COMFOCUS

Community on Food Consumer Science

D6.3 Guideline for measuring food choice behaviour in reconstructed and virtual environments

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Index

Index of Tables

Index of Figures

Glossary

Abbreviation	Full form
AR	Augmented reality
AV	Augmented virtuality
CAVE	Cave automatic virtual environments
DOF	Degrees of freedom
FAIR	Findable, accessible, interoperable and re-usable data
FCS	Food consumer science
FoV	Field of view
HMDs	Head mounted display
HVAC	Heating, ventilation, and air conditioning
IEs	Immersive environments
MP	Megapixels
MR	Mixed reality
PMR	Pure mixed reality
RR	Reconstructed reality
SD	Socio-demographics
SDK	Software development kit
VIMSS	Visually induced motion sickness susceptibility
VR	Virtual reality
XR	Extended reality

Executive Summary

The overall objective of Work Package 6 (WP6) is to explore alternative and behavioural measures and approaches coming from emerging technologies to explain and predict consumer behaviour. The specific objective of Task 6.3 is to document existing methods based on reconstructed and virtual environments and their relevant applications, and to harmonise the conditions under which they can be efficiently implemented. These technological applications (re)create environments, as close as possible to real environments but more easily controlled, to study contextual implications of food choices. In this deliverable, some protocols and measures are proposed in an attempt to cover as many as possible of the different dimensions that in some way are affected by reconstructed and virtual environments and the experiences associated with them.

This report consists of eight chapters. Chapter 1 provides a general introduction to contextual research emerging technologies and the structure of this report. Chapter 2 describes the process of selecting the context based emerging research approaches considered as the most relevant in FCS and the criteria used to decide on their harmonised protocols and measures. Chapter 3 discusses three immersive environments emerging technologies and their application in food consumer science studies, protocol factors that should be considered and reported in all studies involving these technologies, technological recommendations common to the three approaches, suggestions on harmonised measures, stimuli related properties and their reporting standards.

The three chapters that follow deepen general guidelines by providing immersive approach-specific information. Chapter 4 presents guideline for reconstructed reality; mixed reality in Chapter 5; and virtual reality in Chapter 6. Each of the guidelines contains immersive approach-specific information regarding relation to food consumer science, study protocols, technical recommendations, information on harmonised measures, and stimuli. Chapter 7 contains minimum reporting checklists for studies using immersive environments. Finally, Chapter 8 provides conclusions and future steps related to the development and use of this document.

CHAPTER 1

Introduction

1. Introduction

1.1 Background

Food choice is a complex process, which is influenced by several diverse but interrelated factors. For this reason, food choice has been integrated into several extensive frameworks or models (Chen & Antonelli, 2020). Most of these models distinguish between three main factors that influence food choice: the food (product), the consumer and the context or situation (Rozin, 2007). Similarly, in relation to how COMFOCUS project structures data for the measurement of constructs in the food consumer science domain, COMFOCUS Logical framework (D5.1) adheres to various principles outlined in the C-OAR-SE framework (Rossiter, 2002).

Constructs need to be conceptually described in terms of (Figure 1):

- the focal object, be it physical or perceptual; further referred to as "object"
- a dimension of judgment; further referred to as "attribute"
- the identification of the judges' or raters' entity; further "rater"

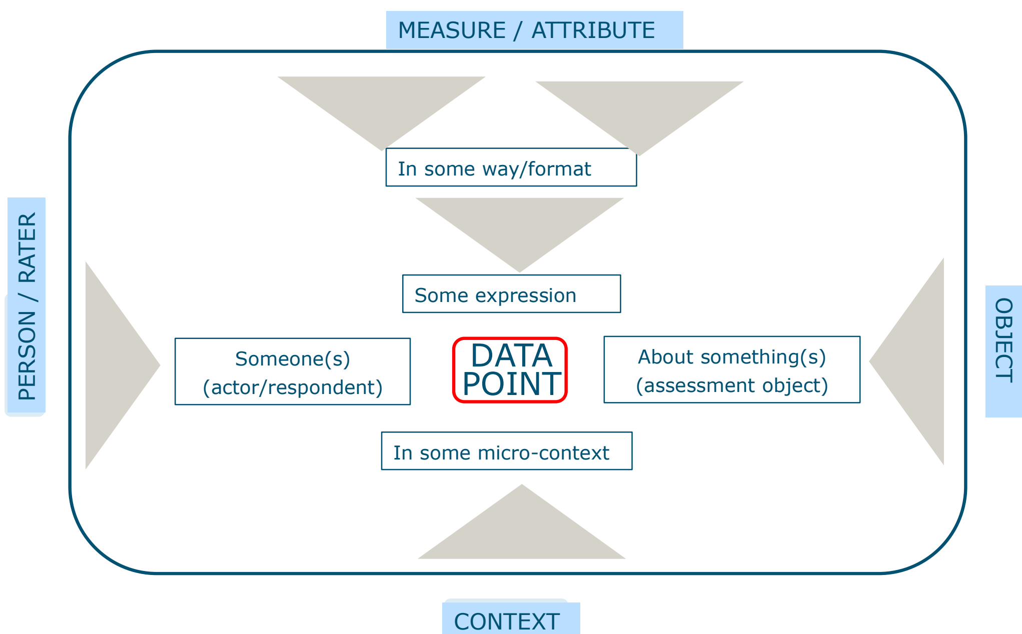

Figure 1. The COMFOCUS interpretation of the C-OAR-SE paradigm for measurement of constructs.

Build on this, COMFOCUS adds the "micro-context" component, referring to the specific context in which measures are collected. How the targeted objects (products, baskets, issues, roles etc.) are represented is crucial and can be very diverse, both in terms of their subject matter and layout.

Incorporating environmental, contextual or situational cues, referring to temporal, physical and/or social settings serve to improve test validity by considering the appropriateness of product use and the usual consumption situation (Jaeger & Porcherot, 2017; Meiselman, 2008).

Traditionally, contextual influences on consumer's food choice have been studied both in the laboratory and in natural or real environments. Laboratory-based contextual research approaches benefit from control to identify the influence of contextual variables leading to good internal validity, while observing consumer eating and drinking behaviour in a naturalistic setting favours external validity (Cardello & Meiselman, 2018).

In recent decades, new approaches have emerged to improve contextual research, overcoming traditional approaches' disadvantage by delivering better imagery and immersion. Techniques such as written and imagined scenarios evoking contexts (Hersleth, 2018) or physical and virtual immersive environments (IEs) recreating multisensory experiences (Porcherot et al., 2018), help to display contextual information creating a sense of presence in a real situation for a more complete meaning, increasing consumers engagement and validity of the responses (Crofton et al., 2019; Dong et al., 2021; Han et al., 2022).

Using consumers own imagination to evoke a context by being stimulated by means of written scenarios, images, sounds and/or scents is a versatile, easy to use and personalized technique. The results, however, remain controversial, as they are highly dependent on the appropriateness in relation to real food choice situations and the sense of reality, presence, and immersion that consumers may experience (Hersleth, 2018; Schöniger, 2022; Spinelli, 2019).

Contextual research using physical and virtual IEs to study consumer behaviour include technological applications that go "beyond reality" that can help to create settings that are difficult to execute and/or control in real life (Hartmann & Siegrist, 2019) and extend consumers' abilities and/or limitations (Ameen et al., 2021) creating interactions that are not possible in the real world (Alcañiz et al., 2019). However, apart from the technological challenges that pose its implementation, requiring a relatively large amount of costly resources and a skilled interdisciplinary research team, they are dependent on how relevant is the context displayed in relation to the consumer's personal context (Han et al., 2022) and how participants approach technologies (Crofton et al., 2019; Javornik, 2018).

In this deliverable, focused on contextual research emerging approaches, some protocols and measures are proposed in an attempt to cover as many as possible of the different dimensions that in some way are affected by reconstructed and virtual environments and the experiences associated with them.

1.2 Objective

The general objective of WP6 is to harmonise protocols for measurement and research procedures related to emerging technologies in order to facilitate the comparability across data from different studies and provide a base of protocols that will be used with different emerging technologies such as psychophysiological measures, virtual and reconstructed reality, data mining, and longitudinal data approaches.

The specific aim of Task 6.3 is to harmonise protocols and measures to assess food choice behaviour in context related studies using emerging research approaches including reconstructed reality, mixed reality, and virtual reality. A set of harmonised protocols and measures will allow collecting comparable data sets across different studies, study populations and countries.

1.3 Structure of the document

The deliverable consists of six chapters. This first chapter provides a general introduction and gives an overall picture of the purpose and considerations that have guided the work and motivated the decisions made during the process of reporting the context related research approaches coming from emerging technologies used to explain and predict consumer behaviour. Chapter 2 describes the process of how these methodologies and their harmonised protocols and measures were selected, and Chapter 3 presents a general guideline for studies using context related emerging research approaches. It provides general information, recommendations, and harmonized protocols on FCS (food consumer science) studies which plan to use them.

Following chapters, from 4 to 6 contain specific guidelines for the 3 emerging approaches: Reconstructed reality (Chapter 4), Mixed reality (Chapter 5) and Virtual reality (Chapter 6). Each is described in its own chapter as an independent methodology so that the reader can use the chapters independently. Chapter 3 presents a general overview, suggestions, technical factors (including harmonized measures) and stimuli properties to be considered across technologies and should be read no matter what technology used. Chapters 4, 5 and 6 are structured very similarly as they contain five main sections. The first section is a brief introduction to the content of the chapter. The second section provides a brief introduction to the methodology and its current use in FCS. The third section describes main factors related to study protocol that need to be considered and reported. The fourth section describes main technological factors that also need to be considered and reported. Finally, the fifth section provides information on stimuli. This means that there will be considerable overlap between the different chapters but writing them as independent units will make them more user-friendly to those who use the documents as guidelines when making decisions about which approach to use. For convenience, in Chapter 7 we provide a minimum reporting checklist that contains the factors that need to be considered and reported in a study using immersive environments emerging research approaches. Finally, Chapter 8 provides conclusions and future steps related to the development and use of this document.

This deliverable is made to work as a set of independent guidelines that can be used by researchers working in FCS. Chapters 4 to 6 will be added to the COMFOCUS knowledge platform as independent documents.

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CHAPTER 2

Method

2. Method

2.1 Process description for selecting COMFOCUS context based emerging research approaches

The process of harmonising protocols and measures to assess food choice behaviour in context related studies in the COMFOCUS community has been done in two steps. First, emerging methods on context research in FCS were documented. Second, the literature on the selected reconstructed, mixed and virtual reality environments research approaches was reviewed with the emphasis on the conditions under which they have been implemented.

Harmonising in this context means providing guidelines on best practices that would include everything from study design and selection of measures to data collection and processing. These recommended protocols and measures will be considered as priority options in different FCS studies within the COMFOCUS community. Thus, enabling generalisation, comparison and combination of datasets over studies, and deepening cross-sectional understanding should provide in the future an opportunity to follow consumers' behavioural tendencies over time. Yet, keeping them as recommendations concedes necessary adaptations when specific needs arise from differences in cultural context, needs of the research question or other such issues. Recommended protocols and measures provide a reference point for these adaptations and future developments.

2.2 Mapping and selecting the context based emerging research approaches to include

The context based emerging research approaches used in consumer food science were mapped by using existing frameworks (e.g., Milgram et al., 1994; Schöniger, 2022), scoping literature on food choice (e.g., Chen & Antonelli, 2020; Köster, 2009; Rozin, 2007) and direct input and discussions among the members of COMFOCUS community.

As starting point for categorisation, we used the "Reality-virtuality continuum", a widely adopted framework in context enhanced research, established by Milgram et al. (1994). This framework emphasizes the diverse categories of "alternative realities" that can replace temporal, physical and/or social contexts existing in real-life. The opposite ends in the continuum are purely real environments, e.g. reconstructed with physical elements, and purely virtual environments, e.g. immersion in computer-generated settings. The idea of a "continuum" provides space for a wide range of combinations of reality and virtuality within the continuum (e.g., augmented reality, pure mixed reality, and augmented virtuality) being mixed reality a commonly used umbrella term when combining virtual and real elements (Rauschnabel et al., 2022).

Next step in the work process was addressing the different methods that can help us provide contextual information for measurement of constructs in relation to targeted objects along the reality-virtuality continuum. Considering that stimulus/target representations in FCS can range from (i) decontextualised memory (as in surveys), (ii) contextualised situation (as in real life interaction with actual foods), (iii) semi contextualised (as in experimental setups), or (iv) physically/virtually recreated context, we adapted the Conceptual Framework of Immersive Environment proposed by Schöniger (2022). The recreated context conceptual framework we propose (Figure 2) is based on three main approaches: imagined, physical and virtual.

<table>
<tr><th>NON-IMMERSIVE ENVIRONMENT</th><th colspan="13">IMMERSIVE ENVIRONMENT
Reality ← → *Virtuality*</th></tr>
<tr><td>**Imagined approach**</td><td colspan="7">**Physical approach**
Physical immersion</td><td colspan="6">**Virtual approach**
Immersive virtual reality</td></tr>
<tr><td rowspan="2">Written scenarios
Evocation protocols
Imagined contexts</td><td>**Settings**</td><td colspan="4">Re-creation of physical environments</td><td colspan="4">Projection of environments</td><td colspan="4">Creation of virtual environments</td></tr>
<tr><td>**Elements**</td><td colspan="3">Physical means</td><td colspan="3">Screens</td><td colspan="3">Head mounted displays (HMDs)</td><td colspan="3">Cave automatic virtual environments (CAVE)</td></tr>
</table>

Figure 2. Recreated context conceptual framework adapted from Schöniger (2022).

Non-immersive environment approaches have been discarded in these guidelines, as it is not key regarding the vision of shared research infrastructures within the FCS community promoted by COMFOCUS. Focusing on immersive approaches, these can have three dimensions: (i) poor vs rich, (ii) physical vs digital, and (iii) static vs dynamic environments. In this guideline we will address emerging technologies in relation to physical and virtual approaches, with the greatest potential to induce experiences through sensory stimuli that create an effect of immersion, presence, and interaction (Hehn et al., 2019), attributes considered central to contextual consumer research in IEs (Flavián et al., 2019; Schöniger, 2022).

2.3 Selecting the harmonised protocols and measures for context based emerging research approaches

To develop a background document for context based emerging research approaches, the core literature was searched with the emphasis on how it has been applied in FCS studies. The databases used to search literature were Scopus, Google Scholar, and Web of Science depending on how well the studies on the concepts are covered in different databases. The literature review was mainly based on review articles or book chapters on the topic. The focus was on FCS literature, however if not relevant or available, more general literature about the methodology was used. The aim was not to do systematic reviews on the context based emerging research approaches per se, but to gather enough background knowledge on the method, and concentrate on the conditions under which they have been implemented and the measures used to assess food choice behaviour. Based on this material the COMFOCUS harmonised protocols and measures were selected as the recommendation to be applied in the future FCS studies in the COMFOCUS community.

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CHAPTER 3

General guideline for measuring food choice behaviour in reconstructed and virtual environments

3. General guideline for measuring food choice behaviour in reconstructed and virtual environments

3.1 Introduction

This guideline details harmonised protocols and standards for studies that use emerging approaches in immersive context for FCS research. In particular, it provides general information that applies to all research projects using any of the following context based emerging methodologies: reconstructed reality, mixed reality and virtual reality. It should be read by researchers prior to reading the technique-specific guidelines.

This guideline provides a brief introduction to three immersive environments emerging research approaches and discusses their applications in FCS (Section 3.2) and a look onto the attributes considered central to contextual consumer research in IEs (Section 3.3). Furthermore, it gives details on protocol (Section 3.4), technology (Section 3.5), harmonised measures (Section 3.6) and stimuli related factors (Section 3.7) that should be considered and reported in a study.

3.2 Immersive environments emerging research approaches and FCS

IEs emerging research approaches make use of physical means and/or technological applications to build environments that enhance context by generating or modifying reality (Rauschnabel et al., 2022). Research areas involved in IEs are diverse, from technology to management and marketing, there is a clear need for an interdisciplinary approach to their study (Bonetti et al., 2018; Javornik, 2018). In FCS domain, IEs have been have extensively used in the study of consumer preferences, education and behaviour change (McGuirt et al., 2020).

IEs and their associated technologies are an evolving paradigm as they evolve to generate different realities. The "new reality" terminology usually is inconsistent and incomplete, being its categorization still controversial between those concentrating on the technological aspects and those focusing on the human experience it can deliver (Flavián et al., 2019; Loureiro et al., 2019; Rauschnabel et al., 2022). Some taxonomies use extended reality (XR) as an umbrella term that fusion of all the realities which consists of technology-mediated experiences supported by a wide range of hardware and software (Shen et al., 2021; XR Safety Initiative, n.d.). Critically, Rauschnabel and colleagues (2022) in their integrative xReality framework argue that, under this categorization, mixed Reality is seen as a combination of augmented and virtual reality, lacking a specific definition, thus, "loosely and vaguely incorporated". They consider that the term XR should have a more open approach "where the X implies the unknown variable: xReality" capable of incorporating any form of new reality (Rauschnabel et al., 2022).

Most prominent IEs emerging research approaches, here placed along the reality-virtuality continuum (Figure 3), recreate the real environment but are more easily controlled, being a bridge between experimental and real-life studies of food choice behaviour. In each of these settings, physical and virtual objects are integrated at different levels (Table 1).

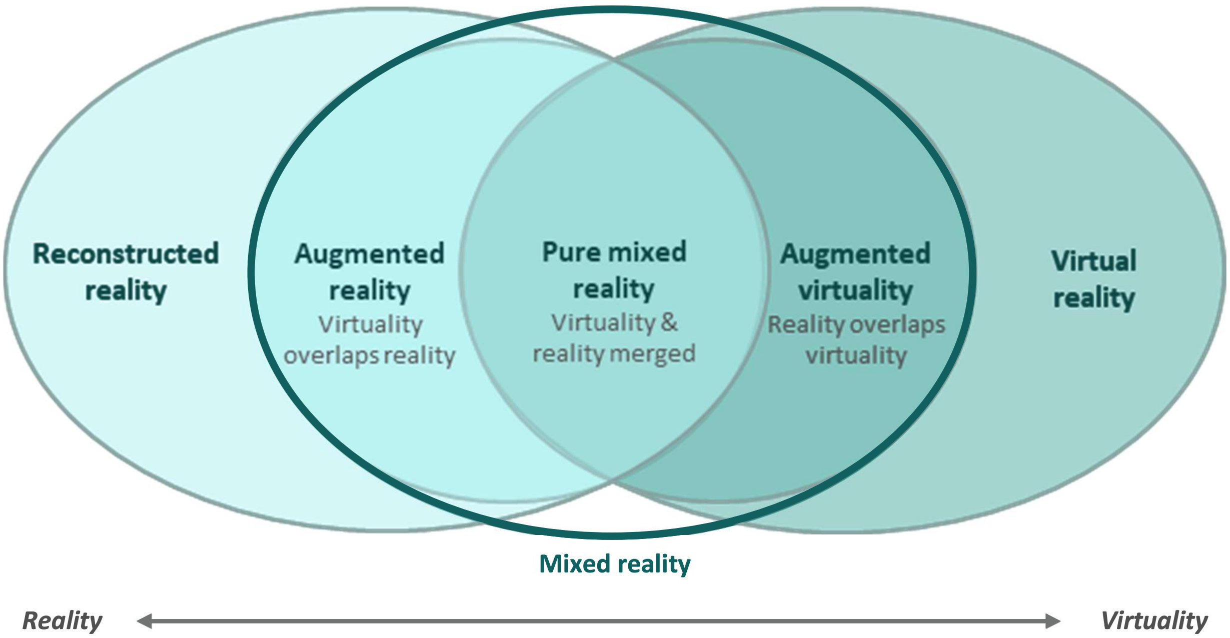

Figure 3. IEs research approaches along the reality-virtuality continuum, adapted from Flavián et al. (2019).

Table 1. Integration of physical and virtual objects in immersive environments emerging research approaches.

Reconstructed reality (RR)	Mixed reality (MR)			Virtual reality (VR)
	Augmented reality (AR)	Pure mixed reality (PMR)	Augmented virtuality (AV)	
Recreation of environments using physical elements and projections on the real world for a multisensory experience (Porcherot et al., 2018)	Computer-generated virtual representations overlaid on the real world. The user can navigate and interact in real time. AR supplements reality (Loijens, 2017; Milgram et al., 1994; Rauschnabel, 2021; Sherman & Craig, 2018)	Recreation of environments integrating the real and the virtual world, allowing interaction with both in real time, and also with each other, real and digital contents (Flavián et al., 2019)	Recreation of environments combining computer-generated world with overlapping elements from the real world. AV enhance reality (Bekele & Champion, 2019; Milgram et al., 1994)	Recreation of IEs using computer-generated elements. The user can navigate and interact in real time with the perception of being physically present in a digital world. VR replaces reality (Flavián et al., 2019; Loijens, 2017; Sherman & Craig, 2018).

3.2.1 Reconstructed reality

Reconstructed reality (RR) physically recreates and enhances real scenarios by means of auditory, visual, tactile and/or olfactory stimuli aiming to provide a multisensory experience that immerses the consumer in the environment to study contextual influences in food choice (Jaeger & Porcherot, 2017).

FCS has implemented RR using physical elements and projections on screens or walls in real-world settings. Contextual cues include furniture, projection of pictures and/or videos, and other sensory stimuli as smell, temperature, lighting, ventilation, ambient sounds or music (Delarue & Lageat, 2019). Socialization and temporal circumstances can also be part of this immersive method (van Bergen et al., 2021).

Drawn on RR, it has been possible to recreate complex immersive scenarios for observing consumer shopping, eating and drinking behaviour as supermarkets, restaurants, bars and coffeehouses under controlled conditions even (Crofton et al., 2019; Delarue & Lageat, 2019). Although is not possible to provide all elements of context, immersive experiences achieved through RR have proven to improve consumers' engagement in food choice tasks (Sinesio, Moneta, Porcherot, et al., 2019), but more research is still needed to unleash its full potential.

For a detailed description of RR, please refer to Chapter 4 Guideline for reconstructed reality in this document.

3.2.2 Mixed reality

Mixed reality (MR) has been traditionally a broad category, based on the widely adopted framework of the reality-virtuality continuum. MR encompasses the different modalities used to digitally enhance and/or recreate environments in which the real world and the virtual world are combined, allowing the user to navigate and interact with both in real time through a single user interface (Milgram et al., 1994). The experiences that can be created in MR typically target a specific segment on the continuum (Figure 4), therefore researchers need to consider the different IEs features, the resources and devices needed for implementation in order to target the subset of their interest (Microsoft, 2022).

Well depicted subsets of IEs in the MR spectrum in the literature are:

- Augmented reality (AR): is situated towards the left in the continuum, near physical reality. Users remain present in their physical reality where computer-generated virtual representations (e.g., images, videos, virtual items, textual info) are overlaid (Flavián et al., 2019; Milgram et al., 1994; Rauschnabel, 2021; Sherman & Craig, 2018). AR supplements reality with visual contextual cues, although technically it can be used to enhance all five senses (Loijens, 2017). In AR the user can navigate and interact in real time with both, the real and virtual worlds, but as virtual elements don't necessarily need to be rendered, they cannot interact with the physical world (Flavián et al., 2019). AR require specific hardware and software to operate, and typically can be displayed on stationary (e.g., magic mirrors), mobile (e.g., smartphones and tablets) or wearable (e.g., see-through glasses and head mounted displays) devices or projected onto real world elements (Loijens, 2017; Milgram et al., 1994).

- Pure mixed reality (PMR): is situated in the middle of the continuum. PMR, also known as fully mixed reality (Microsoft, 2022), can deploy immersive experiences where the real world and the virtual world are blended. Virtual elements (e.g., holograms) are indistinguishable from the physical world and, as they are rendered into the physical world, can keep a relative position to other objects (Flavián et al., 2019). This allows users to interact with both real and digital contents in real time, and with each other as well. As in the case of AR, PMR applications are mainly developed in the sphere of visual contextual cues and require specific hardware and software, being usually displayed on wearable devices (e.g., see-through glasses and head mounted displays).
- Augmented virtuality (AV): is situated towards the right in the continuum, near virtual reality. In AV the recreation of environments is achieved through the combination of computer-generated worlds where elements from the real world (e.g., real objects, live scenes of events) are overlapping, enhancing reality (Bekele & Champion, 2019; Milgram et al., 1994). Users experience a total disconnection from the physical reality around them, what could be misunderstood as a variation of virtual reality, and interaction is possible with both real and digital contents, but not with each other (Bekele & Champion, 2019). The displays used in AV systems are opaque head mounted displays which block out the physical environment (Microsoft, 2022).

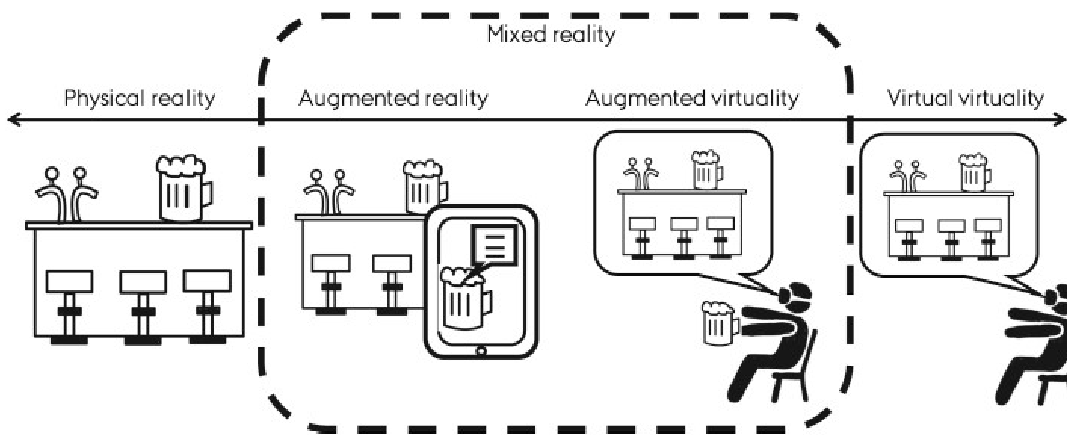

Figure 4. Reality-virtuality continuum illustrated with beer consumption as example (Wang et al., 2021).

MR has been used in FCS studies to create a wide range of immersive experiences to assess food choice and eating behaviour. AR is dominant in studies providing information (e.g., nutritional information, visual and olfactory cues, interactive menus, advertisement messages) (Crofton et al., 2019; Jäger & Weber, 2020; Koui, 2017a2017; Nakano et al., 2019), portion size control and manipulation (e.g., shape deformation, volume augmentation) (Crofton et al., 2019) and manipulation of sensory perception (appearance, luminance, colour) (Hathaway & Simons, 2017; Nishizawa et al., 2016; Ueda et al., 2020). PMR, due to its distinctive feature of interaction between users, reality and virtuality, has been used to assess the impact of context in food product evaluation (e.g., tea-break snacks, yogurts) (Dong et al., 2021; Low, Lin, Jun Yeon et al., 2021) and to manipulate eating experiences (e.g., solitary meals for older adults) (Korsgaard, Nilsson & Bjøner, 2017). The fusion of worlds that can be achieved with MR enables a balance between control and realism, improving ecological validity and participant's engagement in FCS research (Hannum et al., 2020; Low, Diako, Lin et al., 2021).

For a detailed description of MR, please refer to Chapter 5 Guideline for mixed reality in this document.

3.2.3 Virtual reality

Virtual reality (VR) uses three-dimensional computer-generated elements to digitally recreate scenarios, that replace reality. The user can explore and interact IEs in real time with the perception of being physically present in a digital world and be psychologically immersed in the simulation (Crofton et al., 2019; Flavián et al., 2019; Sherman & Craig, 2018). VR operates mainly through opaque wearable devices, typically fully immersive stereoscopic head mounted displays (HMDs), blocking 'real world' sensory experiences (Bonetti et al., 2018; Crofton et al., 2019). Other technologies that immerse the user in a digital world are the "Cave automatic virtual environments" (CAVE). These require images to be projected onto large surfaces or dome screens, and the use of glasses that provide stereoscopic stimulation in relation to what is projected onto the room's surfaces (Cowan & Ketron, 2019). As the participant can walk around a life-size room and can interact in the space, the feeling of presence is higher than in other types of VR (Jung & tom Dieck, 2018).

VR can create IEs through one or more senses, although visual and auditory experiences are prevalent, haptic technologies have been incorporated in recent years adding tactile and kinaesthetic content to the experience (Crofton et al., 2019). The inclusion of social features in virtual environments has led to the emergence of Virtual Worlds (VWs). Virtual worlds enhance perceived immersion through the presence of intelligent agents (e.g., avatars of self/others) able to interact and communicate with the user, as well as with each other (Javornik, 2016).

Consumer food behaviour has been studied in VR environments such as virtual retail settings (Jacobsen et al., 2022; Peukert et al., 2019; Schnack et al., 2019) and virtual restaurants, food courts and buffets (Allman-Farinelli et al., 2019; Cheah et al., 2020). Immersive VR environments can stimulate rich perceptual experiences with a strong sense of presence, but, at the same time, the use of headsets that block reality can cause discomfort and is considered more invasive than other IE techniques (Crofton et al., 2019; Fuentes et al., 2021).

For a detailed description of VR, please refer to Chapter 6 Guideline for virtual reality in this document.

Table 2 presents a list of research topics for which studies have used IEs in the last few decades.

Table 2. Previous applications of reconstructed and virtual environments in FCS.

Topic	RR	MX	VR
Psycho-social consumer characteristics			
Attitudes	X	X	X
Self-efficacy			X
Healthy eating	X	X	X
Environmental concern	-	X	X
Food choice motives	X	X	X
Food neophobia	X		-
Food disgust		X	X
Impulse buying			X
Restraint eating	X	-	X
Emotional eating	X	-	X
Mindful eating	-	X	-
Subjective health	-	-	X
Product & Food Experiences			
Nutrition Knowledge (Subjective/Objective)	-	X	X
Quality expectations	X	-	-
Satiety	-	X	X
Hunger and thirst	X	X	X
Product involvement	-	-	X
Food evoked emotions	X	X	X
Hedonic Response to Food	X	X	X
Situational appropriateness	X	X	X

Table 3. (continuation)

Consumer Behaviour as outcome			
Intentions	X	X	X
Willingness to pay	X	X	X
Food frequency of consumption	X	X	X
Habit	-	X	X
Psychophysiological consumer response			
Heart rate	X	X	X
Eye tracking	-	X	X
EEG	X	-	X
Electrodermal activity	X	X	X
Facial Expression Recognition	X	-	-
Consumers as agents in the food system			
Trust	-	X	X

This list is not exhaustive: it contains examples from current literature where reconstructed, mixed and virtual reality were used in combination with explicit or implicit measures investigating the particular FCS topic. More information about applications of these IEs emerging research approaches in FCS will be presented in the later chapters of this document where we focus on the specific measures.

3.3 Immersive environments attributes

When considering consumer research on IEs, aspects related to the characteristics of the user interface and their affordances needs to be considered given their implications on both, the variables of the study and the user experience (Jung & tom Dieck, 2018).

Immersion and sensory stimulation, comprising sensory modalities and quality of the simulated content, can be considered the main technological influences. Additionally, presence is related to participant's subjective condition, and interaction can be considered a behavioural factor derivative from the interaction between technology and the participant. Some of them can be correlated and all contribute to consumers' experience (Flavián et al., 2019).

3.3.1 Immersion

Immersion refers to the degree to which IEs can offer an illusion of physically inclusive, extensive, vivid and time-matching reality to the senses of a participant (Slater & Wilbur, 1997; Wang et al., 2021). Schöniger

(2022) considers immersion a quantifiable aspect concerning the objective level of sensory fidelity that a system can provide.

In IEs emerging approaches, the different levels of immersion essentially depend on the software and the displayed technology (Figure 5) that determines the resolution, field of vision, fidelity, and variety of the simulated content.

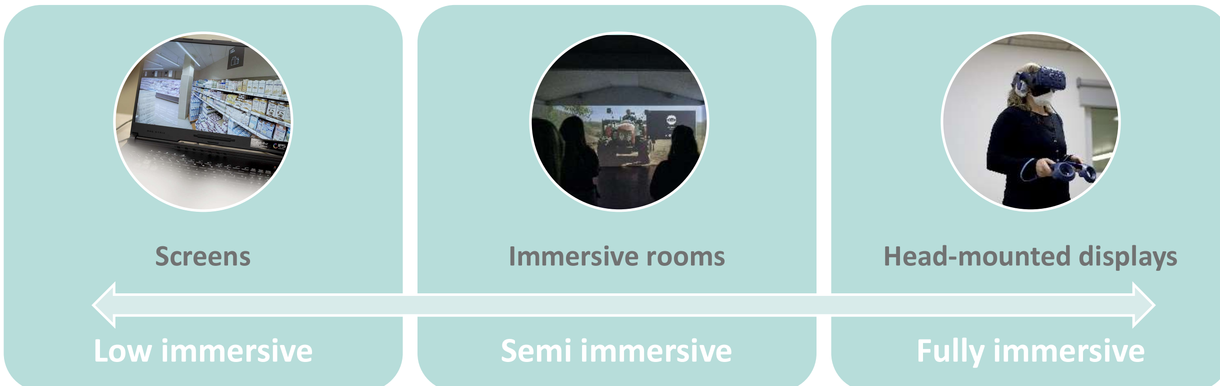

Figure 5. Levels of immersion in relation to IEs technologies.

3.3.2 Modalities of the simulated content

Diversity in relation to the modalities of the simulated content, both in terms of the range of sensory stimuli and the representation of the information presented, influences the responses elicited from consumers.

Range of sensory modalities

Due to the diversity of senses involved in food perception, the inclusion of several sensory modalities may be necessary for IEs to affect consumer responses.

The range of sensory modalities used in IEs include:

- Vision
- Taste
- Smell
- Touch
- Audition
- Balance and movement
- Body awareness (proprioception)

Multisensory integration refers to the process of combining signals from different sensory modalities (Huang et al., 2019). A wide range of sensory modalities in IEs favour immersion and improve reliability of contextual cues and presence (Huang et al., 2019; Xu et al., 2021).

Range of information representation

In IEs research media richness refers to the sensory complexity of the information presented (Kaneko et al., 2018). Consumer responses tend to be more intense when media richness is higher (Javornik, 2016).

The range of information modalities present in IEs experiences can be simplified to the following:

- Visual
- Verbal
- Audio
- Video

Psychological literature supports the merits of visual information over textual cues in terms of its impact on attitudes and knowledge, leading to higher credibility and contributing to a greater immersion. Moreover, the effect of narrative and storytelling has proven to have an even greater impact on the consumer compared to rich media without narrative elements (Javornik, 2016).

3.3.3 Quality of the simulated content

Previous research considers quality of simulated content a proxy for immersion and an antecedent of presence, both of which are related to the technological capabilities of IEs (Flavián et al., 2019).

Quality of the simulated content in IEs will depend on the nature of the research scenario, i.e. its degree of reality or virtuality, their relative quality, and the alignment between the physical and the virtual content (Javornik, 2018).

According to literature (Crofton et al., 2019; Harz et al., 2022; Rauschnabel et al., 2022), standing out factors that affect the quality of the simulated content are:

- Realism: fidelity of the simulated content.
- Vividness: extent to which digital simulated content is lively and detailed.
- Dimensionality: rendering quality of elements to form the virtual simulated content.
- Embodiment: extent to which technological devices can become an extension of a user’s body.
- Contextual embedding: how cues in the simulated content are situated and interpreted.
- Control: level of control users have of the simulated content.
- Stability: response to user’s head movements and/or virtual simulated content.
- Persistence: attachment of virtual elements to fixed locations.

3.3.4 Presence

Presence refers to the user's subjective psychological response of being in the IEs, even when one is physically situated in another environment. This feeling of "being there" consists of an internal component, participants involvement, and an external component, realism of the simulated content (Harz et al., 2022). The subjectivity related to presence may lead to different users perceiving an IEs with the same level of immersion as different as well as a single user can experience different levels of presence when being in the same IEs (Schöniger, 2022). For participants to feel present it is also important that they feel comfortable within the IEs (Wang et al., 2021).

Figure 6 shows the determinants and consequences to "presence," along with direct stimulus–response and psychological feedback to/from the user in response to their experience according to Mestre (2015) and Sherman & Craig (2018).

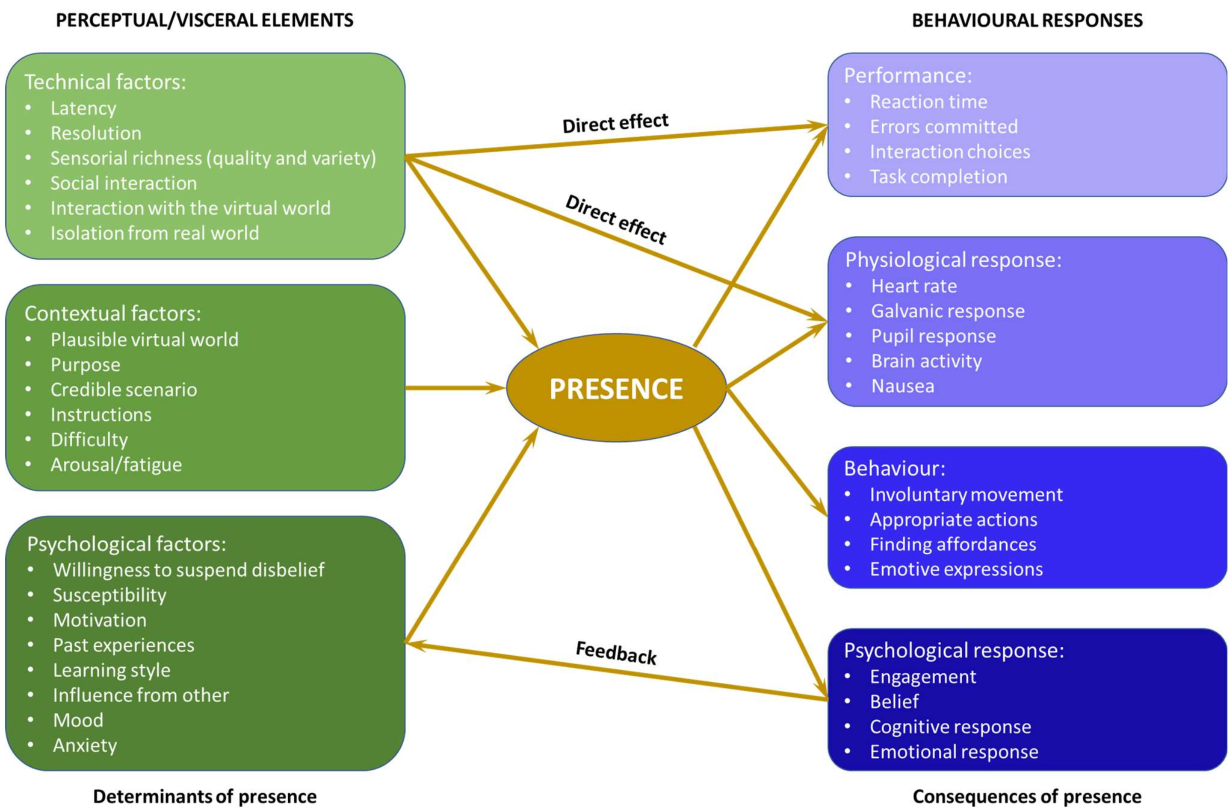

Figure 6. Determinants and consequences of presence (adapted from Sherman and Craig, 2018).

According to these authors, the factors that modulate the sense of presence in an experience can be grouped into three distinct categories: technical factors, contextual factors, and psychological factors. At the same time, the consequences of the individual experience can be classified into four different categories according to the participant's response to the stimulus provided through the selected medium.

3.3.5 Interaction

Interaction can be defined as the extent to which the user has the capacity to influence, modify or receive feedback in relation to the form, content, and the unfolding of events in IEs (Flavián et al., 2019; Meißner et al., 2020). Interaction tasks in MR comprise selection, manipulation, system control, and navigation (Papadopoulos et al., 2021), and allows communication with technology but also with other people, incorporating the social dimension to IEs (Javornik, 2016).

Interactivity addresses the psychological state of the user during the interaction. It is considered a dynamic process mainly determined by the technology used in IEs (Flavián et al., 2019; Meißner et al., 2020). Users' perceived interactivity entails both perceived control in relation to the technology and efficacy, i.e., the responsiveness of the system to the user's actions (Flavián et al., 2019).

Interaction methods between users and technologies in IEs can be summarised as follows (Bekele & Champion, 2019, p.4):

- Tangible interfaces: direct manipulation and interaction with virtual information through physical objects.
- Device-based interfaces: use of graphical user interface (GUIs) and conventional devices to interact and manipulate virtual elements e.g., touchscreen, touchpad, mouse, joystick.
- Sensor-based interfaces: use of sensing devices to perceive users' interaction inputs e.g., hand trackers, gaze trackers, speech recognisers.
- Multimodal interfaces: fusion of two or more sensors, devices, and interaction techniques allowing gestural, gaze-based, and speech-based interaction with virtual content.
- Hybrid interfaces: integrates a range of complementary interaction interfaces.

To summarise, Table 3 aims to provide an overview of IEs attributes and its characteristics in relation to the different emerging research approaches.

Table 4. IEs attribute characteristics in relation to the different emerging research approaches.

IEs attributes	RR	MX	VR
Immersion	Partial to full immersion	Partial to full immersion	Full immersion
Modalities of the simulated content	Multisensory integration	Multisensory integration	Mainly visual and auditory
Quality of the simulated content	Realistic and contextually embedded content	Variable, depending on the settings and the technology used	High technological embodiment and high level of control

Table 5. (continuation)

IEs attributes	RR	MX	VR
Presence	Sense of being "here"	From being "here" to being "elsewhere", depending on the settings and the technology used	Sense of being "elsewhere"
Interaction	Low interactivity through tangible interfaces	Medium to high interactivity through tangible and device-based interfaces	High interactivity through device-based and sensor-based interfaces

3.4 Immersive environments protocol

A study protocol is an essential element in the design and implementation stages of research. It serves a dual purpose: (1) it helps researchers to communicate their methods to a wider science community in the least ambiguous sense (thus allowing reproducibility), and (2) it aids in the implementation stage by serving as a checklist on all aspects that need to be considered and reported.

When designing a study that involves either of the IEs emerging research approaches discussed in this guideline, certain protocol factors overlap. In this section, we present the main factors to consider when designing a protocol for a study involving IEs.

3.4.1 Design

The following table (Table 4) presents a list of factors related to study design that are considered a minimum reporting level in the study protocol.

Table 6. Study design factors for studies using IEs.

Factor	Recommendations
General information	Each protocol should contain general information on study, such as information on researchers and institutions involved, as well as general facts about the study, such as research question, objective, and topic, among others.
Pre-registration	The study protocol should be created in full and then be pre-registered, this includes selection, definition, or identification of all forms (e.g., information sheet, consent form, screening forms, questionnaires), methods, analysis, statistics (including power analyses to ensure enough data will be collected)

	and data management relevant to the study. This can be accomplished through a structured registered report for subsequent journal submission (e.g., Frontiers in Nutrition, www.cos.io/initiatives/registered-reports) or through pre-registering on sites such as Open Science Framework (www.cos.io/initiatives/prereg). This incentivises researchers to think about all aspects of design at an early stage, allows input on design (in registered report) and helps researchers reading the published study know what were planned aspects of the research and which were novel to aid interpretation.
Study design	Study protocol should describe the study design in a detailed and transparent manner. The researcher should report information about study research scenario (s), manipulation(s) involved, task(s) and targeted stimuli (s) used (if any). Some examples of research scenarios quoted by Wang et al. (2021): • See context, then make product selection. • Select and interact with product in context. • See context, then evaluate product in real life. • Taste and evaluate product in context. For detailed information on targeted stimuli and stimuli related factors see Section 3.7. If the study design is informed by a pilot study, this should also be mentioned in the protocol.
Immersive approach	A detailed, clear, and transparent description of the IEs is needed, focusing on the factors that could potentially influence the variables of interest, including: • Scenario theme (e.g., supermarket, coffeehouse, park). • Type of immersion (e.g., physical, mixed, or virtual immersion). • Settings used (e.g., re-creation of physical environments, projection of environments, creation of virtual environments). • Elements used (e.g., physical means, screens, HMDs, CAVE). • Sensory input modalities (e.g., vision, taste, smell, touch, audition). • Social aspects (e.g., alone, presence of others, self/others-avatars).

Sample size	Although there is a strong heterogeneity in sample sizes used in studies using IEs emerging research approaches, we suggest determining number of participants required based on power calculations
Documentation	The protocol should include all the relevant documentation, such as various forms administered to the participants as well as copies of instructions, description of IEs and stimuli. When possible, open sharing of materials online, including IEs setting and targeted stimuli (where applicable), is highly encouraged. To allow the widest use within research community and widest readership within population, open science practices are encouraged (such as providing open data and code).

3.4.2 Sample selection

Although sample selection criteria depend highly on the research question, in general it is recommended to recruit the widest, most representative, and diverse a population as possible for the research objective to allow wider interpretation and prevent bias. To do this, barriers to participation need to be reduced where possible, and incentivisation at a level where those who are time or money poor may be able to take part. If participation in the study is incentivised, researcher should report the incentive scheme.

Participant factors that influence data

Some individual factors are required to be recorded to allow interrogation of the potential population bias in the data. For these reasons the protocol should include a detailed description of the sample. This includes any pre-screening criteria used, sample size, demographic information. When possible, participant factors should be measured by the researchers to avoid biases in self-reporting (e.g., weighing participants in the lab instead of asking them to report their weight). Individual factors need to be recorded and where possible structures put in place to allow diverse individuals to take part.

Although participant factors are highly dependent on the technology, all IEs studies should record[1] information about the participants (Table 5). As socio-demographics (SD) measures can be captured across studies and countries, COMFOCUS has proposed the means/methods through which SD can be captured in a way that will enable comparison across study populations and datasets. We recommend consulting COMFOCUS WP4 deliverable "D4.1 Guideline for harmonisation of measures and protocols linking to other infrastructure and data bases".

[1] When allowed by the National Data Protection Regulations

Table 7. Participant factors to be recorded in all studies using IEs.

Factor	Details
Demographics	• Age • Sex • Gender identity
Relation to technology	Prior experience, technological savviness and cognitive innovativeness/openness to novelty play a strong role in relation to emerging IEs participants' global experience, expectations, engagement, and wiliness to experiment (Javornik, 2016, 2018). Researchers should consider and record: • Prior experience and technological savviness can be assessed with Ad Hoc questionnaires inquiring on participants' background in relation to IEs specific technology, its propensity to use in terms of variety and frequency of usage. • Cognitive innovativeness/openness to novelty can be assessed by means of the UTAUT2 technology acceptance questionnaire (Korsgaard, Bjøner, & Nilsson, 2019)
Clinical factors	• Vestibular disorders which produce vertigo has been found to have relation with visually induced motion sickness susceptibility (VIMSS), also knowns as cybersickness in digital worlds research (Stanney et al., 2021)

Participant factors that influence safety

Some individual factors can influence safety of the technique (Table 6).

Table 8. Participant factors that influence safety in studies using IEs.

Factor	Details
Clinical factors	• VIMSS can lead to a safety risk to participants if they become physically ill, with physiological impact during the experiment and also after exposure. Outcoming adverse symptoms are disorientation, apathy, fatigue, dizziness, headache, increased salivation, dry mouth, difficulty focusing, eye strain, vomiting, stomach awareness, pallor, sweating, and postural instability.

	Depending on the IEs, 20%-95% of the participants experience some form of VIMSS (Stanney et al., 2021). Screeners as the "Visually Induced Motion Sickness Susceptibility Questionnaire" can be used prior to immersion, to assess the risk (Stanney et al., 2021). • Photosensitive epilepsy: certain types of visual stimuli used to recreate/enhance virtual contexts have the potential to elicit seizures in individuals with photosensitive epilepsy. The International Organization for Standardization (2016) provides requirements and recommendations for reducing photosensitive seizures, while viewing images on electronic displays (ISO 9241-391:2016) (XR Association, 2018).
Aversion to IEs	Beyond openness to novelty, some people can't physiologically engage in IEs as they experience a strong feeling of not liking/enjoying the experience. Screening of participants by means of Ad Hoc questionnaires inquiring on participants' for the possible aversion to IEs may be necessary.

Inclusion/exclusion criteria

Participant factors that influence safety as the VIMSS and aversion to IEs also serve as exclusion criteria. Other inclusion/exclusion criteria are usually chosen based on research question.

Please consult the IEs -specific chapters for more information on these individual characteristics.

3.4.3 Ethical factors

IEs studies must comply with local regulations as well as established ethical guidelines for research. The researcher should make sure that all ethical factors have been considered prior to carrying out the study[2]. IEs should be designed to protect and minimize participant's discomfort physically (e.g., collisions, accidents through spilling, or VIMSS) and psychologically (e.g., exclusion, confusion, stressful content, emotionally intense events), to guarantee safe, inclusive, and respectful immersive experiences (Korsgaard, Bjøner, & Nilsson, 2019; Wang et al., 2021; XR Association, 2018). In IEs it is possible to recreate stressful, dangerous or other emotionally intense events, whether real or imagined, that participants may feel as real. Considering the increasing realism of IEs, the possibilities to recreate and experiment with real and imaginary scenarios, as well as to manipulate participants, can be very important, and in some cases even more so than in real-world studies (Pan & Hamilton, 2018; Slater et al., 2020). These aspects are even more relevant when involving

[2] In most cases studies involving IEs also need to be approved by the local or institutional Ethical Committee.

vulnerable participants (e.g. participants with a specific eating disorder, Kellmeyer et al., 2019). Velasco and Obrist (2020) introduced certain questions that researchers and practitioners designing multisensory experiences should consider when evaluating the impact of the experience on users. These questions, which are also applicable in IEs, include: why (the rationale/motive for the IEs experience), what (the impression to be created in the IEs environment), when (the IEs event), how (the sensory elements of IEs), who (the person conducting the experiment) and to whom (the participant). From the answers to these questions, three laws of multisensory experiences can be developed to delineate whether a IEs experience is ethically problematic: (1) it should be used for good and should not harm others, (2) the participants should be treated fairly, and (3) the researcher and sensory elements should be known to the participants. While this is not an exhaustive framework, it can guide the process of thinking about the possible implications of a IEs study.

Since in IEs emerging research approaches it is possible to collect identifiable or special category data directly or through linked data, security (e.g., manipulation of the visual output or capture of the input by impostors) and privacy (e.g., collection of user's data without prior consent) must also be considered (Rauschnabel et al., 2022). The data management plan should ensure that protection from impostors and privacy measures are taken. Participants need to be informed about the potential risks (if any) and be assisted and instructed beforehand on how they should behave during the experiment and to become comfortable to IEs it (i.e., training, familiarization, etc.). Participants should be informed also about their right to withdraw. The novelty and time taken for setup may make participants less likely to withdraw despite the discomfort experienced, therefore researchers need to actively check whether participant feel alright as they proceed through setup and explaining what is going to happen during the study. Moreover, all researchers involved in the study need to be trained how to prepare the setup for the study, this will ensure that setup time is not too long, good hygiene standards are kept, and participants experience minimal discomfort. This will also ensure internally valid and good quality data. In some cases, data collected can also be used for potential diagnostics (e.g., when using embedded sensors). The information sheet should specify if the equipment is for research purposes only. Additionally, it is important to note that FCS researchers are not qualified to diagnose, even in the case of medical devices. More specific procedures (e.g., ask participants to check with medic for suspected abnormality) could be considered dependent on experimental setup. Such information – explanation of complex methods and potential risks, data collected, data storing and interpretation - should be provided in the participant information sheets, while agreement to participate in the study should be collected via informed consent forms (which can be collected digitally or in person). The researcher should not proceed with any other forms (such as gathering demographic data, using screening questionnaires) unless consent is obtained. We recommend consulting COMFOCUS WP8 deliverable "Literature Review on Ethical, Legal and Social Issues (ELSI) relevant to COMFOCUS: A conceptual framework for Responsible Research and Innovation (RRI) for more information on ethics in FCS studies".

3.5 Technological factors

When designing the study with IEs emerging research approaches, technical factors that influence data collection, quality, and analysis can be divided in three areas: (1) equipment factors (such as hardware, software, interface features, etc.), (2) set-up factors (such as temperature, humidity, etc.), and (3) data (such as variables, data management, etc.). As discussed in the section on study protocol, inconsistent reporting, and lack of transparency in methodological details hinders replicability and comparability across studies.

In this section, we present general technological factors that can have an impact on data collected (Table 7); however, we strongly suggest researchers to aim for maximum transparency and detail when describing the technical factors related to the IEs technology used in the study.

In relation to hardware, we also recommend first and foremost to follow user manuals supplied by the respective technology providers as the information presented in this section might not reflect the most up-to-date technological possibilities.

In relation to software, different solutions can be found in the market to enable IEs. The software required will highly depend on the research approach, either RR, MR or VR. Some companies build and market their own products and deliver a standard toolbox for IEs experiences, other options provide IEs software custom services. Open-source software platforms for virtual and augmented reality are also available. Another possibility is to create an in-house solution, which will require expert/trained staff.

Table 9. Technological factors that influence IEs.

Factor	Details
Equipment factors	In many cases, data obtained depends highly on the hardware, the software and other interface(s) used. • Hardware: is used both to display contextual information to the participant (as an output interface, e.g., projectors, screens, smartphone, tablets, speakers, HMDs) and to track the participant's behaviour in the recreated context (as an input interface, e.g., motion and orientation trackers, hand position and touching interactions sensors, voice/sound recognition). Detailed information about the hardware used should include make, type, and version as well as serial number and setting used (e.g., resolution, frame rate, sampling rate).

	• Software: can be also used twofold, to present the IEs to the participant (e.g., IEs modelling, rendering system, synchronisation/ trigger system) and to interact with the IEs (e.g., navigation system, rating/response measurement). Researchers should describe make and version of the software used together with any intrinsic data processing (including defaults). • Other devices: if another device is used to present participants with stimuli (e.g., visual, auditory, tactile, olfactory, gustatory) sufficient information must be given to allow replication by another researcher. For instance, if a scent delivery systems or olfactory display is used to incorporate odour to the IEs the air pressure, air flow rate and duration of the pulse should be reported. For studies that use equipment which is not commercially available, researchers should provide maximum level of detail about the device.
Set-up factors	Study set-up also influences the quality and type of data obtained. In case of IEs research, these factors can be of different nature: targeted contextual cues used to recreate the environment, which make up the variables of study, or non-manipulated environmental factors (e.g., temperature, humidity, noise) of the setting where the study takes place. Targeted contextual cues should be considered as stimuli in IEs studies. All recreated or simulated content that may potentially generate a reaction in the participant should be reported, described in a clear and transparent manner, and controlled. Environmental factors other than targeted contextual cues must be congruent with the recreated environment and kept constant across subjects to avoids unwanted physiological reactions to external, non-experimental, and often unrecorded stimuli.
Data	In many cases, IEs observations allow extraction of multiple measures and the choice made will usually influence the interpretation. The researcher should choose and, ideally, pre-register data related factors such as measures and variables used, as well as the analysis performed before the study is conducted.

	Researchers should also be aware that the measures chosen for the study will affect the interpretation of results and, most likely, will have some caveats. Moreover, some measures can be highly correlated with each other. The methodology used for constructing variables of interest should be described in such detail that analysis replication would be possible by another researcher solely from the explanation reported by the researcher. Each protocol should include a data management plan, that would contain information on data collection (data types), storage (organisation, metadata and documentation), security (backup, access, security), sharing, preservation and responsibilities[3]. Moreover, each variable should have a clear recording and/or analysis timestamp to allow comparisons between observations. In particular, reporting for how long a measure has been recorded, indicators for when it started and finished and whether the whole length of it was used for the analysis. Data processing, set of steps and techniques used to clean, organize, transform, validate and prepare data for analysis, will depend on the measure chosen. Reporting data processing procedures is also very important for transparency and reproducibility.

3.6 Harmonised measures

Although the precise selection of variables depends on the research question, it is the inconsistencies in data reporting, naming and analysis that hinder comparability, replicability, and reproducibility efforts. Thus, to facilitate harmonization of results from different studies, researchers should provide detailed description of the measures used in the studies and their related properties.

In IEs research measures of interest can be diverse:

- Behavioural measures captured by observing the participant.
- Self-reported measures obtained through surveys, questionnaires and interviews.
- Psychophysiological consumer response measures captured by emerging technologies.
- A combination of the aforementioned typologies.

[3] An example of a data management plan can be found at https://www.surrey.ac.uk/library/open-research/data-management-plans or https://dmponline.dcc.ac.uk/.

In this deliverable we will focus on consumer behavioural measures and self-reported measures. Regarding the latter, surveys, questionnaires and interviews included will concentrate on consumer immersive experience. For other psycho-social factors we recommend consulting COMFOCUS WP4 deliverables for more information on other self-reported measures in FCS studies, and COMFOCUS WP6 deliverable D6.1 Guideline for measuring psychophysiological responses for more information on psychophysiological measures.

Chapters 4, 5, and 6 will detail guidelines on IEs technology-specific variables naming, calculation, and reporting where these exist.

3.6.1 Consumer behavioural measures

Behaviour measures can be any behavioural output that can be seen as a motor reaction to external stimulation (Dijksterhuis et al., 2022).

In IEs consumer behaviour can be assessed with custom measures depending on the research question and emerging approach selected, among others:

- Displacement metrics (e.g., total displacement distance, direction of the displacement).
- Gaze-tracking metrics (e.g., direction of the gaze, total time looking at an object).
- Hand-tracking metric (e.g., number of objects picked, number of objects dropped, number of times an object is picked/dropped, total time of an object on the hands).
- Bodily interactions metrics (e.g., Interpersonal Distance (IPD), time to reach maximum IPD).
- Time-based metrics (e.g., total time to complete the task, time spent in a concrete area).

3.6.2 Immersive experience quality measures

In addition to the variables under study, participant's experience should be measured after the completion of the immersion as it can have impact on the reliability and validity of the results. The quality of the experience can be rated through self-reported standardized questionnaires as the presented in Table 8.

Table 10. Harmonized measures for studies using IEs.

Factor	Details
Contextual appropriateness	Assess the degree to which foods can be considered congruent with, or suitable for, a specific time, place and/or person (van Bergen et al., 2021) • *Appropriateness scale,* a 7-pt scale (1 = not at all appropriate, 7 = extremely appropriate) that rates how appropriate is eating/drinking a product in a specific IE

	• *Perceived food-context congruity rating* assesses whether a product is contextually congruent/incongruent in a given IEs
Engagement in IEs	Consumer engagement in an EI can be expressed through a variety of cognitive, affective, and behavioural manifestations (Violante et al., 2019), thus multiple dimensions/factors are often used to rate it. Engagement in IEs questionnaires found in the literature, among others: • *Engagement Questionnaire* by Bangcuyo et al. (2015) consisting of 21 items to grasp participant's experience categorized in eight dimensions: usability, environmental aesthetics, novelty, involvement, sensory awareness, immersion, realism, and distraction • *Engagement Index* by Sinesio, Saba, Peparaio, et al. (2019) • *User Engagement Scale* (O'Brien & Toms, 2010, as cited in Bangcuyo et al., 2015)
Feeling of presence	• *Presence Questionnaire* (Witmer & Singer, 1998, as cited in Richard et al., 2022) • *Slater-Usoh-Steed Presence Questionnaire* (Slater et al.,1994, as cited in Ijaz et al., 2022)
Embodiment	• *Embodiment Questionnaire* by Richard et al. (2022)
Perceived interactivity	• *Interactivity Questionnaire* by Song & Zinkhan (2008) (as cited in Petit et al., 2021)
Participants' comfort	Participants' comfort can be considered also multidimensional as involves both, physical (e.g., postures, movements, collisions, cybersickness, eye strain, etc.) and psychological discomfort (e.g., negative emotional impact, stress, frustration, etc.). Comfort/discomfort ratings found in the literature include: • *Total Discomfort Level* (Tyrrell et al. 2018, as cited in Fang et al., 2021) • *Simulator Sickness Questionnaire* (Kennedy et al., 1993, as cited in Sevinc & Berkman, 2020)

3.7 Stimuli

IEs studies employ a wide variety of stimuli. Moreover, studies can combine different types of stimuli as well as different methods to measure participants' response to them, being its choice, is highly dependent on the research question. In order to accurately compare differences between conditions or stimuli, it is also important to control for any factors that could influence the data other than the ones being studied. Naturalistic stimuli, which cannot be controlled as easily, will require more trials and more examples to ensure that the results are reliable. Alternatively, using a large enough group of stimuli can help to "average out" these confound factors, or researchers can compare different participant groups on the same stimuli. The randomization of the order in which to present stimuli in a collection should also be considered and documented. Whereas in one study the participant's reaction on a stimulus should be independent on what came before or after it, in another study it is perhaps the known fixed order of stimuli that is of interest.

We should note that in IEs research, both the recreated context (e.g., choice situation, eating occasion, product assessment) and the targeted object (e.g., food product, product assortment) can be considered as stimuli, since both responsible for generating a reaction in the consumer participating in the experiment. In this section we will present an overview of stimuli factors to be considered, dealing separately with context related stimuli and product related stimuli.

For transparency, replicability, and comparability purposes, a researcher should provide a detailed description of stimuli and their related properties. Despite the particularities of the IEs research, several recommendations can be applied to all studies measuring psychophysiological response, as presented in Tables 9 and 10. These properties can be divided in three categories: stimuli, instructions, and response, following the Cognitive Paradigm Ontology (CogPO) suggested by Turner & Laird (2012), from which we will introduce several basics concepts (Table 9).

Table 11. Basic concepts within CogPO from (Turner & Laird, 2012).

Concept	Definition
Stimulus Role	The role of a stimulus is attributed to the object(s) which are presented to the subject in a controlled manner in the context of the experiment.
Stimulus	The object or set of objects, internal or external to the subject, which is intended to generate either an overt or covert response in the subject as part of an experimental condition. Stimulus can be explicit (generated under the experimenter's control and exists external to the subject at least at some point in time) and implicit (generated by the subject).
Stimulus Modality	The quality of stimulating a particular sensory system for the perception of an explicit stimulus.

Instructions	An explicit direction that guides the behaviour of the subject during the experimental conditions. Instructions serve the function that they lay out what the response behaviours should be for any set of stimuli in the experiment.
Response Role	The role of response is attributed to the overt or covert behaviour which is elicited from the subject in an experimental condition.
Response	The overt or covert behaviour which is elicited from the subject in an experimental condition.
Response Modality	Class of body parts used to perform the actions which can play the role of an overt response.

Within each category we provide a list of factors that should be reported. For clarification purposes, we also give examples of sub-categories for each property. Please be aware that this list is neither exhaustive nor binding. It is possible that not all the properties presented in this table will apply to the stimuli in your studies. Conversely, it is also possible that your stimuli will have properties that are not mentioned in the list. We recommend reporting at the minimum the properties presented in the table, but always aim to be clear, transparent, and elaborate on the stimuli used in the research project.

3.7.1 Context as stimuli

When we consider context as stimuli, a detailed, clear, and transparent description of the IEs is needed. All recreated or simulated content potentially responsible of generating a reaction in the consumer participating in the experiment should be consider, controlled and reported, for example as presented in Table 10.

Table 12. Stimuli properties to be considered and reported in studies using context as stimuli.

Property	Examples of Sub-Categories
	Stimuli
Setting	Manipulated environmental factors that may potentially generate a reaction in the participant which make up the variables of study E.g., Immersive room description, virtual scenario features
Temperature	Room temperature, degrees Celsius, Fahrenheit
Category	Implicit: generated internally by the subject, such as during a resting state condition, imagining a scene, or re-living a previous experience

	Explicit: exists at least in part externally to the subject, usually visually presented images or tactile stimulation. This also includes objects in virtual environments and social setting
Role	Target (feature that a participant is instructed to attend/respond to); Non-Target (items in the display that are not the target, for example distractors); Reward (involve incentives with a positive outcome or a positive emotional state); Feedback (gives information about the outcome or the performance of the task, whether a response was correct or incorrect, or how well a task was performed); Passive (don't require active engagement or response from the participant)
Modality	Only in case of explicit stimuli. Visual; Tactile; Gustatory; Olfactory; Auditory; Interoceptive; Proprioceptive; Multisensory experiences
Type	(Re)creation included: • Physical objects (e.g., furniture, non-targeted product, tableware) • 3D objects (e.g., furniture, non-targeted product, packaging, menus, shopping trolley) • Film clips (e.g., bar ambience) • Pictures (e.g., food photos, food labels, immersive environments) • Music • Non-vocal sounds (e.g., animals, machines, nature, objects, or other non-human origins) • Odours (e.g., scents, odorous solutions) • Substance that is eaten, drunk, or otherwise ingested different of food (e.g., liquid solutions, gustatory samples) • Symbols (e.g., logos, labels) • Tactile stimulation • Words (e.g., information displays, brands, speech, marketing messages)
Stimulus description	Individual distinctive description of the stimuli
Number of items targeted	Total; number per type

Size/Volume	Dimensions in cm/Pixels; all same size, or range (size of smallest – biggest); volume in ml/oz
Presentation	Delivery system or output interface (e.g., immersive room, projectors, screens, smartphone, tablets, speakers, HMDs)
Order of presentation	Randomized (individual or block randomization); Increasing (decreasing) order
Set (block) of stimuli	e.g., 10 stimuli within a set
Position	For visual stimuli: Central; Left/Right; 4-grid;
Odour concentration	For olfactory stimuli: weak, medium, strong
Length of exposure	Value and units in seconds or milliseconds; duration of the stimulus until response; until end of the experiment
Interstimulus interval	Time interval between stimulus in seconds or msec. in case of more than one IEs is presented
Valence	Positive, negative, neutral
Neutralizing effect for break	For visual stimuli: e.g., neutral picture after a stimulus/set of stimuli
Instructions	
Task topic and types	**Attention:** Passive attention; Visual search; Search; Involuntary Attention; Unconscious Process; Selective Attention; Object-Based Attention; **Emotion:** Arousal (emotion); Happiness; Excitation; Emotional decision making; Taste Aversion; Mood; Valence; Shame; **Executive Control:** Self-control; Planning; Goal Maintenance; Behavioural Inhibition; Proactive control; Resistance to distractor interference; **Language:** Semantic Processing; **Action:** object manipulation; **Learning & Memory:** Emotional memory; Gustatory memory; habit; reward processing; implicit memory; association learning; familiarity; **Motivation:** curiosity; appetitive motivation; desire; intrinsic motivation; aversive salience; **Perception:** Object perception; gustatory perception; preconscious perception;

	Reasoning & Decision Making: Judgement; Decision making; Risk Processing; Categorisation; Subjective value judgement; subjective food value **Social Function**: interaction with environment; ability to fulfil one's role within the environment
Task name	Visual attention task; hedonic liking task; Affect arousal task, motivational arousal task
Task description	e.g., 2-choice task, lasting 30 minutes…
Task presentation	Manual: instructors presents and removes stimuli Automatic: software or robotics presents and removes stimuli
Task instructions	Attend; Detect; Discriminate; Fixate; Name; Read; Recall; Encode; Imagine; Rest; Track; Taste; Smell
Response	
Response category	Overt response: made with a body part that is externally observable by others Covert response: made internal to the body, which is not directly observable by external viewers.
Response modality	Only for overt response, as covert response is unobservable by the experimenter. Hand; Arm; Eye; Face; Mouth; None
Response	Overt response: Button Press; Point; Speech; Write; Demonstrated emotion Covert response: psychophysiological indicators

3.7.2 Product as stimuli

When we focus on a food product/product assortment for its assessment, the following attributes need to be considered, controlled, and reported (Table 11).

Table 13. Stimuli properties to be considered and reported in studies using a product as stimuli.

Property	Examples of Sub-Categories
Stimuli	
Category	Implicit: generated internally by the subject, such as during a resting state condition, imagining a scene, or re-living a previous experience

	Explicit: exists at least in part externally to the subject. This also includes objects in virtual worlds
Role	Target; Non-Target; Reward; Feedback; Passive
Modality	For explicit stimuli: Visual; Tactile; Gustatory; Olfactory; Auditory; Interoceptive; Multisensory experiences
Type	In relation to the targeted food product/product assortment: • Physical object (e.g., food product, product packaging) • 3D object (e.g., food product, product packaging) • Picture (e.g., food photos, food labels) • Tactile stimulation • Symbols (e.g., logos, labels) • Words (e.g., information displays, brands, speech, marketing messages)
Items targeted	Individual distinctive description of the stimuli (e.g., apple; pear; butter; crisps)
Number of items targeted	*Total; number per type*
Size/Volume	Pixels/cm; all same size, or range (size of smallest – biggest); volume in ml/oz
Presentation	E.g., stimuli presented in plastic cups, different coloured lids for ease of recognition; presented through nosepiece
Order of presentation	Randomized (individual or block randomization); Increasing (decreasing) order
Set (block) of stimuli	10 stimuli within a set
Position	For visual stimuli: Central; Left/Right; 4-grid;
Length of exposure	Value and units in seconds or milliseconds; duration of the stimulus until response; until end of the experiment
Interstimulus interval	Time interval between stimulus in seconds or msec.
Stimuli pre-selection	Any trial sessions ran to select a final set of stimuli
Stimuli preparation	For gustatory stimuli: preparation time, process
Temperature	For gustatory stimuli: room temperature, degrees Celsius, Fahrenheit
Taste type	For gustatory stimuli*:* e.g., sweet, bitter
Taste type intensity	For gustatory stimuli: e.g., 4 levels of bitterness (increasing)

Taste neutralizing/ Neutralizing effect for break	For gustatory stimuli: e.g., water, crackers, nothing (e.g., passing time) For visual stimuli: e.g., neutral picture after a stimulus/set of stimuli
Odour concentration	For olfactory stimuli: *weak, medium, strong*
Valence	Positive, negative, neutral
Instructions	
Task topic and types	**Attention:** Passive attention; Visual search; Search; Involuntary Attention; Unconscious Process; Selective Attention; Object-Based Attention; **Emotion:** Arousal (emotion); Happiness; Excitation; Emotional decision making; Taste Aversion; Mood; Valence; Shame; **Executive Control:** Self-control; Planning; Goal Maintenance; Behavioural Inhibition; Proactive control; Resistance to distractor interference; **Language:** Semantic Processing; **Action:** object manipulation; **Learning & Memory:** Emotional memory; Gustatory memory; habit; reward processing; implicit memory; association learning; familiarity; **Motivation:** curiosity; appetitive motivation; desire; intrinsic motivation; aversive salience; **Perception:** Object perception; gustatory perception; preconscious perception; **Reasoning & Decision Making**: Judgement; Decision making; Risk Processing; Categorisation; Subjective value judgement; subjective food value **Social Function**: interaction with environment; ability to fulfil one's role within the environment
Task name	Visual attention task; hedonic liking task; Affect arousal task, motivational arousal task
Task description	2-choice task, lasting 30 minutes…
Task presentation	Manual: instructors presents and removes stimuli Automatic: software or robotics presents and removes stimuli
Task instructions	Attend; Detect; Discriminate; Fixate; Name; Read; Recall; Encode; Imagine; Rest; Track; Taste; Smell

Response	
Response category	Overt response: made with a body part that is externally observable by others Covert response: made internal to the body, which is not directly observable by external viewers.
Response modality	Only for overt response, as covert response is unobservable by the experimenter. Hand; Arm; Eye; Face; Mouth; None
Response	Overt response: Button Press; Point; Speech; Write; Demonstrated emotion Covert response: psychophysiological indicators

3.8 Making immersive studies FAIR

In relation to immersive studies, the main challenges FCS researchers face are the technical barriers when designing and implementing environments. These include availability of digital representations, modelling techniques, and development tools that facilitate the application of IEs emerging technologies. Cooperative work, shared knowledge, and collaborative tools as open-source, modular, and customizable applications (Engelbrecht et al., 2021) will be key for the implementation of these technologies in FCS. Furthermore, it is imperative to bear in mind the open science approach emphasizing the management of data and other research outputs in accordance with the FAIR (Findable, Accessible, Interoperable and Re-usable) principles when undertaking public funded projects.

Table 12 outlines the FAIR principles related to research outputs, including IEs contextual content, targeted objects data and generated datasets, to be considered when implementing immersive research studies.

Table 14. Recommendations to implement FAIR principles in IEs studies.

Factor	Details
Making data Findable	• Prioritize digital formats and convert non-digital data, as real-world objects, to a digital source by means of 3D scanning technologies. • Identify data with a persistent and unique identifier such as DOI (Digital Object Identifier). • Use standardized and machine-retrievable metadata frameworks for data description.
Making data Accessible	• Deposit data in an open data trusted repository.

	• Use open-source licence software and toolboxes. • Store data in non-proprietary standard formats to maximize easy access.
Making data Interoperable	• Use standard vocabularies or ontologies to facilitate communication and data exchange between institutions within the FCS domain and with other adjacent research disciplines.
Making data Re-usable	• Use creative commons or similar licenses. • Workflows, protocols, curation and preservation methodology should be detailed to maximize the re-use of data.

Specific recommendations on the implementation of FAIR principles will be detailed in each IEs emerging research approach section when applicable.

COMFOCUS is strongly guided by the principles of FAIR data and Responsible Research and Innovation (RRI). The use of the reconstructed and virtual reality infrastructures available within the COMFOCUS consortium will build up a data repository from the data obtained from the COMFOCUS Open Calls. Data generated by Transnational and Virtual Access Activities (VA/TNA) and Joint Research Activities (JRA) should be made available through the central access point of the COMFOCUS Knowledge platform, serving as a library of metadata on digitally accessible data sources.

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CHAPTER 4

Guideline for reconstructed reality

4. Guideline for reconstructed reality

4.1 Introduction

Reconstructed reality (RR) recreates and enhances real world situations through auditory, visual, tactile and/or olfactory stimuli with the purpose of providing consumers with a multi-sensory experience that immerses them into the environment to explore contextual influences in food choice (Jaeger & Porcherot, 2017).

FCS has implemented RR through physical elements but also by means of projections on screens or walls in real-life settings (Figure 7). Contextual cues include furniture, projection of pictures and/or videos, as well as other sensory stimuli like smell, temperature, lighting, ventilation, humidity, ambient sounds or music (Delarue & Lageat, 2019). The socialization and time-related circumstances can also be integrated into this immersive method (van Bergen et al., 2021).

Drawn on RR, it has been possible to recreate complex immersive scenarios for observing consumer shopping, eating and drinking behaviour as supermarkets, restaurants, bars and coffeehouses under controlled conditions even (Crofton et al., 2019; Delarue & Lageat, 2019). Although is not possible to provide all elements of context, immersive experiences achieved through RR have proven to improve consumers' engagement in food choice tasks (Sinesio, Saba, Peparaio, et al., 2019), but more research is still needed to unleash its full potential.

Figure 7. Example of two IEs in which a farm and a bar were recreated.

4.2 Reconstructed reality and food consumer science

Literature demonstrates that RR has been applied in several studies with the aim of recreating consumption contexts in the FCS over time. Petit and Sieffermann (2007) assessed the effect of the context on the consumption of iced coffee. They recreated a coffee shop using physical elements and concluded that liking and consumption results obtained in the situational laboratory tests did not differ from the results of classical laboratory tests. However, these differ from those obtained in natural consumption situations.

Sester et al. (2013) conducted an immersive study to evaluate the effect of context on drink choice. They simulate two different bar environments creating a warmer or cooler ambience modifying the colours of the environment and the furniture. In both immersive environments, different clips with visual and musical stimuli were projected on a wall to change and reinforce the overall warmth of the environment. Authors observed that drink choice was led by the ambience warmth and identified differences on the appropriateness.

Holthuysen, et al. (2017) designed a study to assess the effect of context on overall liking and just about-right (JAR) ratings of airline meals. They recreated an airplane environment and compared the results obtained with those observed in a laboratory setting and an actual airplane. No significant differences were determined in terms of overall liking between the recreated and the real aircraft. In the same vein, the JAR ratings obtained in the recreated aircraft did not differ significantly from those observed in the real aircraft. Thus, the authors concluded that the results obtained on a recreated aircraft as a test site are more similar to those of the real aircraft than those of the traditional laboratory.

Bangcuyo et al (2015) recreated an immersive environment mimicking a coffee shop. They displayed a 20 min video via computer feed onto a video wall composed of nine high-definition LCD screens and included the common visual, auditory, and olfactory cues in this environment. The aim of the study was to compare the overall liking scores of five coffees obtained in this environment with those obtained in a traditional sensory testing booth. Data collected in recreated coffee shop were more discriminating and more reliable indicator of future coffee liking than those collected in the sensory booths. In addition, they also obtained higher engagement in this assessment environment.

Hathaway et al. (2017) went a step forward and evaluated the effect of the degree of immersion on the quality of the data obtained. Two different immersive environments (mixed immersion and full immersion) were created to depict the baking of cookies in a home kitchen through an audio-visual presentation and olfactory and were compared with traditional sensory booths environment. In the mixed immersion condition, the context was evoked through a computer screen, headphones and localized scent dispersion while evaluating the cookies in a sensory booth. In the full immersion condition, the same information was presented via video wall, surround sound ceiling speakers and hidden aroma dispersal. Participants evaluated the samples in the three conditions at different points in time. The results showed that the higher the degree of immersion, the higher the degree of discriminability and reliability of consumer acceptance data.

Jiang et al. (2017) examined the effect of immersive environment context on consumer-perceived intensities of green and floral flavours, liking and emotions elicited during wine consumption. These authors used different colours on table settings and decor and projected images of flowers or green plants onto a screen to evoke two different wine consumption contexts. A non-significant effect of the immersive environment was observed on flavour perception, overall liking and emotions elicited by flavour wines.

In the same vein, Sinesio, Saba, Peparaio, et al. (2019) designed an immersive multi-sensory room to simulate real consumption scenario in a countryside setting. They used projections on large wall screens, sound and aroma stimuli and furniture and table setting to match the scenario. Participants evaluated the overall liking and the perceived freshness of two horticultural products at different storage periods in a traditional tasting room and in the immersive multi-sensory room. Interestingly, although in general the samples were better evaluated (in terms of overall liking) in the immersive environment, the discriminant power for freshness perception and liking of fresh and stored vegetables was higher in the laboratory environment than in the immersive environment.

Delarue et al. (2019) evaluate the effect of testing conditions on consumers' perception and liking of fruit-flavoured non-alcoholic beer. They compared the results obtained in three conditions: in a sensory booth and in two recreated environments, a ”tropical beach” and a “nightclub”. These two lasts were recreated by means of a multisensory immersive room equipped with a curved screen allowing a 160° where high-definition videos were projected. To enrich the immersion sensory cues named as sound, aroma, air, temperature, breeze, fog, lighting cues were used, and social interaction was possible. In general, the authors observed minimal differences in beer liking in the three contexts. Nevertheless, the differences between the morning and afternoon sessions detected in sensory booth were not significant when testing was run in the two immersive environments. Hence, authors concluded that recreated immersive environments can be useful to control the undesired limitations of carrying out consumer tests in the absence of context (i.e. time of testing) and provide more robust hedonic data than in a laboratory setting.

van Bergen et al. (2021) investigated how repeated exposure to food in congruent and incongruent immersive contexts affects hedonic perception over time. Participants evaluated three food products (sushi, popsicles and iced tea) in an immersive context (beach or sushi restaurant) for 7 days. On the eighth day, they tested the same 3 products again but in the changed context. To make the experience more immersive, they used decoration, furniture, lighting and sound cues. The results showed that, although expected liking and desire to eat were higher when the product-context combinations were congruent (sushi at the sushi restaurant and ice cream at the beach), the difference between congruent and incongruent combinations in terms of average liking for the product was not significant. However, individual ratings were more consistent over time and greater amounts were consumed when the product-context combinations were congruent. One year later, De Wijk et al. (2022) published the results of the implicit and explicit measures of general and food-evoked emotions collected in the same study (van Bergen et al., 2021), concluding that these are affected by food and by the recreated physical and social contexts of consumption.

The review of all these studies shows that the use of RR to recreate real-life situations, while controlling the test condition of the product, can be tackled from the simplest to the most sophisticated approaches. The simplest approaches consist of recreating real-life environments using only physical means in laboratory settings. The main drawback of these approaches is their limited flexibility, as in these cases it is difficult to assess the perception of a product in several contexts or to move from one context to another easily and nimbly. The use of more sophisticated approaches such as the use of high-definition displays or the projection of images and/or videos of real consumer contexts, using images and/or videos, on immersive room walls can overcome these difficulties (Delarue et al., 2019). In addition, the use of multisensory stimuli and possible social interaction help to increase the reality, presence, and immersion that consumers can experience.

4.3 Reconstructed reality protocol

As mentioned previously, when designing a study that involves either of the IEs emerging research approaches discussed in this guideline, certain protocol factors overlap. In this section, we present the main factors to consider when designing a protocol for a study involving reconstructed reality other than general protocol factors for IEs studies described in Section 3.4.

4.3.1 Design

The following table (Table 13) presents a list of RR specific factors related to study design that are considered a minimum reporting level in the protocol different than those described in Section 3.4.

Table 15. Study design factors for studies using RR different than those described in section 3.4.

Factor	Recommendations
Immersive approach	In studies where RR is used through physical elements such as furniture or other decorative means, and are aimed to compare several immersive environments, it is important, from a practical point of view, to indicate the time it takes to switch from one environment to another.

4.3.2 Sample selection

Participant factors that influence data

Participant factors that influence data are highly dependent on the research questions. In immersive studies using reconstructed reality, we recommend to record, at least, information on demographics such as age and gender (for more information please see COMFOCUS 4.1 deliverable “Guideline for harmonisation of measures and protocols linking to other infrastructure and data bases”). The other factors described in Section 3.4.2 do not proceed.

Participant factors that influence safety and Inclusion/exclusion criteria

Individual factors that can influence the safety of reconstructed reality studies are shown in Table 14. Other inclusion/exclusion criteria are usually chosen based on research question. Please consult the IEs -specific chapters for more information on these individual characteristics.

Table 16. Participant factors that influence safety in studies using RR.

Factor	Recommendations
Claustrophobia	Researchers should be aware that some people may suffer from claustrophobia or from fear or panic of being in enclosed or confined spaces. In cases where the capacity of the immersive room is reduced, this may provoke anxiety in participants, so it is advisable to warn them beforehand or even use claustrophobia or as an exclusion criterion for the study.

4.3.3 Ethical factors

The ethical issues that researchers should consider prior to carrying out an immersive study using RR are described in Section 3.4.3.

4.4 Technological factors for studies in reconstructed reality

In this section, we present RR technological factors that can have an impact on data collected (Table 15); however, we strongly suggest researchers to aim for maximum transparency and detail when describing the technical factors related to the context reconstruction used in the study.

Table 17. Technological factors that influence RR studies.

Factor	Recommendations
Hardware	Researchers must consider and report technological features for capture cameras, displays and multi-sensory devices or diffusers used RR studies (Blois, n.d.): • Camera: high-quality embedded visible light digital cameras are required to capture the real-world environment accurately and in detail. To recreate contexts through projection on a single flat screen, high resolution digital cameras are adequate enough (Bestbuy.com, n.d.). When creating an immersive room, 360-degree cameras are the most suitable as they provide a higher level of immersion. ✓ Features to consider and report when selecting a **digital camera**: a) Type of camera: Digital single-lens reflex, mirrorless cameras, Compact cameras, bridge cameras, Bridge cameras. b) Camera resolution: The resolution of a camera is usually measured in megapixels (MP). The number of MP indicates

	the number of pixels the camera uses to produce an image. Resolution affects the image quality of digital cameras. When creating IE it is recommended to use a camera with high megapixel rating. The image quality of a camera is often erroneously assessed on the basis of its resolution. The pixel size depends on the image sensor and affects the quality more than the resolution. c) Sensor size: A larger camera sensor allows for larger pixels, and this has positive implications for image quality due to reduced noise and increased dynamic range. Different type of sensors exists, full-frame or Advanced Photo System type-C (APS-C) sensor cameras are recommended. d) Audio: The number and arrangement of microphones is important for good audio surround sound. Some models have microphones with wind reduction which may be of interest if you are recording audio outdoors. e) Frame rate: Around 30 frames per second (fps) would be recommended. ✓ Features to consider when selecting a **360-degree camera** and to report on include: a) Image quality: To achieve good quality photographs, it is recommended at least 16MP. b) Video recording: Many of these cameras can record at 4K and even 6K. c) Optical quality: Check wide angle lenses, the maximum aperture value will determine their brightness. d) Shutter speed: The higher the shutter speed, the better the ability to freeze motion. e) ISO range: The sensor's ability to adapt to a lack of light also influences the final image quality. These cameras generally range between 100-3200/6400 ISO. f) Audio: The number and arrangement of microphones is important for good audio surround sound. Some models

	have microphones with wind reduction which may be of interest if you are recording audio outdoors. g) Frame rate: Around 30fps would be recommended. • Display technology: The technologies available to display in IE studies using RR are projection or LED panels. In most of the studies found in the literature, projectors are used probably because of its lower price. LED panels get brighter than projectors and are recommended when there is a lot of ambient light. ✓ **Projectors** technical characteristics to be consider and reported are: a) Projection technology: LCD, CLP, LED, Laser. b) Resolution: the higher the better. 4K is recommended. c) Brightness: it is recommended at least 3,000 ANSI lumens. Other aspects to consider when installing the projectors are: a) Projection factor (how big the projected image will be depending on how far away is the projector): Most manufacturers offer a distance or screen size calculator. b) Ceiling height of the space where the immersive room will be installed: when projectors of immersive rooms are placed at the top of the immersive room it is very important to consider the ceiling height of the space where the immersive room will be installed. Otherwise, there is a risk of not having enough space to accommodate the support structure and the projectors. ✓ **LED panels** technical **characteristics** to be consider and reported are (ClearLED, 2018): a) Brightness: LED brightness plays a very important role in the viewer's viewing experience. A too bright LED panel will cause discomfort to the viewer, while a screen that is too dim will make it difficult to see your content. As a guideline we recommend a brightness between 500 to 1500 nits for indoor displays and a brightness of 1,500 to 2,500 nits for

	indoor displays located in a bright indoor environment or in direct sunlight. b) Pixel pitch: The pixel pitch affects the transparency of the LED display and thus the optimum viewing distance as well as the visual performance of an LED screen. In general, a lower pixel pitch provides a sharper picture and higher resolution. However, the LED display may appear opaque and less transparent when viewed from in the distance; therefore, it is recommended to choose the correct pixel pitch depending on the viewing distance to show the best resolution and transparency for your display. In general, pixel pitch can be estimated with the following formula (ClearLED, 2018): Pixel pitch (mm) / (0.3 to 0.8) = Optimal viewing distance (mm). c) Resolution: The resolution of a screen is determined by the total number of pixels in a display. The higher number of pixels renders higher resolution, which means better picture quality. Nevertheless, higher resolution does not always mean better. The resolution required depends on the viewing distance. A good rule of thumb for LED displays is (Expromo, n.d.) : 1 mm pixel for every metre of viewing distance. d) Multi-sensory devices or diffusers: these devices allow the generation of sensory stimuli (sound, light, humidity, vibration, aroma, etc.) to enhance immersion in the environment. Researchers should describe in detail the nature of the stimuli and the brand, the model, and the specific technical characteristics of these devices to allow replication of the experiment. For instance, if a scent delivery system or olfactory diffuser is used to incorporate odour to the IEs, the air pressure, air flow rate and duration of the pulse should be reported.
Software	Different Software to control IE peripherals exist on the marked. These are used twofold, to represent the IEs to the participant (such as automatic

	camera-based alignment of multiple projectors on any surface, synchronisation system etc.) and to interact with the IEs (e.g., navigation system, rating/response measurement etc.). Researchers should describe make and version of the software used together with any intrinsic data processing (including defaults).
Set-up factors	Other aspects to be considered and reported by researchers when creating an immersive environment by RR include: • Setting type. e.g., portable or fixed immersive room, projection in an existing room, etc. • Setting dimensions (height and size) • Shape of immersive room: rectangular, cubic, cylindrical, open-fronted cylindrical, domed, etc. • Support of projection: walls of pre-existing room, screens (placement, material, number, and dimensions), an immersive room created ad hoc, screens, etc. • Projectors or LED panels configuration (detail number and placement) • Multi-sensory devices and diffusers configuration (technical features, number, and placement must be detailed) • Audio: The number and arrangement of microphones is important for good audio surround sound (technical features, number, and placement must be detailed) • Distance of display • Heating, ventilation, and air conditioning (HVAC): HVAC is sometimes necessary to generate a more immersive environment (temperature and airflow stimuli). HVAC is also necessary to counteract the heat emitted by the projectors. • Decorative features: e.g. wall colour, light colour, furniture, curtains, table-clothes, glasses, paintings, etc. • Possibility of social interaction: e.g. number of people
Data	See Section 3.5 (Table 7)

4.5 Harmonised measures for studies in reconstructed reality

Obviously, the harmonized measures collected in studies using reconstructed reality will largely depend on the research question. However, in this type of studies it is possible to collect either behavioural measures captured through participant observation, self-reported measures obtained through surveys and questionnaires, psychophysiological measures of consumer response captured through emerging technologies, or a combination of the above-mentioned typologies. For more information, please see Section 3.6.

4.5.1 Consumer behaviour measures

Information related to consumer behavioural measures that can be collected in studies using reconstructed reality is presented on Section 3.6.1.

4.5.2 Immersive experience quality measures

As in other immersive studies, when using reconstructed reality, it is worthwhile and advisable to include several measures to assess the participant's experience. These are presented in Section 3.6.2.

4.6 Stimuli for studies in reconstructed reality

As mentioned above, the stimuli used in an immersive study, both in terms of context and product, should be described and reported in a detailed, clear, and transparent way. In immersive studies using reconstructed reality these are described in Section 3.7.1 and Section 3.7.2 respectively.

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CHAPTER 5

Guideline for mixed reality

5. Guideline for mixed reality

5.1 Introduction

Mixed Reality (MR) includes the different modalities used to digitally enhance and/or recreate environments in which the real world and the virtual world are combined, allowing the user to navigate and interact with both in real time through a single user interface (Milgram et al., 1994). Given the latest technology developments and research findings, there are limitations when presenting the diversity of multisensory experiences under the general concept of MR (Flavián et al., 2019). A well-defined framework for classifying the different modalities that combine the virtual and real worlds is still lacking, leading to misconceptions and ambiguities in the discipline of MR (Papadopoulos et al., 2021). Thus, Augmented Reality (AR), Pure Mixed Reality (PMR), and Augmented Virtuality (AV) modalities should be clearly defined to avoid misconceptions.

5.1.1 Augmented Reality

Augmented Reality (AR) is defined as the medium where 3D computer-generated virtual objects or representations (e.g., textual information, images, videos) are overlaid on top of physical reality, but where users don't perceive they have left that reality (Loijens, 2017; Rauschnabel, 2021; Sherman & Craig, 2018; Wang et al., 2021).

Interaction would be the most relevant attribute of AR (Crofton et al., 2019; Javornik, 2016). However, the alignment and interplay between physical objects and virtual elements with each other has been a topic of controversy. Flavian et al. (2019) argue that virtual elements in AR don't necessarily need to be rendered, hindering the interaction with the physical world. Other authors consider that AR "seamlessly align natural world and virtual objects with each other" (Crofton et al., 2019) and there is an "interactive alignment and mutual registration of computer-generated sources with physical reality" (Azuma et al. 2001 cited in Javornik, 2016). Regarding modalities, AR typically supplements reality with visual contextual cues, although, depending on the display technologies other senses modalities can be incorporated by means of add-on technologies as audio players, scent diffusers, 'haptic' gloves or electric taste devices that use electric currents and temperature to communicate tastes (Loijens, 2017). Immersion and presence cannot be considered outstanding features of AR as users don't experience complete detachment from physical reality. This is due to limited capacity of AR technology to create a disruption between the physical and virtual world (Javornik, 2016)

Augmentation can be achieved by superimposing virtual elements onto persons, objects, or surroundings (Javornik, 2016). Typically, video based techniques capture real-world data through a digital camera (Bonetti et al., 2018), this data is then processed through specialized hardware and software, and digital content is displayed onto stationary (e.g., magic mirrors) or handheld mobile (e.g., smartphones and tablets). Optical see-through techniques perceive the environment directly through user's eyes and virtual images are display on top by means of wearables (e.g., see-through glasses and head mounted displays) devices (Loijens, 2017; Milgram et al., 1994). Finally, projection-based displays overlays the virtual scene onto real world elements by means of a projector. These can be devices attached to a fixed structure, or held in the hand, worn on the chest or head, as in the recently developed miniaturised projectors (Syed et al., 2023).

5.1.2 Pure Mixed Reality

In Pure Mixed Reality (PMR), also known as "fully mixed reality" (Microsoft, 2022a), virtual content is fully integrated into the real world. The digital elements used in PMR are 3D rendered holograms, objects made of light and sound, different from traditional 3D objects. These are indistinguishable from the physical world, spatially aware and responsive, improving the visual coherence of the blended world (Flavián et al., 2019; McGuirt et al., 2020). This allows the user to navigate and interact with both digital and real content, and enable interaction between the two, simultaneously and in real time. Digital content can be holographic objects as well digital avatars that allows to be personally and digitally present in the physical world, allowing asynchronous collaboration with others at different points in time (Microsoft, 2022a).

The rendering of virtual objects, accurately determining the precise location, boundaries, depth, and identity of a three-dimensional object in an uncontrolled environment, is one of the most challenging tasks for computer vision applications (Loijens, 2017). This is what is behind Flavián et al.'s (2019) proposal to distinguish PMR as a specific type of reality, situated between AR and AV. It is worth noting that the use of this specific term, PMR, is lately moving towards the use of "realistic AR" (Rauschnabel et al., 2022).

In PMR quality of the simulated content, interaction and presence are improved in relation to AR, generating a more realistic and immersive experience, changing the notion from being "here" to being "elsewhere". As in AR, PMR application are mainly developed within the sphere of visual contextual cues, being the diversity of the sensory modalities limited depending on the oclusiveness of the display technology.

PMR experiences are enabled by means of dedicated software and wearable holographic devices such as smart see-trough glasses and HMDs, that scans user's the real surroundings to create a 3D model of the scene, and at the same time, displays holographic elements superimposed on the streaming of the environment in the semi-transparent glasses screen. Interaction is made possible by sensors (e.g., gyroscopes, microphones, depth cameras) in the device that captures voice, gaze movements or gestures, triggering programmed actions in response to these events (Rositi et al., 2021).

5.1.3 Augmented Virtuality

On the other side, Augmented Virtuality (AV) involves real-world elements (e.g., user's hands, people physically present, real objects, live event scenes) with which users can interact, superimposed on a virtual environment (Flavián et al., 2019; Milgram et al., 1994), creating an experience disconnected from the physical reality around participants. In AV real-world elements usually need to be transformed into stylised representations which are integrated to match the virtual environment. Digital elements, apart from setting components, can also include objects, avatars, or live video streaming of other users (Bekele & Champion, 2019).

AV create fully immersive interactive experiences which have been recognized by certain authors (Fuentes et al., 2021) as a IEs technique that make participants believe they are in a different place but at the same time, feeling more realistic than VR.

Even though simulations which include interactive fully virtual IEs have demonstrated to be more engaging compared to physically reconstructed environments (Korsgaard, Bjøner, & Nilsson, 2019), these are scarce. Technical challenges include the tracking of real-world elements and the difficulty of straightforward 3D reconstruction and transmission of real-world scenes to the virtual world (Bekele & Champion, 2019). AV technology comprises software tools and hardware devices, as opaque HMDs, to block out participants from the physical environment and replacing it with a fully immersive digital experience (Microsoft, 2022a).

5.2 Mixed reality and food consumer science

First applications of MR in FCS were in the AR realm, starting in 2010s (Chai et al., 2022). Foundations of AR focused on the manipulation of food perception. Narumi and colleagues (2010) proposed AR-cookies which could be perceived as a specific flavour by presenting a superimposed computer graphics in combination with the diffusion of aroma artificially, leading the participants to perceive a change of taste in the plain cookies. The same research group included the manipulation of food portion size. In 2012, they applied a real-time shape deformation processing method to increase the volume of food, leading to a 15% reduction in consumption while maintaining the perception of fullness (Narumi et al., 2012, cited in Crofton et al., 2019). Other projective-AR manipulations of the appearance of food were conducted to evaluate taste perception by modifying food colour of a sponge cake and chips (Nishizawa et al., 2016). Results showed a significantly altered sweetness perception in relation to chroma for the sponge cake and modification of the flavour when changing the hue of colour in the chips. Recently, Dong et al. (2021) investigated the effects of diverse AR environments (sensory booth, AR coconut view, AR dairy view) on the emotional responses, purchase intent, and consumer purchasing behaviours towards different yogurts (dairy, non-dairy, and mixed yogurt).

Despite being also one of the early applications of AR, the visualisation of food nutrition information, particularly using smartphones and tablets, has continued to maintain the interest of researchers over the years. Bayu et al. (2013) aimed to provide nutritional information visually to consumers to help them improve their health. They developed an AR prototype intended to be used with a smartphone to easily display nutritional information in the form of a gauge meter visualization. Other works promoting healthier food choices by improving food nutrition visualisation are reported by Crofton et al. (2019) as the case of research conducted by Csakvary (2017), with drinks ranging in healthiness as case study. Recently, Pini et al. (2023) investigated the impact on selection of different display modalities in relation to the accesses to food-related information with cold breakfast cereals and granola bars as targeted category products. The study was conducted in controlled conditions recreating physical shelves of a supermarket. They conclude that AR technology facilitated the access to nutritional facts in packaged food products.

Another field of application for AR is in providing information in contexts where food-related decisions are made, such as during eating occasions when choosing from a menu or at the point of sale. Koui (2017) assessed consumer expectations and appetite behaviour when using AR to display interactive food menus, including images of the dishes. Also in the catering area, AR has been used to assist takeaway food packaging design (Gu et al., 2023). Their findings demonstrate that interactive packaging has the potential improve consumers' negative perceptions of takeaway food. Regarding point of sale, digital in-store technologies were used by Jäger and Weber (2020) to investigate the promotion of sustainable products in grocery stores using a magic mirror AR application in comparison to digital signage and control conditions. Using milk as case study, results showed that AR displays attracted more attention but did not impact on sales compared to the digital signage. In fact, the use of technology only report higher sales in large stores in relation to control condition.

To complete the overview of AR applications in FCS, we shall mention the work of Fritz et al. (2022) who examined the effects of AR-induced mental simulation of food consumption and its influence on food desirability. Using AR to visually superimpose depicted food items via a camera-enabled mobile device onto a consumer's real-time environment, they evaluate its impact on desirability and purchase likelihood, finding positive effects on both.

Jumping to PMR, a less explored space of MR in comparison with AR due to its recent progress. Fuchs et al. (2019) explored the potential of wearable PMR headsets in real food selection context. They used a PMR wearable headset to evaluate healthy food purchases in vending machines. The PMR environment included the physical vending machine to which digital visualization of the Nutri-Score resembling frames and detailed nutrient displays were incorporated. The intervention effectively increased awareness and importance placed on topics in which users already possess food literacy and the ability to recognize healthy alternatives (e.g., mineral water) even without support. In relation to food education and learning, Rositi et al. (2021) digitally transformed a conventional nutrition workshop addressed to post-surgery patients who had to carry out diet modifications. By means of PMR headsets participants were able to select from a virtual buffet of about thirty different 3D foods models for their meal composition. 60% of patients who participated in the study assessed that PMR approach was preferable to a more conventional computer setting.

Other applications of PMR assess how enhanced eating experience impacts on food consumption. Low, Lin, Jun Yeon et al. (2021) investigated the impact of context on consumer emotional response. The study evaluated two tea-break snacks across three different contexts (sensory booth, evoked mixed-reality café, real life café) using rate-all-that-apply and EsSense 25 questionnaire. Results suggest that PMR is a useful technique for evaluating ecologically valid consumer response as mixed-reality evoked similar emotional responses and discrimination between the snacks as the real café.

In the same direction, AV has been used for food evaluation, recreating the act of eating unifying both virtual and physical sensory cues, allowing the visual and auditory information coming digitally, together with smell, taste, and tactile properties of the food (Wang et al., 2021). Nakano et al. (2019) have used AV systems to present noodles, which were changed with vision-induced gustatory manipulation. They successfully manipulated participants' gustatory sensations, with visual modulation being the most effective technique in changing the food recognition. Korsgaard, Bjøner, & Nilsson (2019) have used AV technology to display virtual environments in opaque HMDs to manipulate eating behaviour of senior adults. Different digitally created environments were presented while eating and participants were asked about their preferences, which were perceived as engaging and suitable for pleasurable eating. Park environment was favoured over eating in a the kitchen. The same research group performed other studies where social interaction elements were introduced to facilitate remote social eating for solitary older adults with very positive feedback from all participants (Korsgaard, Bjøner, Bruun-Pedersen, et al., 2019; Korsgaard, Nilsson & Bjøner, 2017)

5.3 Protocol for studies in mixed reality

As mentioned previously, when designing a study that involves either of the IEs emerging research approaches discussed in this guideline, certain protocol factors overlap. In this section, we present the main factors to consider when designing a protocol for a study involving mixed reality other than general protocol factors for IEs studies described in Section 3.4.

5.3.1 Design

The following table (Table 16) presents a list of Mixed Reality specific factors related to study design that are considered a minimum reporting level in the protocol, other than general protocol factors for IEs studies described in Section 3.4.1.

Table 18. Study design factors when using MR different than those described in section 3.4.

Factor	**Recommendations**
Study type	Most common study designs in MR are of analytical nature.

	• Observational studies with no randomization. • Intervention experiments with randomization (control vs. experimental group).
Study setting	MR studies usually avoid laboratory settings, favouring naturalistic settings or those that resemble real-life scenarios: • AR studies are mostly conducted in real-life environments. • PMR studies can be conducted in real-life environments or controlled recreated environments depending on the aim of the study and specific IEs requirements. • AV can be carried out in a dedicated room with no specific requirements as digital elements help to create virtual environments that can recreate/enhance naturalistic consumption or shopping settings (e.g., restaurant, home, supermarket, park). Collisions and accidents can happen in MR environments, caused through distraction or misinterpretation (AR/PMR), or due to the disconnection with the real world when using opaque HMDs (AV) (Rauschnabel et al., 2022). When designing IEs settings, one should consider how solid objects, both real and virtually rendered, are placed to prevent and mitigate risks.
Environmental factors	• In case of AR where users remain present in the physical reality and naturalistic settings are employed, environmental factors should be kept constant across subjects to avoid unwanted physiological reactions to external, non-experimental, (and often unrecorded) stimuli. • When using digitally enhanced (PMR) or virtual recreated (AV) environments, environmental factors apart from the IEs targeted contextual cues (e.g., temperature, humidity, noise, lighting) must be congruent with the recreated environment and should be controlled and reported.
Experimental design	Design factors should be described as detailed as is necessary given the specificity of the design as treatments, levels, and randomization (e.g., two-group, factorial, randomized block, repeated measures).

	Both, within-subjects & between- subjects design are present in MR experiments. • Within-subjects design is recommended to account for individual differences and decrease the impact of external factors, but confounding factors as fatigue and learning effects should be addressed by counterbalancing the design (Swan et al., 2006). • Between-subjects design could introduce potential confounding factors due to consumer heterogeneity across conditions (Lichters et al., 2021).
Exposure to IEs	Exposure duration and repeated exposures in MR impact on participant's experience in relation to its engagement and comfort (Kennedy et al., 2000). PMR and AV, when using HMDs, are the most sensitive modality in relation to exposure characteristics, similar to VR. Best practices when using HMDs include: • Optimal length of total exposure: 20 to 30 min. at the longest (Kennedy et al., 2000). • Intersession interval: minimum 5 min. break between different conditions (Ledoux et al., 2013; Ung et al., 2018) and 30 min. between sessions (Stanney et al., 2021). • Repeated exposure reduces the severity of cybersickness due to habituation (Risi & Palmisano, 2019), but should be used with caution as it can generate learning effects.

5.3.2 Sample selection

Participant factors that influence data

Although participant factors are highly dependent on the research questions, all mixed reality studies should record certain information about the participants (Table 17), other than the ones described in Section 3.4.2 for general guidelines of IEs protocol.

Table 19. Participant factors that influence data in studies using MR.

Factor	**Recommendations**
Vision correction	The use of corrective lenses may hinder wearing MR glasses and HMDs. Therefore, it is recommended to investigate if participants wearing glasses

	can replacement them for contact lenses during the experiment (Schnack et al., 2019).

Participant factors that influence safety and inclusion/exclusion criteria

Individual factors, other than the ones described in Section 3.4.2 for general guidelines of IEs protocol, can influence the safety of mixed reality studies (Table 18).

Table 20. Participant factors that influence safety in studies using MR.

Factor	Recommendations
Visually induced motion sickness susceptibility (VIMSS)	Occurrence may vary depending on the MR modality (Rauschnabel et al., 2022): • Rare in AR and PMR studies. • Frequent in AV studies using opaque HMDs.

Participant factors that impact safety identified in Table 18, as well as those identified in Section 3.4.2 for general guidelines of IEs protocol, may act as exclusion criteria. No specific criteria to consider, other than those chosen based on research question, has been found in the MR literature.

5.3.3 Ethical factors

No ethical factors other than those identified in Section 3.4.3 for general guidelines of IEs have been found in the MR-specific literature.

5.4 Technological factors for studies in mixed reality

As a starting point and given the diversity of technological devices and software used in MR approaches, we synthetize the main characteristics of the different display technologies (Table 19), interfaces enabling user-machine interactions (Table 20) and software and development tools needed to create MR environments (Table 21), as well as their advantages and drawbacks.

Table 21. MR display technologies characteristics (Crofton et al., 2019; Loijens, 2017; Scholz & Smith, 2016; Syed et al., 2023).

Display	Characteristics
Stationary interactive displays (e.g., magic mirrors)	Apply front-projection to display images onto physical objects' surfaces, usually through publicly accessible screens that may or may not be disguised as ordinary mirrors. These displays are commonly associated with AR.

	- Users can perceive themselves as part of the augmentation. This can be achieved by viewing their own reflection, or by watching his actions on a screen from a third-person perspective. - Is not user dependent, as everyone experiences the same visual output. This characteristic may be perceived as a disadvantage in certain contexts, but it can also be regarded as an advantage in others.
Handheld mobile displays (smartphone and tablets)	- The camera incorporated in the device captures the environment and projects virtual content through its screen. These displays are also associated with AR. - Powerful and easy to use smartphone applications. - User experience may be less comfortable, as is required to maintain a consistent position with the device, resulting in potential discomfort or strain.
Wearables (e.g., see-through glasses and opaque HMDs)	Devices integrated into the human body that display MR, enabling the super-imposition of digital content in users' personal space. Head mounted displays (HMDs) are the most common type, being used both in PMR and AV, with stereoscopic transparent see-through lenses or opaque screens. - Improved user experience, extending sensory, cognitive, and motor functions. - Support more sophisticated levels of technology as voice recognition, spatial mapping, and gesture detection. - Higher cost and bulkiness. - Limited consumer demand beyond recreational or gaming applications.
Projectors	Digital elements are not displayed onto a screen or device, but onto real objects or dummies. This display technology is associated to AR. Restricts the display to the location of projection

Table 22. MR user interface characteristics (Bekele & Champion, 2019; Papadopoulos et al., 2021; Syed et al., 2023).

User interface	Characteristics

Tangible interfaces (e.g., tabletop, objects, QR markers, dummies)	Facilitate users' direct manipulation and interaction with virtual information through physical objects. This class of interfaces are typical of AR. • Intuitive and natural way of interaction. • No possible interplay between physical objects and virtual elements. • Doesn't allow remote collaboration.
Device-based interfaces (e.g., touchscreen, controllers, mouse, gamepad, joystick)	Use of graphical user interface (e.g., icons, buttons, menus, and windows) as well as conventional devices to interact and manipulate virtual elements. These interfaces can be found in AR, PMR and AV. • Engagement will depend on the skills needed to effectively use the devices, limiting users' sense of presence in the virtual environment. • Ensuring a consistent interaction between the user, reality, and virtuality can be challenging. • Designed for individual use, not allowing collaboration.
Sensor-based interfaces (e.g., hand trackers, gaze trackers, body movement, speech recognisers)	Use sensing devices to perceive users' interaction inputs. Modalities included are: visual-based interfaces which captures user state and its changes through cameras and optical sensors; audio-based interfaces that respond to actions and give feedback based on sound perception and stimuli as sound effects, speech, and music; and haptic-based interfaces use tactile feedback and touch-based interactions. These interfaces can be found in AR, PMR and AV. • Low effort to operate the interface. • High engagement and feeling of presence, as the interface doesn't require physical manipulation. • High-performance requirements. • Higher cost.
Multimodal interfaces	Fuse and integrate a wide range of complementary sensors, devices and interaction techniques. • High levels of engagement due to the interface's ease of use and the possibilities to resemblance how we interact with our physical environment.

	• Allows collaboration. • High-performance requirements. • Higher cost.

Table 23. MR software and development tools characteristics (Syed et al., 2023).

Software & tools	**Characteristics**
Low-level software development tools	Allow developers to write code that interacts directly with the hardware, giving them more control over the system's behaviour to create MR experiences from scratch. Low-level software development tools can be integrated in Software Development Kits (SDK) that typically include a set of libraries, Application Programming Interfaces (APIs), sample code, and other tools that help developers build software applications more efficiently and effectively. • Open-source versions are available. • Usually require additional software or libraries. • Needs high technological and programming skills.
Rapid prototyping	Allow developers to quickly create and test interactive prototypes, simulating and trying out all interactions within the MR environment, being constantly tested and adjusted by potential users in the process. • Shorter development and launch times.
Plugin-based	Plug-ins are devices that could be plugged into the existing software packages adding more functionalities. • Comparatively, a simple way to create MR experiences from scratch. • Problematic when used for 3D content, only working efficiently in 2D. • Freely available options. • Payment options when complete support is needed. • Need of proprietary software.
Standalone tools	Specifically designed for non-programmers as they have been developed on a graphical user interface. Allows quickly adding of video, 3D models, sound, text, and images • Does not require additional software or libraries.

	• Non-experts can build and use them. • Does not support adding new interactive features.

Once overviewed the technology used in MR, we present MR technological factors that can have an impact on data collected (Table 22); however, we strongly suggest researchers to aim for maximum transparency and detail when describing the technological factors related to the context recreation used in the study. Concerning instructions or guidance on how to use a particular equipment effectively and safely, we recommend first and foremost to follow user manuals supplied by the providers, as the information offered in this section might not reflect the most up-to-date technological possibilities.

Table 24. Technological factors that influence MR studies.

Factor	Recommendations
Hardware displays	Hardware configuration in MR studies should include the selection and setup of devices and also involves ensuring the compatibility and optimal performance of the hardware components. We need to take into consideration technological features for capture cameras, displays, tracking and sensing systems, performance of the hardware used, as well as ergonomics in relation to users' experience. • Technological features: ✓ **Capture cameras**: for video see-through techniques it is crucial to use high-quality embedded visible light digital cameras to capture the real-world environment accurately and in detail. In case of wearable devices, this can be equipped with multiple cameras to capture the surroundings from various perspectives and monitor user's movements. Features to be addressed include camera resolution, low-light performance, colour accuracy, focus and depth sensing. Configurations mentioned in the literature include 12.6MP, RGB, 4K at 30fps or 1920x1080 @ 60fps for video. ✓ **Displays**: display technologies are one of the key components of MR. These include single display panels that present a flat or 2D image to the user, and stereoscopic displays, which present two offset images separately to the left and right eye of the viewer

	creating the illusion of depth and producing a single 3D image in the brain. Most significant display's features include: a) Screen resolution: high-resolution displays, are recommended for clearer and sharper image. For screen-based displays, both stationary and handheld, resolutions starting from 1920 x 1080 pixels or 2k are recommended. Common configurations in the market for see-through holographic lenses in wearables are 1440 x 1760 px or 2 k. For opaque HMDs 2160 x 1200 or 4k are recommended. b) Refresh rate: higher refresh rate will provide a smoother, more responsive and immersive experience. For screen-based displays, the recommended minimum refresh rate is 60 Hz; however, a refresh rate of 90 Hz is currently considered optimal. Wearable displays can achieve even higher refresh rates up to 120 Hz. c) Field of View (FOV): relates to the size of the recreated image perceived by the viewer, with higher values providing a more immersive experience (Wedel et al., 2020; Xiong et al., 2021). Commercial devices, usually referred in diagonal degrees, starting from 40° in case of screen-based displays, up to 115°in wearables. ✓ **Tracking and sensing systems**: these technologies monitor the interactions between digital and real worlds, including participant's physical actions, position and orientation within the recreated/enhanced environment. In this context, Degrees Of Freedom (DOF) make reference to the number of independent parameters that can be measured or tracked by a system or device. 3 degrees of freedom (3DOF) devices allow partial orientation monitoring, by tracking rotational movements (pitch, yaw and roll), but not translational movements (forward/backward, up/down, left/right). In turn, 6DOF devices allow full positional tracking, including rotational and

	translational movements (forward/backward, up/down, left/right, yaw, pitch and roll). Main categories and features of tracking and sensing systems are (Syed et al., 2023): a) Sensor-based tracking systems: information is obtained from sensors present in the device. Sensors can be based on Inertial Measurement Units (IUM) (e.g., accelerometer, gyroscope), GPS, magnetic fields, audio devices (e.g., microphones, speakers), marker-based (e.g., QR code, artificial landmarks). b) Vision-based tracking systems: data is captured from cameras and optical sensors (e.g., visual and infrared cameras, 3D structure tracking). c) Model-based tracking: based on computer vision methods that map relative positions in relation to fiducial markers or 3D models (e.g., Simultaneous Localization and Mapping technique). d) Hybrid tracking systems: combine different tracking technologies to overcome the challenges of a single-tracking technology. Commercial wearable devices can integrate up to 18 different cameras and sensors, enabling them to comprehensively comprehend the characteristics of the environment in which they are situated. • Performance: ✓ **Processing power**: Mixed reality experiences can be resource-intensive, needing considerable processing power to render high-quality graphics and provide precise tracking. Powerful processors and graphics cards are essential to ensure a smooth and seamless experience. ✓ **Connectivity**: depending on the specific MR a reliable and fast internet connection may be necessary to download and stream data in real-time.

	✓ **Battery**: battery life can be a limiting factor in MR devices due to their high-performance requirements, resulting in a short active use time (2-3 hours). Therefore, researchers must plan to either recharge the device during the day or use an external battery to maintain operational capacity throughout the day. • Ergonomics: ✓ **Freedom of movement**: features that improve mobility (untethered vs. tethered device) often provide better experiences. ✓ **Lightweight and compact** devices offer a more physically comfortable user experience.
User interfaces	Allow users to interact and manipulate virtual elements in a MR environment. Machine-user interfaces can comprise hardware, software and a combination of both, being their main attributes (Bekele & Champion, 2019; Flavián et al., 2019; Petit et al., 2021): • Engagement: related to the experiential aspect of user-machine interactions, includes ease of use, clarity of information and design, naturality as key aspects. ✓ Interacting with virtual content by mean of tangible interfaces increases user involvement within virtual environments. ✓ The expertise required to operate device-based interfaces can pose a limitation, as challenges may affect users' sense of presence. ✓ Sensor-based interfaces foster heightened engagement due to their non-reliance on physical manipulation, which in turn leads to reduced cognitive effort. ✓ Multimodal interfaces can provide enhanced engagement given its anticipated ease of use and ability to mimic natural interaction. • Technological embodiment: refers to the user's sense of integration between its body and the MR devices, having a crucial role assisting the involvement of the user's senses. As embodiment increases, the

	technology becomes more closely integrated with user's actions enhancing their capacities. • Interactivity: defined as the psychological state of the user during interaction, being perceived control functionality and responsiveness key dimensions. ✓ Tangible interfaces pose limited interactivity as physical objects and virtual elements cannot interrelate. ✓ Expertise needed to operate device-based interfaces can be also a limitation in terms of perceived control. ✓ Sensor-based interfaces exhibit high levels of interactivity due to its responsiveness. ✓ Multimodal interfaces enable enhanced interactivity given the multiple modes of interaction.
Software and development tools	Enable developers to create MR experiences by providing its digital content, ensuring smooth operation and reliable data collection. Software configuration involves not only the construction of the virtual elements but also includes the deployment and integration of the real and the virtual world, and the configuration of the user interfaces. Software and development tool factors to bear in mind include: • Functionalities: software and development tools can provide different types of content depending on the MR modality (Microsoft, 2022b). ✓ Enhanced environments applications place digital elements in the user's environment. Software tools for 3D modelling are used to create the digital elements. ✓ Blended environments create a digital layer overlaid on the user's space. Spatial mapping support the creation of a digital representation of the physical space in which the MR environment is being deployed. ✓ Full immersive environment applications change user's physical surroundings, placing them in a different time and space. Need

	3D scanning functionalities to capture real-world objects and environments and convert them into digital assets. • Programming skills: previous experience and programming capability is a limitation factor in case of low-level software development tools, SDKs and rapid prototyping development tools. In case of non-experts, plugin-based developments and stand-alone tools are recommended. • Budget: software and development tools are available either for a fee or free of charge. Financial resources should incorporate the price of licenses or subscriptions, the ability to access necessary hardware and infrastructure at a reasonable cost and the availability of free or open-source alternatives. Depending on the specific platform and tools being used: ✓ Fee-based commercially available solutions can range from SDKs intended for experts, to custom service applications developed by experts to specifically meet the needs of a particular organization, or self-service platforms with a limited menu of basic services in which non-experts can create simple MR experiences. ✓ Free of charge solutions include not publicly available source code and open-source solutions, the latter based in collaboration platforms where developers can create and share repositories for MR projects.
Set-up factors	Contextual cues of the location where the study is taking place should be considered as stimuli as they may potentially generate a reaction in the participant. These factors should be reported, described in a clear and transparent manner, and controlled. Physical surroundings only apply in case of AR and PMR, as opaque HMDs used in AV prevent users to see their real environment. Environmental conditions apply to all MR approaches. Set-up factors should be reported, described in a clear and transparent manner, and controlled.

Data	MR studies have the potential to generate considerable volume of data including (Cloete et al., 2021): • Data from inputs captured by sensors, cameras, microphones, etc. • Data from outputs displayed by screens, speakers, etc. • Data from the MR systems themselves: environment representations, digital objects, etc. This high volume of relevant and detailed data has implications on data processing and data management planning.

5.5 Harmonised measures for studies in mixed reality

Obviously, the harmonized measures collected in studies using mixed reality will largely depend on the research question. However, in this type of studies it is possible to collect either behavioural measures captured through participant observation, self-reported measures obtained through surveys and questionnaires, psychophysiological measures of consumer response captured through emerging technologies, or a combination of the above-mentioned typologies.

5.5.1 Consumer behaviour measures

Information related to consumer behavioural measures that can be collected in studies using mixed reality is presented on Section 3.6.1.

5.5.2 Immersive experience quality measures

As in other immersive studies, when using mixed reality, it is worthwhile and advisable to measure several indicators to assess the participant's experience. These are presented in Section 3.6.2.

5.6 Stimuli for studies in mixed reality

As mentioned above, the stimuli used in an immersive study, both in terms of context and product, should be described and reported in a detailed, clear, and transparent way. In immersive studies using reconstructed reality these are described in Section 3.7.1 and Section 3.7.2 respectively.

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CHAPTER 6

Guideline for virtual reality

6. Guideline for virtual reality

6.1 Introduction

Virtual reality is difficult to define as there is no single agreed definition in the scientific literature (Aukstakalnis, 2017). In a simple and generalist way, virtual reality (VR) could be defined as immersion in an alternative reality or examined from a specific point of view (POV). According to this definition, we can perceive the things around us or even those we do not know in two different ways: as an alternative, new and unknown world, or as what we already know from a familiar point of view or from a totally new and different point of view. This alternative world can be either a representation of a real space that exists elsewhere, or a purely imaginary environment. Imaginary worlds are usually created in the minds of artists, who express their creativity in different ways (novels, films, plays, paintings, etc.) and try to convey and share it in their productions. Imagination is the basis for the creation of virtual worlds, for what can be done in them and for the possibilities and limitations they offer. The power of imagination allows people to live wherever they want, whenever they want and with whomever they want, to move around the environment and to carry out activities that are impossible in the real world: flying, fighting dragons, travelling through the universe or creating objects from scratch with their own hands. The only limitation is what can be imagined and the ability to communicate it. VR is a medium that allows to have a simulated experience that approximates that of physical reality, but it also permits to deliberately reduce the danger of physical reality and create scenarios that are not possible in the real world.

According to Sherman & Craig (2018), before being able to define more precisely what virtual reality is, it is necessary to define and understand a series of relevant concepts within this technology that in some way modulate it:

1. Immersion: this is the sensation of being in a given environment and can be a purely mental state or be achieved by physical means. Physical immersion is the defining characteristic of VR, as opposed to the mental immersion that is usually the main goal of most media creators (novels, films, etc.). In VR, immersion begins with physical immersion when entering the virtual world, which does not imply that all senses and the whole body is immersed/absorbed, whereas mental immersion may or may not occur depending on multiple factors, mainly individual involvement and engagement and the credibility of the experience. Generally speaking, the term "being immersed" usually refers to an emotional or mental state, the feeling of being involved in the experience. The idea of immersion refers to the user's feeling of being "inside" the virtual reality experience. To achieve this, the user must normally be totally isolated from the physical environment around them (Gigante, 1993; Kalawsky, 1993; Bryson, 1995). Agrawal et al. (2020) define immersion as "a phenomenon experienced by an individual when they are in a state of deep mental involvement in which their cognitive

processes (with or without sensory stimulation) cause a shift in their attentional state such that one may experience disassociation from the awareness of the physical world".

2. Presence: being mentally immersed. The notion of presence, although similar to immersion in the sense that it also refers to the user's feeling of being "inside" the experience, differs from it in that presence is obtained from the "realism" or "vividness" of the experience generated (Biocca, Kim & Levy, 1995; Biocca & Levy, 1995; Slater & Usoh, 1993). However, according to Zahorik and Jenison (1998) it is much more accurate and generic to speak of a sense of coherence of the experience. For these authors, "Presence is tantamount to successfully supported action in the environment", and they indicate that "Successfully supported action in the environment is a necessary and sufficient condition for presence".
3. Interactivity: reciprocal action, relationship or influence between or among two or more persons or things. Indeed, interaction is an essential ingredient in an immersive system that allows the user to act on the virtual world. For VR to appear authentic, it must respond to the user's actions and provide feedback. The VR system should provide direct sensory information to participants based on their physical position. In most cases, it is the visual sense that receives the feedback, although there are VR environments that include haptic (tactile) experiences, sound experiences and may even involve other senses. In order to be able to base the sensory output of the VR system on the position of the participant, the system must be able to track their movement.

In any case, it should be noted that neither immersion, presence, nor interaction are unique features of virtual reality and should not be central or exclusive elements of its definition.

According to Sherman & Craig (2018), virtual reality is “a medium composed of interactive computer simulations that sense the participant’s position and actions and replace or augment the feedback to one or more senses, giving the feeling of being mentally immersed or present in the simulation (a virtual world)”. Crofton et al. (2019) define it as "an immersive human-computer interaction in which an individual can explore and interact with a three-dimensional computer-generated environment". For Jerald (2015) VR is simply "a computer-generated digital environment that can be interacted with as if that environment were real". Although markedly different, two fundamental elements underlie all definitions: two-way human-computer interaction, the need for immersion, the need to feel the virtual space as real.

There are currently three types of virtual reality: (1)Head Based, (2) Stationary and (3) Hand Based. Head Based VR consists of a device placed on the head, like a kind of helmet, or a screen mounted in front of the eyes, which may or may not allow the outside world to be viewed. Images of the created world are displayed on a pair of screens (one for each eye) on the helmet or glasses. A position sensor tells the computer system where the participant is looking, or at least where the participant's eyes are located. The participant can observe the computer-generated world in a way that is similar to the real world (within the limits of current technology), making it a natural and intuitive interface. Other devices can be added to allow the participant to interact with the virtual world and not just look around. Instead of screens near the participant's eyes, the participant can wear a projection system on their head that moves with their head and projects onto walls or other surfaces they are looking at. This technique is called head-based projector display (HBPD). A stationary system is one in which the participant does not wear the VR equipment, but rather the VR equipment is located at a fixed point in space and the participant moves to where the system is located to participate in the experience. An example of this type of technology is the Cave Assisted Virtual Environment (CAVE), which is a three-dimensional virtual environment in a cube-shaped room with projectors facing the different walls, floor and ceiling. Depending on the desired result, the image will be projected on all or only some of the walls of the room. Using special stereoscopic glasses inside a CAVE, the user is completely immersed. The images appear to float in space, and the user is free to walk around without losing perspective. The CAVE was the world's first virtual reality technology that allowed several users to be fully immersed in the same virtual environment at the same time. More current versions exist such as the NextCAVE and CAVE2™ systems (youtube.com/watch?v=uKeL0CXp54I). A hand-based VR system is one in which the participant holds a device in their hand, such as a smartphone or smart tablet, to get the information. This can be something that is held close to the eyes (such as smart glasses) or it can be held at a distance, as is the case with many augmented reality (AR) applications. Although all three methods can be considered as virtual reality (Sherman & Craig, 2018), this document focuses only on the first one, Head Based VR, as CAVE can be considered as a middle ground between reconstructed reality and virtual reality and handheld devices as a combination of virtual reality and mixed reality.

Virtual reality requires three fundamental elements: the participant, the user interface and the virtual world. Figure 8 describes the most relevant elements to be taken into account within each of them. These aspects are described and discussed in the following sections of this chapter.

6.2 Virtual reality and food consumer science

Numerous studies show how consumers' emotional and hedonic responses are conditioned by the context in which a food is consumed (Hein et al., 2010; Jaeger et al., 2017; Jaeger & Porcherot, 2017). Context can be created through written or imaginary scenarios to evoke certain situations (Hein et al., 2010), through more realistic and ecologically valid environments such as the Restaurant of the Future developed at Wageningen University or through immersive physical environments such as a bar (Sester et al., 2013), a coffee shop (Bangcuyo et al., 2015) or an aeroplane (Holthuysen et al., 2017) in which visual, auditory, olfactory and tactile stimuli are combined to convey contextual information to the consumer. Real or imaginary worlds developed in virtual reality that stimulate one or more senses at the same time (Crofton et al., 2019), typically sight, hearing and touch, can also be created.

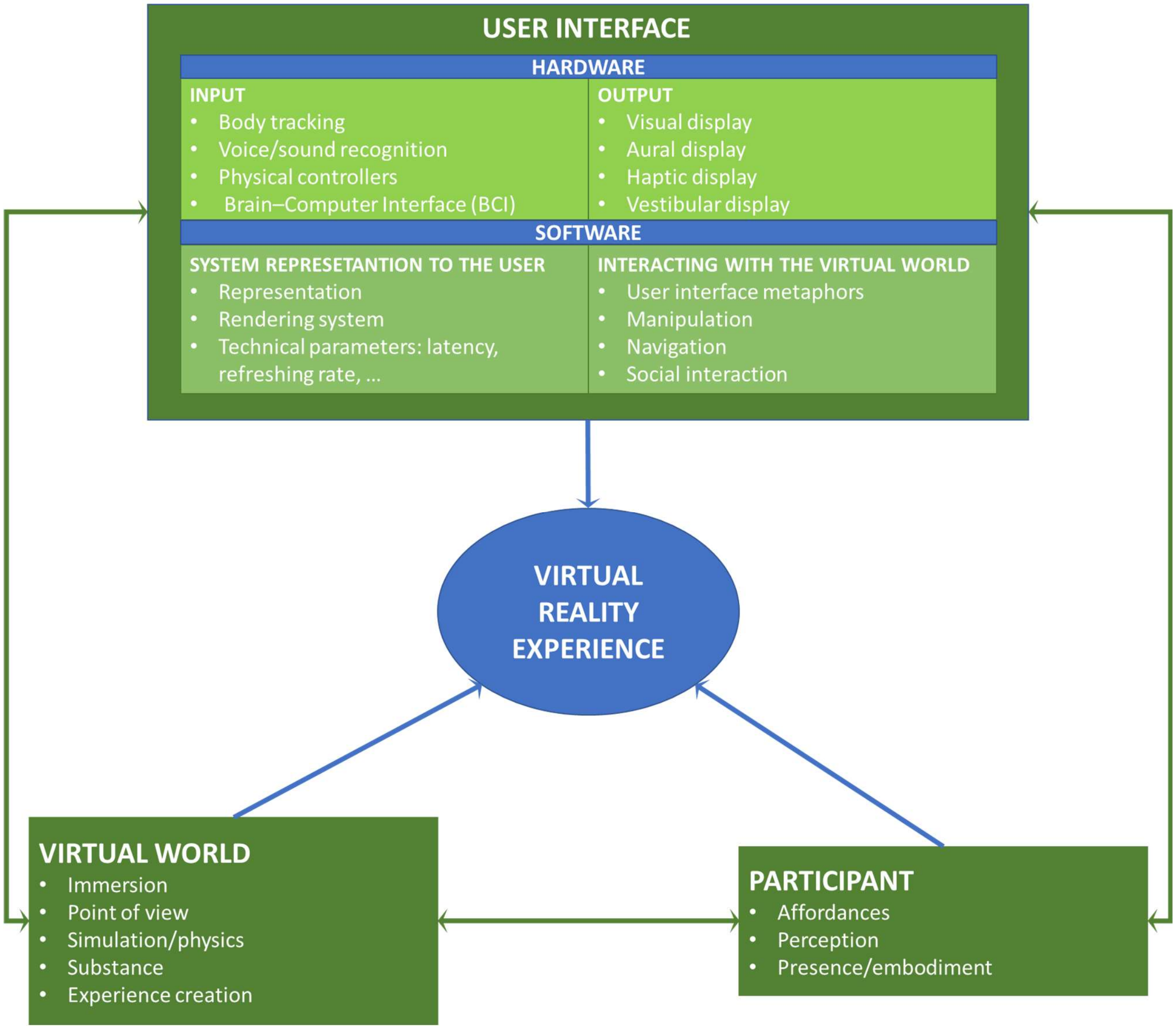

Figure 8. Elements that make up a virtual reality experience.

Virtual reality has numerous applications, from education and training (Jensen & Konradsen, 2018), product design and manufacturing (Berg and Vance, 2017), psychology (Wilson & Soranzo, 2015), medicine (Li, Yu, Shi et al., 2017) or food (Xu et al., 2021; Wang et al., 2021) among many other scientific disciplines.

Within the food domain, Xu et al. (2021) conducted an extensive literature review of published work on virtual reality between 2005 and 2021, as they considered earlier work to be exploratory and its applications focused on other types of research (e.g. aeronautical simulation, military use) and entertainment. These authors identified three main areas of research: (1) sensory evaluation of food products in VR; (2) exposures and responses to virtual food or food-related cues and environments; and (3) consumer behaviour towards food in VR environments. This last area of research was further classified into the following categories (1) shopping behaviour and product perception in VR supermarket environments; (2) food choices in VR buffet environments; and (3) other applications. In many cases, research has focused on food choice scenarios involving VR in which food is not consumed, such as product perception (Lombart et al., 2019, 2020; Sinesio, Saba, Peparaio, et al., 2019), food choice (Allman-Farinelli et al., 2019; Andersen et al., 2019; Cheah et al., 2020; Fang et al., 2020; Goedegebure et al., 2020; Persky et al., 2018; Persky & Dolwick, 2020; Ung et al., 2018), and purchase behaviour (Higuera-Trujillo et al., 2017; Xu et al., 2021). In the following, we discuss some of the reviewed works that are mostly located in the areas described by Xu et al. (2021).

Some researchers focus on the use of 360º video footage to generate VR content. This is undoubtedly a very simple, practical, and easy to implement option as it only requires a 360º filming camera (currently available on the market at very affordable prices and with excellent image quality), although the possibilities of interacting with the virtual world are usually quite limited (Wang et al., 2021). In fact, for some authors, immersive content based on 360-degree video would not constitute a true virtual reality experience, which requires computer-generated images (Aukstakalnis, 2017; Siegrist et al., 2019). However, the experience can still be considered immersive and through minor modifications and inclusions can be provided with a certain degree of interactivity (e.g. through some virtual tour software) or even the addition of computer-generated elements (e.g. navigation menus, information labels, audio, video, animations, 3D computer-modelled objects, etc.). For example, Andersen et al. (2019) studied the impact of exposure to an isolated sunny beach situation on the desire to consume beverages using a 360-degree VR video viewed through an HMD device. Other authors have also recently used 360-degree VR to explore the effects of different environments (park bench, cow barn and sensory evaluation booth) on the sensory perception of blue cheese (Stelick et al., 2018).

In many other cases, researchers choose to create their own virtual experience using specific software or contract the creation of the virtual world to a specialised company. This option undoubtedly generates more interactive and versatile content, although its main limitation may be the realism of the experience obtained and its possible degree of immersion and credibility (van Kerrebroeck et al., 2017; Sherman & Craig, 2018; Siegrist et al., 2019). Many studies have been carried out in this way. Several scientific papers have studied aspects of consumer eating behaviour in fully 3D computer-generated VR environments, such as a supermarket (Schnack et al., 2019; Siegrist et al., 2019; Verhulst et al., 2017) or a food buffet (Persky, et al., 2018; Ung et al., 2018), in which participants could move around and immerse themselves in the virtual space using an HMD. Most likely, as discussed above, the main limitation of this system is to achieve adequate realism of the food used. Thus, for example, as observed by Siegrist et al. (2019), fruits and vegetables developed in a 3D virtual world might be perceived as less palatable than in the real world. In any case, the speed at which technology is advancing and the possibility of scanning real products using advanced photogrammetry systems that even capture the textures of different objects, already makes it possible to obtain 3D digital foods that are difficult to distinguish from those in the real world.

An interesting aspect of VR is that it also allows the use of physiological or biometric sensors. Gorini et al. (2010) used heart rate and skin conductance in their VR experiments, observing that aversive physiological responses to food were like those in real life. In Burn's (2017) study, they even captured the emotional responses of consumers using facial recognition technology while they were immersed in a VR world. There are also devices that incorporate eye-tracking within the VR equipment itself, both to optimise the view of the virtual world by minimising the processing resources required and to navigate inside the virtual world. These eye-tracking systems also allow information to be obtained about individual behaviour within the immersive environment. Other authors, such as Pfurtscheller et al, (2006) have even investigated the use of brain-computer interfaces (BCI), successfully demonstrating the ability to navigate a virtual street using thought-modulated electroencephalogram (EEG) brain signals. Thus, the options available are much the same as in the real world with some minor limitations arising from the head-mounted device itself.

Undoubtedly, most of the published studies in the field of FCS focus on sensory properties. When it comes to actually tasting food in VR, studies tend to fall into two categories: First, studies where VR is used only to induce context, and the food is not represented in VR (Barbosa-Escobar et al., 2021; Chen et al., 2020; Kong et al., 2020; Picket & Dando, 2019; Torrico et al., 2020; Worch et al., 2020; Wen & Leung, 2021). In this case, responses are mostly collected after removing the VR goggles. The difficulties of having participants taste the food while wearing the HMD is perhaps why some researchers have used VR only to present a context, and then had participants evaluate the product outside the virtual context (e.g., in the context of a winery visit described by Wen & Leung, (2021)). The limitation of this procedure is that the exposure to the virtual context is separated from the actual evaluation of the product, so we cannot effectively measure the true influence of the context on their evaluation. Second, there are studies in which the participant can interact with the food itself in VR. These studies face more programming and execution challenges, with the trade-off of achieving greater immersion and reality. It is possible to alter the visual appearance of food in VR (Ammann et al., 2020; Wang et al., 2020), which offers rapid possibilities for product development, but also novel ways to study multisensory integration. Most of the research conducted has been based on relatively low-resolution simulations of foods, such as chocolate pieces (Ammann et al., 2020; Torrico et al., 2020; van der Waal et al., 2020), drinks served in narrow cups or glasses (Ammann et al., 2020; Wang et al., 2020), fruits and vegetables (Lombart et al., 2019, 2020), and buffets with geometric strips of chicken, carrot sticks and pasta (Ung et al., 2018). An additional challenge is to ensure that the food in question can be comfortably and easily consumed while wearing an HMD. So far, researchers have overcome this challenge by using finger foods (Gorini et al., 2010; Ammann et al., 2020), narrow cups (Ammann et al., 2020) and the use of straws (Nivedhan et al., 2020; Wang et al., 2020).

The integration of olfactory and gustatory stimuli within these VR environments is challenging and highlights an obvious limitation of these systems, although notable advances have been made in stimulating olfactory and gustatory experiences within different virtual environments (Carulli et al., 2016; Dinh et al., 1999; Harley et al., 2018; Li & Bailenson, 2017; Munyan et al., 2016; Persky & Dolwick, 2020; Porcherot et al., 2018; Risso et al., 2018; Stelick et al., 2018; Verhulst et al., 2020). Thus, simultaneous stimulation of multiple sensory modalities in a virtual environment has been observed to provide a perceptually enhanced sensory experience (Dinh et al., 1999; Gallace et al., 2012), including, of course, sound (Spence et al., 2019).

In all the studies conducted a major problem is how to measure the individual response. Clearly, the simplest way is to ask participants to remove their VR headset and make their assessments in physical reality. However, this takes participants out of the virtual experience. Alternatively, the experimenter can verbally ask participants questions while they are in the virtual experience. The experimenter then records the participants' responses, (Ammann et al., 2020; Wang et al., 2020). This process can also be automated, either through smart speaker technology (Morotti et al., 2020), or even AI (Wirtz et al., 2018). One of the advantages of voice interaction is the ability to record and transcribe participants' experiences as they naturally express them, as they might describe them to someone else, rather than having to translate their experiences into numerical scales, as is often the case in consumer research. This also allows for testing at home or remotely, without the experimenter having to be present. Finally, questionnaires can also be presented in the VR environment itself where participants can use a controller (Worch et al., 2020), a mouse (Huang et al., 2019) or head movement/gaze (Picket & Dando, 2019) to choose the correct answer.

VR offers countless opportunities for both exploring and inducing changes in human behaviour, although it can still be considered a nascent technology full of possibilities and improvements yet to be explored.

6.3 Protocol for studies in virtual reality

6.3.1 Design

The following table (Table 23) presents a list of VR specific factors related to study design that are considered a minimum reporting level in the protocol different than those described in Section 3.4.

Table 25. Study design factors for studies using VR different than those described in Section 3.4.

Factor	**Recommendations**
Study type	Most common study designs in VR are of analytical nature. • Observational studies with no randomization. • Intervention experiments with randomization (control vs. experimental group).
Study setting	VR studies usually performed in laboratory settings. The venue itself will shape the way a participant experiences the virtual environment. Because the experience is so affected by the state of mind of the participant, anything that affects the participant's subconscious mind may affect how the

	experience is perceived. In addition to the locations of a VR system, the way in which the venue is adorned affects how one approaches the experience (Sherman & Craig, 2018). Therefore, whenever possible and in order to make the experience more credible, both the location of the experiment and the decoration of the room where the experiment is conducted should be related to the type of study to be carried out. While conducting the study, it is important to remember that participants will be disconnected from the real world and the existing objects around them. Thus, if participants are standing and can or have to move around the available space, it is important to remove all objects or elements that could pose a risk to their integrity. Most existing VR systems allow the activity or play area to be delimited by means of two different systems (Sherman & Craig, 2018): • sensors located in the room • defining the action space within the virtual world itself In any case, it is important to make sure that these limitations are activated before starting the experiment.
Environmental factors	• Environmental factors should keep constant across subjects to avoids unwanted physiological reactions to external, non-experimental, (and often unrecorded) stimuli. • Environmental factors apart from the IEs targeted contextual cues (e.g., temperature, humidity, noise, lighting) must be congruent with the recreated environment, should be controlled and reported.
Experimental design	Design factors should be described as detailed as is necessary given the specificity of the design as treatments, levels, and randomization (e.g., two-group, factorial, randomized block, repeated measures). Both, within-subjects & between- subjects design are present in VR experiments. • Within-subjects design is recommended to account for individual differences and decrease the impact of external factors, but confounding factors as fatigue and learning effects should be addressed by counterbalancing the design (Swan et al., 2006).

	• Between-subjects design could introduce potential confounding factors due to consumer heterogeneity across conditions (Lichters et al., 2021).
Exposure to IEs	Exposure duration and repeated exposures in VR impact on participant's experience in relation to its engagement and comfort (Kennedy et al., 2000). VR is the most sensitive modality in relation to exposure characteristics. Best practices when using HMDs include: • Optimal length of total exposure: 20 to 30 min. at the longest (Kennedy et al., 2000). • Intersession interval: minimum 5 min. break between different conditions (Ledoux et al., 2013; Ung et al., 2018) and 30 min. between sessions (Stanney et al., 2021). • Repeated exposure reduces the severity of cybersickness due to habituation (Risi & Palmisano, 2019), but should be used with caution as it can generate learning effects.

6.3.2 Sample selection

Participant factors that influence data

Although participant factors are highly dependent on the research questions, all virtual reality studies should record certain information about the participants (Table 24), other than the ones described in Section 3.4.2 for general guidelines of IEs protocol.

Table 26. Participant factors that influence data in studies using VR.

Factor	**Recommendations**
Vision correction	The use of corrective lenses may hinder wearing VR HMDs. Therefore, it is recommended to investigate if participants with glasses can replacement them for contact lenses during the experiment (Schnack et al., 2019). Some devices have an additional space for the participant to wear his or her corrective glasses. Other gadgets allow the addition of external corrective lenses making the experience much more pleasant without the need to feel the oppression of the HMD over the regular glasses.

Other disabilities	If the participant has a hearing or tactile impairment, it will be necessary to assess its possible impact on the quality of the virtual experience, their ability to interact in the virtual world and therefore whether they can participate in the study.

Participant factors that influence safety and inclusion/exclusion criteria

Individual factors, other than the ones described in Section 3.4.2 for general guidelines of IEs protocol, can influence the safety of Virtual Reality studies (Table 25).

Table 27. Participant factors that influence safety in studies using VR.

Factor	Recommendations
Visually induced motion sickness susceptibility (VIMSS)	In VR experiences high latency between an action and its reaction can cause nausea (a not uncommon symptom of simulator sickness), which can be even enhanced when dealing with interfaces that rely on body motion to interact with virtual controls (Sherman & Craig, 2018). Cyber sickness can be induced by many other factors such as when content (dynamic content while sitting still, a potential issue with showing 360 videos) and human factors (the participants' previous experience with VR) (Chang et al., 2020). The degree of cyber sickness experienced by each participant should also be measured in order to control for its effects in experimental results. Typical VR tasks in sensory and consumer science do not involve much movement, especially when the participant is sitting still, so the risk of cyber sickness in those cases is relatively low.

6.3.3 Ethical factors

The ethical issues that, in general, researchers should consider prior to carrying out an immersive study using IE's are described in Section 3.4.3. However, there are certain specific ethical issues and concerns associated with VR that need to be considered.

VR is the most important technology currently available for entering an alternative virtual world (Han & tom Dieck 2019). Sometimes, this form of escapism from reality can turn into self-indulgent escapism, which is often based on pleasurable content, such as that presented in (online) games, which induce feelings of euphoria that help a person to distract themselves from stimuli and/or stressful situations (Han et al., 2022).

Psychological consequences of indulging in self-indulgent escapism may include, for example, depression and anxiety, increased aggression and reduced self-control (Panova & Lleras, 2016). Social consequences include decreased interpersonal skills (Engelberg & Sjöberg 2004), social anxiety (Hardie & Tee, 2007) and increased feelings of loneliness (Morahan-Martin & Schumacher 2003). These negative consequences may, in turn, reinforce the difficulties of life and thus further increase the desire to escape from real life. This two-way relationship constitutes a dangerous vicious circle that may ultimately have detrimental effects on individual health and well-being, and therefore requires detailed analysis from an ethical point of view.

6.4 Technological factors for studies in virtual reality

This section summarises the main aspects to consider in VR with respect to the HMD (Table 26), the devices that enable interaction between the individual and the virtual world (Table 27), and the software needs to create immersive VR space (Table 28).

Table 28. Main technical characteristics of the VR HMDs.

Parameter	Characteristics
Peripheral vision	Peripheral vision of the external environment reduces cybersickness, although it may reduce realism and the sense of presence. Depending on the virtual environment to be recreated (e.g. depending on the existing and intensity of the movement in it) it should be decided whether or not it is necessary to maintain a certain degree of peripheral vision (Moss & Muth, 2011).
Delay	Visual feedback latency affects the quality of the user experience and interaction. Latency in the display update of the viewfinder screen has a marked impact and should be avoided or limited to very short latencies of less than 30-35 ms. In the case of joystick or handheld controller latency, higher latencies are acceptable, but always below 0.5 ms (Brunnström et al., 2020).
Refresh rate	A low refresh rate can have negative effects in VR, such as a reduced sense of presence and influence performance and user response (Martirosov & Kopecek, 2017). VR manufacturers try to maintain a refresh rate of at least 75 Hz (Hořejší et al., 2016).
Resolution	Display resolution and pixel density play a significant role in terms of image quality (Angelov et al., 2020). These parameters affect the Screen-door

	artifact (a grid that outlines the contours around the pixels). Most commercial devices have minimum resolutions of 1280x1440 pixels per eye and pixel densities starting at 11 pixels per degree.
Field of view (FoV)	The binocular FoV of a human being reaches 190° (Al Zayer et al., 2019). Therefore, the closer the FoV of a device is to this value, the more natural the perceived image will appear to be.

Table 29. Main characteristics of the VR user interface.

User interface	**Characteristics**
Tracking	Tracking is a fundamental element of any modern VR equipment and an important point of interaction between the individual and the virtual world. It determines users' viewpoint position and orientation. The quality of immersion in VR depends, first, on how efficiently the tracking system works. There are two types of tracking: orientational and positional. The type of tracking determines the number of degrees of freedom (DoF) within which changes in the position of the target devices are tracked. (Angelov et al., 2020). Positional tracking provides more opportunities for implementing software systems with more complex, realistic user interactions with the environment in VR, and is generally more suitable for providing full immersion experience.
Controllers	The controllers allow the user to interact directly with the VR environment providing a more immersive experience. They can be used not only as an input system, but also as an output system, allowing the user to experience tactile feedback because of their actions. Most of today's devices work with 6DoF controllers.
Ergonomics	The ergonomics of any device depends on many factors, such as: design, comfort, usability, user-friendliness of the software, responsiveness to user input, etc. The weight of the equipment plays a major role in its usability as the device must be worn on the head. Also, having wireless devices makes the immersive experience significantly better, especially if the user needs to move around freely. The possibility for the user to wear his or her glasses while using the HMD, the possibility to add corrective lenses, the option to adjust the interpupillary distance or headphones for a better hearing

	experience are other factors, which although optional, can improve the overall experience in a remarkable way.

Table 30. Software and other tools for creating VR content.

Software and tools	Characteristics
Commercial software available	The main software options for creating virtual reality (VR) content are: • Unity: A popular and widely used VR game and application development platform. It provides tools and resources for creating interactive VR environments. • Unreal Engine: Similar to Unity, Unreal Engine is a game engine with VR capabilities. It is known for its graphical power and is used both in the entertainment industry and in VR simulation and training applications. • Blender: Although primarily a 3D modelling and animation software, Blender also supports VR content creation. It can be used to create 3D environments and characters that can then be exported to VR platforms. • Adobe Creative Cloud: Adobe offers several tools in its Creative Cloud suite that are useful for VR content creation. Adobe Dimension and Adobe Aero are two popular options for designing and visualising VR content. • 3ds Max: This is another 3D modelling and animation software that enables the creation of VR content. It provides specific tools for creating immersive VR experiences. There are many other programmes and tools available for VR content creation. The choice of software depends on needs, level of experience and personal preferences.
360 video	Numerous 360° cameras are now available to record immersive video quickly, simply and inexpensively. These videos can be included in virtual tour programmes, allowing the creation of very real, high quality and highly interactive virtual experiences.

Once overviewed the technology used in VR, other factors that can have an impact on data collected are presented in Table 29. However, for maximum transparency and detail when describing the technological factors related to the context recreation used in the study, we strongly recommend researchers to provide as much details as possible. Concerning instructions or guidance on how to use a particular equipment effectively and safely, we recommend first and foremost to follow user manuals supplied by the providers, as the information offered in this section might not reflect the most up-to-date technological possibilities.

Table 31. Other factors that can influence virtual reality studies.

Factor	Recommendations
Set-up factors	Contextual cues of the location where the study is taken place should be considered as stimuli as may potentially generate a reaction in the participant. This factors should be reported, described in a clear and transparent manner, and controlled. Environmental conditions apply to all MR approaches, thus including VR. Set-up factors should be reported, described in a clear and transparent manner, and controlled.
Data	VR studies have the potential to generate considerable volume of data including: • Data from inputs captured by sensors, cameras, microphones, etc. • Data from outputs displayed by screens, speakers, etc. • Data from the VR systems themselves: environment representations, digital objects, etc. • Behaviour inside the virtual world. This high volume of relevant and detailed data has implications on data processing and data management planning.
Length of exposure to VR	Length of time exposed to a virtual environment may influence likelihood and severity of VR sickness (Duzmanska et al., 2018). Longer exposure times increase the risk of VR sickness (Stanney et al., 2003). The optimal exposure time depends on various factors such as movement within the virtual world, latency, the individual's experience or personal sensitivity among other factors, so it is difficult to provide a general recommendation at this point.

6.5 Harmonised measures for studies in virtual reality

Obviously, the harmonized measures collected in studies using virtual reality will largely depend on the research question. However, in this type of studies it is possible to collect either behavioural measures captured through participant observation, self-reported measures obtained through surveys and questionnaires, psychophysiological measures of consumer response captured through emerging technologies, or a combination of the above-mentioned typologies. For more information, please see Section 3.6.

6.5.1 Consumer behaviour measures

Information related to consumer behavioural measures that can be collected in studies using virtual reality is presented on Section 3.6.1.

6.5.2 Immersive experience quality measures

As in other immersive studies, when using virtual reality, it is worthwhile and advisable to measure several indicators to assess the participant's experience. These are presented in Section 3.6.2

6.6 Stimuli for studies in virtual reality

As mentioned above, the stimuli used in an immersive study, both in terms of context and product, should be described and reported in a detailed, clear, and transparent way. In immersive studies using virtual reality these are described in Section 3.7.1 and Section 3.7.2 respectively.

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Chapter 7

Minimum Reporting Checklists

7. Minimum reporting checklists

In Chapter 7 we provide minimum reporting checklists across all studies using immersive environments.

7.1 Minimum reporting checklist for all studies using immersive environments

Category	Examples of Sub-Categories
General information	
Researchers involved	*Name and surname of each researcher involved*
Institution	*University, Research Institution*
Study name	*E.g., "Study on psychophysiological measures"*
Start/end date	*Date when the project was started and finished*
Research question(s)	
Objective	
Topic (keywords)	*E.g., eye tracking, eco packaging, attention*
Theoretical background	*Theoretical background behind the hypotheses raised*
Country that research took place in	
Study type	*E.g., Experiment, longitudinal study*
Study design	
Immersive approach	*E.g., Reconstructed reality (RR), Mixed reality (MR), Augmented reality (AR), Pure mixed reality (PMR), Augmented virtuality (AV), Virtual reality (VR)*
Research scenario	*E.g., See context, then make product selection; Select and interact with product in context; See context, then evaluate product in real life; Taste and evaluate product in context*
Appropriateness of the immersive approach used	*Explanation why this immersive approach should be used in that research scenario with the chosen research question*
Study setting	*Laboratory settings, naturalistic settings or those that resemble real-life scenarios*

Environmental factors	*Non-manipulated environmental factors different from the targeted contextual cues (considered as stimuli in IEs studies) used to recreate the environment of the setting where the study takes place.* *E.g., Illumination: White fluorescent ceiling panel lights used to illuminate the participant booth, minimal lighting from the monitor; Temperature: 22 degrees Celsius in the laboratory during the study; Sound: no additional sound in the laboratory*
Experimental design	*Design factors should be described as detailed as is necessary given the specificity of the design as treatments, levels, and randomization* *E.g., Two-group, factorial, randomized block, repeated measures, within-subjects & between- subjects design*
Study set-up	*E.g., individuals were seated by the table, 30cm away from the monitor*
Study timing	*E.g., study was conducted over multiple days, with each session run between 10 am and 11 am.*
Exposure to IEs	*E.g., Exposure duration, repeated exposures, total exposure duration*
Task(s)	*Task(s) used in the study (if tasks involved stimuli, please see the section "Stimuli" of this table)*
Sample	
Screening factors	*List of screening factors*
Recruitment source	*E.g., university subject pool, online advertisements*
Inclusion/exclusion criteria	*E.g. only participants who indicated being regular smokers were included in the study*
Sample size	*Number of participants in a study and per condition (if any)*
Demographics	*Participants' age, gender, race, ethnicity*
Incentivisation	*Did participants receive any renumeration for the participation in the study; if yes, describe in details*
Barriers to participation	*E.g., Clinical factors, aversion to IEs*
Participant characteristics	*E.g., whether participants have corrected vision, are taking cardioactive medication*

Relation to technology	*E.g., Prior experience, technological savviness, cognitive innovativeness/openness to novelty*
Ethical Factors	
Informed consent	*Copy of the informed consent*
Privacy	*What measures were taken to ensure privacy*
Right to withdraw	*Were participants given right to withdraw; if yes, when and how could they withdraw from the study*
Correct training	*Have researchers and assistants received correct training needed for the particular study*
Bias and Equality	*Did the researcher ensure equality and minimize biases between participants*
Validity and Comfort	*Was participants' validity and comfort taken into consideration*
Openness and accessibility	*What measures were taken to make data Findable, Accessible, Interoperable and Re-usable*
Documentation	
Participant Information Sheet	*Copy of the participant information sheet*
Informed Consent form	*Copy of the informed consent form*
Demographic form	*Copy of the demographic questionnaire form*
Screening form	*Copy of the screening form*
Instructions	*Copy of the study instructions*
Pre-registration/ Registered Report	*Was the study pre-registered; if yes, links to the form*
Technological factors	
Hardware	*Manufacturer, type, version*
Software	*Type, version*
Software defaults	*Data processing parameters (including defaults)*
Other device(s)	*Manufacturer, type, version*

Set-up factors	*E.g., camera was placed above the monitor at an approximately 20 degree angle*
Data	
Measures	*Type of measures (behavioural measures and/or immersive experience quality measures) and methodology used for constructing variables of interest* *E.g., Observational, self-reported measures, psychophysiological measures*
Timestamps	*Recording and/or analysis timestamp, including for how long a measure has been recorded, indicators for when it started and finished and whether the whole length of it was used for the analysis* *E.g., Psychophysiological measures were taken for 15s starting at 5s from the onset of the stimulus presentation*
Analysis	*How the data will be analysed, including data processing, set of steps and techniques used to clean, organize, transform, validate and prepare data for analysis*
Data management plan	*A document outlining how the data is planned to be managed (collected, stored, shared, preserved) during and after your research project*
Data quality check	*How the data quality was checked*
Data cleaning	*Missing values, outliers, implausible values*
Stimuli	
Setting	*Manipulated environmental factors that may potentially generate a reaction in the participant which make up the variables of study* *E.g., Immersive room description, virtual scenario features*
Category	*Implicit: generated internally by the subject, such as during a resting state condition, imagining a scene, or re-living a previous experience* *Explicit: exists at least in part externally to the subject. This also includes objects in virtual worlds*
Role	*Target; Non-Target; Reward ; Feedback; Passive*

Modality	*Only in case of explicit stimuli. Visual; Tactile; Gustatory; Olfactory; Auditory; Interoceptive; Proprioceptive; Multisensory experiences*
Type	*In relation to the context (re)creation included:* • *Physical objects (e.g., furniture, non-targeted product, tableware)* • *3D objects (e.g., furniture, non-targeted product, packaging, menus, shopping trolley)* • *Film clips (e.g., bar ambience)* • *Pictures (e.g., food photos, food labels, immersive environments)* • *Music* • *Non-vocal sounds (e.g., animals, machines, nature, objects, or other non-human origins)* • *Odours (e.g., scents, odorous solutions)* • *Substance that is eaten, drunk, or otherwise ingested different of food (e.g., liquid solutions, gustatory samples)* • *Symbols (e.g., logos, labels)* • *Tactile stimulation* • *Words (e.g., information displays, brands, speech, marketing messages)* *In relation to the targeted food product/product assortment:* • *Physical object (e.g., food product, product packaging)* • *3D object (e.g., food product, product packaging)* • *Picture (e.g., food photos, food labels)* • *Tactile stimulation* • *Symbols (e.g., logos, labels)* • *Words (e.g., information displays, brands, speech, marketing messages)*
Stimulus description	*Individual distinctive description of the stimuli*
Number of items targeted	*Total; number per type*
Size/Volume	*Dimensions in cm/Pixels; all same size, or range (size of smallest – biggest); volume in ml/oz*

Presentation	*Delivery system or output interface in relation to the context (re)creation (e.g., Immersive room, projectors, screens, smartphone, tablets, speakers, HMDs)* *Presentation of the targeted food product/product assortment (e.g., stimuli presented in plastic cups, different coloured lids for ease of recognition; presented through nosepiece)*
Order of presentation	*Randomized (individual or block randomization); Increasing (decreasing) order*
Set (block) of stimuli	*10 stimuli within a set*
Position	*For visual stimuli: Central; Left/Right; 4-grid;*
Length of exposure	*Value and units in seconds or milliseconds; duration of the stimulus until response; until end of the experiment*
Interstimulus interval	*Time interval between stimulus in seconds or msec. in case of more than one IEs is presented*
Stimuli pre-selection	*Any trial sessions ran to select a final set of stimuli*
Temperature	*For gustatory stimuli: room temperature, degrees Celsius, Fahrenheit*
Taste type	*For gustatory stimuli: e.g., sweet, bitter*
Taste type intensity	*For gustatory stimuli: e.g., 4 levels of bitterness (increasing)*
Taste neutralizing/Neutralizing effect for break	*For gustatory stimuli: e.g., water, crackers, nothing (e.g., passing time)* *For visual stimuli: e.g., neutral picture after a stimulus/set of stimuli*
Odour concentration	*For olfactory stimuli: weak, medium, strong*
Valence	*Positive, negative, neutral*
Task topic and type	*Attention: Passive attention; Visual search; Search; Involuntary Attention; Unconscious Process; Selective Attention; Object-Based Attention;* *Emotion: Arousal (emotion); Happiness; Excitation; Emotional decision making; Taste Aversion; Mood; Valence; Shame;* *Executive Control: Self-control; Planning; Goal Maintenance; Behavioural Inhibition; Proactive control; Resistance to distractor interference;*

	Language: Semantic Processing; *Action: object manipulation;* *Learning & Memory: Emotional memory; Gustatory memory; habit; reward processing; implicit memory; association learning; familiarity;* *Motivation: curiosity; appetitive motivation; desire; intrinsic motivation; aversive salience;* *Perception: Object perception; gustatory perception; preconscious perception;* *Reasoning & Decision Making: Judgement; Decision making; Risk Processing; Categorisation; Subjective value judgement; subjective food value* *Social Function: interaction with environment; ability to fulfil one's role within the environment*
Task name	*Visual attention task; hedonic liking task; Affect arousal task, motivational arousal task*
Task description	*2-choice task, lasting 30 minutes…*
Task presentation	*Manual: instructors presents and removes stimuli* *Automatic: software or robotics presents and removes stimuli*
Task instructions	*Attend; Detect; Discriminate; Fixate; Name; Read; Recall; Encode; Imagine; Rest; Track; Taste; Smell*
Task response category	*Overt response: made with a body part that is externally observable by others* *Covert response: made internal to the body, which is not directly observable by external viewers.*
Task response modality	*Only for overt response, as covert response is unobservable by the experimenter.* *Hand; Arm; Eye; Face; Mouth; None*
Task response	*Overt response: Button Press; Point; Speech; Write; Demonstrated emotion* *Covert response: psychophysiological indicators*

Chapter 8

Conclusions and future directions

8. Conclusions and future directions

Extended reality includes several types of technologies, all of them different, with diverse peculiarities, advantages, disadvantages, applications and levels of immersion. This deliverable gathers the most common ones in FCS and provides recommendations on the relevant aspects to take into account when carrying out a study of this type.

Like any other technology, extended reality changes and evolves very quickly, so some of the recommendations mentioned in this document may no longer be relevant in the near future and may require an update to include improvements and even new technologies associated with them.

Generally speaking, extended reality requires three basic elements: 1) a recreated context, which can be virtual, physical or a combination of both and is usually the place where a certain stimulus is presented, 2) the stimulus on which the study is based, which can be a product, an idea or even the recreated context itself, 3) an individual who interacts with the two previous ones in some way, either digitally or analogically. Each of these elements, in turn, has a range of specific needs associated with it depending on the technology applied as described in this document. The possibilities of combining the options offered by extended reality are very broad and can be adapted to each specific need. Thus, we can tackle both simple problems with simple tasks and complex problems with complex tasks. The main problem in the latter case lies in the hardware and software requirements necessary for them, both to create the experience and to interact with it.

The use of extended reality, in any of its varieties, allows to go beyond laboratory studies, taking the use and consumption of food and other products to a more real situation and therefore with greater ecological validity. The possibility of recreating all kinds of situations, even those that do not even exist in the real world, allows to expand the knowledge and understanding of human behaviour to almost any scenario and context. Nowadays, technological advances make possible to integrate and include different stimuli, not only visual, but also smell, tactile sensations, sounds and even the movement of the participant (simulators), which, added to the development of more powerful software equipment, with lower latencies, higher resolutions, and higher image quality, brings the experience to a higher level of realism, credibility, and immersion. Finally, it is worth mentioning the possibilities to interact with the recreated contexts. For an individual to feel part of an experience, it is important that they can interact with it in the same way as they would in real life. In this sense, although a lot of progress has been made in recent years, there is still a long way to go in terms of eliminating wires, including less invasive and heavy movement sensors, etc.

In short, we can consider that extended reality, although relatively young, is consolidating itself as a powerful tool in FCS, and that it will most probably grow continuously in the coming years, facilitating all kinds of experiences, from those we are currently familiar with to situations and ways of working that we cannot even imagine.

This document describes what extended reality is and how to put it into practice, as well as a series of general and specific recommendations and advice for each of the three types of technologies addressed (chapters 4, 5 and 6). However, as mentioned above, there are a number of limitations and recommendations inherent in this type of document, which are described below:

1. This document is intended to be used as a user's guide, so it should be a document in which it is easy to locate the information, which incorporates examples, images, videos, etc. To achieve this in a written document is quite complex, so it would be highly recommended to explore the possibility of creating a more interactive document. As proposed in deliverable 6.1, converting the document into an interactive digital format such as a "wiki" would allow more universal and simple access, greater interactivity, the inclusion of all kinds of audio-visual media and even easier updating of information.

2. As mentioned above, updating this document is a key element for its continuity and usefulness. Science is a living, changing and evolving entity, in which it is necessary to update and incorporate new developments, which is even more relevant when it involves different technologies as in the case of extended reality. Some of the information contained in this document could become obsolete in a relatively short period of time, so it would be advisable to design a system that allows for frequent updating in order to make it a truly useful tool in FCS.

3. One of the keys to extended reality is to achieve the immersion of the participant, i.e. to increase the ecological validity of the measures, which is why everything that helps to create more real experiences should be promoted. Human beings, although mainly driven by the sense of sight, also receive continuous input from the rest of their senses. For example, the film industry is aware of the importance of the soundtrack in the overall experience (we can confirm it for ourselves by watching an action scene with or without audio) and take care of it. Therefore, the stimulation of senses other than sight during the recreation of any context plays a fundamental role in the quality, credibility, and immersion in it. In this sense, there is still much work to be done to approximate the sensations we perceive in the real world with those we perceive in a recreated environment.

4. Another interesting aspect, closely related to the previous point, is the ability to interact in the recreated world, both with the elements included in it and with other people. Most human beings live in society, so it is unrealistic to participate in an experience in isolation without being able to interact with other people. While this is easily assumed in some technologies, in others such as VR it is an issue that is not yet well resolved.

5. Finally, it is important to mention everything related to the measurements that can be obtained from an individual immersed in a recreated environment. The use of artificial intelligence opens up a wide range of possibilities for oral communication between the recreated world and the individual. It should not be

forgotten that filling in a questionnaire, whether on paper or digitally within the immersive environment itself, is an atypical situation that does not correspond to reality. When you are in a bar with a friend drinking a beer, you can comment on what you feel, what you perceive, your opinion, but it is totally unnatural to take out a paper and a pen and write it down. Therefore, oral communication represents the simplest and most natural way of gathering opinion and interacting with an individual. In the coming years we are likely to see a breakthrough in this respect. Other ways of capturing information about the participant are the incorporation of less invasive and wireless physiological sensors (Heart rate, Galvanic response, etc.) and the recording and interpretation of their behaviour both in the real world (expressions, sounds, emotions) and in the recreated world.

Extended reality is probably one of the fields in which FCS might have a great potential for growing in the coming years. We must not forget that in the end our experiences are nothing more than an accumulation of sensations that we perceive from the outside world with our senses and that we should therefore theoretically be able to recreate them in a controlled environment. Perhaps in the future the most sustainable way to travel to any place in the universe will be a virtual experience that involves all our senses and that we can perceive as if it were real...

"Nothing ever becomes real till experienced - even a proverb is no proverb until your life has illustrated it." (John Keats)

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