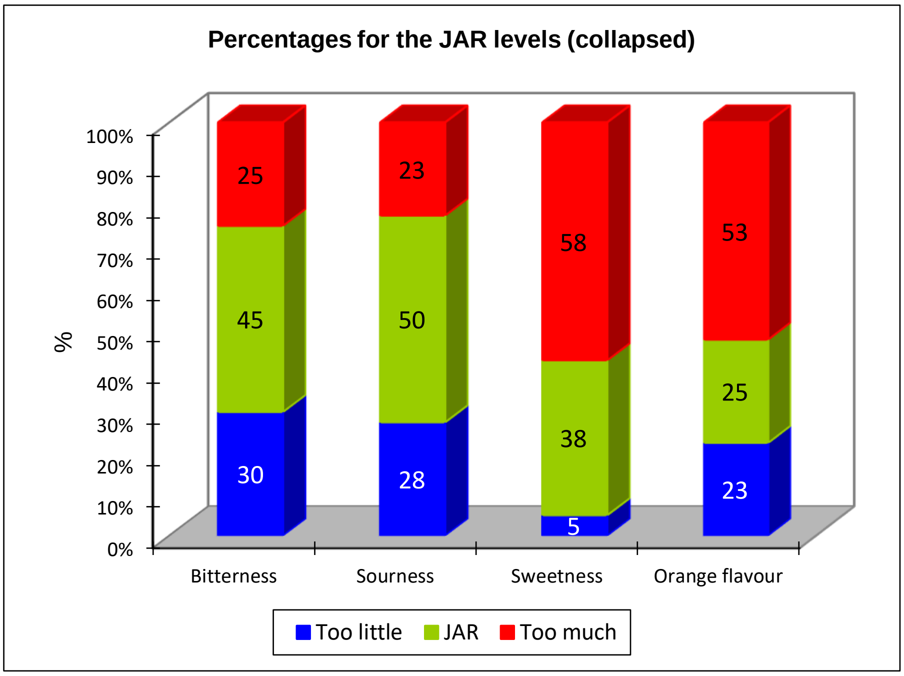

Figure 25 : Sample 531 environment

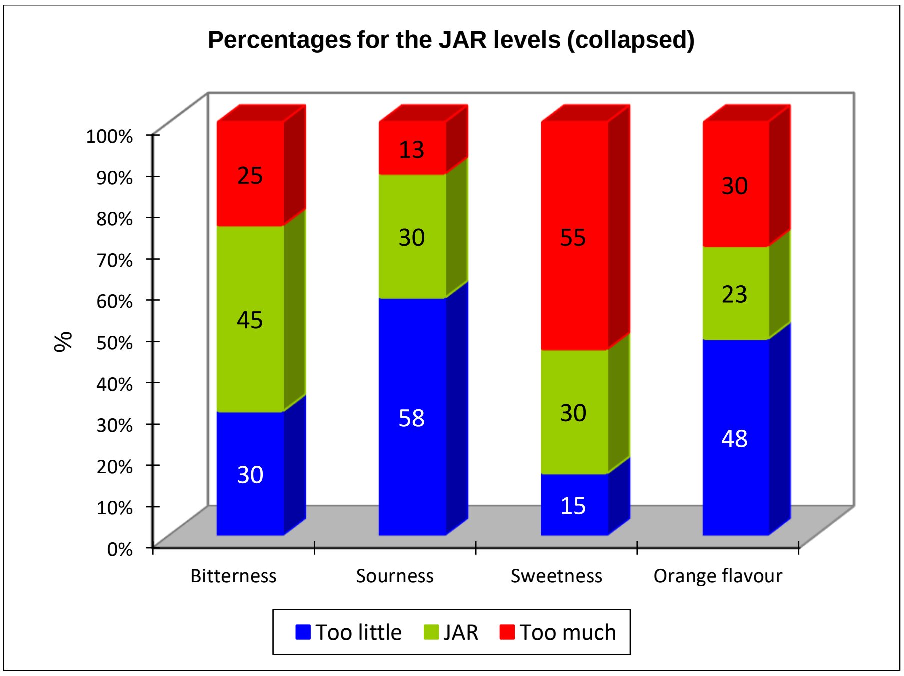

Figure 26 : Sample 134 SB

Bitterness:Tesco orange juice obtained a bitterness JAR rating of 45%, meaning more than half of participants perceived the bitterness as far from ideal. Sample also gained a JAR rating of 45% for the bitterness rating, so, JAR ratings under similar conditions remained quite constant. This implies that the perception of bitterness for Tesco orange juice is stable across both settings.

Sourness: The scoring received for sourness in Sample of the Sensory Booth was, with 30%, far removed from ideal, and most participants agreed that the sourness was off. However, Sample increased substantially, showing the lowest score of 50%, possibly revealing an enhancement to a sourness level that might concur more closely with the sensory preferences of the participants in the environment.

Sweetness: The JAR rating for sweetness in the sensory booth of Sample is 30%, to which one can infer a great deal of agreement that the sweetness could be improved. In contrast, the increase in the rating of 38% from the environmental Sample meant that there was a more favorable perception of sweetness, which may be ascribed to the sense of relaxed or natural ambiance associated with the environment.

Orange Flavor Intensity:The orange flavor intensity was given a JAR rating of 23% to Sample of the sensory booth, and the majority of the participants found it less than ideal. In the other sample from the environment, Sample, a slight increase to 25% was recorded, thereby reflecting a low evaluation yet not significantly different from that of the sensory booth.

Conclusion:JAR ratings for Tesco orange juice in terms of bitterness are found to be perceptually consistent in both the sensory booth and the environmental method. However, sourness and sweetness perceptions were in relation to the environmental method and differ substantially with sensory attributes, suggesting that such sensory attributes are influenced by factors like ambiance or other ambient elements. Sensory analyses of orange flavor intensity did not vary greatly with the ambience and can hence be deemed not influenced by environmental conditions. In summary, the results above support the view that the ambience should be taken into consideration while designing sensory tests of food products (figure25,26).

4.7.3. Happy day - sample 359

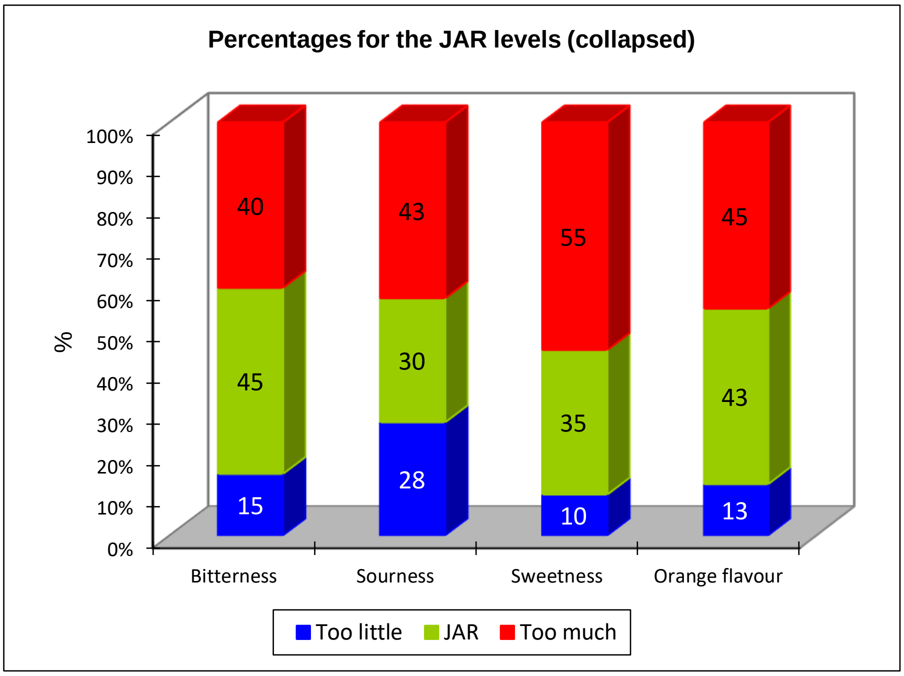

Figure 27 : Sample 717 environment

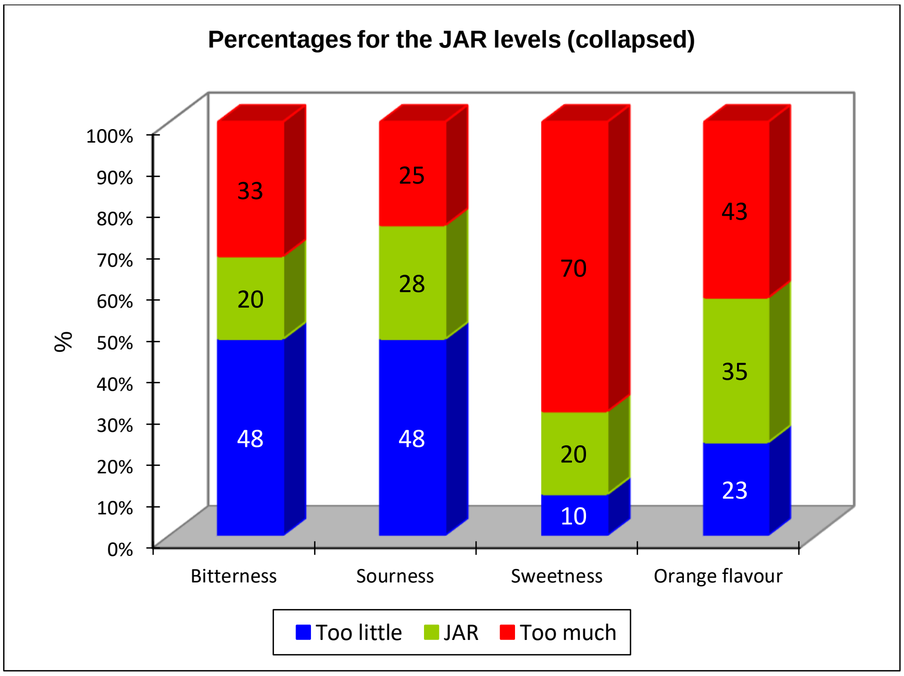

Figure 28 : Sample 359 SB

Now, let's look at the Just-About-Right (JAR) ratings for happy day orange juice, comparing the Sensory Booth Sample to the Environmental method Sample :

Bitterness:

Sensory Booth Sample :A JAR rating of 20% shows that the majority of participants did not find the bitterness ideal in the booth setting.

Environment Sample : Conversely, the environmental setting shows a significant increase in the JAR rating to 45%, showing that participants found the bitterness level acceptable or idealperhaps due to the environmental influence upon the taste perception.

Sourness:

Sensory Booth Sample : A JAR rating of 28% shows that sourness in the sensory booth setting seems to be less than ideal for most participants.

Environment Sample : There is a little increase to a JAR rating of 30% in the environmental method, suggesting that the setting might be enhancing the perception of sourness to a more favorable level.

Sweetness:

Sensory Booth Sample: With a JAR rating of 20%, it is clear that participants generally thought the sweetness level to be lacking in the sensory booth.

Environment Sample: There is a better score on sweetness with an environmental method, which is a good increase to 35%. That may mean that the setting might help to bring out sweeter juice, making it more palatable.

Orange Flavor Intensity:

Sensory Booth Sample : The participants rated 35% of the orange flavor intensity as JAR.

Environment Sample: A noticeable increase to a 43% JAR rating for orange flavor intensity is noticed in the environmental setting, indicating that participants may be experiencing a more intense and acceptable orange flavor from engaging and multisensory surroundings.

Conclusion:

Compared to the Sensory Booth Sample, in general, the factors which interact with the environment have tremendous effects on perception for different sensory attributes associated with orange juice. Given the significant difference in the JAR ratings of bitterness between the two contexts, there seems to be some relation to the ambient environment around sensory evaluation regarding bitterness. The rise in JAR ratings for both sourness and sweetness in the environmental method may imply that the setting positively influences the taste perception of these traits. The general increase across all attributes in the environmental method can be indicative that participants are more likely to rate the sensory attributes as Just-About-Right in a more natural, noncontrolled environment. This impact is pivotal in underpinning consumer preferences across different environments and has great implications for the design of new orange juice products (figure27,28).

4.8. Comparison of CATA (Sensory Booth and Environment) – orange juice

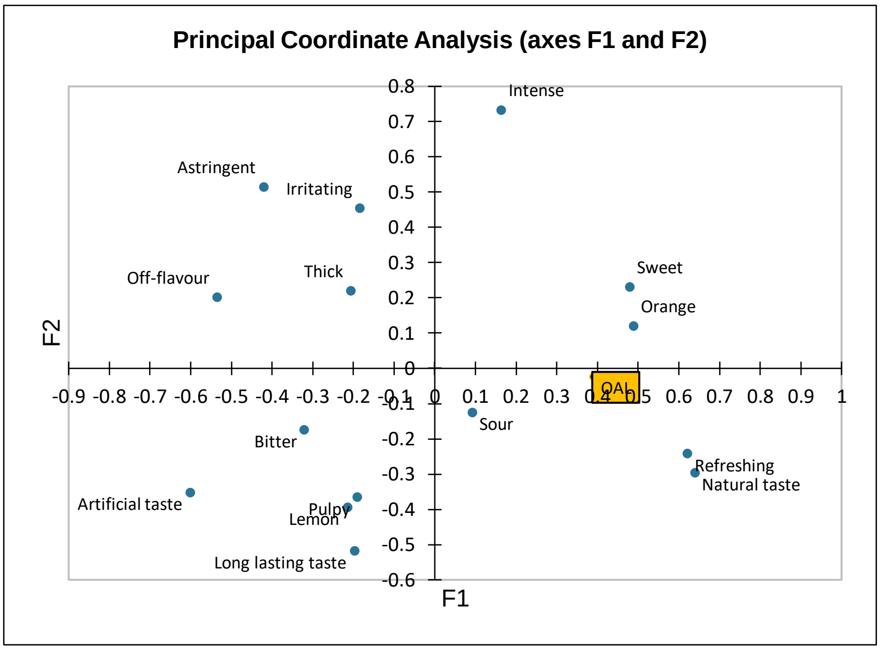

Figure 29 : CATA results for orange juice (environment).

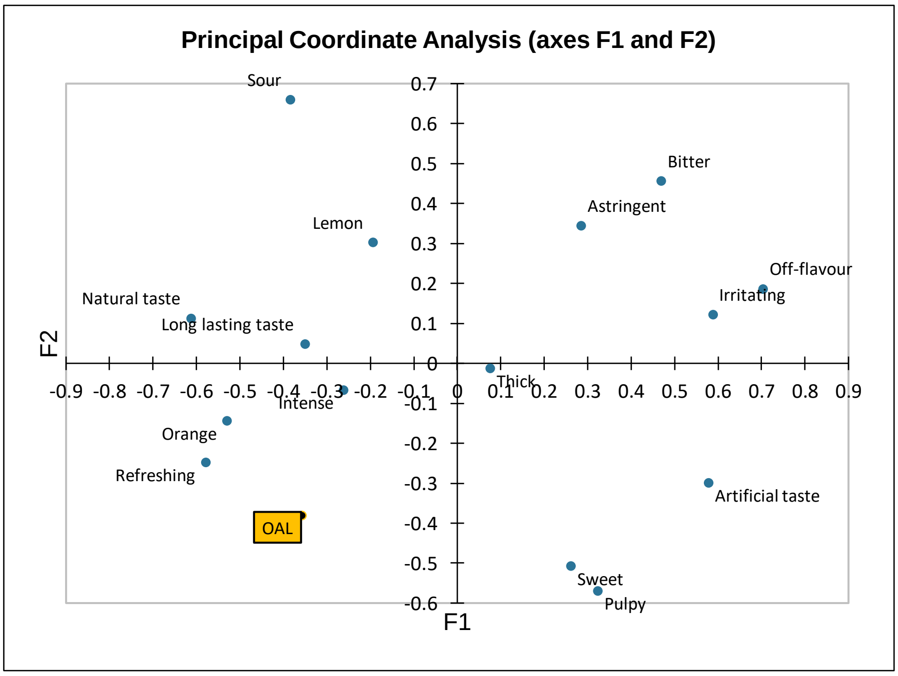

Figure 30 : CATA result for orange juice (sensory booth)

Refreshing: A positive coefficient of F1 in the environment method with a negative F1 coefficient in the sensory booth would suggest a more favorable perception of refreshment.

Sweet: This descriptor has positive F1 coefficients for both methods but with stronger coefficients, meaning the sensory sweetness of the orange juice is perceived differently in a sensory booth.

Natural Taste: Very high in the environment method, suggesting a natural setting is leading to an increased sensory perception of the orange juice.

Bitter: Distinctive between the methods, the negative F1 coefficient in the environment method and the positive F1 coefficient in the sensory booth indicate possible negativity in regard to bitterness in the sensory booth.

Artificial Taste: Negative F1 coefficients in both methods, but more strongly pronounced for the sensory booth, may imply stronger rejection of artificial taste in a controlled environment.

Interpretation of OAL:

In the Environment Method: Positive F1 but close to zero on F2 might mean that OAL is generally accepted but with slight variation between the two principal components.

In the Sensory Booth: Negative coefficients of F1 and F2 denote that overall acceptance is less for orange juice, with a possibility of more variation at the controlled environment.

Interpretation:

The Overall Acceptance Level (OAL) indicates that the participants in the environmental setting had a more positive acceptance of the orange juice. This thus suggests that environmental factors may boost the positive sensory attributes like refreshing, sweet, and natural taste, while it suppresses the perception of the negative attributes, like "bitter" and artificial taste. On the other hand, sensory booth-controlled conditions might increase the negative sensory attributes and lead to a low OAL.

These results imply that the contextual factors in sensory evaluation are crucial and that the sensory perceptions can vary with different environmental settings. The ambiance and setting of the evaluation can change not just the perception of one attribute but the whole perception of the product (figure 29,30).

4.9.Simulator sickness questionnaire

Table 10 : Simulator sickness questionnaire results (environment)

Simulator Sickness Questionnaire (SSQ) Symptoms	Score
Nausea	10.2555
Oculomotor	12.6965
Disorientation	16.008
Total Score	14.586

Table 11 : Simulator sickness questionnaire results (SB method)

Simulator Sickness Questionnaire (SSQ) Symptoms	Score
Nausea	18.3645
Oculomotor	23.877
Disorientation	32.712
Total Score	27.7695

Considering the Simulator Sickness Questionnaire (SSQ) results for the Sensory Booth (SB)method and the Environment, below is a comparison of both methods (tables 10,11):

Nausea:

In the SB method, nausea scores (18.3645) were higher than in the Environment (10.2555), indicating that participants had experienced more symptoms related to nausea when using the SB method. It might mean that some controlled aspects of the SB environment might trigger extra nausea symptoms.

Oculomotor:

With regard to the oculomotor symptoms that relate to eye movements and strain, higher scores were recorded in the SB method (23.877) compared with the Environment (12.6965). Higher scores may suggest that the SB method's greater immersion might have caused strains in the participants' visual systems.

Disorientation:

The scores on disorientation were recorded as being almost doubled in the SB method (32.712) against that of the Environment (16), meaning there was a very significant increase in disorientation symptoms for the participants in the SB method. The possible immersion could have resulted in disconnection from the physical space.

Total Score:

In terms of the discomfort overall, the scores of the SSQ, which is a summative measure of discomfort, are higher in the SB method (27.7695) compared to the Environment (14.586). This means, in general, the levels of discomfort experienced by participants through engaging in the sensory analysis in the SB method were significantly greater than those experienced during a natural environmental setting. Considering the interpretation of the SSQ score, all the scores in this comparison fall under significant to concerning, with the scores of the SB method being closer to the severe category, particularly in terms of disorientation. This shows that the needs of comfort and well-being of participants must be paid attention to when using immersive virtual environments to undertake sensory testing. It also brings out the need for further study into causes of these symptoms and possible methods to alleviate them for correct use of VR in sensory studies.

4.10. Post VR participants experience.

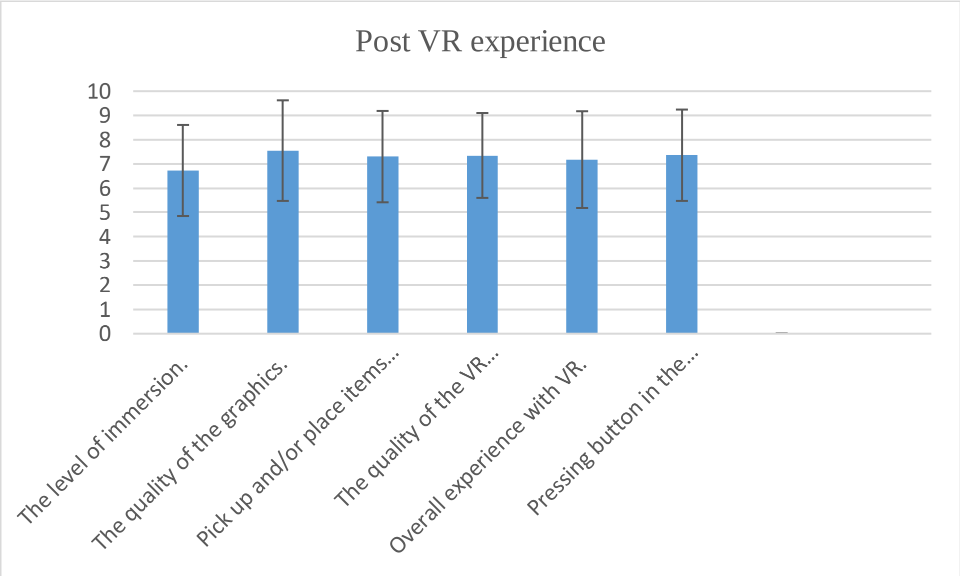

Figure 31 : VR participants rating (SE METHOD)

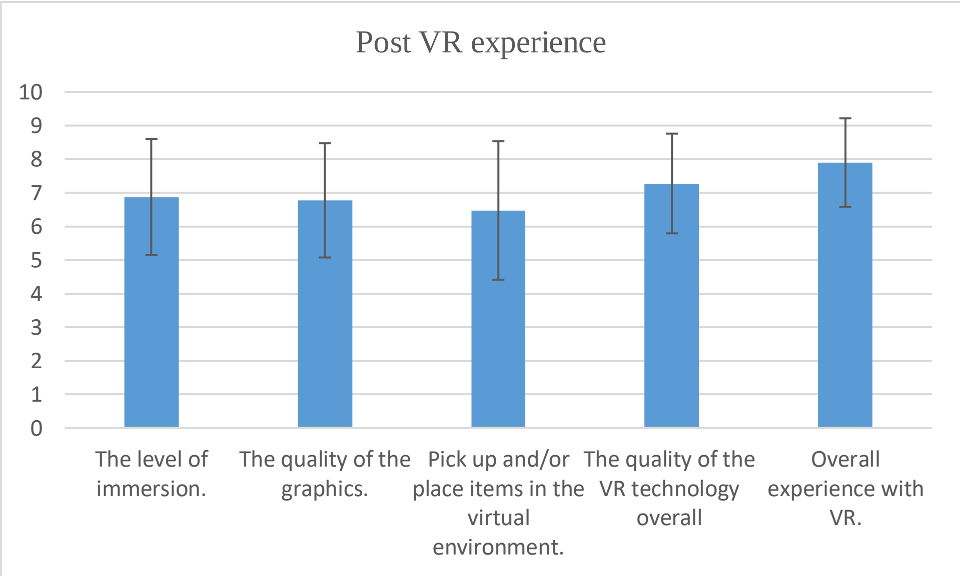

Figure 32 : VR participants rating (SB METHOD)

The majority of participant's responses in VR sensory analysis test for both sensory booth method and environment, participants portray a good expression (Fig. 33 and 34) which indicates a foreign method that is interesting and can be promising at the same time. particularly in food science technologies. A lot of people do like to notice and find cool the VR experience, making similarity to the real world.

While playing game usually much interaction people used to have. Also, nice things said.

We emphasized on the importance of such method in demonstrating usefulness and effectiveness of it and also said how the testing methods were related to people learning. Yet there was also helpful feedback that pointed out specific insight that could be done better. People who took part said they sometimes had trouble seeing clearly, which suggests that the quality of the vision needs to be improved, especially for people who wear glasses. The way real and virtual things move and interact with each other, as well as the ergonomic setup of the virtual world.

The participant had the chance to comment on their experience within the post-VR. Most of the comments were positive for both methods, SE and SB, with a slight preference for the improvement in the sensory environment. The comments were like 'it’s cool’, ‘very practical', and 'positive to use in the food industry'; however, the constructive criticism largely centered on graphic quality and blurriness.

4.10.1. Discussion and comparison

The post VR experience shows in the Methods (SB) and Environment parts of VR seems that participants mostly had a great performance with the VR technology and easy to use. But, in terms of operation, some of them had a problem, for instance, in the button pressing or item licking. In the general sense, the VR experience was rated with positive comments, which show that improving physical-virtual connection and the final adjustments should be taken into consideration. Hands on Methods and Environment ratings show a high extent of happiness from environmental immersivity, which was a little more than the interaction methods in terms of people's involvement and overall experience. It suggests the successful sensory engagement in the VR environment because the user is fully involved with the virtual world and it let's deduce the immersion in interactive elements that lead to a more natural experience for the users (figure 33,34).

5. Conclusions and suggestions

This study embarked into the innovative landscape of utilizing Virtual Reality (VR) technology within the field of sensory science. By employing Just About Right (JAR and Check All That Apply (CATA) tests in VR environments and sensory booth method, we tried to highlight VR's capabilities as a dynamic and adjustable platform for product creation and evaluation. The experiment was designed not only to align VR-based sensory analysis with traditional methods but also to push the edges of what is conventionally possible in sensory evaluation. As we aimed to evaluate two different VR environments (Food court and park) on the perception of samples to those participating in this research.

In view of results obtained from our current study on virtual reality (VR) sensory testing, it is clear that VR enhances sensory perception through the provision of an immersive and dynamic environment that, compared to traditional methods, is more engaging. The results of the study revealed that even though VR sensory testing was performed in a wide range of virtual environments, from sensory booths to food courts and parks, and appropriately provided higher stimuli, this clearly enhanced sensory perception and authenticated sensory responses.

Effectiveness of VR Sensory Testing: This research found that virtual reality sensory testing can effectively magnify perception due to the realistic and dynamic environment, hence an incredibly engaging sensory evaluation process.

Effect on Sensory Perception: The experiment indicated that cleared virtual environments, such as sensory booths, food courts, and parks, strongly impacted sensory perception. Real-life environments appear to boost the accuracy of sensory responses, with those that perfectly replicate their real-life settings.

Technological Features: The use of advanced VR technologies aided in sophisticated sensory analyses while being able to offer a variety of sensory stimuli; hence, the use of VR amplifies the scope of sensory evaluation.

Participant Response: This showed remarkable differences in sensory evaluation depending on the VR environment, hence giving an indication that an environmental setting is important in evaluation.

It also opens a new front in suggesting that VR technology not only enriches sensory testing methods but also offers an insight into how different settings influence sensory perception and consumer behavior. Our study also lighted areas requiring further improvement. The Simulator Sickness Questionnaire (SSQ) scores were low, signifying a need to address the elements contributing to simulator sickness. Common feedback from participants pointed to the visual resolution within the VR SB method and environment and the time required for individual calibration. The main result of the study is that participants in 360 video-based environments had a much better experience compared to the self-generated environment.

Future research may further the methodological and technological advancements in VR that could change sensory science into groundbreaking science in multiple domains. Further exploration will be carried out on a wider spectrum of VR environments in order to determine the range of such an impact on human sensory perception. Longitudinal studies, allowing time over to know the long-term effect and reliability of VR sensory testing in contrast to conventional techniques. Investigation on new VR technologies being developed that could bridge the gap between the real and virtual experiences. Cross-cultural studies to explore how cultural differences impact sensory perception across different VR environments can give deeper insights into the consumer behaviors of the world. Integration with biometric technologies can further extend the understanding of physiological responses that occur during sensory evaluations.

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MATE Organizational and Operational Regulations
III. Requirements for Students
III.1. Study and Examination Regulations
Appendix 6.13: The MATE Uniform Thesis /
thesis / final thesis / portfolio guidelines
Annex 4.1: Consultancy statement

DECLARATION

BOUABID ICHOU (name) (student Neptun code: AALJGT)
as a consultant, I declare that I have reviewed the final thesis[1] and that I have informed the student of the requirements, legal and ethical rules for the correct handling of literary sources.

I recommend / do not recommend[2] the final thesis to be defended in the final examination.

The thesis contains a state or official secret: yes no*[3]

Date: 2024. 04. 15.

insider consultant

[1] The other types should be deleted while retaining the corresponding thesis type.
[2] The appropriate one should be underlined.
[3] The appropriate one should be underlined.

DECLARATION

on authenticity and public assess of final essay/thesis/mater's thesis/portfolio[1]

Student's name:	**BOUABID ICHOU**
Student's Neptun ID:	**AALJGT**
Title of the document:	**Master's thesis**
Year of publication:	**2024**
Department:	**Department of Postharvest, Supply Chain,**

I declare that the submitted final essay/thesis/master's thesis/portfolio[2] is my own, original individual creation. Any parts taken from an another author's work are clearly marked, and listed in the table of contents.

If the statements above are not true, I acknowledge that the Final examination board excludes me from participation in the final exam, and I am only allowed to take final exam if I submit another final essay/thesis/master's thesis/portfolio.

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