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The Impact of Multisensory Integration on Decision, Cognition and User Experience

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Résumé

Comprendre comment les utilisateurs réagissent à certains stimuli, ainsi que les liens entre les processus psychologiques et cognitifs, permet aux designers UX de concevoir des interfaces centrées sur l'utilisateur, capables de répondre efficacement à leurs besoins. Dans cette optique, l'intégration multisensorielle, un processus par lequel plusieurs stimuli sensoriels interagissent pour générer une réponse, reste encore sous-explorée. Des phénomènes comme la synesthésie, où certaines personnes perçoivent une sensation automatique dans un autre sens que celui initialement stimulé, illustrent pourtant le potentiel transformateur de cette approche pour l'expérience utilisateur et la conception d'interfaces.

Certaines industries utilisent déjà des effets inspirés de la synesthésie pour renforcer l'immersion ou améliorer la prise de décision. Toutefois, ces usages se limitent souvent à deux sens (la vue et l'ouïe) ce qui limite la compréhension des effets complets d'une intégration multisensorielle plus étendue sur la qualité des décisions. Cette étude approfondit ces pistes dans le domaine du jeu vidéo, en explorant les effets cognitifs et expérientiels de l'utilisation de plus de deux sens dans des contextes interactifs.

À travers une méthodologie mixte combinant entrevues et questionnaires basés sur des scénarios auprès de joueurs, les résultats montrent qu'une stimulation sensorielle modérée améliore la concentration, l'immersion et la satisfaction. En revanche, une surcharge ou un conflit entre les différents sens entraîne une fatigue mentale et une baisse des performances. Ces résultats soulignent l'importance du design de l'interface, du contexte environnemental et des possibilités de personnalisation pour créer des systèmes multi-sensoriels efficaces.

En identifiant les seuils de saturation sensorielle, cette recherche propose des recommandations concrètes pour concevoir des expériences à la fois immersives, agréables, accessibles et non épuisantes pour l'utilisateur.

Mots clés : Conception de l'expérience utilisateur; Intégration multisensorielle; Attention intermodale; Stimuli sensoriels; Charge cognitive; Prise de décision; Immersion; Interfaces de jeu.

Méthodes de recherche : Questionnaire basé sur des scénarios; Entretiens semi-directifs; Test de Friedman; Test des rangs signés de Wilcoxon; Analyse qualitative.

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Abstract

Understanding how users respond to certain stimuli, and the interrelation of psychological and cognitive processes can guide designers in crafting user-centered interfaces that effectively respond to users' needs. As we strive to understand diverse user needs, the potential of multisensory integration, where two or more sensory inputs interact and create a response, remains largely unexplored. Phenomena such as synesthesia, where individuals, known as synesthetes, experience automatic, involuntary responses in a second sensory pathway when one sensory pathway is stimulated, reveal how this process could revolutionize user experience and interface design.

Existing industries use synesthetic effects to enhance immersion and improve decision-making. These applications generally limit sensory integration to two sensory inputs (audiovisual), leaving a lack of understanding of the full effect of multisensory integration on decision-making quality. This study extends those applications in the gaming industry by exploring the various effects of using more than two sensory inputs in interactive contexts.

Through a mixed-methods study involving interviews and scenario-based surveys in the gaming community, findings show that moderate multisensory integration enhances decision focus, immersion, and enjoyment. However, excessive or conflicting stimuli introduce cognitive overload and reduce players' performance. These results highlight the significance of interface design, environmental context, and players' customization in designing effective multisensory systems.

By identifying thresholds for sensory saturation, this research offers practical recommendations for creating immersive yet enjoyable, accessible, and not mentally tiring user experiences.

Keywords : User Experience Design; Multisensory Integration; Cross-Modal Attention; Sensory Stimuli; Cognitive Load; Decision-Making; Immersion; Gaming Interfaces.

Research methods : Scenario-Based Survey; Semi-Structured Interviews; Friedman Test; Wilcoxon Signed-Rank Test; Qualitative Analysis.

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List of tables and figures

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List of abbreviations and acronyms

UX User Experience

AR Augmented Reality

VR Virtual Reality

MSI Multisensory Integration

CMA Cross-Modal Attention

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Preface

This thesis is the result of a personal and professional journey to understand the impact of senses not only in the gaming industry, but in all industries. The interest in this research stemmed from both my academic interests, while pursuing a Master's degree in User Experience, and my work as a game developer. As a lifelong gamer, I have always been interested in how players interact with game interfaces, not just from a user experience standpoint, but from a personal perspective. I was curious about why players love gaming so much and sometimes use it as an escape from reality. My curiosity deepened as I was exposed to virtual reality, where I began questioning how far immersion could go and what it would take to design truly game-changing, engaging, yet humane user interfaces.

The idea for this research came from a recurring theme in the gaming community: the desire for immersion not only to enhance gameplay but to offer a meaningful escape from reality. I became interested in how we can design better experiences that can stimulate the senses in a way that respects cognitive boundaries without dehumanizing the user or hindering their interactions with the real world. My initial instinct was to explore how many senses could be integrated into a gaming experience, trying to include as many as possible. However, through the process of developing this study, my thinking evolved, and I realized that the real question was not how much we can add, but how we can do so optimally, while supporting the player without overwhelming them.

Conducting this research came with its own challenges, particularly the lack of time and access to physical lab equipment that might have supported a real-world implementation with even more applicable results. However, I was surprised and encouraged by the enthusiasm participants showed for the study and the thoughts they shared during interviews.

Their perspectives helped tremendously in crafting a user-centered approach to this thesis and applicable to real gaming environments.

Over the two years I spent developing this research, I witnessed new innovations in gaming technology focused on the addition of senses gaining more attention. From Sony's recent exploration of scent feedback in controllers to the emergence of new haptic gloves for virtual reality. These developments confirmed and reinforced the relevance of my work, convincing me that human-centered, multisensory design has the potential to drive the evolution of gaming and other technologies in the future.

This thesis is both a contribution to academic findings and a reflection of my personal goal as a UX designer: to find the best ways to innovate while always keeping the user in mind. I hope that this study will inspire other researchers and designers to consider how we can design engaging experiences, but also how we should always ensure they remain meaningful, respectful, and accessible to users.

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Acknowledgements

I would first like to express my appreciation to my thesis supervisor, Ruxandra Monica Luca, whose constant support and direction were the backbone of this entire project. She was my academic mentor and a strong pillar throughout the research process, always available to answer questions, provide feedback, and ensure I stayed on track week by week. Her patience and commitment helped me meet every deadline, and submit my thesis on time, graduating with my Master's degree.

I would also like to thank Annemarie Lesage, who supported me during the early stages of this thesis. Her interest in my career aspirations gave me the confidence to pursue a direction that aligned with them. Her initial ideas and feedback during the introduction and literature review helped shape the foundation of this study.

Thanks to all the participants who took the time to complete my survey and contribute to the interviews. Your interest, enthusiasm, and kind words in the subject really inspired me to keep going forward. All of the quality responses I received reminded me that this research has a purpose and is not only for academic achievement, but for a community I deeply care about.

I am also very thankful to my friends and family for their encouragement, emotional support, and belief in me throughout my entire program of study. Your beliefs in my skills and performance, especially when I doubted myself, meant more than I can put into words. I would also like to acknowledge the company I worked for as a game designer during my Master's program. Although I no longer work there, the lessons and experiences I gained during that parallel year of working and studying really changed my thinking and helped shape this work.

Lastly, I need to acknowledge my own efforts through this journey. I learned that long-term dedication and responsibility truly pays off. I never thought I would be able to complete a Master's and even less so this thesis, and yet, here it is. One step closer to overcoming that impostor syndrome.

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Introduction

1.1 Context

General Problem

With global revenues nearing 455 billion U.S. dollars in 2024, the video game industry stands as one of the most lucrative entertainment markets worldwide (Clement, 2024). As competition rises and user expectations shift, developers are no longer just building games but instead they're crafting fully immersive experiences. In fact, 68% of U.S. gamers aged 18 to 34 report interest in games with immersive features (Clement, 2023), major companies like Sony are aware of that trend and have begun exploring scent-based gameplay (Shirey, 2023; Shutler, 2025). These developments reflect a broader shift: today's users expect interfaces that deepen their engagement which can be translated by stimulating more senses, a demand that places multisensory integration at the core of UX innovation.

With this shift in mind, user experience development requires knowledge of how users process multiple senses to create interfaces which heighten immersion and user engagement. Studies indicate that multisensory interfaces which use multiple senses (sensory inputs) deliver better user performance than single-input traditional interfaces (Broadbent, Osborne, Mareschal, & Kirkham, 2020). Those sensory inputs are unconsciously automatically integrated into our everyday experiences, guiding our responses and social interactions. The brain uses multisensory integration (MSI) to unite those daily different sensory information into cohesive perceptions which leads to better attention and improved decision-making abilities (Driver & Spence, 1998). Overall, individuals' decision making process benefit from multiple associations of sensory cues which is a phenomenon demonstrated by synesthesia and synesthetes cases, in which one sense triggers another (Murray, 2021). Knowledge of these multisensory effects and related phenomena offers designers essential tools to create better user experiences while providing researchers with insights to build more intuitive interfaces.

The scientific field of MSI has already inspired various industries to develop user-centered designs through their implementation of its different elements (Petit, Velasco, Cheok, & Spence, 2015). The gaming industry utilizes these effects to develop immersive environments, while retail spaces use background music, and visually appealing displays to influence consumer behavior (Biswas, Labrecque, Lehmann, & Markos, 2014). Another example is emergency healthcare environments which use visual and auditory signals to streamline workers decision-making in high-pressure situations (Wandile & Kanyal, 2023). Despite these advancements, real-time decision-making and user experience knowledge and improvement through combined sensory inputs remains an underdeveloped field.

Today's cutting-edge technologies, such as augmented reality (AR) and virtual reality (VR) represent current technological advancements which stem from sensory research breakthroughs (Navarro et al., 2020) and the previously mentioned trend and interest of users on immersive experiences. These tools merge visual and auditory elements to build simulated environments which gets a step closer to real-world scenarios while enabling multiple uses across various settings (Navarro et al., 2020). This study chose to focus on gaming interfacts and will evaluate if the addition of even more sensory inputs to digital experiences could produce more realistic and effective results which would enable quicker and more precise choices during intense game situations.

The expanding use and advancement of multisensory technologies creates new rapid opportunities for gaming but also other various sectors including retail and education (Petit, Velasco, Cheok, & Spence, 2015). The significance of understanding user responses to multiple sensory signals becomes evident from this observation. User experience and interfaces innovation can be unlocked through studying how different senses function together and how to optimize their integration which leads to new possibilities for accessibility and inclusivity of all users.

Key concepts

To realize that full potential of gaming interfaces, this thesis focuses on multisensory integration, the brain's ability to merge different sensory cues into a more cohesive process (Driver & Spence, 1998), and explores how far designers can enrich those cues before benefits turn into negative feelings such as sensory overload, which happens when the senses take more information than the brain is able to process (Sweller, 1988). This phenomenon has been defined and understood by previously studied theories such as the Information Processing Theory and Cognitive Load Theory, which tracks how this sensory information flows into memory and identifies that there is a point where extra input overwhelms that processed information (Bouchrika, 2025; Sweller, 1988).

These sensory stimuli or modalities refer to inputs related to senses like visuals, sounds, touch, taste and smell that are intentionally designed into interactive experiences. These sensory cues in the environments and interfaces are often indirectly combined with ambient conditions such as lighting and temperature which are partially integrated into the gaming setup players put themselves in (Bao & Fan, 2020). These ambient conditions will also be taken into consideration into this study to understand their influence on the sensory effects and on the gaming experiences. To understand how these users manage those multiple inputs the thesis considers cross-modal attention (CMA), a phenomenon closely related to MSI and involving the process of individuals indirectly selecting to focus on certain sensory inputs while filtering out others (Driver & Spence, 1998). An example of this interaction of senses and its processing is synesthesia, a neurological condition where individuals known as synesthetes involuntarily experience one sense through another (hearing a certain sound when seeing a color…ect) (Itoh, 2024). These synesthetic experiences illustrate the potential impact of those sensory associations and show how intentional pairings of senses might be used in interfaces to enhance user engagement and immersion.

This study will examine the effect of those sensory processes through performance of gamers, measured by speed and accuracy, and how it is altered by the mentioned inputs. The thesis intends to understand how enjoyment and immersion, representing overall user experience, as well as cognitive load is evaluated by players after changing the parameters of the digital interfaces. The interaction between all of those concepts and processes is presented in the theoretical model as follows:

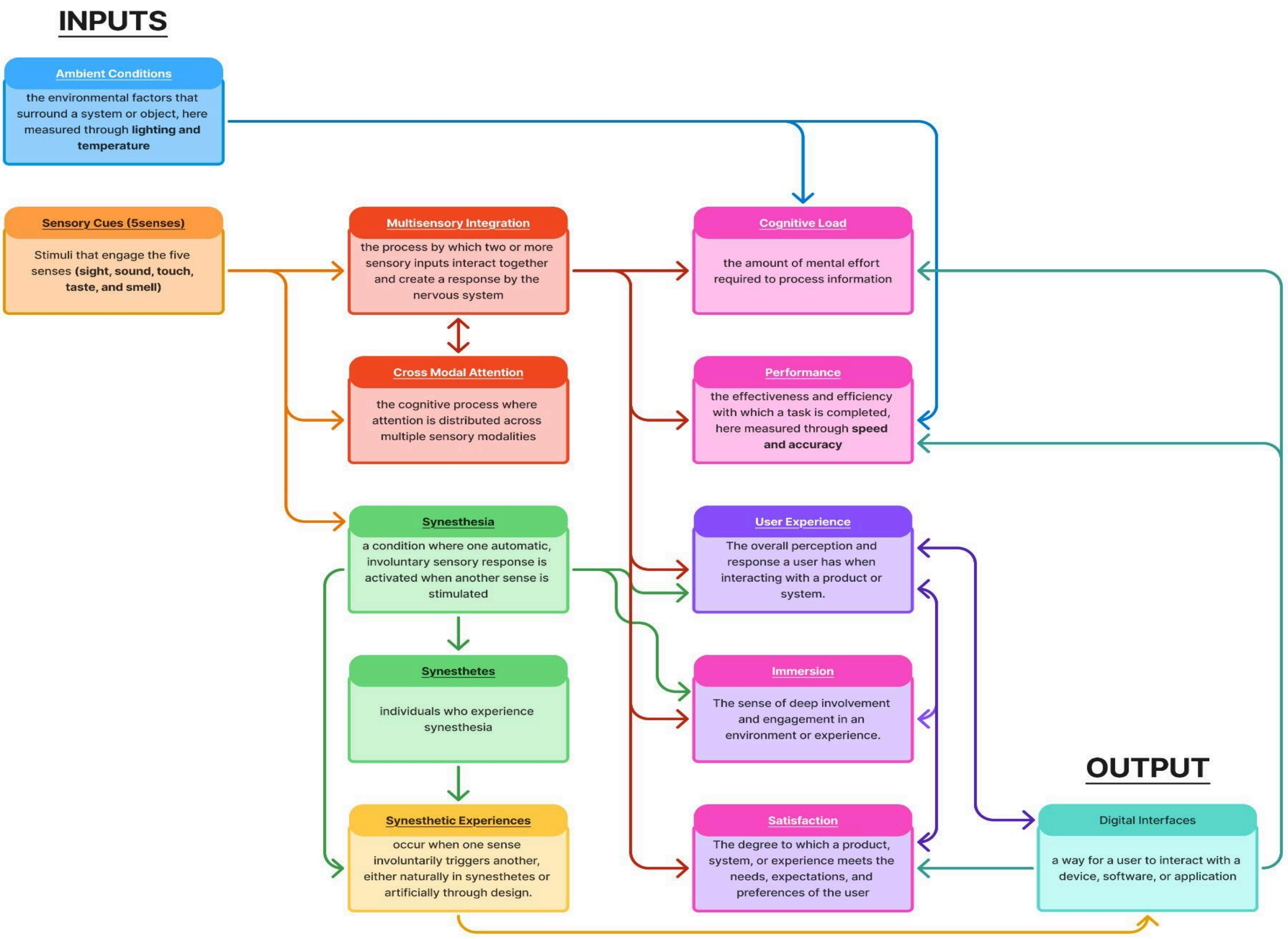

Figure 1. Diagram (Theoretical Model) of Key Constructs and Their Functional Relationships for the Current Study

What is known

Building on these foundational and theoretical concepts, previous research on multiple senses in digital interfaces has predominantly been focused on the interaction between visual and audio cues. This audiovisual combination of senses has consistently shown benefits across various domains, especially in improving user attention without overloading the user's cognitive load and still enhancing decision making (Doucé, Adams, Petit, & Nijholt, 2022). It has been observed that when sensory cues are well-aligned, such as sound matching the visuals on a screen, the brain is able to process that information more effectively (Broadbent, Osborne, Mareschal, & Kirkham, 2020). Leading to more intuitive interfaces and effective user experiences, which are particularly useful in fast paced situations.

The theoretical explanations for these outcomes are illustrating in depth the cognitive processes of multisensory interfaces where, according to Information Processing Theory, inputs can enter sensory memory and hold the information but most information will end up getting ignored to prevent the individual to get overwhelmed, however, this information can be filtered through more effectively when they are temporally and spatially synchronized (Bouchrika, 2025). Meanwhile Cognitive Load Theory explains that these senses reduce the strain on working memory by creating concrete representation of what individuals are feeling, allowing them to respond faster and more accurately (Sweller, 1988). These theories demonstrate that the explored audiovisual combination is advantageous in many ways and shows the potential for more senses if explored.

These studies exploring the audiovisual combination have taken as an example multiple real world applications such as the gaming industry where audio-visual feedback is used to guide player decisions and increase engagement (Navarro et al., 2020). This phenomenon has been witnessed in healthcare emergency response systems as well where alarms and visual signals are combined to reduce response time in high pressure tasks (Le Mitouard et al., 2020). Retail environments similarly utilize background music and visual displays to influence consumer perception and behavior (Doucé, Adams, Petit, & Nijholt, 2022). Overall this combination is very much used across industries in different contexts.

While the benefits of audiovisual cues can't be denied, current research has been very limited to these two modalities. The broader question of how additional senses could be integrated into digital interfaces has received considerably less attention.

What remains Unknown

Despite these advancements in research about the implementation of multiple senses into different environments, important questions remain about the integration of underexplored senses, such as touch, smell and taste, into interactive digital experiences and their effects. Significant gaps are left in our understanding of how additional senses could be implemented effectively. While some studies suggest that tactile (touch) or olfactory (smell) inputs may enhance immersion or awareness (Biswas, Labrecque, Lehmann, & Markos, 2014), the combination of those senses with other senses and how they influence UX is unclear.

Alternatively, it is also still unclear how many sensory cues can be integrated before users start to feel overwhelmed or distracted. Although theories like Cognitive Load Theory suggest there is a point at which additional input becomes counterproductive, current literature offers little consensus on where that point lies or how it may vary across different contexts and users (Sweller, 1988). Similarly, while ambient conditions such as lighting and temperature are indirectly part of different environments, their influence on MSI and UX isn't studied.

Overall, designers and developers still lack concrete frameworks or best practices for how to combine multiple sensory modalities in a way that is both effective and cognitively sustainable. As a result, most interfaces remain rooted in conventional audiovisual pairings, even as user expectations for immersive, responsive, and inclusive experiences continue to evolve.

Rationale for the Study

Despite the growing interest by gamers of more immersive environments and game experiences, the integration of multiple sensory cues beyond sight and sound remains poorly understood. Most interfaces still rely essentially on audiovisual cues, and the potential of adding additional cues remains unexplored which highlights a critical need for research that understands this potential and how to strategically integrate those additional senses to enhance decision-making and UX without exceeding cognitive thresholds. This research will benefit the opportunity to respond to the demand shift towards richer and more personalized gaming experiences, but also help in building more inclusive and adaptable interfaces for different needs.

In an industry context, addressing these gaps is essential for enhancing interface design and overall UX (Argouslidis, Baltas, & Mavrommatis, 2015). By systematically investigating how these additional sensory inputs can be put to use without overwhelming the user in any way, researchers can develop guidelines for more inclusive, accessible, and immersive digital experiences (Doucé, Adams, Petit, & Nijholt, 2022). While the primary focus of this thesis is on gaming applications, insights derived from this research can also inform other fields such as emergency response, education, and retail. In all of these contexts, developing innovative design frameworks that optimize cognitive load and effectively balance multisensory experiences have the potential to significantly boost performance and satisfaction across diverse user bases. By examining how these underexplored senses and environmental factors can be balanced and included into immersive digital interfaces, this research aims to fill a critical gap in multisensory design, ultimately improving the quality and inclusivity of user experiences across diverse applications.

1.2 Research Question and Objectives

Research Question

Building on the previously identified gaps in current MSI research, the main question that arises and that will be guiding this thesis is:

> **How can multisensory integration, beyond traditional auditory and visual combinations, and ambient conditions enhance decision-making speed and accuracy, cognitive processes and user experience in the gaming context?**

This research question aims to expand our understanding of MSI by incorporating the under explored sensory inputs: tactile, olfactory, and gustatory, as well as ambient factors like lighting and temperature, to develop more immersive and satisfying virtual gaming environments. Addressing this question is crucial for improving user experience, effectiveness, and inclusivity in digital interfaces.

Research Objectives

Based on this research question, the thesis outlines the following objectives:

1. **Evaluate the Impact of Multisensory Integration on Decision-Making Quality (measured by speed and accuracy)**

The thesis aims to examine how the integration of underexplored sensory inputs (tactile, olfactory, gustatory) alongside traditional ones (auditory, visual) affects decision-making speed and accuracy, which we will define as performance, in gaming contexts.

2. **Enhance Immersive Experiences in gaming and improve overall user experience.**

The thesis will determine how incorporating a broader range of sensory inputs and tweaking existing ambient conditions can create realistic interactions that closely mimic real-world experiences and assess how these integrations influence cognitive load and user performance. The research will investigate the optimal combination and thresholds of multisensory cues to avoid sensory overload, thereby improving the effectiveness, satisfaction, and intuitiveness of digital interfaces

3. **Improve Accessibility and Inclusivity of Digital Interfaces**

The thesis will have for objective to investigate how knowledge of MSI can be tailored to accommodate individuals with diverse sensory needs, including those with sensory impairments . It will propose design guidelines that ensure digital interfaces are inclusive and accessible to a wide range of users, thereby maximizing user satisfaction across different contexts.

1.3 Research Contributions

Theoretical Contributions

This research extends the theoretical current understanding of MSI by focusing on the integration of added senses and ambient conditions in gaming digital interfaces. Prior research has focused on audiovisual cues and their integrations in digital interfaces in various industries, leaving significant gaps in how additional senses might affect cognition and behavior. By basing this study on previous theories such as Information Processing Theory and Cognitive Load Theory (Sweller, 1988; Bouchrika, 2025) the study can further contribute to the theory behind MSI and its effect on decision making speed and accuracy as well as how it is affected by the environment by first providing new insights into how integrating less studied sensory input affect user attention and perception in different gaming scenarios.

Currently the theoretical body of literature informs designers and researchers of a limit to the addition of senses which would transform the benefits to negative feelings for users. This study will close the existing gap by identifying points of sensory overload, contributing to a deeper understanding of optimal and excessive multisensory combinations. It draws on concepts from cross-modal attention and synesthetic experiences to demonstrate how subtle combinations of input can shape UX without conscious awareness.

Going further on the identification of optimal combinations of senses, finding will continue supporting Cognitive Load Theory (Sweller, 1988) and understand further how the design of cues together affect decision making in users, if it has an effect on cognitive burden and importance. Rather than considering sensory cues in isolation, this research examines their interactive effects, examining if congruent or incongruent or excessive combinations have an effect on mental fatigue, distraction, or performance.

Overall, this thesis contributes to the current theoretical framework by evaluating the benefits and limitations of MSI in digital environments. It moves the field beyond audiovisual studies and opens new ways of understanding how expanded sensory inputs affect user experience, cognition, and interaction. Through its experimental design and theoretical grounding, the study not only provides addition to existing frameworks but also provides a foundation for future research that seeks to optimize digital experiences in a playerbase requesting further immersion.

Managerial Implications

Beyond its theoretical contributions, this research also offers value to professionals in the UX design field, gaming design and game development across a range of industries. As the need for immersion in digital experiences increases, the need for evidence based sensory design practices is increasing. This thesis seeks to answer the need by presenting frameworks and recommendations for professionals seeking to implement sensory cues in their interfaces in an optimal way that would enhance user engagement and avoid sensory overload. With the most immediate managerial implication of this work being the development of guidelines to help design interfaces seeking balance between immersion and overload, the findings of this study will be able to be used to refine user experiences without compromising clarity or performance. These insights will be particularly valuable in dynamic contexts and gaming, augmented or virtual reality environments where overstimulation can negatively impact enjoyment.

The study's managerial implications will extend beyond the gaming industry, providing important implications for industries such as healthcare emergency environments, education or even retail. Those findings could even extend to designing a more accessible and inclusive digital environment and opening interfaces to more individuals with diverse needs. Those practical guidelines will inform the development of different tools or the development of platforms that could accommodate a wide range of disabilities, promoting equity and more various participation in those interfaces.

While the primary focus of this research is on the gaming industry, the general aim is to apply those frameworks and design recommendations across industries, demonstrating how multisensory design could be tailored to different contexts in a positive manner. Overall, this thesis bridges academic insight with practical application, giving designers and stakeholders the ability to make informed decisions about sensory integration in digital interfaces. By aligning immersive design with cognitive and perceptual principles, the research aids the development of digital experiences that are not only immersive and effective but also inclusive and responsive to the complex needs of real-world users across industries.

1.4 Thesis Structure

The following sections of this study aim to address the current gaps in MSI research by expanding on the underexplored areas introduced in the previous introduction section. The next section reviews existing research about synesthetic experiences together with MSI and CMA to examine existing studies further and build the theoretical foundation. The first chapter presents detailed explanations of essential theoretical frameworks which support this work while demonstrating their connection to research objectives. The second chapter describes the research methodology, detailing the overall approach used to evaluate user performance, cognition and satisfaction with altered ambient conditions and added sensory cues. Chapter 3: Results reveals the findings obtained through these methods which demonstrate how various multisensory arrangements impact the measured variables. The discussion analyzes findings through existing literature to demonstrate how UX benefits should be balanced against sensory overload prevention, highlighting theoretical and managerial implications, acknowledging limitations, and suggesting future research directions. Finally, the conclusion provides a concise summary with key insights and contributions to both theory and practice in the areas of user experience, multisensory design, and cognitive performance in gaming and related domains.

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Literature Review

2.1 Purpose and Scope

This literature review aims to establish a comprehensive understanding of the central study concepts of MSI, synesthesia, and CMA in the context of UX design. It begins by defining key terms and examining historical developments that set the stage for these ideas. The review will analyze current theories and empirical studies to clarify how various sensory stimuli interact to influence decision-making across diverse contexts, highlighting both well-established findings and underexplored ones (Broadbent, Osborne, Mareschal, & Kirkham, 2020). It will identify critical gaps in the literature that would shape the study's experimental design and hypothesis development.

Furthermore, the review will discuss the practical application of these principles in industry, providing insight into how recent technological advancements have shaped multisensory strategies (Doucé, Adams, Petit, & Nijholt, 2022). This review aims to pinpoint where innovation in MSI can most effectively enhance user performance, cognitive load management, and overall engagement by prioritizing research from the past 15 years, incorporating foundational studies as well as newer evolutions in the industry. The findings from this literature review will guide the formulation of a clear roadmap for developing inclusive and user-centered multisensory interfaces, laying the basis for the subsequent chapters of this thesis.

2.2 Background and Definitions

Synesthesia represents a neurological condition which causes automatic and involuntary stimulation of one sensory or cognitive pathway to result in another pathway activation (Murray, 2021). Individuals experiencing this phenomenon are referred to as synesthetes, they report experiencing simultaneous sensory inputs such as seeing colors when they listen to specific sounds or taste certain flavours from reading certain words (Merter, 2017). Although this condition is considered as rare, its mechanism highlights the broader concepts and opportunities of MSI and offers valuable insights into how individuals merge sensory information, showing how to use these synesthetic effects to our advantage.

Historically, synesthesia was first documented by George Tobias Ludwig Sachs in 1812 (Murray, 2021) while describing his own experience of associating music with colors which scientists now classify as chromesthesia. During the early stages of discovery in the 19th century, synesthesia was largely overlooked by scientists and scientific communities. It wasn't until the late 1800s that researchers began to pay more attention to the phenomenon, then classifying into different types (Murray, 2021). Among the most prevalent synesthesia types, grapheme-color synesthesia enables people to see specific colors when they encounter letters and numbers; chromesthesia where colour perceptions are produced when people listen to auditory inputs; and mirror-touch synesthesia describes a unique empathetic reaction where individuals feel tactile sensations on their own body when observing someone else being touched. (Murray, 2021; Itoh, 2024).

While synesthesia itself is rare, the mechanisms that underline this phenomenon, including the brain's ability to create those sensory associations, are not exclusive to synesthetes. Non-synesthetic people also experience MSI in more subtle ways (Itoh, 2024; Nair & Brang, 2019). The brain functions through CMA to unite and organize data from various sensory inputs (Driver & Spence, 1998) which demonstrates its capability to integrate multiple senses during everyday events which demand mixing senses together to create clearer, unified perceptions of external events. The field of cognitive and neuroscience research has demonstrated that integrated processing functions are critical for both efficient attention and context based awareness (Driver & Spence, 1998).

Closely related to these synesthesia-like principles is the concept of CMA, which refers to the ability to selectively prioritize and relate inputs across different sensory information (Driver & Spence, 1998). When stimuli across sensory channels are aligned spatially and temporally, the brain integrates them more efficiently, improving perceptual clarity and enhancing cognitive performance (Broadbent, Osborne, Mareschal, & Kirkham, 2020; Bouchrika, 2025). This plays a crucial role in optimizing UX and response to more complex environments.

Multisensory stimuli, on the other hand, involves stimuli that simultaneously engage multiple senses and is closely related to CMA (Driver & Spence, 1998). MSI reveal the methods by which different sensory channels collaborate to improve both attention and perception. These combined signals are processed more rapidly and efficiently when they occur in synchronously (matching cues), thus supporting better comprehension and decision-making (Broadbent, Osborne, Mareschal, & Kirkham, 2020). Multisensory stimuli, therefore, act as a foundational element in designing immersive experiences that take advantage of the human brain's natural abilities to integrate those sensory inputs.

2.3 Overview of existing studies

The current body of research on MSI and cognitive performance covers multiple disciplines including psychology, neuroscience, human to computer interaction and UX design, all aiming to understand how the brain processes information (Negen et al., 2023; Roohi & Forouzandeh, 2019). These different fields and studies can be applied to MSI, as they aim to understand how this process influences decision making, attention and cognitive load to apply it in a beneficial way for users and to increase their satisfaction (Argouslidis, Baltas, & Mavrommatis, 2015).

A recurring pattern in the foundational literature around this study is the emphasis on audiovisual integration as the most prominent combination available in digital interfaces, making it the foundation for multisensory combination (Yang, Chang, Chen, Lin, & Ross, 2022). Numerous studies have shown that synchronized audio and visual cues have beneficial effects such as enhancing attention and immersion, reducing reaction time and improving decision making accuracy in various situations (Broadbent, Osborne, Mareschal, & Kirkham, 2020). This dual combination of senses serves as the base for much of the existing research across contexts.

The studies exploring other, more complex singular sensory inputs (smell, taste,touch) remain limited and the combination of those underexplored senses remains insufficient. While foundational studies demonstrate the benefits of CMA and MSI, few researchers have fully investigated the cognitive and perceptual impact of integrating three or more senses in different contexts (Biswas, Labrecque, Lehmann, & Markos, 2014). The potential of those combinations, especially combined with the adaptation of the environment with ideal ambient conditions remains very underdeveloped.

Another theme that is recurrent in previous studies shows the common concern about negative effects and sensory overload (Biswas, Labrecque, Lehmann, & Markos, 2014). While combining multiple sensory cues will initially improve performance and overall positive benefits, multiple studies indicated that stimuli shouldn’t exceed a certain threshold, as it would lead to increased mental fatigue, and invert the initial benefits (Bouchrika, 2025).

These findings demonstrate the need to identify that exact threshold to understand the optimal range of sensory inputs. This aims to create interfaces balancing benefits with potential cognitive strain.

Previous studies explored the phenomenon of synesthesia and insights into how the involuntary associations of sensory inputs can improve cognitive processes (Hagtvedt & Brasel, 2016). Research on synesthetes has shown that those connections between senses through CMA can enhance attention and performance which is useful during fast-paced contexts (Itoh, 2024). This phenomenon has been applied positively to non-synesthetes and induced more research on how these synesthetic effects might benefit a larger population if designed properly, while trying to avoid the risk of overload (Nair & Brang, 2019).

Research has also been conducted on specific industries such as retail, game design, and emergency response alert systems (Wandile & Kanyal, 2023; Motoki et al., 2019; Napoli & Chiasson, 2018). These studies confirm that user engagement, responses and satisfaction increase when sensory cues are carefully crafted so they relate together (Doucé, Adams, Petit, & Nijholt, 2022), yet it also echoes the need for cognitive and sensory thresholds to be respected to avoid diminishing returns.

The existing literature suggests that MSI offers clear benefits across various fields, especially in contexts that demand high performance and engagement (Driver & Spence, 1998). However, the lack of extensive empirical studies on underexplored senses, limited integration of ambient conditions, and absence of precise overload thresholds present significant gaps in the field (Biswas, Labrecque, Lehmann, & Markos, 2014; Bao & Fan, 2020). These observed gaps provide the foundation for the thematic breakdown in the next section. To address the nuances of multisensory design, the literature will be analyzed thematically across six areas: foundational theories of MSI and attention, the phenomenon of synesthesia and its cognitive limits, current industry applications, the boundaries of sensory thresholds, the integration of underexplored sensory modalities, and the interaction between sensory input and ambient conditions.

Building on these observations, a research model (Figure 2) was developed to organize the relationships between key variables influencing multisensory decision-making. This framework distinguishes four core independent variables, the number, type, and combination of sensory cues, along with ambient conditions, which are theorized to impact three primary dependent variables: performance, cognitive load, and user experience. These relationships form the basis for four interlinked hypotheses, each grounded in previous findings and aimed at addressing gaps identified within that literature. While the full presentation and development of these hypotheses will follow in the thematic analysis in Section 2.4, the model serves to visually clarify how the variables interact and guide this review.

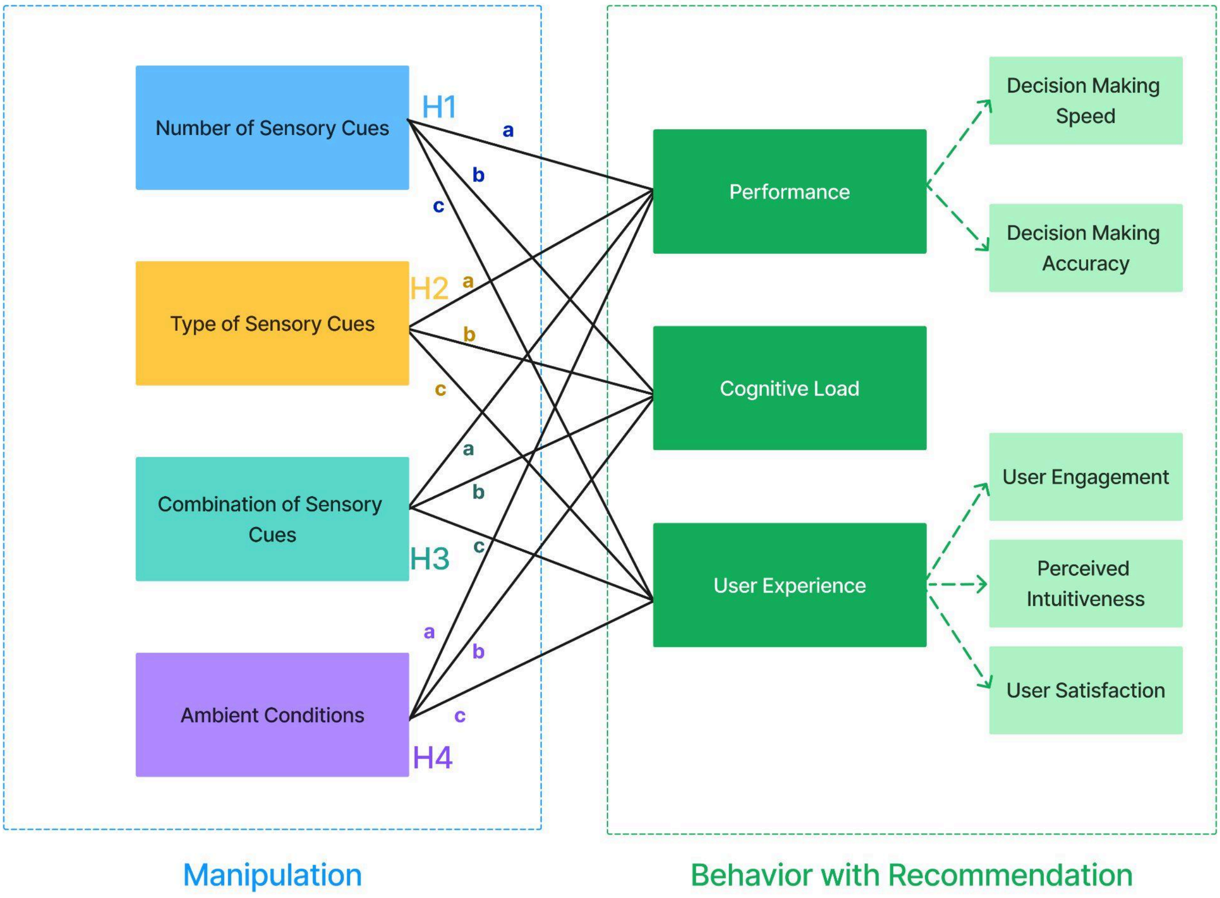

Figure 2: Proposed research model

2.4 Thematic or chronological breakdown of key topics

The Role of Multisensory Integration and Cross-Modal Attention in Cognitive Performance

MSI, the process by which the brain combines and integrates the information from different senses to create a coherent and unified environmental perception (Broadbent, Osborne, Mareschal, & Kirkham, 2020), improves our ability to interact with the world, especially when the different sensory inputs complement each other. This section explores the role of this phenomenon and CMA, which is closely related to it, in improving cognitive performance through decision making tasks (Driver & Spence, 1998).

Previous research evidence shows that MSI enhances the ability for individuals to process things more easily by reducing their mental load and improving speed and accuracy of decisions (Alamia, Zénon, VanRullen, Duque, & Derosiere, 2019). When an individual experiences multiple sensory inputs from different modalities such as audiovisual stimuli for example, the brain is able to process the information and environment more effectively than relying solely on a single sense (Broadbent, Osborne, Mareschal, & Kirkham, 2020). This has been proven by the human brain's capacity to integrate information from different sources more easily, thus facilitating faster and more accurate choices (Driver & Spence, 1998), this can be especially useful in high pressure situations where fast responses are needed.

One of the key tools contributing to this improved performance is CMA which refers to the brain's ability to distribute attention across multiple and appropriate sensory channels which will then create a unified perception (Hagtvedt & Brasel, 2016). Studies have shown that when attention is appropriately associated across modalities, individuals can process the information way more effectively, which explains the improved decision making performance (Driver & Spence, 1998). This has been studied through various examples in different contexts, for instance attention to auditory cues can enhance visual perception which allows individuals to react faster to the environment around them . This research is most common in emergency and healthcare response situations where rapid decision making can be life-changing (Kinateder, Warren, & Schloss, 2019; Lee & Lee, 2018).

Previous studies and theories have explained that the combination of different senses, allows for reducing cognitive load by simplifying the brain's processing of complex information (Sweller, 1988). However studies are largely focused on the two senses we use the most daily, audiovisual cues and leaves the research with a significant gap in knowledge on how these theories apply to more than two senses with underexplored sensory modalities. Audio visual cues have been found to be effective in improving reaction times and decision making performance because of their high processing synergy which is important to lead decision making processes (Broadbent, Osborne, Mareschal, & Kirkham, 2020). However, it is unknown if adding underexplored modalities to audiovisual MSI provide the same benefits such as faster and more accurate decision-making, in part by reducing cognitive load and influence the integration of information.

Based on these gaps limiting the current knowledge to two common modalities at a time and the uncertainty on the effect of a larger number of inputs, we propose the following hypothesis to investigate further:

H1a: Adding more than two sensory inputs (going from the standard two senses to three or more) will lead to faster and more accurate decision-making

With the null and alternative hypotheses as follows:

H_0: Increasing sensory inputs beyond two does not affect decision-making speed or accuracy.

H_1: Increasing sensory inputs beyond two improves decision-making speed or accuracy.

Synesthesia, Cross-Modal Integration, and the Limits of Sensory Processing

While MSI can enhance cognitive performance, it is also known that excessive sensory stimuli, whether from the same pathway or different pathways, can lead to cognitive overload, especially when moving beyond single modality or dual modality design, which would transform those positive effects into negative ones, affecting mental load (Sweller, 1988). This is due to the brain's inability to filter out information appropriately and allocate attention efficiently across all modalities (Bouchrika, 2025). This suggests that there is a maximum number of inputs beyond which the benefits of MSI begin to decline.

To explore this aspect of MSI, it is important to look at previous studies and consider the phenomenon of synesthesia in individuals, where the experience involuntarily triggers a sensory pathway from another sensory pathway (Itoh, 2024). Synesthetic experiences that are felt by both synesthetes but can also be experienced by non-synesthetes reveals the neurological capacity for cross-modal integration (Merter, 2017), which is the ability to process different senses results in enhanced perception and associations, leading to better processing of information or higher recall of information (Itoh, 2024).

However, among all individuals experiencing synesthetic experiences, synesthetes and non-synesthetes prone to more complex sensory inputs, there has been lots of discussion about a sensory processing threshold. Research has indicated that when individuals are exposed to too much information, especially when this information doesn't match or isn't harmoniously integrated, it can overwhelm the person and hinder performance (Biswas, Labrecque, Lehmann, & Markos, 2014). The original benefits from providing appropriate information from various sources could start to shift, reaction times may slow, errors may increase and users might experience fatigue or overload. This phenomenon is known as sensory overload and shows not just the benefits of MSI but also its limits (Sweller, 1988).

Studies on audiovisual pairings have shown that the processing of MSI through cross-modal integration operates most efficiently when cues are synchronous and match which helps the brain integrate signals together and understand the environment better (Broadbent, Osborne, Mareschal, & Kirkham, 2020), which could be harder if there are more sensory inputs. However, since the combination of senses in those studies have been strictly limited to two or less sensory inputs, research is unclear on the actual effect on cognitive systems with additional sensory inputs. Understanding the effect of the integration of more senses on decision speed and accuracy is critical for the design of systems with higher number of cues and for them to be immersive and cognitively sustainable. Consequently we propose the following hypothesis:

H1b: While initially beneficial, adding more sensory inputs eventually triggers sensory overload, slowing down or impairing decisions once a certain threshold is surpassed.

With the null and alternative hypotheses as follows:

H_0: Adding additional sensory inputs indefinitely does not lead to cognitive overload.

H_1: Past a certain point, adding further sensory inputs shows signs of cognitive overload.

Industry Applications of Multisensory Integration

While the previous section addressed the cognitive and perceptual limitations of MSI, it is important to understand that in real life application, UX designers and developers increasingly utilize the theory behind MSI to enhance UX more broadly and develop even more user centered designs (Hagtvedt & Brasel, 2016; Motoki et al., 2019). In commercial, educational or even entertainment, MSI is often implemented to create more customizable, intuitive and immersive interface interactions, rather than solely focusing on performance of the user (Li, 2021).

This shift towards developing even more user centered and personalized interfaces reframes the known goal of performance to also understand and optimize user interactions and satisfaction when navigating interfaces and how likely they are to stay engaged. The success of this aspect of MSI is measured through different behavioral metrics such as user satisfaction, time spent on a task, purchase or intent to commit the desired action or emotional response rather than cognitive output alone (Doucé, Adams, Petit, & Nijholt, 2022).

Previous research has shown that MSI is frequently used to make the user feel closer and interact more intuitively with interfaces (Li, 2021). In retail environment for example, it has been found that crossmodal processing of music and online store visuals significantly increased enjoyment ratings, store evaluation and purchase intent (Doucé, Adams, Petit, & Nijholt, 2022). This suggests that harmonized sensory cues not only support efficiency but also strengthen the relationship between the interface and the user. Meanwhile in accessibility cases it has been demonstrated that synesthetic product design enhances usability and purchase intention. By translating complex interaction into multi senses feedback, users found the information more easy to understand, reinforcing the idea that intuitive MSI can help bridge informational gaps (Li, 2021).

Again, these results are still limited to audiovisual correspondence with little findings about more unconventional senses. Subtle audiovisual correspondences such as matching high frequency audio with light colored visuals enhanced click-through rate and user attention in retail cases (Hagtvedt & Brasel, 2016). These results put insights on MSI and how it can subconsciously guide user behavior. Taken together all of these studies in different areas shows that the addition of multiple sensory cues can impact UX positively if well executed, to explore this potential in greater depth, applying it to a higher number of sensory cues than originally known we propose the following hypothesis:

H1c: As the number of sensory cues increases, the user experience (defined by engagement, satisfaction, and perceived intuitiveness) improves.

With the null and alternative hypotheses as follows:

H_0: Increasing the number of sensory inputs does not affect user engagement, satisfaction, or perceived intuitiveness.

H_1: Increasing the number of sensory inputs increases overall user engagement, satisfaction, or perceived intuitiveness.

Challenges and Thresholds in Multisensory Design

While previous literature has recorded the benefits and the growing application of MSI in improving decision making, attention and user engagement, these benefits have been often found in contexts involving one or two modalities only (Broadbent, Osborne, Mareschal, & Kirkham, 2020). A growing number of neurological theories are now acknowledging that multisensory systems might not improve performance indefinitely (Sweller, 1988). As the number and complexity of senses increase, the potential of negative effects might increase as well. This raises the importance of potential limits and tradeoffs of MSI especially in situations involving more than two simultaneous sensory cues.

In contexts where multiple senses are involved, uncertainty rises around the reliability of sensory inputs. Existing research tends to assume more inputs will lead to higher performance in users Driver & Spence, 1998) however, this overlooks the potential state of the cues with cue conflict or poor integration that might affect attention and decision quality. Some studies focus on highly synchronized or matched cues which limits the consideration of how the brain handles inputs that are partially conflicting or even unmatching. There is little understanding of how the weighting of the matching cues, based on context, affects decision performance when more than two inputs are involved (Broadbent, Osborne, Mareschal, & Kirkham, 2020). This presents a gap in understanding the role of cue reliability and attentional allocation in complex MSI environments. Consequently, we introduce the next hypothesis as follows:

H2a: When more than two sensory inputs are present, improvements in speed and accuracy only occur if each cue is weighted according to its reliability; conflicting or unaligned cues may degrade performance.

With the null and alternative hypotheses as follows:

H_0: The weighting or reliability of multiple cues does not affect decision speed or accuracy.

H_1: Decision performance with more than two inputs depends on proper weighting of those inputs, such that conflicting or unreliable cues hinder performance.

Another concern insufficiently explored in the literature is how working memory and attention respond to multisensory environments where more than 2 senses are used (Broadbent, Osborne, Mareschal, & Kirkham, 2020). Again, reliability of cues is uncertain and while theoretical frameworks such as Cognitive Load Theory and Information Processing Theory suggest that there is a limit to which the information processed would hinder user experience, few empirical studies test this directly in the context of MSI (Sweller, 1988; Bouchrika, 2025). Most previous studies either examine whether MSI is beneficial in limited conditions or assume that more cues would help until an undefined overload point is reached without taking into consideration the relationship between the presented cues (Broadbent, Osborne, Mareschal, & Kirkham, 2020). However there is no consensus in the literature regarding the specific cognitive consequences in raising the sensory inputs number, and the type of sensory inputs, whether congruent or not in relation to reaction time, error rate or other variables (Curley, Murray, MacLean, & Laybourn, 2017).

Although we're exploring the effect of added sensory cues on cognitive load in H1b, the gap about incongruent cues remains. To explore this limited knowledge, we present the following hypothesis:

H2b: Cognitive load rises as incongruent sensory inputs are introduced, potentially leading to slower decision times and/or higher error rates.

With the null and alternative hypotheses as follows:

H_0: Incongruent sensory inputs do not increase cognitive load.

H_1: Incongruent sensory inputs raises cognitive load.

Finally, while MSI is often associated with improved user experience, including higher engagement, satisfaction and perceived intuitiveness, there are very limited studies that investigate how the congruency between sensory inputs and gameplay context influences these outcomes (Hagtvedt & Brasel, 2016). Existing studies examine the presence of additional modalities or the sensory environment, without examining the true nature of those inputs and if they are aligned with each other or even the task at hand (Doucé, Adams, Petit, & Nijholt, 2022; Yang, Chang, Chen, Lin, & Ross, 2022). Some studies exploring crossmodal congruency have shown potential for further investigation of these inputs and to extend it to decision driven environments such as games. It remains unclear whether the benefits of MSI in gaming context depends on the number of inputs or on how well those are congruent with the environment and expectations of users. This gap in research leads to the following hypothesis:

H2c: User experience (engagement, intuitiveness, satisfaction) improves when sensory inputs are congruent with each other and the gameplay context, whereas incongruent sensory combinations reduce engagement and satisfaction.

With the null and alternative hypotheses as follows:

H_0: Sensory input congruency significantly influences user experience

H_1: Sensory input congruency has no significant effect on user experience

Exploring the Effects of Multi-Sensory Combinations by Integrating Underexplored Modalities

While the integration of audiovisual inputs has been thoroughly studied in previous studies in cognitive performance and UX research (Yang, Chang, Chen, Lin, & Ross, 2022), there remains a significant lack of research about the role of other senses, such as smell, taste and touch, in user interfaces. These senses are often overlooked in various contexts, in gaming the sense of touch has been slightly covered with the release of controllers and handheld consoles but the research on their effect on performance is still limited (Navarro et al., 2020). The potential of these underexplored senses to enhance decision making, immersion and user satisfaction has been overlooked even though highly relevant across industries especially in gaming with tools such as AR and VR (N., Shashaank & Feiner, 2022).

Existing studies tend to focus on traditional dual combinations (audiovisual) and rarely extend to more combinations such as touch but even less so including scent or taste.

When they do, these studies are often limited to retail or marketing interactions rather than exploring performance and outcomes in gaming environments with those unexplored cues (Biswas, Labrecque, Lehmann, & Markos, 2014). This creates a notable gap, while those limited senses have the ability to trigger strong emotional and memorable reactions, their roles in practical studies is undertheorized and under-tested.

Additionally the ideal combinations of all these unexplored cues isn't talked about even though optimal combinations of senses (including underexplored ones) is necessary for designers to create adapted interfaces (Li, 2021). While cross-modal performance has been a strong area of research in audiovisual interfaces, few studies have explored further combinations of senses and how they could enhance, impair or even override audiovisual processing. As these sensory modalities are underexplored their impact might be more variable or context dependent.

Moreover, the initiation to unfamiliar or new senses to the user might introduce additional cognitive load due to the user not being used to those types of senses in their typical interfaces. This suggest a more complex interaction between modality and cognitive effort (Sweller, 1988). In terms of UX , novelty in sensory cues might initially enhance engagement or enjoyment adding something new to the environment, however if these added cues aren't combined properly the gains might be short lived if it turns into confusion, discomfort or perceived sensory clutter (Doucé, Adams, Petit, & Nijholt, 2022) .

These gaps in the literature show the need to understand not just whether additional sensory cues can improve performance but how their integration might hinder or enhance user outcomes. This leads to the following three hypotheses related to the effects of those underexplored senses:

H3a: Underexplored sensory cues can significantly enhance decision speed and accuracy when added to audiovisual input, but these benefits depend on how well the sensory cues are combined or aligned. Mismatched combinations may reduce or negate the gains.

With the null and alternative hypotheses as follows:

H_0: Adding underexplored sensory cues to audiovisual input has no net impact on decision speed or accuracy, regardless of how the cues are combined.

H_1: Adding underexplored sensory cues to audiovisual input significantly improves decision speed or accuracy, but only when the sensory cues are effectively combined.

H3b: Cognitive load increases as more underexplored sensory inputs, particularly unideal or poorly matched combinations, are introduced..

With the null and alternative hypotheses as follows:

H_0: The number and type of underexplored sensory inputs, including unideal or poorly matched combinations, have no significant effect on cognitive load..

H_1: Introducing more underexplored sensory inputs, particularly unideal or poorly matched combinations, significantly increases cognitive load.

H3c: As more uncommon senses and complex sensory combinations are introduced, user experience and satisfaction improve. However, beyond a certain point, overload from poorly integrated inputs diminishes usability and overall enjoyment.

With the null and alternative hypotheses as follows:

H_0: Introducing additional uncommon senses or complex sensory combinations has no significant effect on user experience, satisfaction, or usability.

H_1: Introducing uncommon senses and complex sensory combinations initially enhances user experience and satisfaction, but beyond a certain point, poorly integrated inputs lead to decreased usability and enjoyment.

Interactions Between Sensory Inputs and Ambient Conditions

While considerable attention has been given to the effect of MSI on cognitive performance and UX , the role of ambient conditions, such as lighting and temperature, which are an indirect part of gaming interfaces through the users' gaming setup (Bao & Fan, 2020), remains a relatively underexplored area in relation to MSI. Much of existing literature treats these factors as contextual backgrounds or don't take them into considerations while they also affect our senses and interfaces (Driver & Spence, 1998). However, emerging studies suggest that these ambient variables may meaningfully interact with sensory inputs either supporting or hindering the experience and user interface (Bao & Fan, 2020).

Previous studies investigated how ambient temperature affect gaming productivity using server scores and data from an existing popular MMORPG. Findings revealed decrease in performance during extreme temperature conditions (both cold <5°C and warm >21°C) (Bao & Fan, 2020), even when gaming time increased. Players in heated environments playing indoors revealed higher performance than those without access to heating during cold periods. This indicates that ambient conditions might affect performance indirectly (Bao & Fan, 2020), however, previous studies do not consider how temperature might interact when multiple senses are already involved in the gaming experience, it also didn't take into consideration the potential added negative effect when combining environmental discomfort with overwhelming cue discomfort.

Similarly, findings from previous studies show that lighting conditions may influence attention and performance in various scenarios (Yan, He, Lin, & Huang, 2024), however their role in accompanying MSI is still unclear. In the context of gaming environments, it has been demonstrated that controlled appropriate lighting design can significantly affect decision making and engagement. However all previous experiments even in other UX and online environment contexts have always assumed optimal conditions for ambient parameters without examining how suboptimal senses could interfere with MSI when multiple senses are involved (Bao & Fan, 2020; Yan, He, Lin, & Huang, 2024).

This lack of consideration of ambient conditions in the current literature represents a meaningful gap. Despide the understanding and recognition of benefits of multisensory inputs, few studies consider how these may depend on or can be disrupted by the surrounded environmental conditions and gaming setup of players. To investigate this gap, we formulate the following hypotheses:

H4a: Well-designed ambient lighting and optimal temperature can improve sensory integration, thus enhancing decision-making accuracy.

With the null and alternative hypotheses as follows:

H_0: Changing ambient lighting and temperature has no effect on decision-making performance.

H_1: Proper ambient lighting and temperature design raises decision performance by improving synergy with other cues.

H4b: suboptimal lighting levels (harsh or flickering light) and temperature (too cold or too hot) increase cognitive strain and degrade performance.

With the null and alternative hypotheses as follows:

H_0:Suboptimal lighting and temperature do not affect cognitive strain or performance.

H_1: Suboptimal lighting and temperature increase cognitive strain and impair decision-making performance.

H4c: Suboptimal lighting levels (harsh or flickering light) and temperature (too cold or too hot) hinder user experience, decreasing satisfaction, engagement, and perceived intuitiveness.

With the null and alternative hypotheses as follows:

H_0: Suboptimal Lighting and Temperature have no effect on user experience (satisfaction, engagement, and intuitiveness).

H_1: Cooler environments and optimal light promote better user experience (satisfaction, engagement, and intuitiveness).

2.5 Synthesis of the Literature, Research Gaps, and Hypothesis Development

This literature review demonstrates strong evidence that MSI and CMA enhance decision making (speed and accuracy of decisions), reduce cognitive load and improve UX (Driver & Spence, 1998), especially through the overstudied landscape of audiovisual stimuli (Broadbent, Osborne, Mareschal, & Kirkham, 2020). However a deeper look into previous foundational studies reveals several key research gaps that limit broader application, especially in the environment of this research that is focused on gaming interfaces.

Most existing studies focus only on two sensory inputs, the most common audiovisual combination that appears in our everyday interactions, leaving the impact of integrating three or more inputs or underexplored cues largely untested. Additionally the types of cues (congruency and reliability) is often overlooked, despite its importance in real-world practical applications where sensory inputs may not always align (Doucé, Adams, Petit, & Nijholt, 2022). Finally, ambient environmental factors (lighting and temperature) are rarely put in parallel of MSI, despite its known effect on performance and experience of users (Bao & Fan, 2020; Yan, He, Lin, & Huang, 2024).

To address these gaps, this study proposes four hypotheses, separated in three sub hypotheses each, organized around the independent variables, number of cues, types of cues, combinations of cues and ambient conditions, and their effect on the dependent variables, decision making (speed and accuracy), cognitive load and UX . The full set of hypotheses is outlined as follows:

H1a: Increasing sensory inputs beyond two improves decision-making speed and accuracy.

H1b: While initially beneficial, adding more sensory inputs eventually triggers sensory overload.

H1c: As the number of sensory cues increases, user experience (engagement, satisfaction, intuitiveness) improves.

H2a: When more than two inputs are present, decision performance depends on cue reliability; conflicting cues degrade performance.

H2b: Cognitive load increases as incongruent sensory inputs are introduced, leading to slower responses or more errors.

H2c: User experience improves when sensory inputs are congruent with each other and with gameplay context while incongruence reduces satisfaction.

H3a: Underexplored cues (smell, touch, taste) can enhance decision performance when well-integrated with audiovisual input.

H3b: Poorly matched underexplored cues increase cognitive load.

H3c: Complex or uncommon sensory combinations initially enhance user satisfaction but may reduce usability when overloaded or poorly integrated.

H4a: Optimal ambient lighting and temperature improve decision-making.

H4b: Suboptimal lighting and temperature increase cognitive strain.

H4c: Suboptimal lighting and temperature reduce user satisfaction, engagement, and perceived intuitiveness.

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Chapter 1
Theoretical Framework

3.1 Definition and explanation of key theories

To understand how MSI affects decision speed, accuracy, cognitive load and UX in gaming contexts, this study bases itself on four foundational theories: Information Processing Theory (Bouchrika, 2025), Cognitive Load Theory (Sweller, 1988), CMA (Driver & Spence, 1998) and the Five Sense Theory (Hariprasad, 2016). All together these frameworks provide a good theoretical basis through which MSI and perceptual interaction can be interpreted in the design of those immersive, engaging gaming experiences.

Information Processing Theory (IPT) prepares the basis for understanding how senses and sensory information enters and is managed inside of the brain. According to IPT, stimuli pass through different stages, beginning with sensory memory and moving towards working memory before ending in long term storage, however only the most relevant filtered information is retained for further processing (Bouchrika, 2025). At each stage of this process, information is filtered to see which information the brain decides to keep or ignore. When multiple inputs arrive at the same time, as is common in gaming or other interfaces, this theory explains how the information from those games is filtered and prioritized (TheoryHub, 2025). Because of this filtering process, IPT is useful in highlighting the risks of overstimulation of MSI, if too many cues enter the sensory memory, it can lead to bottlenecks in processing information through each step in the brain, reducing clarity and overall performance (Bouchrika, 2025).

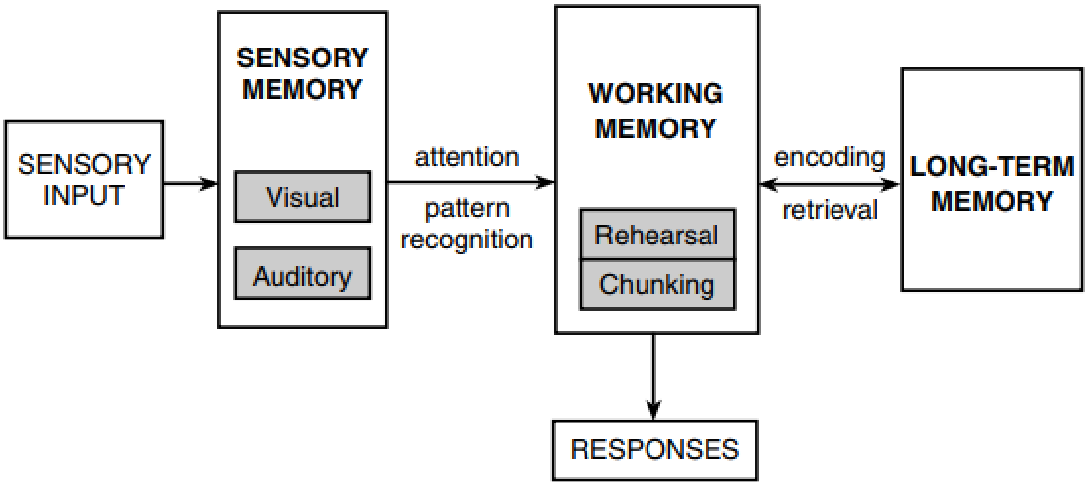

Figure 3: Information Processing Theory (Bouchrika, 2025)

Building on this idea, Cognitive Load Theory (CLT) shows through this framework the concept of mental effort and the importance of balancing the right amount of inputs to match complexity with processing capacity (Sweller, 1988). CLT explains that when users receive too much information, especially poorly organized or excessive, working memory becomes overwhelmed and in turn affects cognitive load and performance. While integrated sensory cues can reduce cognitive lead by making the cues more intuitive, CLT explains that past a certain threshold, the mental burden will increase and hinder decision making processes (speed and accuracy) (Sweller, 1988). CLT is used in the context of this study to explore how different senses in MSI can affect cognitive strain in real time.

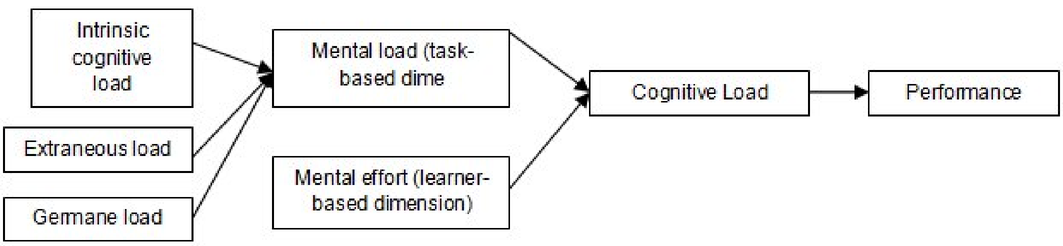

Figure 4: Cognitive Load Theory (Sweller, 1988)

Cross-Modal Attention (CMA) is another cognitive framework that comes to complement the two previously stated theories. CMA provides insight into how users consciously or unconsciously shift their attention onto different sensory inputs if received simultaneously. CMA suggests that when inputs are distributed in a spatial and temporal manner and cues are congruent with each other, as seen in previous literature mostly in audiovisual environments, they are processed more efficiently (Driver & Spence, 1998). When those senses are optimally imputed into the brain, they can contribute to enhanced perception and decision making (Napoli & Chiasson, 2018). In the context of games, it is essential for designers and developers to understand how players may handle simultaneous cues and which combinations are considered optimal to facilitate responsiveness of players (Broadbent, Osborne, Mareschal, & Kirkham, 2020). CMA supports the argument that attention isn't evenly distributed and interface design is responsible to guide users towards an easy path to comprehend different modalities in different scenarios.

Finally, the Five Sense Theory, which emphasizes the full range of human sensory inputs, sight, sound, touch, taste and smell, and broadens the discussion beyond the traditional audiovisual integration. While most digital experiences use the audiovisual senses, this theory shows the potential of underexplored senses like smell and taste to enhance immersion (Lee, 2013). This theory takes into consideration the gaming industry and shows how the sense of touch has been integrated into the Nintendo Wii which was an innovation compared to previous game consoles at the time and saved the company when released (Hariprasad, 2016). By incorporating these less used senses, designers can create richer and more inclusive experiences (Li, 2021). The Five Sense Theory here serves as the conceptual backbone for the expansion of MSI and exploring the benefits and limits of different inputs.

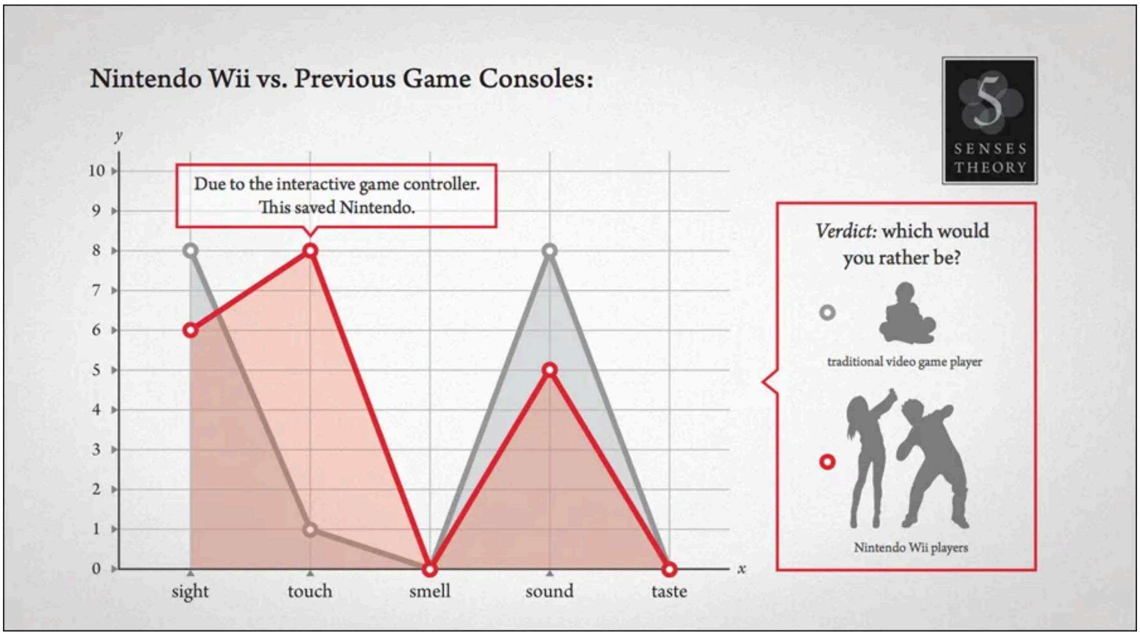

Figure 5: The Five Senses Theory (Hariprasad, 2016)

Combined and used together, these four theories form a framework that is interconnected to evaluate how cognitive systems interact with different gaming sensory environments with different complexity. They provide justification for the previously stated hypotheses and inform the practical implication of balancing sought benefits without hindering UX in gaming interfaces.

3.2 Rationale for Theoretical Framework

The selection of these theories described in the previous section, presenting the theoretical framework of the study, came from their ability to explain how sensory stimuli influence the human cognitive systems, behavior and UX in digital environments. This research builds on those theories to investigate the impact of MSI in decision making speed, accuracy, cognitive load and overall UX in gaming. Each selected theory contributes uniquely to the perspective and arguments of this thesis and altogether forms a theoretical model to examine the potential outcome of MSI in complex gaming settings.

Information Processing Theory was picked because it explains how stimuli is received in the brain before being filtered and stored. IPT provides a good structure to understand the human cognitive processes by detailing how different sensory inputs move from sensory memory to the working memory and potentially into long term storage if selected as relevant (Bouchrika, 2025). In the context of gaming, this theory helps to understand the risks of potential bottlenecks and overwhelmingness of sensory inputs (Alamia, Zénon, VanRullen, Duque, & Derosiere, 2023). This theory is also useful as it shows important concepts of neuroscience research, such as when the sensory memory is overwhelmed, essential stimuli may be ignored (TheoryHub, 2025). This process would then lead to slower responses from the players.

Cognitive Load Theory adds a dynamic understanding of mental effort and mental load to this study. CLT explains that humans' working memory is limited in capacity and might become overloaded when it is facing excessive or incongruent sensory inputs (Sweller, 1988). Because this study measures performance, cognitive load and UX, CLT offers a lens to evaluate if additional senses enhance or affect gameplay in a negative way (Sweller, 1988). Existing literature shows that while MSI can lead to the decrease of cognitive load by making experiences more intuitive, it is possible this transforms into cognitive fatigue if it is not properly implemented (Yang, Chang, Chen, Lin, & Ross, 2022).

The CMA framework was selected as part of MSI as it is closely related to it and as it can address how players allocate their attention during the process of MSI. CMA outlines that sensory inputs don’t all have the same hierarchy in the brain, rather attention is based on the cues that are most temporal, spatial and depend on contextual factors (Driver & Spence, 1998). In gaming, where players must respond to fast decisions, CMA is essential in understanding which cue is prioritized, the cognitive mechanisms behind it and how it affects the outcome (performance) (Broadbent, Osborne, Mareschal, & Kirkham, 2020). The theory also explains why cues that are aligned together are processed more efficiently than not and their positive effect on users’ decision making processes, immersion and satisfaction (Doucé, Adams, Petit, & Nijholt, 2022).

Finally, the Five Sense Theory (Lee, 2013) was selected in this study to explain the potential in expanding beyond the dual sense inputs that is present in most existing studies. This theory pushes designers to consider underexplored modalities such as touch, taste and smell. This addresses the central research question of this study and how MSI beyond those audiovisual inputs can be optimized. The Five Sense Theory justifies the exploration of emerging sensory technologies such as scent or haptic controls in games (Hariprasad, 2016). These concepts align with the current industry trends and simultaneously addresses gaps in current MSI research.

This overall theoretical framework aligns with the study’s objective. IPT and CLT provide insight into the brains’ cognitive function and structural consequences of MSI. CMA helps understand the attention dynamics and the Five Senses Theory justifies the expanded sensory inputs in gaming interfaces. This theoretical foundation is a good basis to interpret the study’s findings and provide evidence based recommendation for future multisensory design in gaming interfaces.

3.3 Integration of the Key Theories Into the Study

The theoretical foundations built in the previous sections were not only used to give context to the thesis but also gave some information to understand the design, structure and analysis of this study. The integration of all those theories guided the development of the experiment that allowed findings for this study, the selection of variables and the interpretation of both quantitative and qualitative findings.

Information Processing Theory was central to the structuring of the scenario-based survey of this study, designing the scenarios accordingly and varying the number and type of sensory cue presented to then understand how participants ended up filtering and prioritising stimuli during their gaming sessions (TheoryHub, 2025). IPT explains the limit of sensory memory to process information and the filtering of excessive inputs, which was reflected and helped in the building of the previously stated hypotheses, where it was stated that increasing the number of sensory cues beyond a certain point would decrease performance (Bouchrika, 2025). IPT helped in the selection of analysis methods to reflect appropriately what the theory states in the results of the scenario based responses.

Cognitive Load Theory CLT also directly had an impact on the evaluation of variables, such as mental effort and cognitive strain, throughout the scenarios. Scenarios with added sensory inputs were designed to examine the basis of this theory, which stated that the added inputs made intuitive understanding more natural, or instead, created excessive cognitive load (Sweller, 1988). The measures of perceived mental effort, distraction and overwhelm were chosen specifically to reflect and measure the cognitive load mentioned by CLT. The focus on identifying threshold for sensory overload was also a focal point in the analysis and stemmed from CLT as well as other empirical contributions rooted in that same theory (Biswas, Labrecque, Lehmann, & Markos, 2014).

The CMA framework helped the organization of sensory cues in the experimental and prompted for the added scenarios, both aligned (congruent) and mismatching (incongruent), sensory stimuli to identify the difference in responses. CMA's argument stating that attention is selectively distributed across MSI depending on the cues' relevance and congruence helped shaping previous hypotheses, survey and interview questions about distractions and performance (Driver & Spence, 1998). Interview questions used CMA further by crafting the interview guide while keeping the goal of understanding how players shift attention across modalities in real time, adding qualitative observation to the survey's quantitative findings.

Lastly the Five Senses Theory (Lee, 2013) served as the justification for this study and expanding sensory integration beyond the most common empirical view of audiovisual combinations. It inspired the inclusion of less commonly studied senses such as touch, smell and even taste in certain scenarios, justifying the investigation of further environmental variables like temperature and lighting as ambient contributions to UX (Hariprasad, 2016). By integrating these under-tested variables to MSI, the study was able to challenge the dominance of audiovisual cues in user interfaces and introduced survey participants to new parameters in gaming, evaluating their initial feelings and behaviors around it.

Together these four theories provided a complete, inclusive framework for investigating the research question. IPT and CLT framed the mental mechanism and overload discussions, CMA clarified how attention is selective and how it changed based on the relevance of sensory inputs and the Five Sense Theory motivated the exploration of further sensory input in MSI. The integration of this theoretical framework into the study enabled the development of testable hypotheses, scenarios and guided the analysis and interpretation of the gathered data. These theories helped shape empirical evidence and future guidelines for further research and interface design in gaming contexts.

3.4 Challenges and Limitations

While the four selected theories together provide a detailed framework to understand how multisensory integration (MSI) influences the parameter of our research, they also introduce limitations when applied to this thesis.

The first challenge we can identify concerns both the Information Processing Theory (Bouchrika, 2025) and the Cognitive Load Theory (Sweller, 1988). Both theories can be seen as overlapping on a conceptual level, both models similarly describe how information is filtered and stored within the limits of cognitive abilities. While IPT focuses on the information and its pathway through memory (Bouchrika, 2025), CLT details the mental effort associated with the process of this same information (Sweller, 1988). This limitation causes the separation of the two theories during data analysis and arguments being complex in nature, especially when measuring sensory overload or overwhelm, as both theories can justify similar outcomes. This theoretical overlap might make the findings seem weaker than they were.

The Five Sense Theory (Lee, 2013) expands the scope of MSI and motivates the purpose of this research by encouraging the inclusion of understudied senses like taste, smell and touch (Hariprasad, 2016). However the empirical foundation as well as the future justification of this theory remains limited, especially in the digital environment. Unlike vision and sounds which are heavily tested in digital environments, other sensory inputs are more difficult to simulate and control in virtual interfaces. This limitation affected the experiment and findings of this study, as we opted for a scenario based study to avoid control and simulation concerns.

The CMA framework provides valuable insights but some of the variables mentioned in that framework are highly sensitive to context. Player's attention in gaming can shift depending on the type of tasks, the congruence of the cues or personal preferences in sensory cues (Driver & Spence, 1998). Similarly mental effort, and overwhelm, existing in both CLT and CMA are highly subjective and measured through self-report instruments. While this study tried measuring these measures to the best of its ability, standardising player responses across scenarios and interpreting findings was more difficult.

Finally one of the central ideas in both IPT and CLT as well as in other foundational studies is the existence of a threshold where sensory inputs shift to negative feelings (Bouchrika, 2025; Sweller, 1988). However this variable might vary based on individual preferences and context, while the study identified the most common patterns where additional sensory cues decreased performance, determining a universal limit is difficult and the final results reflect the average response of participants instead of something that can be applied to every individual.

The selected theories collectively offer a strong foundation to explore the cognitive mechanism behind MSI in gaming interfaces. While each theory contributes in a valuable way to the study, some theoretical and practical challenges can't be denied. Despite these limitations, the integrated framework remains an essential part of the thesis, guiding the structure, analysis and future interpretation of findings that will follow.

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Chapter 2
Research Methodology

4.1 Overview of Research Methods

Literature Review Methodology

Before moving to the experimental methodology of the study, the research methodology chapter explains briefly the methods used for the development of the literature review. To conduct a research on the impact of synesthesia and sensory integration on fast decision-making processes, a high-quality research approach was applied to the literature review. The following outlines an effective strategy, guided by thesis supervisors, for collecting and analyzing relevant academic literature:

Database

The following databases were mostly used in the presented study: Web of Science, Google Scholar, ACM digital library as well as previous Tech3Lab (HEC UX lab) research. Web of Science was mostly used because of its ease of use and my personal familiarity with the tool.

Keywords

This research was guided by multiple keyword across the literature review, which are included in the following subsections:

- Overall Multisensory Experiences - regardless of the industry
    - Multisensory, Synesthesia, Synesthetic Experiences, Sensory processing, decision making, Crossmodal attention, Sensory Stimuli, Intermodal, Cognitive effects, Decision Making, Decision making speed, Decision making

accuracy + senses (color, vision, smell, taste, …), Ambient Conditions, Temperature, Lighting

- Multisensory Experiences in the Gaming Context
  - immersion, gaming experiences, Augmented Reality, Virtual Reality, sensory cues, sensory feedback, + senses, +ambient conditions.
- Multisensory Experiences in the Emergency context
  - Emergency responses, Stress-Inducing situations, Hospitals, color coding, visual and auditory cues, sensory based communication, decision making, multisensory signals. + senses

Inclusion and Exclusion Criteria

To ensure the relevance and applicability of the research, considering the evolution of new technologies across various industries, studies published within the last 15 years were included, excluding this criteria for empirical research about discovery of the different phenomena in the center of this study such as synesthesia or cross modal attention, to gather the most current insights and understanding the phenomenon better. The number of times these papers have been cited was also taken into consideration to understand the validity of the existing research. Studies focusing on fast decision making without mentioning any sensory experience, which is the main variable for this study, were excluded.

Experimental Methodology

This study adopted a mixed methods research design to explore the influence of MSI and ambient conditions on decision making, cognitive load and UX within gaming context. The methodological approach of this study was built on the theoretical framework from the previous chapter including Information Processing Theory (Bouchrika, 2025), Cognitive

Load Theory (Sweller, 1988) and other MSI frameworks (Driver & Spence, 1998; Lee, 2013). The research was designed in two key phases, the qualitative phase including semi-structured interviews and the quantitative phase with the scenario based survey experiment.

During the qualitative phase, semi structured interviews were conducted with a small sample of players to identify overall gaming experiences, the key sensory variables individuals were typically exposed to during gaming sessions as well as contextual influences and personal thresholds of sensory overload (overwhelm…). These interviews informed the construction of the gameplay scenarios (Appendix 5) and questions asked to the participants during the quantitative phase.

The quantitative phase exposed participants to five distinct gaming scenarios with different increasing sensory intensity. The gamers' responses and subjective preferences were recorded through Likert scale survey answers which measured multiple relevant variables from the empirical and theoretical studies (Driver & Spence, 1998) as well as themes from the interviews. These variables included mental effort, immersion, enjoyment, distraction and effectiveness to focus, additionally, participants had the opportunity to develop further their answers through open-ended contextual and preference based questions.

The choice to use scenario-based testing for this study allowed the manipulation of sensory conditions, and assessed their effect on dependent variables, without having to control the environment or the independent variables. Measures were selected and adapted to reflect as much as possible real life scenarios based on information gathered from research and interviews.

For the analysis of the collected data, to ensure statistical accuracy, non-parametric analysis was used. Friedman tests were used to detect overall differences in different variables across different scenarios before Wilcoxon Signed Rank tests were then applied to provide pairwise comparisons for scenarios and understand the effect of independent variables on dependent ones.

The different types of data allowed for a complete understanding of how players might perceive and respond to MSI and its different layers. This ensured that both subjectives and numerical measures were captured and taken into considerations before making conclusions in the study.

4.2 Participants

Participant or subject characteristics

The research participants came from the gaming communities and consisted of adults with different gaming habits and experience levels. The research sample was composed of people aged 18 to 35 (Figure 6) who mostly matched the main target audience for mid-core gaming habits. Gender distribution was balanced (Figure 7) which prevented biased results and allowed comprehensive evaluation of UX. The study required all participants to have substantial game experience but did not need any professional or competitive gaming background.

Sampling procedures

The research used convenience sampling as its sampling strategy. The research participants joined through Discord and Reddit gaming communities and forums. The recruitment materials presented a brief overview of the research and its objective, with estimated participation duration and clear statements about the voluntary and anonymous nature of participants’ participation. The semi-structured interviews reached participants individually but the quantitative survey was made accessible to all eligible and interested participants.

The study provided a $200 gift card draw as an incentive to participate in the survey. For the interviews, 10 eligible participants who showed interest and availability were selected to participate in the pre-survey interviews with their participation being solely on a voluntary basis.

Sample size and power

The final sample for the quantitative phase used 96 survey participants after removing participants who didn’t meet the recommended minimum criterias, this met the recommended minimum sample size for non-parametric within subject tests including the Friedman and Wilcoxon Signed-Rank tests in this study. The within-subjects design of the scenario-based approach enabled participants to act as their own controls which enhanced the reliability of scenario comparisons.

The qualitative pre-survey interviews involved a total of 10 participants who were enough to reveal essential experiential themes, sensory thresholds and individual preferences which helped to shape the survey design (Appendix 2). The mixed methods approach enhanced the findings' depth and applicability even though the sample size remained moderate.

4.3 Materials

Primary measures

The qualitative phase of this study used semi structured interviews based on an interview guide (Appendix 1) crafted with the foundational empirical knowledge from the literature review. This interview guide (Appendix 1) contained open-ended questions about participants' gaming habits, sensory preferences, experience of sensory overload and ambient conditions. These interviews were used to inform the scenario design and the selection of variables for the quantitative phase.

A custom designed online survey, based on previous studies, theoretical research, interview results and real-world game design considerations, was the primary instrument for the quantitative phase and contained five fictional gaming scenarios (Appendix 5). Each scenario presented a different combination of sensory cues. After each scenario, participants rated their experience using a series of 5-point Likert scale questions. Participants also had the opportunity to answer behavioral questions to understand their preferences around ambient conditions in their gaming setup, these were separated from sensory cues answers to truly understand the difference between those variables. The key dimensions measured included:

- Mental effort
- Overwhelm (sensory overload)
- Enjoyment
- Immersion
- Distraction
- Effectiveness to focus

In addition to the previously mentioned responses, survey participants had the opportunity to answer open-ended questions at the end of the survey to elaborate on their preferences, perceived feelings about the introduction of new senses in gaming interface and any discomfort or confusion.

Secondary measures

The survey also collected the following information:

- Demographic information (age, gender, gaming frequency, preferred gaming genres)
- Contextual gaming habits (environmental setup, sensory customization or gaming platforms)
- Prior experience with sensory feedback (use of haptic devices, VR/AR systems…)

These variables served to contextualize the findings and helped identify patterns or moderating effects across different player profiles.

Quality of measurement

The materials were grounded in both foundational and applied research on sensory integration, cognitive processing and decision making. Measures and variables were informed with the help of previous studies to align with validated constructs of cognitive load and sensory design.

To ensure the materials captured intended constructs, the scenarios were refined using previous empirical studies (Driver & Spence, 1998) as well as insights gathered from the qualitative phase (Appendix 2) . Interview themes directly influenced how scenarios were structured, ensuring contextual realism and emotional relatability for participants to then be able to apply it to real life decisions. Likert-scale items were grouped by constructs and consistent phrasing was used to minimize confusion and burden.

While the fictional nature of the scenarios did prevent precise control and adapting physical sensory exposure, descriptive details and strategic sequencing of questions were used to simulate immersive decision-making contexts as realistically as possible within a digital survey format.

By building scenarios that mirror real gaming experiences with appropriate graphs and images, the survey was able to elicit responses that reflect actual user preferences and cognitive responses in real gaming environments as closely as possible.

4.4 Procedure

Data collection methods and research design

The research began with a qualitative phase, involving semi-structured interviews with 10 participants. These interviews explored players' typical gaming setups, prior exposure to sensory cues, individual sensory preferences, personal thresholds of sensory overload and other ambient factors such as lighting and temperature. An interview guide (Appendix 1) was developed to structure the conversations while allowing flexibility for participants to elaborate their answers. These interviews were conducted online via audio calls and transcribed for thematic analysis (Appendix 2). This phase delivered information used to develop the five hypothetical game scenarios which served during the quantitative phase but also used to evaluate dependent variables for analysis including mental effort, enjoyment, immersion, distraction and focus effectiveness.

The interview phase was followed by an online scenario based experimental survey. Five fictional game scenarios (Appendix 5) mimicked real life sessions while asking participants to experience various combinations of sensory complexity and environmental preferences. The simulation of increasing sensory input occurred through increased exposure to various stimuli (Appendix 5). The survey presented Likert-scale questions to participants after immersing themselves of each scenario in order to collect response regarding all selected parameters (mental effort, overwhelm, immersion, enjoyment, distraction and effectiveness to focus).Some participants also completed open-ended questions which requested information about their preferences with their sensory comfort levels as well as their feelings about those new senses. Those artificial game scenarios functioned appropriately to modify sensory components in a research setting mimicking physical laboratories.

Data diagnostics

The survey presented the five scenarios and on average lasted between 20-30 minutes of participant time. The analysis of data showed complete participation without significant missing value problems. The study required a non-parametric statistical approach because the Likert scale items were ordinal in nature and the design involved within-subjects measurements.

Analytic strategies

Data from the survey was analyzed through non-parametric tests such as Friedman and Wilcoxon Signed-Rank Tests. Friedman Tests analyzed whether significant variations existed between the five scenarios for all measured variables. Wilcoxon Signed-Rank Tests served for making post-hoc comparisons between scenario pairs to test specific research based hypotheses. Thematic analysis techniques were used to analyze both interview responses and open-ended survey comments. The research identified recurring patterns about sensory preferences as well as overload experiences and contextual gaming behavior that were then connected to the quantitative research results before making conclusions for the study.

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Chapter 3
The Impact of Multisensory Integration on Decision, Cognition and User Experience (Results)

5.1 Participant flow and recruitment period

The participant recruitment occurred between January and March 2025 through purposive and convenience sampling methods. The recruitment process mainly occurred through social media platforms that are known to be heavily used by gaming communities such as Discord gaming communities and Reddit gaming communities. The research aimed to gather participants from different gaming backgrounds to achieve a complete understanding of MSI in gaming contexts.

The study accepted participants who fulfilled the following criterias: The participants needed to be at least 18 years old, the participants needed to be gamers regularly playing games (at least 3-5 hours per week), the participants needed access to gaming devices which included PCs, consoles or mobile devices. The survey required participants to fill it out in English.

100 individuals expressed interest in participating in the survey, 110 if pre-survey interviews are included. The selection of 10 participants for pre-survey interviews helped researchers gather qualitative data to develop the survey instrument. These interviews were conducted through online platforms in the form of audio calls with each session lasting between 30 to 45 minutes. Results from the scenario-based survey showed a total of 52 participants answered all of the questions of the survey, others either left before finishing or just chose not to answer certain questions.

The research participants showed a variety of answers in their age range and gender identity as well as their geographical locations, gaming experience levels and selected gaming platforms. The participants spanned from 18 to 35 years old with almost equal numbers of cis-males and cis-females (Figure 7) and participants from all over the world. Most participants spent on average 10-15 hours (Figure 8) per week gaming while using PCs, consoles and mobile devices.

Overall, the research design combined interview findings with survey data to achieve both detailed understanding and general application to the population.

5.2 Overview of Results

A mixed-methods approach combined semi-structured interviews and a scenario-based survey to study the effects of MSI and ambient environmental conditions on decision speed and accuracy, cognitive load and UX in gaming environments. The research evaluated both positive aspects and negative factors of integrating new sensory inputs such as touch and taste and smell together with established visual and audio feedback.

The research results will be presented in three parts which cover pre-survey interview findings, quantitative survey data and an integrated analysis section. The descriptive data, showing demographic data and gaming behavior statistics show the age range and gender breakdown of participants as well as their gaming activities, platform choices and their exposure to sensory experiences. The study used Friedman tests together with Wilcoxon Signed-Rank tests to examine how mental effort and immersion along with enjoyment, perceived distraction and decision-making effectiveness changed across five gameplay scenarios with different sensory stimulation intensities.

Key trends that were observed in the results include moderate MSI, with a few modalities significantly enhancing user focus, enjoyment and immersion. Meanwhile excessive or conflicting sensory cues or combinations were consistently associated with negative feelings, increased mental effort, higher distraction and performance decline. Qualitative interview data also supported these findings, emphasizing the importance of the congruence of sensory inputs and the need for personalization of interfaces to prevent cognitive overload depending on suggestive sensory boundaries. Ambient conditions were found to meaningfully influence comfort and cognitive clarity of players. Dim lights and cool temperature were generally preferred for immersive and effective gameplay experiences. The following sections will offer detailed assessments of those research outcomes.

5.3 Pre-Survey Interview Results

Through the semi-structured interviews researchers aimed to discover unknown dimensions in player experiences and gameplay elements while studying their impact on player decision-making, immersion levels and cognitive workload. All participants who participated in the interview described themselves as frequent gamers, with all of them gaming at least 5 hours per week, even though their gaming preferences included different genres and platforms and gameplay approaches. The participants engaged with different types of games that included first-person shooter (FPS), MOBAs together with strategy, puzzle and simulation genres. Most interviewees demonstrated a strong preference for multiplayer games because they find them highly dynamic and social. Single-player games received praise especially when the focus was on deep narratives and emotional storytelling. The amount of time participants spent playing games covered both weekly limits and extended periods reaching up to 25 hours daily. Most participants used their PCs as their primary gaming platform, while operating with mouse and keyboard controls. However there was variety in results with a mobile gamer and multiple console or controller players.

Participants highlighted environmental comfort as their top priority when discussing their gaming environments. Most participants kept their work and gaming stations at the same desk location because they mentioned doing both on the same platform. The choice between dim or colored lighting for game immersion and bright lighting for eye comfort showed differences in preferences among players. However, all gamers mentioned temperature as a critical element which influences their performance since they struggled with hand movements and focus in environments with extreme temperatures. Some participants used blankets and hoodies as well as fans to regulate the environment and stay focused while playing games.

The participants showed positive interest toward incorporating additional sensory integration features into games that go past the basic visual and auditory elements. Gamers found value in touch feedback, as some of them already experienced it through simple controller haptic feedback, alongside smell and taste cues because these features could enhance game immersion and strengthen in-game actions. However, almost all participants asked if these novel cues would reflect negative experience in game as well, such as bad scent or taste which they would disapprove of. Most participants were confident that the implemented cues would improve reaction times together with situational awareness especially during quick-paced games that demanded immediate decisions. Several participants highlighted how multisensory cues such as colorblind modes and vibration indicators provide accessibility benefits to players with sensory impairments.

The interviewees maintained positive attitudes toward the idea yet expressed worries about receiving too much stimulation. Multiple participants recalled moments when games delivered too many stimuli simultaneously through complex controls and fast screen movements and excessive audio alerts which caused mental fatigue and frustration leading to complete game abandonment. The main requirement from players was to have customizable settings for a balanced experience. Players demonstrated clear preference for systems which let users turn sensory features on or off based on their individual preferences and gameplay methods which shows that sensory features should enter games step by step instead of simultaneously because this approach protects users from becoming overwhelmed and maintains performance levels.

The environmental factors of lighting and temperature were proven to be essential for determining player concentration levels and immersive experience. Players underlined that extreme temperatures created adverse effects on their physical comfort and motor skills. Players experienced delayed reaction times when playing in cold temperatures meanwhile they felt uncomfortable and lost focus in hot temperatures. Lighting was similarly influential. Some players enjoyed playing games in dim lighting because it improved their immersion especially during story-driven games. The players experienced difficulty staying focused when lighting conditions became too bright during fast-paced or competitive gameplay. The majority of participants became aware afterward that performance problems often occurred when they were uncomfortable about their environment.

The participants agreed that casual narrative and simulation games offered the most suitable environments for testing experimental sensory features; they described it as a fun feature to test out with friends. Serious games and training simulations represented suitable areas for expanded sensory input when realism was the primary objective. However, the majority of participants indicated that competitive esports and high-level ranked gameplay required basic simplicity in their interfaces and weren't as comfortable introducing MSI in that context. The interviewees stated that additional sensory stimuli in these specific settings would transform into hindrances instead of advantages.

All interviewees emphasized that user control and customization features represented absolute requirements if gaming interfaces were to consider MSI. Every player has different preferences so participants agreed that customization options must accompany any MSI feature. The introduction of sensory cues needs to be optional and non-intrusive while players should maintain full control over experience customization according to their personal comfort. Overall, the participants demonstrated positive attitudes toward MSI in gaming environments as long as developers implement features with thoughtfulness.

5.4 Scenario Based Survey Results

Descriptive statistics

The scenario-based survey reached a total of 100 participants who evaluated how MSI affects decision-making together with immersion and cognitive load in gaming environments, 96 participants' answers fitting the requirements and 4 responses were rejected as part of the study's ethics considerations.

The study participants were mostly young adults between 18 to 25 years old followed by people from 26 to 35 years old (Figure 7). The study's target population consists of digital gamers thus the age distribution matches expectations. The majority of respondents identified as female with a smaller percentage of male participants alongside participants who identified as non-binary or other gender identities (Figure 8). The survey participants originated from

North America and Europe but received some responses from Asia and South America according to Figure 9. The study included participants from different cultures and backgrounds which helped evaluate diverse preferences and sensory experiences.

Study participants engaged in various levels of gaming activity. The majority spent between 11 and 20 hours gaming each week although another large group spent 6 to 10 hours per week which indicates their medium to intense gaming habits (Figure 8). The gaming platforms preferred by respondents included PCs and consoles alongside mobile devices (Figure 9). The survey data showed keyboard/mouse combinations and game controllers were the dominant control devices used by participants (Figure 10).

The survey data showed multiplayer games remained the preferred choice among respondents even though numerous participants chose single-player narrative games as their preferred option. Most players experienced visual and auditory cues but haptic feedback through controller vibration was witnessed for some(Figure 11, 14). Players ranked vision and hearing as their most important senses in gaming yet they acknowledged touch provided realistic feedback as well (Figure 12).

When asked about their gaming environment, a high proportion of participants reported having a dedicated gaming setup (Figure 13). A majority of respondents modify both their lighting and temperature conditions to create better comfort and performance while gaming (Figures 24, 26). A third of the participants have used non-visual non-auditory sensory inputs including tactile gloves and scent-based interactions which shows their growing exposure to new multisensory technology (Figure 14).

The gaming population profiled here consists of a diverse group of moderately experienced gamers who understand standard game sensory feedback yet show interest in multisensory enhancements. The subsequent statistical evaluations will try to use this data added to more in depth analysis as a basis to answer the study's hypotheses.

Inferential statistics: Cognitive Load and Performance (H1a, H1b, H2a, H2b, H3a, H3b)

Multiple survey responses analyzed in scenario-based conditions demonstrated complex relationships between MSI and cognitive load which affected both mental effort ratings and decision-making performance.This section presents findings related to hypotheses H1a, H1b, H2a, H2b, H3a, and H3b, which explore how the number, type, and congruence of multisensory inputs influence cognitive load, decision-making, and UX.

The evaluation of participant ratings throughout the five scenarios demonstrated a moderate mental effort perceived in most scenarios with an increasing trend as cues were being added. Starting scenario 4, most answers described mental effort as high and extremely high (Figure 16). In Scenario 3 combining audiovisual elements with touch and smell features resulted in moderate mental effort (Figure 15) however participants noted that their experience was very immersive and enjoyable (Figure 17, Figure 19). The additional sensory inputs above three started to diminish perceived benefits and sometimes produced opposite effects starting Scenario 4 and became most pronounced in Scenario 5 when various conflicting sensory cues were presented simultaneously. The Friedman test validated statistical evidence for mental effort differences across scenarios because it demonstrated a significant variation ($\chi^2(4) = 107.67$, $p < .001$)(Figure 30) that revealed different multisensory combinations imposed different cognitive burdens on participants.

The Wilcoxon Signed-Rank tests provided supplementary evidence to demonstrate these differences between groups. The mental effort ratings between Scenario 3 and the audiovisual only condition in Scenario 1 proved significantly different ($S = -387.5$, $p < .001$)

(Figure 32). The combination of all five sensory inputs in Scenario 4 produced increased mental effort compared to Scenario 1 (S = -307, p <.0013) since our results were coded in Likert scale values (1 to 5) negative sign in the test result indicates that the addition of touch, smell, and taste in Scenario 4 resulted in a higher perceived cognitive load compared to the baseline scenario. These results indicate that a particular MSI threshold works best for cognitive processing. Scenario 5 showed elevated mental effort when compared to both Scenario 3 (S = 637.5, p <.0001) and Scenario 4 (S = 386, p< .0001) (Figure 33, 37) thus confirming the anticipated sensory overload when a high number of cues is introduced with inputs that don't match. The study confirms that multisensory environments use CMA to distribute workload across modalities yet excessive or disorganized implementations can create user overload that diminishes performance. These results support the theoretical framework around hypotheses H1a and H1b by providing experimental data that demonstrates the threshold model of MSI.

The examination of participant overwhelm and distraction revealed consistent patterns. The Friedman tests together with Wilcoxon comparisons indicated that Scenario 5 produced substantially higher feelings of being overwhelmed and distracted when compared to both Scenarios 3 and 4. The comparison between Scenario 5 and Scenario 3 produced substantial increases in reported overwhelm (S = 709, p <.0001) alongside distraction (S = 637.5, p <.0001) (Figure 34, Figure 35), note that these results don't show negative sign as scenario 5 was put against scenarios 4 and 3 and not the opposite. The scenario 4 results showed parallel patterns because Scenario 5 generated a significant elevation in both overwhelm (S = 526.5, p <.0001) and distraction (S = 386, p <.0001) ratings (Figure 36, Figure 37). The analysis revealed major deterioration in participants' capacity to concentrate while these effects occurred. The focus effectiveness ratings showed significant decline when participants evaluated Scenario 5 in comparison to both Scenario 3 ($S = 390.5$, $p < .0001$) and Scenario 4 ($S = 611.5$, $p < .0001$)(Figure 38, Figure 39). These results demonstrate that sensory congruence together with coherence plays an essential role. The processing of information through MSI becomes smoother when aligned cues are distributed but incongruent or unnatural sensory pairings such as those found in Scenario 5 create disturbances in attention and task focus. The experimental results support the fundamental statements of Hypotheses H2a, H2b, and H3b by showing that multisensory cue quality and their contextual relevance and congruence matter equally to their quantity.

These statistical findings received additional support from self-reported performance assessments of participants. When asked at what point participants thought the addition of sensory inputs would become too much and slow them down, 43% reported Scenario 5, 26% Scenario 4 and only 20% for the third scenario (Appendix 3). This outcome matches prior investigations about sensory thresholds together with cognitive load theory and Hypothesis H3a which stated that neglected sensory inputs like touch and smell would boost decision-making through integrated use with established senses. The benefits of these cues disappeared or turned into negative effects when their alignment and amount exceeded acceptable limits, which was perceived when the sense of taste was added.

Participants' perceived effectiveness to focus was evenly distributed in scenario 3 (Figure 22) while being lowest in Scenario 5 (Figure 23) thus demonstrating the necessity of precise matching cues for MSI. The introduction of sensory mismatch in Scenario 5 diverted user attention from the task which led to decreased focus along with higher levels of frustration. Participants provided open-ended feedback which supported this effect by calling

Scenario 5 too extreme and mentally exhausting thus demonstrating that sensory complexity needs proper management to prevent cognitive load. The progression of all parameters across all five gameplay scenarios is better illustrated by the comparison table in Figure 44, which summarizes the average participant ratings and difference between each consecutive scenario. This visual comparison shows that Scenario 3 is the optimal MSI configuration before overload effects emerged in Scenarios 4 and 5.

Overall, the results strongly support Hypotheses H1a and H1b, confirming that increasing sensory inputs beyond two initially maintained a moderate level of mental effort without negatively impacting UX (H1a). However, once the number and complexity of inputs exceeded a certain threshold, cognitive overload emerged, impairing performance and increasing mental strain (H1b). The findings also support H2a and H2b, demonstrating that congruent, well-aligned cues are essential, as conflicting or disorganized sensory inputs elevated cognitive load and disrupted attention. Additionally, H3a and H3b are supported by evidence that underexplored sensory modalities like touch and smell can contribute positively when effectively integrated, but contribute to overload when mismatched or excessive. These results reinforce the importance of not only how many sensory cues are presented, but how meaningfully they are combined.

Inferential statistics: User Experience and Immersion (H1c, H2c, H3c)

The second thematic cluster of hypotheses: H1c, H2c, and H3c, examines the perceived quality of UX as influenced by sensory integration. In particular, these hypotheses explore how increasing the number of sensory cues, as well as their congruency and novelty, affect engagement, intuitiveness, satisfaction, and immersion. Together, they examine the extent to which a richer multisensory design can increase subjective enjoyment of a game and how long these effects last or how they may be negatively impacted by sensory overload.

Statistical analyses showed that sensory integration had a significant effect on immersion and enjoyment. The Friedman tests showed that there were significant differences between scenarios in enjoyment ($\chi^2(4) = 77.54$, $p < .001$; Figure 31) and immersion ($\chi^2(4) = 67.92$, $p < .001$; Figure 41) indicating that different sensory combinations affected the gameplay in consistent and measurable ways. The most positive results across both dimensions were obtained for Scenario 3 where participants felt highly immersed and still felt moderately to high enjoyment (Figure 17, 19) even though that scenario included touch and smell in addition to audiovisual inputs (4 senses). This confirms H1c, which stated that the more sensory cues, the better the UX. Notably, Scenario 4, which introduced taste as a fifth input, did not produce a significant additional gain in enjoyment, with participants' answers being more spread out (Figure 20) but extremely immersed (Figure 18) suggesting a point of diminishing returns.

Hypothesis H2c predicted that the UX would improve with contextual alignment of sensory cues and would decline with incongruent cues. This was clearly observed in Scenario 5, which introduced mismatched or conflicting sensory inputs. Scenario 5 scored significantly lower in enjoyment compared to Scenario 4 ($S = 410.5$, $p < .0001$; Figure 40), and Scenario 3 ($S = 20.5$, $p < .4151$; Figure 42). Similarly, immersion ratings dropped when congruency was lost; Scenario 5 immersion was significantly lower than Scenario 4 with almost 50% of participants describing scenario 5 as “not enjoyable at all” (Figure 21). These comparisons support the idea that congruency and thematic alignment between sensory modalities are central to maintaining a positive UX . Participant feedback further supports these quantitative results. In open-ended responses, users described Scenario 5 as overwhelming or confusing, and showed concern about extreme stimuli or stimuli “being off” or expressing that the addition of too many mismatched sensory cues made the game feel artificial rather than immersive.

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The hypothesis concerning the effects of uncommon or underutilized senses (H3c) was also supported with nuance. As previously stated, participants enjoyed and immersed themselves more in Scenario 3 when smell was introduced, but the positive effects plateaued or reversed in Scenario 4 and declined sharply in Scenario 5. Scenario 4 did not differ significantly from Scenario 3 in enjoyment ($S = 20.5$, $p < .4151$; Figure 43), indicating that adding taste did not further enhance the experience for most users. Furthermore, enjoyment decreased significantly between Scenario 4 and Scenario 5 ($S = 410.5$, $p < .0001$; Figure 40), reinforcing the importance of balance and integration quality over sheer quantity of sensory stimuli. Participants described smell as an interesting cue that they would want to experience in cooking games while other were skeptical about being nauseous or allergic to some odors, skepticism rose again as players don’t want to experience negative feelings, such as bad smells, highlighting the challenge of implementing certain sensory modalities meaningfully.

The results provide strong support for Hypothesis H1c, demonstrating that increasing the number of sensory cues can enhance UX by improving immersion and enjoyment, up to a certain point. Hypothesis H2c is also supported, as enjoyment and immersion were significantly influenced by the congruence and context of sensory cues, with mismatched inputs in Scenario 5 leading to noticeable declines in UX quality. Finally, Hypothesis H3c is supported with nuance as underexplored senses such as smell positively contributed to the experience when thoughtfully integrated, but the benefits plateaued or reversed when additional uncommon inputs like taste were introduced.

Inferential statistics: Environment and Ambient Conditions (H4a, H4b, H4c)

The study examined how ambient lighting and temperature influence UX together with cognitive load and performance while also studying direct sensory inputs. Research hypotheses H4a through H4c investigate how proper environmental design through lighting and temperature control will improve sensory integration while enhancing decision-making abilities and UX. The research showed these environmental factors directly impact comfort levels while simultaneously influencing processing speed and gaming experience quality.

The quantitative survey results showed that participants had defined preferences regarding lighting and temperature in their gaming experiences. Research findings shown in Figure 24 demonstrated that participants had different beliefs concerning lighting in their gaming setup. Further data indicated harsh or flickering lighting exposure caused participants to experience difficulty processing sensory information (Figure 25). These results can explain the values being more spread out when asked about "well-lit" environments as multiple participants stated enjoying dimmer lights (Figure 26). When presented with extreme temperatures, like excessive warmth, participants strongly agreed with feeling "lethargic and less accurate" (Figure 28). The results validate Hypothesis H4b and H4c which states poor lighting conditions cause mental fatigue while impairing decision-making performance and UX .

The survey results in Figure 27 showed that players rated cool temperatures beneficial for cognitive performance in games. Similarly players mentioned enjoying slightly cold, not warm or cold or slightly warm temperatures rather than extreme temperatures when playing games. Players disclosed that dimmer lights were ideal for them to stay focus in a gaming context rather than extreme lighting conditions (Figure 26). These results show that optimal perceived light and temperature can improve focus and sensory integration for players, these optimal conditions are considered as dimmer light and non-extreme temperatures. This supports H4a and gives empirical data for perceived well-designed ambient cues for gamers.

The assessment of UX revealed that lighting and temperature conditions influence both user engagement and satisfaction levels and perceived system intuitiveness. The survey results presented in Figure 29b showed that participants selected temperate environments because they reported better comfort and enhanced play satisfaction. The results in Figure 29a showed disagreement between users if temperature changes during crucial gameplay moments could create immersive effects if applied correctly with approximately 20% of users somewhat disagreeing and almost 30% somewhat agreeing. However, when presented with extreme temperatures, like excessive warmth, participants strongly agreed with feeling “lethargic and less accurate” (Figure 28). The study validated H4c by showing that unsuitable ambient conditions produce decreased satisfaction levels together with reduced engagement and showed skepticism around introducing temperature cues matching gameplay environments, showing that players are not ready to change temperature into more than an environment cue. The right balance of environments improved focus and increased emotional impact of gameplay leading to an easier and more rewarding experience.

The research evidence demonstrates support for H4a together with H4b and H4c. Well-designed ambient lighting together with appropriate thermal conditions provided both preference and substantial effects on cognitive load reduction and performance improvement as well as enhanced gaming quality. The results demonstrate how ambient compatibility stands as a crucial factor for multisensory design since players need comfortable and consistent spaces which align with their cognitive processes. Game developers must consider light and temperature as dynamic elements of the environment that influence player experience at the same level as mechanics and storytelling components without involving them in the actual gameplay experience.

5.5 Integrated Analysis

The qualitative and quantitative data in this study provides a comprehensive picture of how MSI and environmental conditions affect cognitive performance and UX in gaming environments. The semi-structured interviews gave a richer understanding of player preferences, expectations, and gaming experiences to craft the survey, while the scenario based survey provided empirical evidence to support or refute these views. Together, they form a complementary framework for understanding the boundaries and opportunities of sensory-enhanced gameplay.

Both datasets showed Scenario 3, which involved sight, sound, touch, and smell, as the most preferred scenario. Participants described this combination as highly immersive yet manageable, supporting Hypotheses H1a, H1c, and H3a. Interview participants had expressed cautious optimism adding underused senses such as touch and smell and noted their potential for deeper engagement but showed skepticism when taste was mentioned. Survey data revealed that these inputs, when integrated congruently, enhanced focus and enjoyment without overwhelming users. This cross-method agreement identifies Scenario 3 as the optimal MSI configuration, where UX, cognitive load, and decision making were positively balanced.

This is consistent with the broader trend identified in both methods: users are open to new sensory inputs especially when they are thematic and intuitive. However, the results also emphasized the importance of sensory congruence and personal customization. The findings of the interview participants included the need for adjustable sensory settings which is consistent with the quantitative finding that incongruent cues in Scenario 5 caused distraction, overload, and decreased performance, supporting Hypotheses H1b, H2a, H2b and H3b. Both data sources concur that more is not always better and the threshold for MSI seems to be just before the inclusion of mismatched or excessive cues, especially when taste is introduced, which several interviewees considered as potentially unpleasant.

The interviews also showed that players are particularly sensitive to the comfort of the environment, and this was echoed in the survey results supporting H4a to H4c. Players described temperature and lighting as critical to their ability to focus and the theme was echoed statistically by the fact that poor ambient conditions increased mental effort and impaired decision making. Interviewees appreciated the ability to adjust their set-up to enhance their comfort but were highly doubtful about incorporating temperature or lighting into the gameplay mechanics. This caution was echoed in the survey's findings, which revealed that ambient cues were helpful as passive modifiers, but not suitable as active interface elements.

5.6 Summary of Key Findings

This study investigated the impact of MSI and ambient environment on decision speed, cognitive load and UX in gaming environments using a mixed methods approach. Several consistent and meaningful findings emerged from the integration of qualitative interview insights with quantitative scenario-based survey data:

Performance, immersion and user enjoyment were best achieved in Scenario 3 which combined sight, sound, touch and smell. The interview and survey participants ranked this condition as immersive yet cognitively manageable and thus it is a strong candidate for future MSI interface design. Additionally, the findings strongly suggest that there is a sensory threshold, since too many sensory inputs, particularly those that are incongruent or excessive, such as taste, cause cognitive overload, distraction, and a decrease in user satisfaction (H1a, H1b, H2a, H2b, H2c, H3b).

The research showed that congruence between cues was as important as the number of cues. The alignment of stimuli to the game themes and mechanics improved user engagement and focus while mismatched cues, particularly in Scenario 5, consistently disrupted attention and enjoyment (H2a, H2b, H2c).

There was a positive attitude toward underexplored senses such as touch and smell (H3a, H3c) as long as they were implemented thoughtfully. There was, however, some scepticism towards taste cues, especially those that could cause unpleasant experiences. Both qualitative and quantitative findings highlighted a strong preference of players for customization and user control, and players were requesting the ability to toggle sensory features based on personal comfort and gameplay context and personal preferences.

Lighting and temperature were found to affect user performance, cognitive clarity, and comfort in a way that was consistent across all participants. Dim lighting and cool or temperate conditions were most commonly associated with improved focus and reduced mental effort (H4a, H4b, H4c). However, there was a high level of resistance to the incorporation of ambient cues as interactive features even though they were effective as supportive environmental elements. Players expressed a desire to keep these cues as background modifiers, not gameplay mechanics.

These findings confirm the study's hypotheses across three thematic clusters: Cognitive load and performance (H1a, H1b, H2a, H2b, H3a, H3b), UX and immersion (H1c, H2c, H3c), and environmental influences (H4a, H4b, H4c). They provide a robust foundation for the discussion of theoretical implications, user-centred design strategies and future research directions in the next chapter.

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Discussion

6.1 Summary

The research investigated the impact of MSI together with ambient conditions on decision-making processes, UX and cognitive load in gaming environments. The research findings show that balanced sensory inputs which combine touch and smell with audiovisual cues lead to faster decisions, better immersion and enjoyment without increasing mental workload. The research supports Cognitive Load Theory (Sweller, 1988) and Information Processing Theory (Bouchrika, 2025) by showing that properly aligned multisensory inputs enhance processing efficiency without exceeding working memory capacity. User experience and performance results showed negative effects when participants encountered sensory stimulation that was either incompatible or excessive according to the threshold effect previously identified in MSI literature. The research demonstrated that ambient environmental factors such as lighting and temperature directly impact both focus and comfort levels thus proving their importance beyond their background status. The research builds upon previous studies by providing empirical evidence about uncommon sensory channels while stressing the necessity of personalization to accommodate different user requirements and cognitive abilities.

6.3 Implications

Theoretical Contribution

Research expands theoretical knowledge of MSI by showing how strategic integration of touch and smell with audiovisual cues enhances user experience, decision-making performance and cognitive efficiency in gaming environments. The findings from scenario-based experiments and empirical analysis directly support Cognitive Load Theory (Sweller, 1988) and Information Processing Theory (Bouchrika, 2025) by showing that proper sensory input alignment improves information processing without exceeding working memory capacity. The research validated these cognitive theories by showing that appropriate sensory load improves user focus and immersion along with enjoyment.

The experimental results offer detailed support to the Five Sense Theory (Lee, 2013) through empirical evidence that shows the effectiveness of integrating touch and smell as underdeveloped senses in interactive digital spaces. This research provides unique experimental findings about using less typical senses for enhanced immersion while maintaining mental clarity through effective integration. Through its implementation the study supports the Five Sense Theory's comprehensive sensory design approach while demonstrating its practical use in gaming applications.

The research strengthens Cross-Modal Attention Theory (Driver & Spence, 1998) by demonstrating how users automatically select scenarios with synchronized cues but filter out other scenarios with overwhelming ones. The filtering was explained by users' experience decreasing as well as performance and satisfaction which verified the threshold effect concept found in MSI literature.

The research highlights how ambient environmental factors such as lighting and temperature function as integral components that shape the multisensory integration process. These environmental elements went above their background role by showing a more direct influence on both concentration and comfort experiences of participants. The experimental model introduced in this research pushes existing MSI frameworks to reconsider ambient cues as integral components which future theories of immersive system design should incorporate.

This research provides essential new paths for inclusive and adaptive design theory. The study reveals distinct variations between individuals regarding their tolerance and responses to multisensory and environmental stimuli which demonstrates why personalized approaches must be implemented in multisensory interfaces. The research provides critical evidence for UX theories which recommend flexible systems that accommodate different cognitive and sensory processing approaches.

The research supports these previously presented theories through empirical evidence while expanding their applicability to enhance theoretical knowledge of Cognitive Load Theory (Sweller, 1988) and Information Processing Theory (Bouchrika, 2025) as well as Cross-Modal Attention Theory (Driver & Spence 1998) and the Five Sense Theory (Lee, 2013). MSI functions as a complex multidimensional process which requires both sensory congruence and individual threshold consideration and ambient consideration. The findings support an appropriately integrated and personalized digital experience design approach which uses cognitive science principles to meet evolving user needs.

Managerial Contribution

This research delivers practical knowledge to game developers and UX designers who work on immersive experiences and product teams which implement multisensory integration and ambient responsiveness. The study provides designers with a solid basis for real-time multisensory design through its demonstration of how balanced sensory input combinations, specifically touch and smell integration with audiovisual cues, improve decision speed while maintaining enjoyment and immersion levels and avoiding cognitive load. The results demonstrate how previous empirical and practical theories used in the UX domain work together to show that properly aligned sensory cues improve processing efficiency while staying within the user's working memory capacity.

Developers who create games and other AR/VR content need to be aware of the sensory input limits which prevent additional elements from becoming unproductive. User attention weakens when sensory cues become excessive or incompatible according to the study which simultaneously elevates mental effort and disrupts performance. The results demonstrate the requirement for designing sensory cues that work together in harmony without producing sensory overload or conflict.

The research demonstrates that ambient conditions such as lighting and temperature play an essential role in addition to multisensory design principles. Research data indicates that background variables like lighting and temperature actively shape both comfort and concentration levels. The implementation of adaptive lighting systems and thermal feedback mechanisms in responsive environments enables designers to enhance user focus and maintain user engagement during extended attention periods or gaming sessions.

The most important managerial implication results from the necessity of delivering personalized sensory settings to users. Users who had sensory sensitivities or neurodiverse profiles together with others strongly wanted control over their sensory environment according to research findings. Users can enhance accessibility through toggling features which let them customize their experience based on personal preference thresholds leading to inclusive experiences instead of exclusionary ones. User-centered adaptive systems now focus on empowering individuals through inclusive design which supports diverse cognitive requirements. Organizations dedicated to accessibility standards and inclusive design can leverage these insights to create innovation through personalized technology development and user experience strategies.

6.4 Limitations

The research brings up important findings about MSI effects on decision-making speed, accuracy and UX however, some essential limitations need to be recognized.

The main limitation lies in the simulated findings of this thesis. The research depended on participant feedback through surveys and hypothetical scenarios instead of live experimental gameplay using physical multisensory equipment. Self-reported measures together with scenario-based surveys demonstrate limited validity because participants may not represent their full experience of using multisensory inputs or ambient conditions during actual gameplay, relying heavily on assumed behaviors. The research introduced new sensory modalities and modeled ambient conditions through simulations and descriptive methods because it did not employ actual sensory devices. The study cannot provide definitive information about the practical impact of these senses on cognition and performance in gaming interfaces because it uses simulated sensory inputs and ambient conditions instead of real-world implementations.

Additionally, the survey and interview methodology allowed researchers to explore multiple sensory combinations but the study faced constraints when analyzing all possible sensory cue permutations or testing sensory congruence effects in different gameplay scenarios. The research explored only a restricted set of sensory cue combinations which may not encompass all possible interactions between sensory elements in complex environments.

6.5 Recommendations for future research

Future research should focus on addressing the research limitations identified in this study while building upon its findings through the following suggestions:

Future research should use more adapted physical multisensory devices or even neuroscience related devices to study participants' reactions in actual or simulated environments. Physical multisensory devices will provide researchers with detailed and realistic findings about how multiple sensory inputs affect decision-making and cognitive load.

Additional empirical investigations are required to properly study the integration of untested sensory modalities including smell and taste. Researchers should study them individually as well as in combination with audiovisual and tactile inputs to understand their effects better.

Future research needs to systematically control congruent and incongruent sensory cue combinations to determine their effects on UX and cognitive performance. Research experiments which actively modify lighting conditions along with temperature and spatial variables will deliver more precise findings about contextual factors affecting multisensory perception. The research will help establish optimal conditions that enhance both performance outcomes and user comfort.

More lengthy research experiments must be conducted to study how users adjust to multisensory interfaces after prolonged use. The desig,n of permanent digital platforms requires knowledge about how users experience novelty decline and decreased cognitive strain from repeated interactions.

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Conclusion

The research question targeted by this thesis focused on the domain of multisensory interface design and gaming cognitive performance, it is repeated as follows:

How can multisensory integration, beyond traditional auditory and visual combinations, and ambient conditions enhance decision-making speed and accuracy, cognitive processes and user experience in the gaming context?

This study provided insights into a current challenge in interface design that involves using multiple senses in digital environments and understanding their relationships. The study which employed both scenario-based surveys and semi-structured interviews made it possible to understand how different senses (touch, smell, taste) can be integrated with traditional audio-visual interfaces to develop more sophisticated digital environments.

The study found that when these senses are used in moderation and in a way that is suitable for the context, they greatly enhance user concentration, interest and cognitive efficiency. The participants who were provided with multisensory stimuli in the scenarios described themselves as being more immersed and more satisfied. This supports and expands on Cognitive Load Theory, Information Processing Theory and Cross-Modal Attention which define our brain processes and perception as a cognitive process and a system with limited capacity.

However, the research also brought out an important discovery that there is a point of saturation in the process of integrating different sensory experiences. Moderate, properly integrated sensory inputs create a more natural and enjoyable experience, but too many or poorly matched inputs can result in cognitive overload, diminished immersion, and impaired performance.

It turned out that a frequently overlooked aspect of this process that acted as a mediator was ambient environmental conditions such as lighting and temperature. These aspects that were previously given little attention in UX research were found to affect the way sensory information is received and processed. The participants stated that appropriate ambient settings made them feel more immersed and focused better and that harsh or poorly calibrated conditions made it difficult for them to integrate sensory information. This indicates that the interface is not limited to the screen; it extends into the physical space that the user is in. The designers have to take into account not only the digital interface but the ecosystem of experience in which that interface is situated without integrating them fully to game experiences which users disliked.

The research has a number of theoretical and practical implications. For the UX and game designers, the study presents theoretical backing for designing multisensory features that increase user engagement while staying within the limits of stimulation. It supports the idea of adaptive systems which are interfaces that can adapt to the sensory preferences and thresholds of the users and provide personalization as a form of accessibility. This has a potential of being particularly beneficial for people with disabilities and can therefore make digital environments more accessible and accommodating to diverse cognitive and perceptual profiles.

Theoretically, this work advances the knowledge on multisensory integration by expanding its scope to other combinations of senses than those that have been studied before. It provides empirical evidence for underexplored theories, discussions about sensory limits, overload and provides directions for the future research on the way different senses combine, enhance or conflict with each other in the high engagement environments such as gaming. It also shifts ambient factors from being treated as background conditions to being treated as design consideration elements.

Future research directions that this thesis has opened up for include new studies on multisensory interaction. We need to consider not only the integration of these new technologies into the design, but how to integrate them in a meaningful way. How do we make sure that these sensory additions become means of clarity and connection rather than causes of confusion or distraction? How can they be used to augment and enhance, rather than eliminate, the human element of experience?

This paper challenges the designers and researchers to question the current interface design paradigm. It challenges designers to think of digital spaces that are not only more engaging but do so without losing their humanity, which was an important skepticism factor for our participants, where the full spectrum of sensory experience is considered while taking into account the realism preferences of the users.

Digital experiences will find their true future through innovating while UX Designers shouldn’t forget about why they are researching and innovating for: the user, interfaces should be developed not in the purpose to maximize simulation, but remembering that innovation exists to serve human experience and not replace it.

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Appendix

Demographics

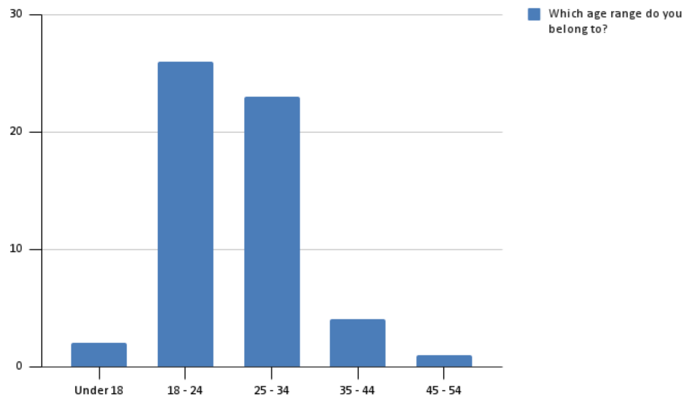

Figure 6: Distribution of Survey Participants by Age Group

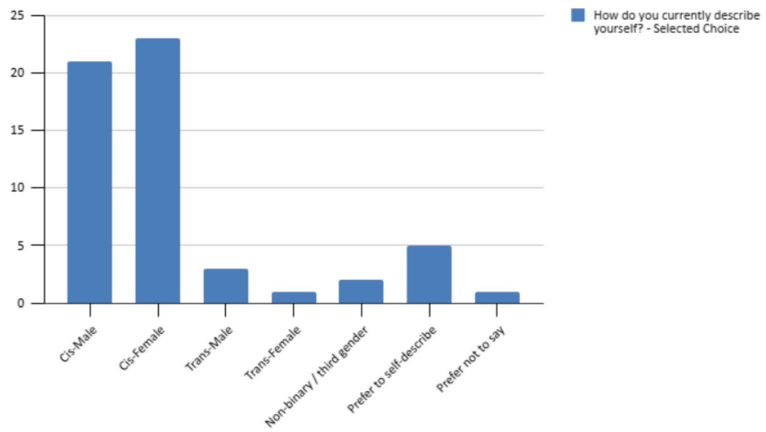

Figure 7: Distribution of Survey Participants by Identified Gender

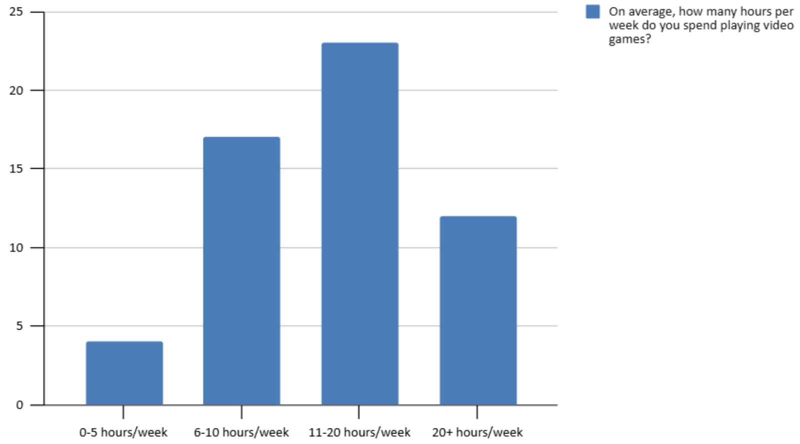

Figure 8: Distribution of Survey Participants by Gaming Habits (hours played/week)

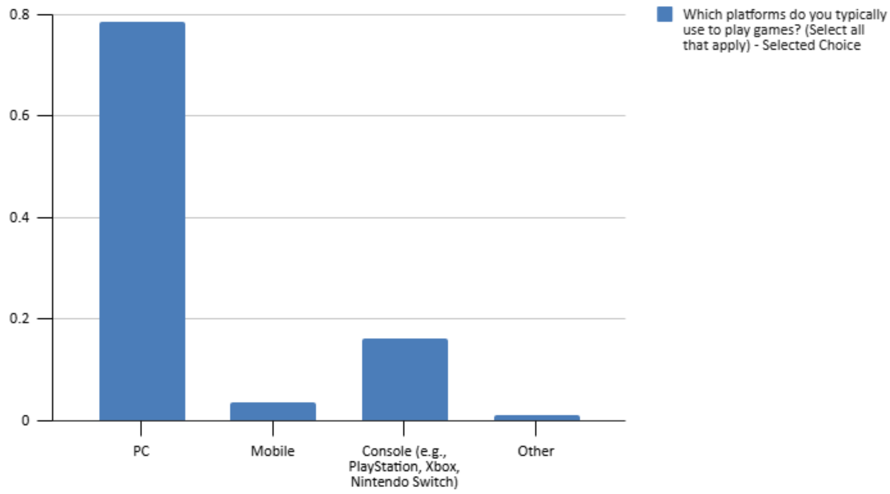

Figure 9: Proportion of Participants Using Each Gaming Platform

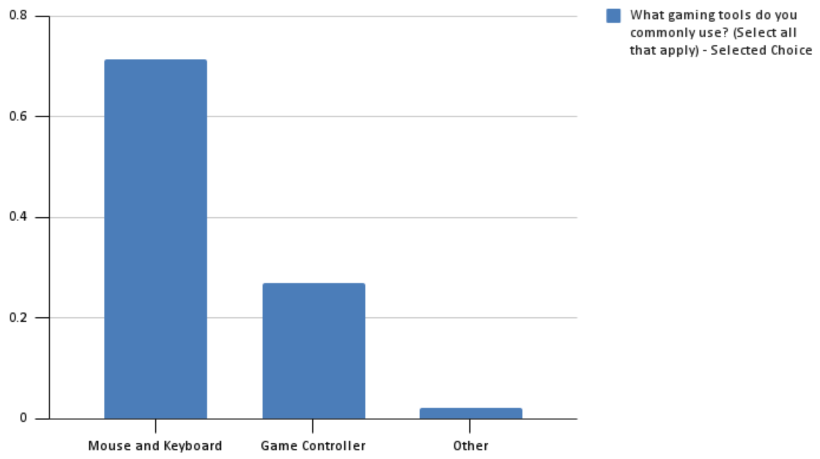

Figure 10: Proportion of Participants Using Per Gaming Controls

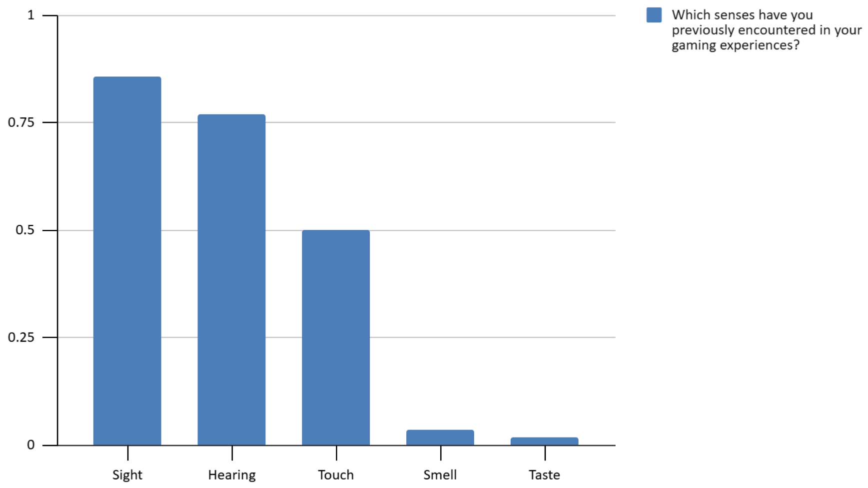

Figure 11: Sensory Modalities Experienced in Gaming (Proportion of Participants)

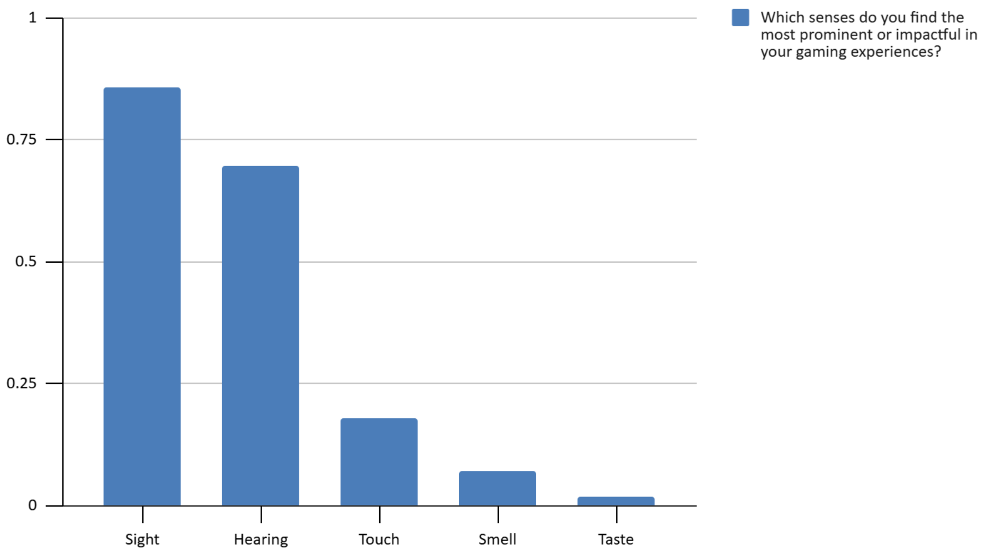

Figure 12: Most Impactful Senses in Gaming (Proportion of Participants)

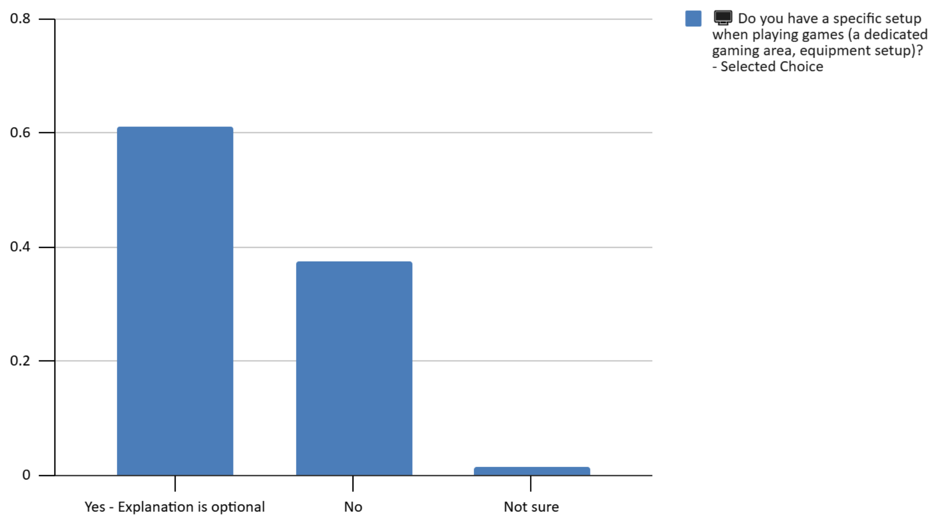

Figure 13: Proportion of Survey Participants with a Dedicated Gaming Setup

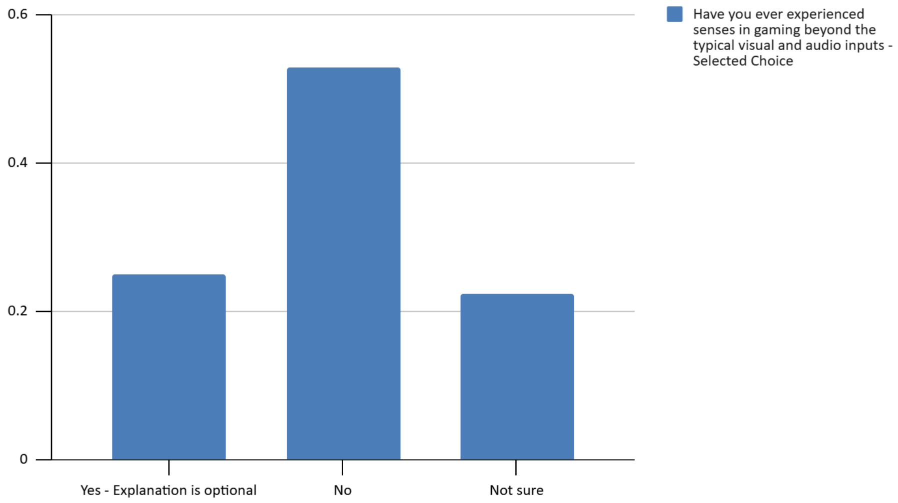

Figure 14: Proportion of Survey Participants Who Have Experienced Non-Visual, Non-Auditory Sensory Inputs in Gaming

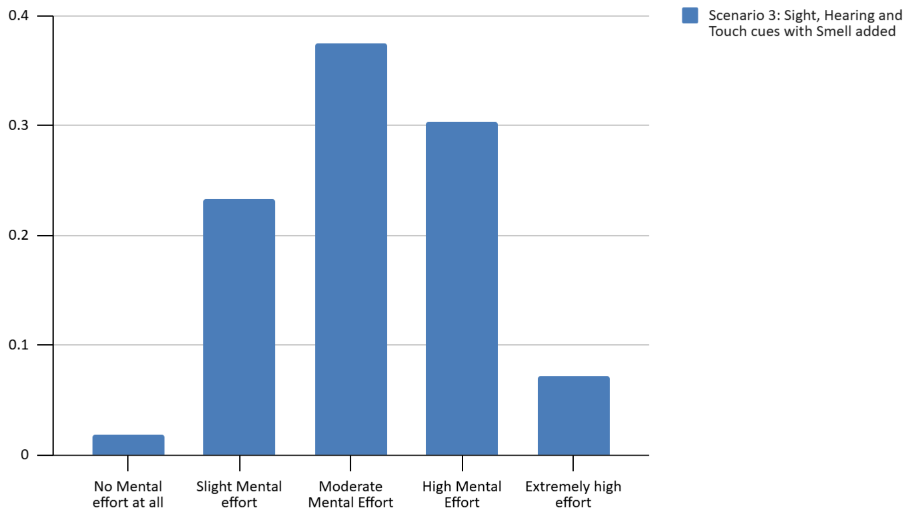

Figure 15: Perceived Mental Effort in Scenario 3: Sight, Hearing, and Touch Cues with Smell Added

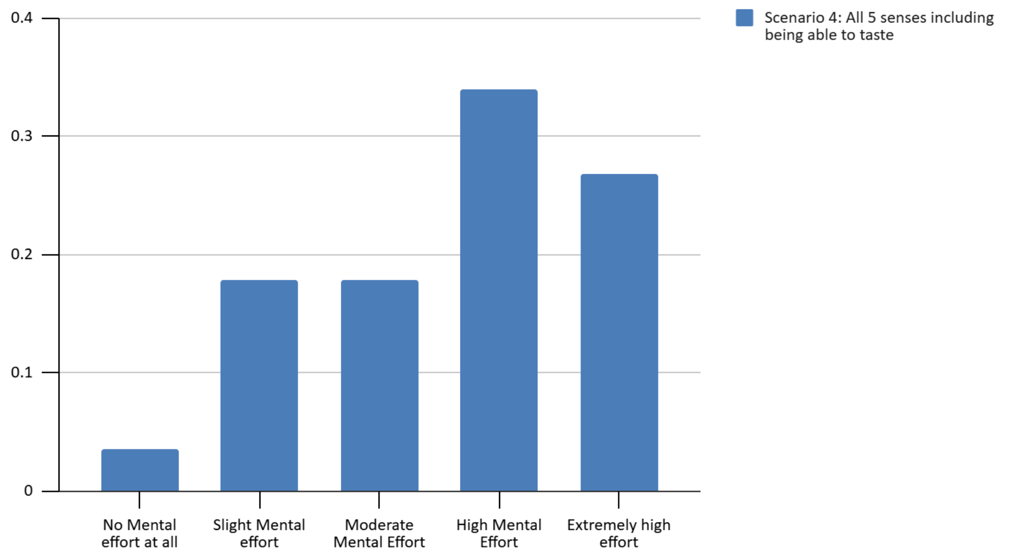

Figure 16: Perceived Mental Effort in Scenario 4: All Five Senses Including Taste

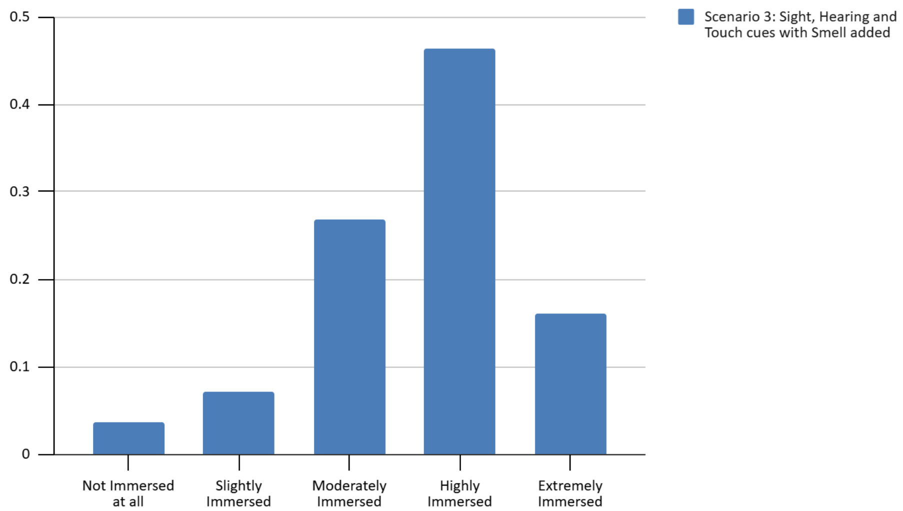

Figure 17: Perceived Immersion in Scenario 3

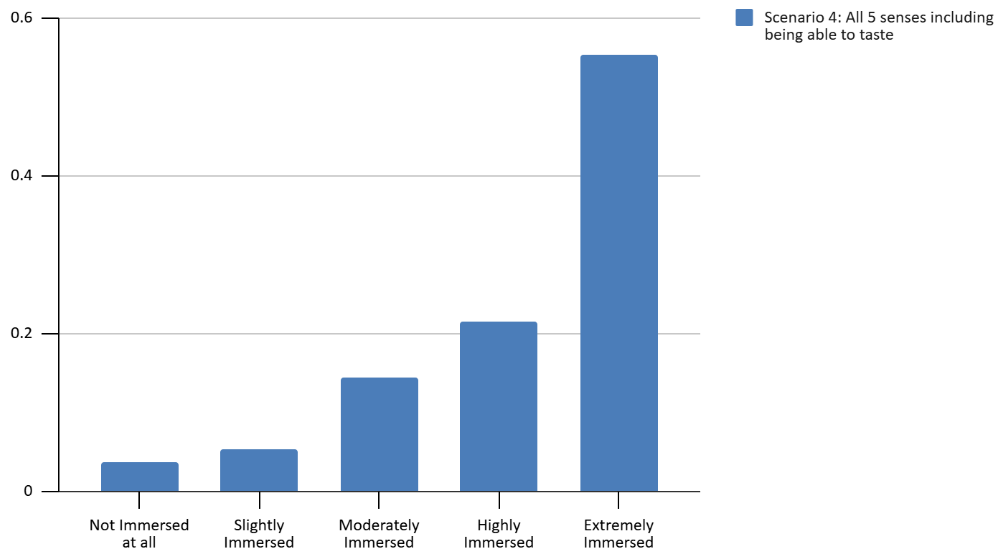

Figure 18: Perceived Immersion in Scenario 4

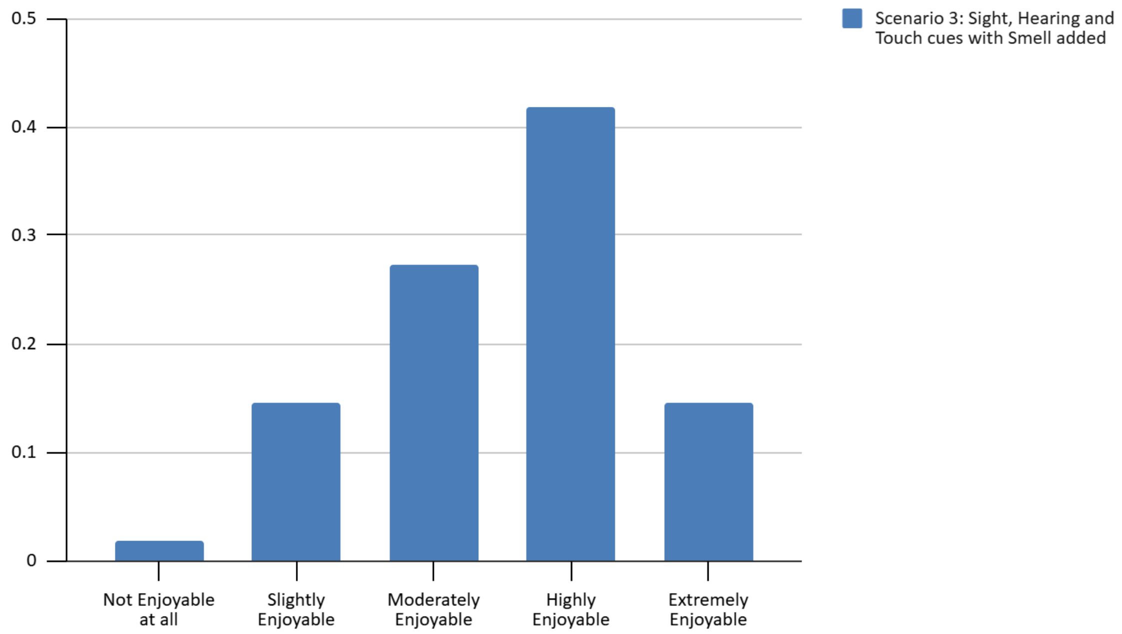

Figure 19: Perceived Enjoyment in Scenario 3

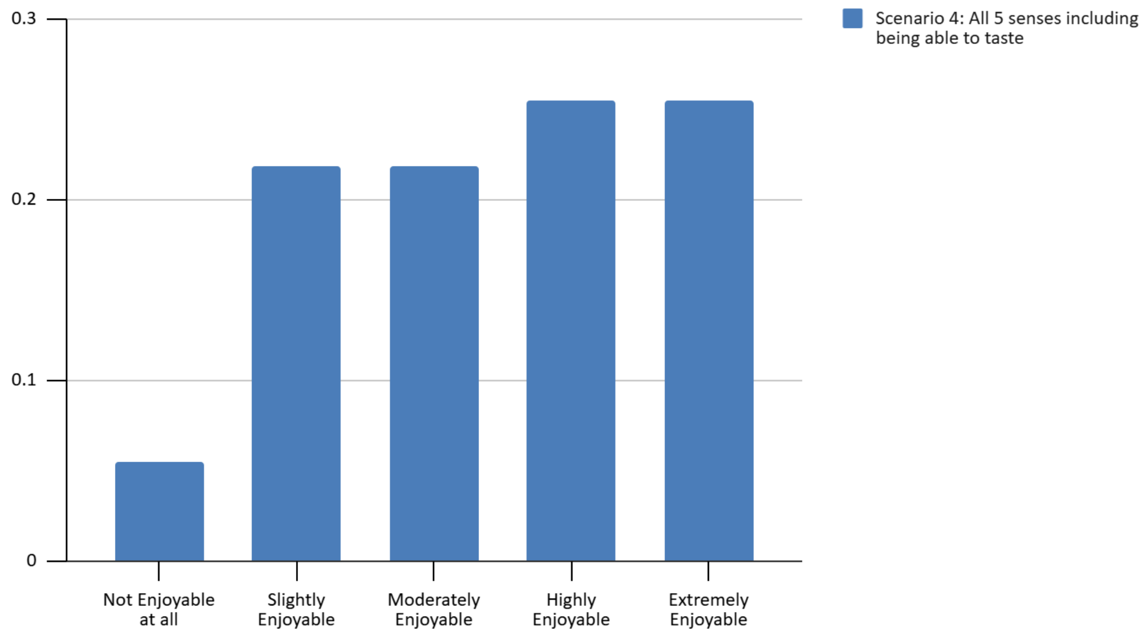

Figure 20: Perceived Enjoyment in Scenario 4

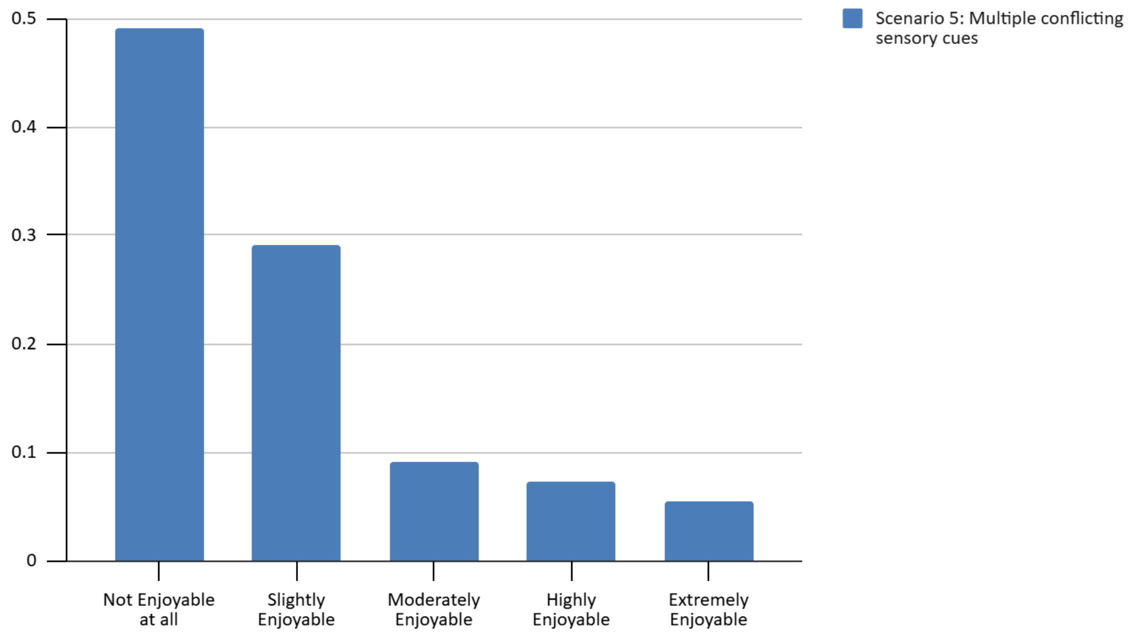

Figure 21: Perceived Enjoyment in Scenario 5

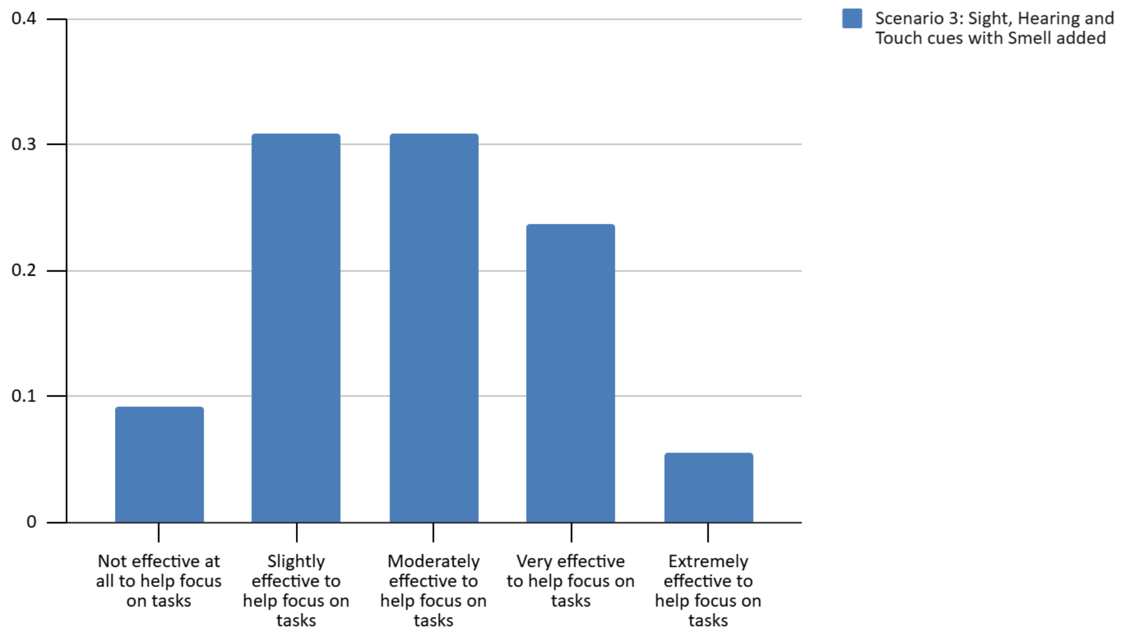

Figure 22: Perceived Effectiveness to focus on tasks in Scenario 3

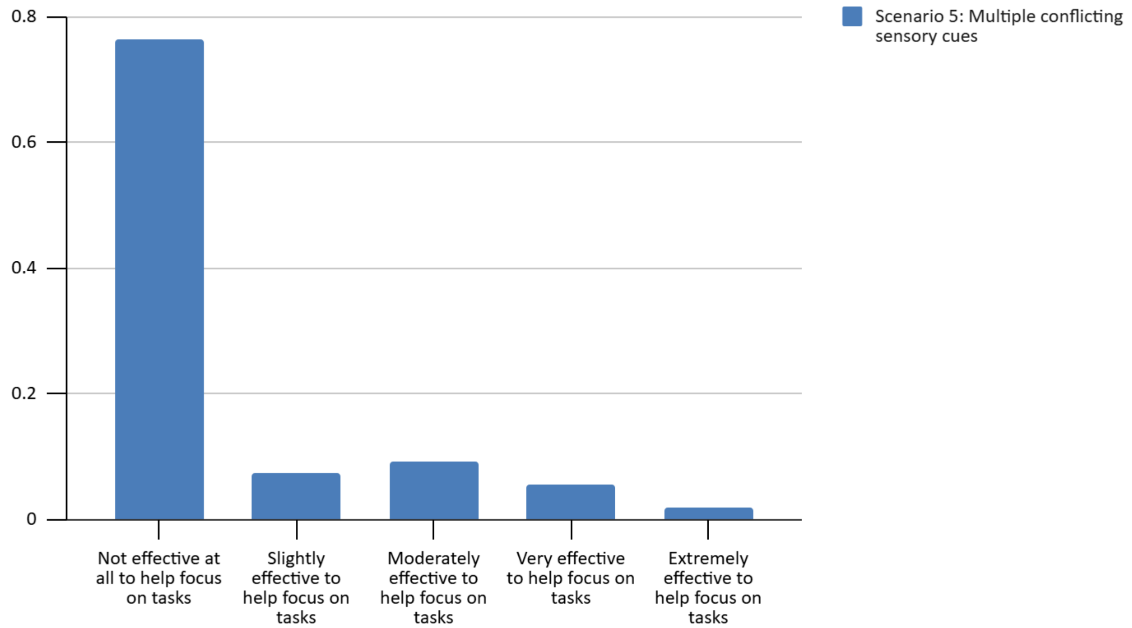

Figure 23: Perceived Effectiveness to focus on tasks in Scenario 5

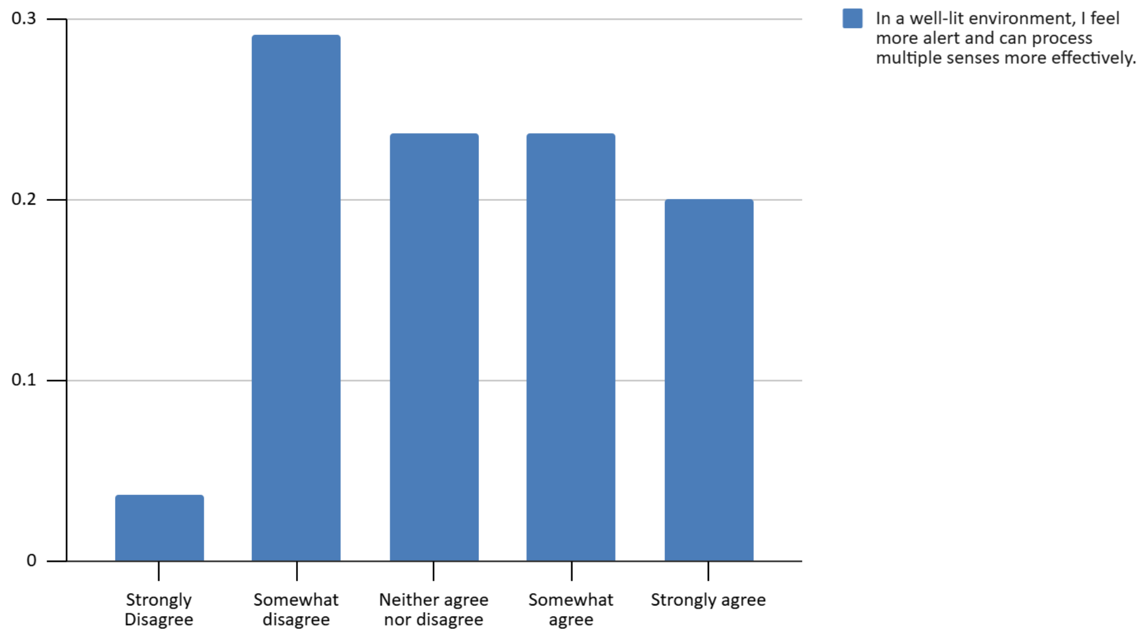

Figure 24: Survey Participant Agreement on the Effect of Well-Lit Environments on Alertness and Multisensory Processing

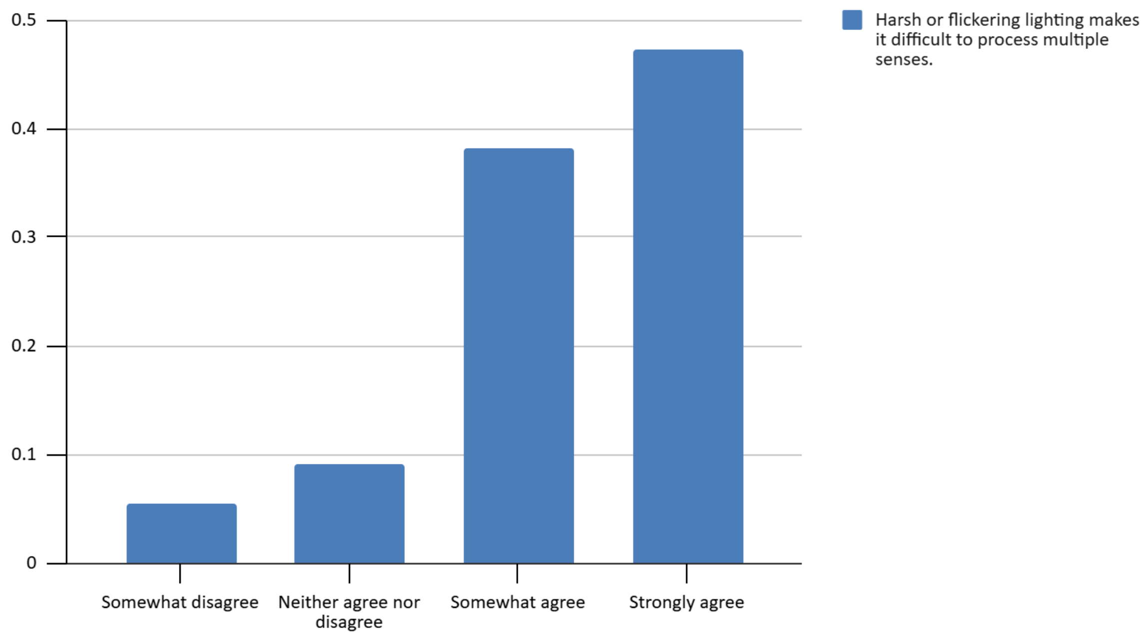

Figure 25: Perceived Difficulty Processing Sensory Cues Under Harsh or Flickering Lighting

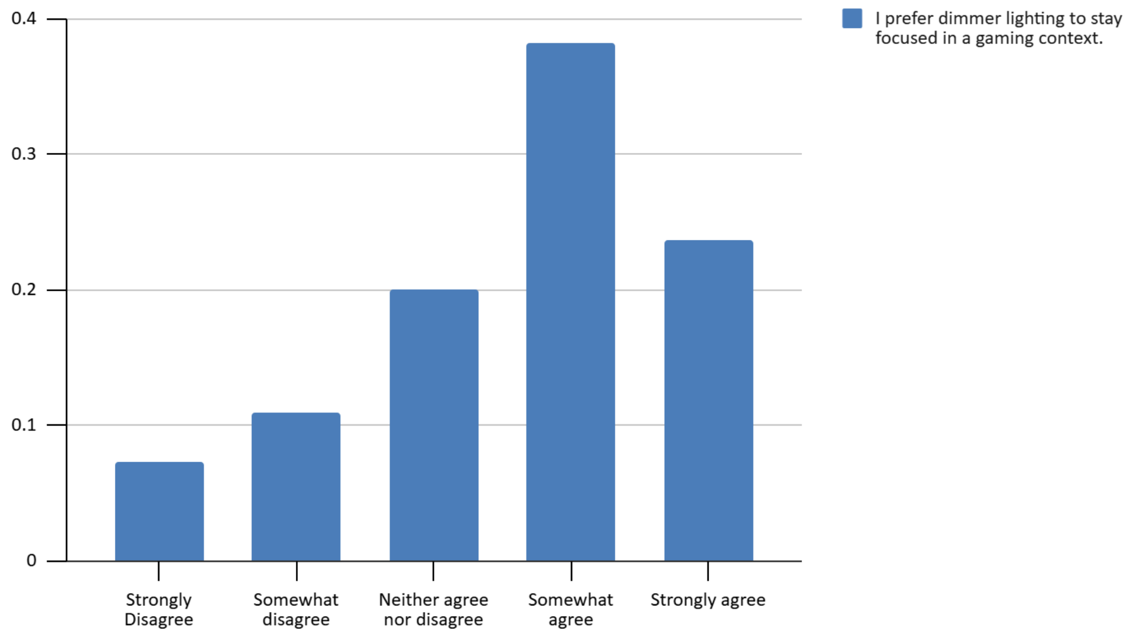

Figure 26: Survey Participant Preferences for Dim Lighting to Support Focus During Gameplay

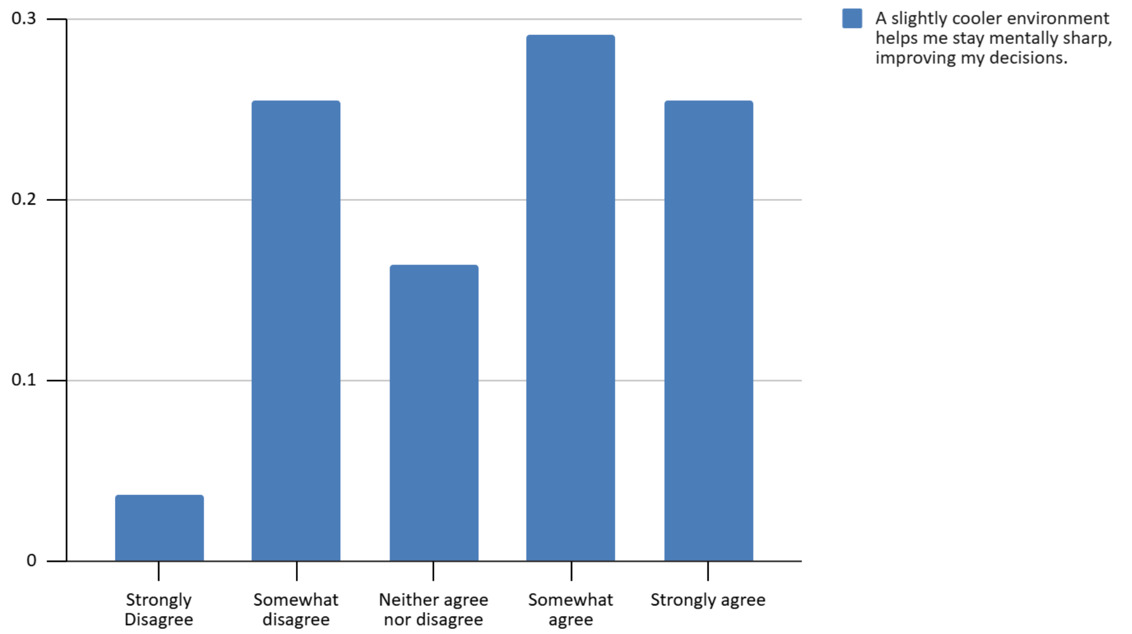

Figure 27: Perceived Cognitive Benefits of Cooler Environments During Gameplay

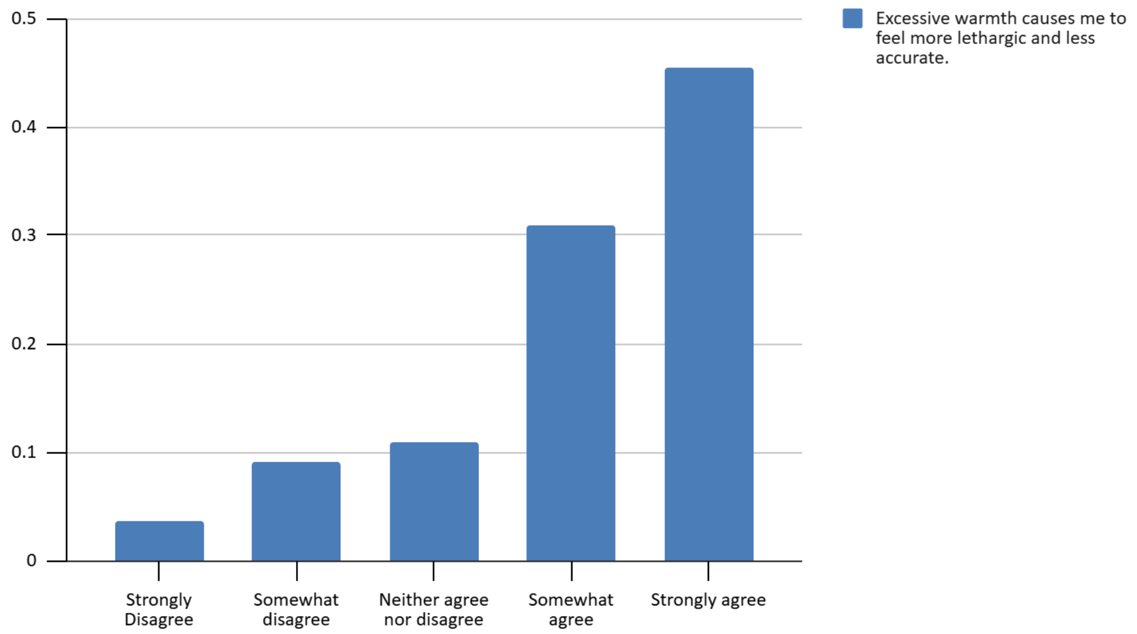

Figure 28: Impact of Excessive Warmth on Cognitive and Performance Efficiency During Gaming

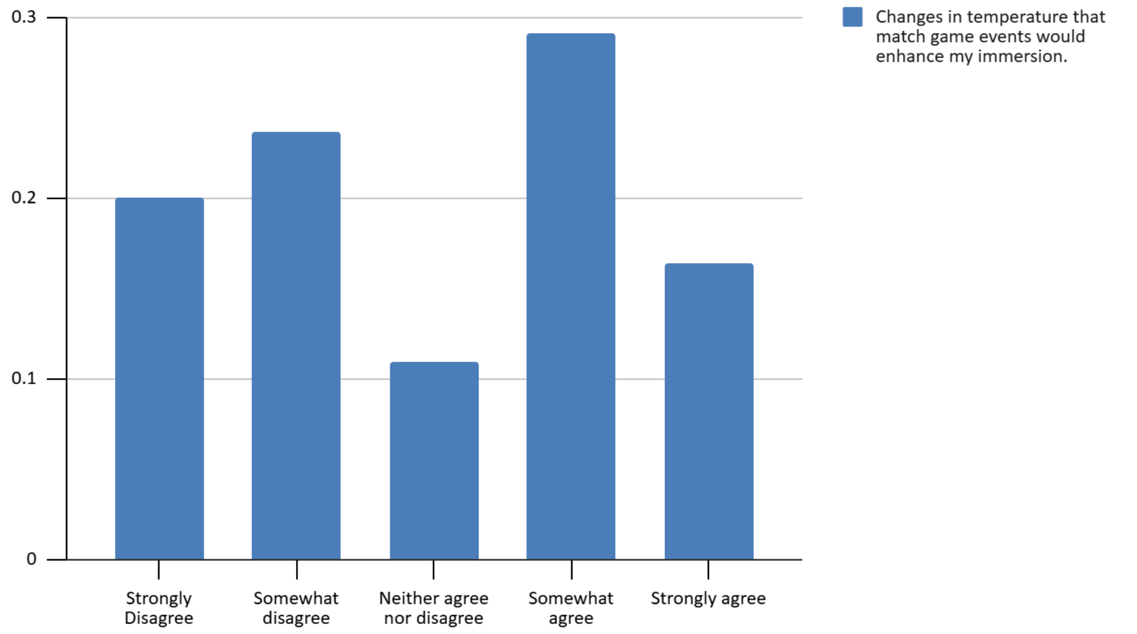

Figure 29a: Survey Participant Agreement on Temperature Changes Enhancing Game Immersion

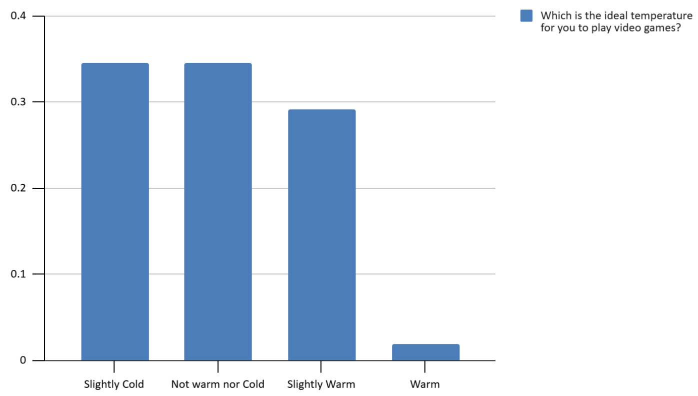

Figure 29b: Preferred Thermal Conditions for Optimal Gaming Experience

Existing experience and feelings about gaming

Friedman Tests by Survey Parameter

The FREQ Procedure

Summary Statistics for Scenario by Rank
Controlling for Subject

Cochran-Mantel-Haenszel Statistics (Based on Table Scores)				
Statistic	Alternative Hypothesis	DF	Value	Prob
1	Nonzero Correlation	1	94.9375	<.0001
2	Row Mean Scores Differ	4	107.6698	<.0001
3	General Association	32	236.0223	<.0001

Figure 30: Friedman Test Results for Mental Effort Across Scenarios

The FREQ Procedure

Summary Statistics for Scenario by Rank
Controlling for Subject

Cochran-Mantel-Haenszel Statistics (Based on Table Scores)				
Statistic	Alternative Hypothesis	DF	Value	Prob
1	Nonzero Correlation	1	43.5021	<.0001
2	Row Mean Scores Differ	4	77.5385	<.0001
3	General Association	32	173.1751	<.0001

Figure 31: Friedman Test Results for Enjoyment Across Scenarios

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	-5.23957	Pr > |t|	<.0001
Sign	M	-13.5	Pr >= |M|	<.0001
Signed Rank	S	-387.5	Pr >= |S|	<.0001

Figure 32: Wilcoxon Test Results Scenario 3 (adding touch and smell) vs Scenario 1

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	11.51491	Pr > |t|	<.0001
Sign	M	21.5	Pr >= |M|	<.0001
Signed Rank	S	531.5	Pr >= |S|	<.0001

Figure 33: Wilcoxon Test Results for Hypothesis 6: Scenario 3 vs. Scenario 5 Enjoyment

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	16.88464	Pr > |t|	<.0001
Sign	M	25	Pr >= |M|	<.0001
Signed Rank	S	637.5	Pr >= |S|	<.0001

Figure 34: Wilcoxon Test Results Scenario 5 vs. Scenario 3 Distraction

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	18.53956	Pr > |t|	<.0001
Sign	M	25.5	Pr >= |M|	<.0001
Signed Rank	S	709	Pr >= |S|	<.0001

Figure Figure 35: Wilcoxon Test Results Scenario 5 vs. Scenario 3 Overwhelm

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	13.97858	Pr > |t|	<.0001
Sign	M	22	Pr >= |M|	<.0001
Signed Rank	S	526.5	Pr >= |S|	<.0001

Figure 36: Wilcoxon Test Results for Scenario 5 vs. Scenario 4 Overwhelm

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	9.153962	Pr > |t|	<.0001
Sign	M	18.5	Pr >= |M|	<.0001
Signed Rank	S	386	Pr >= |S|	<.0001

Figure 37: Wilcoxon Test Results for Scenario 5 vs. Scenario 4 Distraction

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	8.291869	Pr > |t|	<.0001
Sign	M	19.5	Pr >= |M|	<.0001
Signed Rank	S	390.5	Pr >= |S|	<.0001

Figure 38: Wilcoxon Test Results for Scenario 5 vs. Scenario 3 Effectiveness to focus

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	11.40365	Pr > |t|	<.0001
Sign	M	23.5	Pr >= |M|	<.0001
Signed Rank	S	611.5	Pr >= |S|	<.0001

Figure 39: Wilcoxon Test Results for Scenario 5 vs. Scenario 4 Effectiveness to focus

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	11.51658	Pr > |t|	<.0001
Sign	M	19.5	Pr >= |M|	<.0001
Signed Rank	S	410.5	Pr >= |S|	<.0001

Figure 40: Wilcoxon Test Results for Scenario 4 vs. Scenario 5 Enjoyment

The FREQ Procedure

Summary Statistics for Scenario by Rank
Controlling for Subject

Cochran-Mantel-Haenszel Statistics (Based on Table Scores)				
Statistic	Alternative Hypothesis	DF	Value	Prob
1	Nonzero Correlation	1	8.2261	0.0041
2	Row Mean Scores Differ	4	67.9186	<.0001
3	General Association	32	187.7287	<.0001

Figure 41: Friedman Test Results for Immersion Across Scenarios

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	11.51491	Pr > |t|	<.0001
Sign	M	21.5	Pr >= |M|	<.0001
Signed Rank	S	531.5	Pr >= |S|	<.0001

Figure 42: Wilcoxon Test Results Scenario 3 vs. Scenario 5 Enjoyment

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	0.960161	Pr > |t|	0.3504
Sign	M	2	Pr >= |M|	0.4807
Signed Rank	S	20.5	Pr >= |S|	0.4151

Figure 43: Wilcoxon Test Results for Hypothesis 9: Scenario 3 vs. Scenario 4 Enjoyment

SCENARIOS AVERAGE RESPONSE 1 = LOW 5 = HIGH	MENTAL EFFORT	OVERWHELM	IMMERSION	ENJOYMENT	EFFECTIVENESS TO FOCUS	DISTRACTING
SCENARIO 1 Your typical game with traditional Sight and Hearing cues	2.803571429	1.553571429	2.767857143	3.6	3.836363636	1.454545455
SCENARIO 2 Scenario 2: Sight and Hearing cues with Touch added gloves	2.910714286	1.964285714	3.321428571	3.636363636	3.436363636	2.018181818
S2-S1	+0.1071428571	+0.4107142857	+0.5535714286	+0.03636363636)	-0.4	+0.5636363636
SCENARIO 3 Sight, Hearing and Touch cues with Smell added	3.178571429	2.589285714	3.642857143	3.527272727	2.854545455	2.727272727
S3-S2	+0.2678571429	+0.625	+0.3214285714	-0.1090909091	-0.5818181818	+0.7090909091
SCENARIO 4 All 5 senses including being able to taste	3.625	3.25	4.196428571	3.436363636	2.927272727	3.272727273
S4-S3	+0.4464285714	**+0.6607142857**	+0.5535714286	-0.09090909091	+0.07272727273	+0.5454545455
SCENARIO 5 Multiple conflicting sensory cues	4.607142857	4.410714286	2.785714286	1.909090909	2.927272727	4.454545455
S5-S4	**+0.9821428571**	**+1.160714286**	**-1.410714286**	**-1.527272727**	**-1.436363636**	**+1.181818182**
OBSERVATIONS	S3 less mental effort than S4 and far less than S5 +0.26 increase between S2 and S3 is minimal	Scenario 3's overwhelm score increased from previous scenarios, but remained well below the levels seen in Scenario 4 and 5	S3 highest immersion score except S4. S3>S5>S1 without significant increase in **distraction** or **loss of focus compared to S4**	S3 score only slightly lower than S2 and S1 S3 dramatically higher than S5	Scenario 3 had slightly reduced focus effectiveness compared to Scenario 2	Distractibility for S3 is lower than S4 dramatically lower than S5

Figure 44: Comparative Analysis of Participant Ratings Across Scenarios

Appendix 1: Interview Guide

Interview Guide Overview

Objective of the survey: uncovering other observations and qualitative insights to guide to the refinement of the designed survey and their scenarios.

The objectives are to identify factors or variables that were not yet considered in the literature review or survey, understand how participants view the subject and how they conceptualize gaming experiences and their feelings about sensory inputs in that context.

We want to analyze and discover if there are any sensory dimensions or contextual factors that might be missing in our research and how they might influence decision making and user experience.

The type of questions we decided to conduct are semi-structured interviews that will last approximately 30 to 45 minutes each. We want to interview 5 to 10 participants with different backgrounds in gaming, VR or any similar environment.

The data will be audio recorded with the participant consent. Participants can decide to stay anonymous. Notes will also be taken by the moderator.

Introduction

Little introduction speech for an overview of the research to the participants. It would be as follows:

Thank you for your participation in this interview. The answers to the interview will serve in a thesis context. The purpose of the thesis study is to understand how people perceive and use their senses in gaming environments. We'll talk about your experiences with different sensory cues such as visuals, sounds, tactile feedback, and even smells or tastes and how these might influence decision-making and immersion in those video games.

Your answers will be used to help us create and modify our survey and future scenarios to make sure that we cover all aspects that matter the most to users in our research to then ideally improve gaming experiences. There are no right or wrong answers please feel free to speak openly. Everything you share will remain confidential.

Appendix 2: Analysis (Thematic Summary) of the Interviews

Overall Gaming Habits and Experiences

- All participants identify as gamers, although their preferred platforms vary:
    - Primarily PC gamers using mouse and keyboard.
    - Some also use console controllers or mobile devices.

    - One participant focuses predominantly on mobile but has experience with other platforms.
- Gaming frequency ranges from daily play of several hours up to 20–25 hours per week.
- Genres mentioned include first-person shooters (FPS), MOBAs, sports games, strategy, puzzle, and more.
- No significant overlap in the specific games played, suggesting a broad diversity in preferences.
- Most participants prefer multiplayer experiences (for engagement and social interaction), though single-player modes are also enjoyed, especially for certain genres.
- Several participants stop playing games that feel too complex or overwhelming (ex. Elden Ring's controls, League of Legends' learning curve).
- Overload occurs from:
    - Too many mechanics introduced at once.
    - Excessive visual effects and information on-screen.
    - Need to remember complex control schemes or button combinations.
- Temperature is repeatedly stressed as critical to performance:
    - Participants mention feeling uncomfortable or unable to react quickly if the room is too hot or cold.
- Lighting preferences vary:
    - Some prefer dim lighting for an immersive experience.
    - Others adjust lighting based on time of day or to reduce eye strain.
    - Often, the gaming setup and the working environment are the same setup.

Opinions on Multisensory Integration

- General enthusiasm for expanding senses beyond sight and sound, with participants positive about touch feedback, temperature changes, or smells.
- Taste is met with **skepticism**:
    - Seen as more intrusive or difficult to implement without risking discomfort or disgust.

- Examples include temperature cues signaling danger, scent in an adventure or cooking game, or subtle airflow to simulate motion.
- What the interviewees had to say about improved performance:
    - Additional sensory cues (vibrations, sound cues) can aid faster decision-making, especially in fast-paced titles.
    - Spatial audio and tactile feedback help players identify threats or navigate environments more intuitively.
- Accessibility considerations
    - Multisensory options can cater to people with different abilities (example those who are visually or hearing impaired).
    - Participants see this as a significant benefit
- Cognitive load - overstimulation
    - Multiple participants worry about too many stimuli at once (sensory overload), which could cause discomfort or prompt them to abandon the game.
- Impact those new senses might have on players:
    - Concerns about dizziness, nausea, or confusion when senses are stimulated in ways the body is not used to.
    - Keeping the line clear between reality and fiction was another point of caution.
- Adaptability and types of plays/games:
    - While it might enhance immersion or fun, many felt that these features might not align with competitive esports or high-level ranked matches, where players often minimize distractions to focus on performance. Instead, players mentioned party games, fun games or more serious or narrative games without the competitive aspect.

Customization - enabling the added senses.

- Participants emphasize customizability, the ability to toggle features on or off to manage personal comfort and avoid overload.
- Some gamers feel frustrated by too many combined features if it complicates control schemes in other previous experiences.

- Gradual introduction of senses or additional stimuli is preferred over an immediate flood of new inputs.

Ambient and environmental factors

- Room temperature significantly affects player comfort and hand movements.
- Hoodies, blankets, or hand warmers are common solutions to maintain optimal performance when it's cold.
- Lighting can either help or hinder performance:
    - Dim lighting is often cited as immersive for shooters or atmospheric games.
    - Bright or inconsistent lighting can distract from the on-screen action.
- Many participants prefer the same setup for both work and gaming to ensure comfort and reliability

Potential applications

- Party or casual games are seen as the best initial fit for experimental sensory features:
    - Temperature, scents, or airflow can be fun and creative in these settings.
- Narrative-driven or adventure games could benefit from immersive sensory cues that enhance storytelling.
- Serious games and simulations (ex. training scenarios) may improve realism and engagement.
- Additional senses can bridge gaps for players with visual or hearing impairments through vibrational cues, colorblind modes, advanced 3D audio or temperature feedback to signal in-game events.
- Choice and customization remain critical to ensure these features address varied needs without overwhelming anyone.

Conclusion

- While participants show enthusiasm for multisensory integration, carefully modulate intensity and allow toggling to prevent overload

- Sight and hearing remain foundational. Touch and subtle temperature or airflow cues are a welcome addition if implemented thoughtfully.
- Participants are intrigued but cautious about taste and smell. These require careful design to avoid discomfort.
- Multisensory features are exciting and immersive for casual, narrative, or party games.
- High-level competitive scenarios may benefit more from clear audio-visual cues and less from additional stimuli.
- Expanded sensory options could enhance accessibility for a range of players.
- Developers should integrate these features to address specific needs (ex, hearing-impaired, colorblind)
- thoughtful, optional multisensory integration has the potential to enrich gaming experiences, aid in performance under certain conditions, and broaden accessibility.
- Overstimulation and practical concerns must be carefully addressed in future implementations.

Appendix 3: Notable Quantitative Observations of the Survey Responses

Comparisons of scenarios:

How important are visual cues (sight) to your gaming performance?

- **Extremely important 67%**
- **Very important 25%**

How important are auditory cues (hearing) to your gaming performance?

- **Extremely important 43%**
- **Very important 38%**
- **Moderately important 18%**

How important are tactile cues (touch) to your gaming performance?

- **Not at all Important 31%**
- **Slightly important 31%**

- **Moderately important 25%**

Do you have a specific setup when playing games (a dedicated gaming area, equipment setup)?

- **Yes 61%**
- **No 38%**

Do you adjust lighting (dimming or brightening the room) to improve your comfort or performance while playing games?

- **Yes 67%**
- **No 32%**

Do you adjust temperature (using fans, adjusting air conditioning or heating) to improve your comfort or performance while playing games?

- **Yes 57%**
- **No 40%**

Have you ever experienced senses in gaming beyond the typical visual and audio inputs

- **Yes 25%**
- **No 53%**

which scenario do you think your response time would be the fastest?

- **Your typical game with traditional Sight and Hearing cues 49%**
- **Sight and Hearing cues with Touch added gloves 34%**

At what point do you think the addition of sensory inputs would become too much and slow you down?

- **Multiple conflicting sensory cues 43%**
- **All 5 senses including being able to taste 26%**
- **Sight, Hearing and Touch cues with Smell added 20%**

With additional senses included in my games, my performance would be better.

- Somewhat Agree 34%
- Somewhat Disagree 28%
- Neither 20%

Beyond a certain number of new sensory cues, my speed and accuracy could start to decline.

- Somewhat Agree 51%
- Strongly Agree 28%

Mental Effort for each Scenarios

1) Scenario 1: Your typical game with traditional Sight and Hearing cues - 46% Moderate Mental Effort 32% slight mental effort
2) Scenario 2: Sight and Hearing cues with Touch added gloves - 55% Moderate Mental Effort
3) Scenario 3: Sight, Hearing and Touch cues with Smell added - 38% Mental Effort - 30% High Mental Effort
4) Scenario 4: All 5 senses including being able to taste - 34% high mental effort
5) Scenario 5: Multiple conflicting sensory cues - 70% extremely high effort

Overwhelmingness for each Scenarios

1) Scenario 1: Not overwhelming at all 59% - Slightly Overwhelming 32%
2) Scenario 2: Slightly Overwhelming 39% Not Overwhelming at all 36%
3) Scenario 3: Moderately Overwhelming 39% - Slightly Overwhelming 36%
4) Scenario 4: Moderately Overwhelming 34% - Highly Overwhelming 29% - Slightly Overwhelming 21%
5) Scenario 5: Extremely Overwhelming 55% - Highly Overwhelming 32%

Immersion for each Scenarios

1) Scenario 1: Moderately Immersed 39% - Slightly Immersed 30%
2) Scenario 2: Highly Immersed 39% - Moderately Immersed 39%
3) Scenario 3: Highly Immersed 46% - Moderately Immersed 27%
4) Scenario 4: Extremely Immersed 55% - Highly Immersed 21%

5) Scenario 5: Not Immersed at all 34% - Extremely Immersed 27%

Enjoyable for each Scenarios

1) Scenario 1: Highly Enjoyable 55% - Moderately Enjoyable 29%
2) Scenario 2: Highly Enjoyable 51% - Moderately Enjoyable 18%
3) Scenario 3: Highly Enjoyable 42% - Moderately Enjoyable 27%
4) Scenario 4: Extremely Enjoyable 25% - Highly Enjoyable 25% - Moderately Enjoyable 22% - Slightly Enjoyable 22%
5) Scenario 5: Not Enjoyable at all 49% - Slightly Enjoyable 29%

When a third sensory input was added to audio and visual cues, my overall performance in the game significantly improved.

1) Scenario 1: Somewhat agree 35% - Neither agree nor disagree 27% - Somewhat disagree 25%
2) Scenario 2: Highly Enjoyable 51% - Moderately Enjoyable 18%
3) Scenario 3: Highly Enjoyable 42% - Moderately Enjoyable 27%
4) Scenario 4: Extremely Enjoyable 25% - Highly Enjoyable 25% - Moderately Enjoyable 22% - Slightly Enjoyable 22%
5) Scenario 5: Not Enjoyable at all 49% - Slightly Enjoyable 29%

When a third sensory input was added to audio and visual cues, my overall performance in the game significantly improved.

Somewhat agree 35% - Neither agree nor disagree 27% - Somewhat disagree 25%

Using both tactile and smell cues at the same time felt more distracting than helpful.

Somewhat agree	33%
Neither agree nor disagree	31%
Somewhat disagree	16%

I noticed that my mental effort increased substantially when I added a third or fourth sense.

Somewhat agree	35%
Somewhat disagree	22%
Strongly agree	20%

Certain combinations of senses (sound and vibration - touch) were easier to process than others (sound and smell).

Strongly agree	**47%**
Somewhat agree	**36%**

Effectiveness to focus on tasks

Scenario 1	● Very effective to help focus on tasks 53% ● Extremely effective to help focus on tasks 20% ● Moderately effective to help focus on tasks 18%
Scenario 2	● Moderately effective to help focus on tasks 38% ● Very effective to help focus on tasks 31% ● Slightly effective to help focus on tasks 16% ● Extremely effective to help focus on tasks 15%

Scenario 3	● Slightly effective to help focus on tasks 31% ● Moderately effective to help focus on tasks 31% ● Very effective to help focus on tasks 24%
Scenario 4	● Not effective at all to help focus on tasks 22% ● Slightly effective to help focus on tasks 20% ● Moderately effective to help focus on tasks 22% ● Very effective to help focus on tasks 16% ● Extremely effective to help focus on tasks 20%
Scenario 5	● Not effective at all to help focus on tasks 76%

How distracting is the scenario

Scenario 1	● Not distracting at all 71%
Scenario 2	● Slightly distracting 47% ● Not distracting at all 29%
Scenario 3	● Slightly distracting 35% ● Moderately distracting 33% ● Very distracting 22%
Scenario 4	● Moderately distracting 31% ● Very distracting 25% ● Extremely distracting 18% ● Slightly distracting 16%
Scenario 5	● Extremely distracting 64%

Which sensory combination did you find most distracting or difficult to manage?

All 5 senses including taste 82%

Audio + Visual felt more natural than Audio + Touch.

Strongly agree 53%

Somewhat agree 29%

Visual + Touch improved my focus more than Audio + Touch

Somewhat agree 25%

Strongly agree 24%

Neither agree nor disagree 22%

Adding smell to Audio + Visual gave me a clearer sense of the environment.

Somewhat agree 42%

Strongly agree 18%

Somewhat disagree 22%

In a well-lit environment, I feel more alert and can process multiple senses more effectively.

Somewhat disagree 29%

Somewhat agree 24%

Strongly agree 20%

Harsh or flickering lighting makes it difficult to process multiple senses.

Strongly agree 47%

Somewhat agree 38%

I prefer dimmer lighting to stay focused in a gaming context.

Somewhat agree 38%

Strongly agree 24%

Neither agree nor disagree 20%

A slightly cooler environment helps me stay mentally sharp, improving my decisions.

Somewhat agree 29%

Strongly agree 25%

Somewhat disagree 25%

Excessive warmth causes me to feel more lethargic and less accurate.

Somewhat agree 31%

Strongly agree 45%

Which is the ideal temperature for you to play video games?

Slightly Cold 35%

Not warm nor Cold 35%

Slightly Warm 29%

Changes in temperature that match game events would enhance my immersion.

Somewhat agree 29%

Somewhat disagree 24%

Strongly Disagree 20%

Which platforms do you typically use to play games?

PC 79%

Console (ex. PlayStation, Xbox, Nintendo Switch) 7%

What gaming tools do you commonly use?

Mouse and Keyboard 71%

Game Controller 16%

Do you typically play single player or multiplayer games?

Mostly Singleplayer 34%

Mostly Multiplayer 25%

Multiplayer and Singleplayer equally 23%

Which senses have you previously encountered in your gaming experiences?

- Sight 86%

- Hearing 77%
- Touch 50%
- Smell 4%
- Taste 2%

Which senses do you find the most prominent or impactful in your gaming experiences?

- Sight 86%
- Hearing 70%
- Touch 18%

Appendix 4: Qualitative Open-Ended Answers Transcript of the Survey Responses

Do you have a specific setup when playing games

- PC setup
- Wired gaming mouse, no lag, low ping, gaming keyboard, good refresh rate screen
- A quiet room with my screen at an angle that avoids light glare
- When gaming, I use either a handheld (Switch, GBA, DS, PSP, phone) or on a gaming laptop that I can move the screen to where I want. Desktop gaming is "too far" away.
- PC, Roccat keyboard and mouse, Hyperx Cloudmix headset - Everything works together consistently. Consistency is very important to me.
- I have a pc in my bedroom on a clean desk! :)
- I've got a standing desk and two monitors stacked vertically
- gaming laptop
- I like to sit on my bed with my headset on, microphone down, for recording.
- I have my laptop on a stand tilted toward me with my second monitor to the left on a little wire platform. I use headphones and a wireless mouse. I always have my game on my laptop in front of me with notes/forums/discord/youtube on my second monitor.

- I have a keyboard tray with my mouse up on my desk, so my mouse is slightly higher than my keyboard- personally I would prefer an even mouse and keyboard but I would rather have room on my desk and to actually move my mouse!
- Standard setup. A PC on a desk with two monitors, a mic, a comfortable chair.
- My own desk with my pc
- pc, 3 monitors, left with whatever maybe video, middle game, right discord
- I have a dedicated gaming area with a corner desk and three monitors.
- PC
- room with table 3 monitors and pc / tv with retro consoles and ps5/xbox series
- My desk
- I perfer to have a 60 percent keyboard and a wireless mouse for my fps games because I don't like when the keyboard is too big and for the mouse I don't like when the cord is on the mouse because it feels like there is drag on the mouse

Do you adjust temperature (using fans, adjusting air conditioning or heating) to improve your comfort or performance while playing games?

- I like a bright room
- Dimming the room
- Usually soft ambience lighting and covered windows.
- Sometimes
- Brighten the room, to reduce (hopefully) eye strain.
- Depends on the amount and quality of natural light.
- I had seizures, so I use mainly LED backwall lights, and one ring light to help balance my green eyes against my two monitors. Light eyes are sensitive to light.
- I adjust brightness and colour depending on the game I play (ex. red and blue lighting when I play spiderman).
- Depending on the game! For ex. while playing a Horror, I'll dim the lights for better immersion!
- Depend on the game
- I relocated my setup in a room with less light exposure.
- improve brightness

- I typically play in a darker room with my lamp on above me (it sits on a little shelf to illuminate my desk)
- I prefer a darker room, I feel like I'm able to take in visuals better when the room is dark- even if there isn't much glare with the light on, having it off just makes the ambience better and I'm able to focus more
- I have led lights i dim and use diffrent colors to create vibes for gaming (red for horror, as example)
- I sometimes dim the lights, and if the sun is glaring at my chair I close the curtains
- Depends on the mood and how much I'm gaming
- Because i strain my eyes pretty often the light needs to be on. Else I get headachez and it just hurts
- Love low lighting / dim lighting. Less distraction and makes the screen appear brighter.
- dim light to make more enjoyable and easier on eyes
- Light can affect what I see on the montior.
- Play with lights on to not damage my eyes but thats it.
- Dimming light
- I like to have light on while I'm playing fps games but when I'm playing scary games I like the lights off to make the game better/

Have you ever experienced senses in gaming beyond the typical visual and audio inputs: Yes - Explanation is optional

- If we conssider intuition as a sixth sense
- Some tactile feedback from the controller occasionally
- haptic feedback via controller (specifically ps5 controllers)
- Vibration ?
- 'Game sense' is the only thing that would come to mind, although intuition might be more apt.
- I suppose so, I played with the omni one gaming station.
- Controller vibration
- that rumble

- emotional in certain games depending on story being told
- Only other is touch. Vibrations from controller
- Controller rumble/haptics counts right? There's also motion gameplay, like the Wii, rhythm games, Tony Hawk Ride game, etc

What concerns, if any, do you have about using additional sensory cues like smell or advanced temperature feedback?

- I think the addition of sensory cues like smell will not be necessary for the majority of games because we would need to ignore other senses in order to smell something unless it has a strong odour.
- If the smell and temperature are extremely realistic to like very cold weather or very hot weather or a very strong aroma
- I'm concerned about the amount of stimuli with so many senses, and those specifically being too extreme (bad smells or extreme temperatures).
- If another sense messes up it might break immersion or be very distracting.
- Neurodivergent players might find it extremely overwhelming, and in a realistic scenario, I do not trust companies to use safe chemicals or technology to accomplish this type of thing.
- "While adding temperatures may be VERY immersive, they'll also negatively affect me - cold temperatures make me shiver and my finger joints stiffer. It can be really hard to handle a controller or any sort of fast hand-eye coordination (such as any FPS) when my hands get too cold. I think players with arthritis, muscle sprains (playing as a distraction during healing) and other such would struggle with temperatures.
- Also, depending on the smell compounds used to make the smells happen - what if the player is allergic? How would you handle players going into a surprise anaphylactic shock?"
- If extra sensory cues were added, I think I would be most worried about overstimulation and just getting overwhelmed with multiple senses being triggered while in a game. It would have nice novelty for the first couple times playing, but I feel I would get distracted or annoyed with additional sensory cues.

- While I do want immersion with my games, I also don't want real life. I can do all of that in my own kitchen, or outside, etc. I'm concerned with how detached humans are these days as it is.
- Being "off", not representing the intended cue well (like highly artificial smells)
- Maybe it's too much, but cool to test
- Being distracted depending on the setup of the game.
- "I think most os the study focus on sensory stimulation doesn't account for the type of game we're playing.
- In a cooking game smell, warmth could be a game changer.
- In a more arcade / competitive shooter game the smell input wouldn't be as important. "
- Concerns about the bad senses : bad smell, high temperature, etc.
- So i will be distracted too much when the game is getting serious/difficult
- It might be too distracting... temperature would certainly be annoying. But everything else sounds fun!
- I would be worried about bad smells or bad tastes invading my senses and making it harder to focus on gameplay. Also, how realistic would the temperature change be? Because some games have very harsh climates like tops of mountains or inside volcanoes. And how would the temperature change happen? Would I have to be enclosed in a small box with my gaming setup?
- Smells often make me nauseus.
- How strong it is controlling it at a good normal standard.
- I personally can't move my hands and fingers really well when I'm cold, so I'd rather not play games in a colder room. The smell I don't mind, but I think the touch might be auite overwhelming.
- anything uncomfortable would negativly impact the experience
- Having the ability to control it / stop it at will / any moment thoughout gameplay. And of course the set up needed to get it to work. And probably also the cost of the equipement.
- Smell, taste and temperature can be easily unpleasant and could detract from the experience in a way that lingers more than sound or sight.

- Certain smells and temperatures would affect people mentally in different ways and might change the mood of the player or even make them not want to play. They could also potentially make it uncomfortable at certain points in gameplay. For example when congolala farts in monster Hunter wilds, it'd be gross to smell that lol. Also in order to simulate smells you'd need specific chemicals and they might be harmful to health. Likewise temperature adjustment would mean greater power consumption and so on.
- With smell it might add a dimension that I donâ€™t want to experience in some scenarios.
- Smell will add new level of mental strain causing major distraction and annoyance
- The intensity of smell and temperature. Obviously I wouldn't want to be burned alive if my character was set on fire.
- I don't have the best sense of smell, so could see it getting confusing. I'm also prone to migraines, and sometimes smells can be an issue if I'm already not feeling the greatest. I run hot, so I think temperature changes would not feel good for me in games.
- I feel like there are some people who are very sensitive to smell and they would not want to play games with bad smells.

Please describe any personal experiences with too many stimuli at once

- Can't think of one currently
- VR is over stimulating, being fully immersed for long periods of times is stressful and makes you feel seasick.
- I've had bad experiences with too many sounds, they remind me of people having a fight and yelling at each other.
- When I first started playing Overwatch, I was extremely confused and distressed. Because before playing that game, my experience was mainly with Valorant. The fast game play with also how these different alerts are dropped made it unable for me to process or adapt.
- If I can even hear people chewing, I start to get overwhelmed. I do not like certain sounds or tactile sensations. Overstimulation can be day-ruining.

- Whenever I get overstimulated in games, it is usually from hyper-realistic games or too much camera movement in games. I don't have an issue if the game is more cartoony like Marvel Rivals or Minecraft, but if it's more realistic and has excessive motion blur, I tend to feel sick or get a headache.
- I have photosensitive seizures, so some scents, sounds, patterns, lights can trigger those.
- I played a fair share of VR games and they do tend to be a bit overwhelming. (Doom VR and Serious Sam VR comes to mind). Once you go in setting and disable some of the HUD and lower some sounds it gets better but the first time i was a bit taken aback. I did experienced the same in Monster Hunter world as a first time player when it first came out. Heavy HUD (japanese game style), tons of thing to learn and pay attention to.
- "I easily feel overwhelmed by multiple input sounds, such as multiple people speaking over each other.
- Enven more difficult to focus in a stressing game environment (helldivers 2 and multiple teamates speaking at the same time) "
- Any combo of "attacks" to my senses can spike my anxiety and make my experience much less enjoyable. Such as being in a loud environment when it's really hot, or maybe someone nearby smells like body odor. Or maybe it's a really bright day and the sun is making me sweat so I feel all sticky and gross. I also get overwhelmed when there's lots of noise and things moving on my screen while playing games
- too much noises and touch just make me zone out
- "I actually have to turn off controller vibration and damage numbers when playing newer Monster Hunter titles because I find the visuals and controller vibration distracting
- I also donâ€™t appreciate things dangling off of my rear view mirror or little stickers on my windscreen while driving as I feel like they overwhelm me, I also prefer driving in silence rather than having the radio on, as I feel like that is too much stimulation."
- Most is apex, a lot of movement, controls, and sounds. The other sense not really.

- When I play rhythm games games (osu, fnf, etc.), more stimuli makes it harder and therefore more engaging for me. Other types of games don't really have this effect for me though so I would get overwhelmed.
- to many people talking, trying to focuse on a task with distressed people in the room
- Its similar to playing lazer tag. Although more physical in the sense that you're actively moving. All senses are activated. Smells in the area, feedback from the gun, visual effects. Although no particular taste.
- Working in an open office can be very annoying due to multiple people talking at the same time while I try to focus on my tasks.
- Real life and video games aren't the same. Likewise the experience would be different. In games multiple stimuli can be good for hard to do tasks when you need to focus on certain cues visual or auditory. You can turn off one , for example, the audio to focus on visual cues only and vice versa. So yeah it improves accessibility in my opinion. In real life it can be overwhelming or feel calm or lively depending upon the specific context. Different scenarios affect me (and others) differently and they're constantly changing with response to many variables.
- In 2016 I went to egx gaming was difficult with extra smells and I was also given a chance to try a smelling vr headset that allowed me to smell the odour in southpark and it was extremely off putting and hard to focus
- Can be confusing. Easy to miss
- Crowded venues. Travelling to a different country where the native language isn't my own but I know some of it. Sometimes games can get overwhelming with how much is going on visually, I find myself using audio clues more than I rely on visual ones.

How would you personally ‘draw the line’ between helpful vs. overwhelming sensory cues?

- If a game requires more than your sense of sight, touch and hearing, I believevthe task would need to be deligated
- Haptic feed back, anything more than that is distracting and overwhelming.
- I feel I would get overwhelmed with too much sensory cues introduced in the beginning but along the line maybe playing the game more or multiple games with the

same idea I would get used to it so Iâ€™d draw the line if too many sensory cues are involved in the beginning stages of a game.

- I guess its hard to explain, but things like touch and smells could be ok as long as they don't go too overboard.
- Depending on the type of game as well as mode of the game (causal or competitive), I believe helpful queues would be alerts and visual aid. But adding feeling and vibrations may get too stimulating. And for an FPS I would not want to be able to smell or feel any stimulation, but it would be different for a more calmer indie-game, or a game that would allow me to want to smell like cooking games.
- Sensory cues that aren't helpful in gameplay could potentially be overwhelming.
- I'd need to at least have a toggle menu for the additional stimuli, or I would be unlikely to play. ASMR-type things are certainly unacceptable, and it would need to be accessible for players with auditory processing issues. Too many sounds when there's a specific one I'm supposed to pay attention to would be stressful.
- If I can't keep track of a simple quest between the quest being given, getting the items, and bringing them back, there's too much going on. I should be able to mentally keep a fetch quest in mind, even when 'splorin or getting other lore content, without forgetting fully about it.
- A sensory cue would become overwhelming for me if it were a strong or jarring sensory cue. If multiple strong cues were combined, I would get overwhelmed with too much and feel less immersed in things such as loud sounds, strong smells, or fast movement.
- Too much realism. There needs to still be the line between real life and digital life.
- in terms of gaming, the addition of sensory cues can provide further immersion and overall enjoyment of the game depending on the scenario. For example, if a player was able to smell the food they were cooking in a game like 'Overcooked!', they would likely enjoy their experience more. I think the usage of sensory cues is highly context-dependent, however I would draw the line at using more than one sensory cue in addition to visual and sound cues.
- For me the line is the touch, sight hearing and touch is good. More is overwhelming

- Having played multiples games in a trditionnal setup and also in VR, i have to say that having a very heavy HUD, visual cues and uneven sound equalizing is very distracting, i experienced games with very little "on hand" presence from the developers and i do prefer when i can focus on music, ennemy sounds and have a clear view of my surroundings.
- I think that senses should be made from a gameplay perspective to add a depth and not as an innovation.
- "overwhelming : bad sensory cues, like bad smell, bad taste.
- helpful : good senses, that add immersion
- Depends also on the type of games : a slow game is a good field for more senses/immersion, an action game needs to be more focused on the action"
- i think temperatures are too much but smell, taste and touch are fine with me - also there are different kind of games, if I am playing some farming game I'd love a touch sense, if im playing cooking one I'd love smell and taste. Temperatures are okay-ish when Im playing cozy games for example.
- My biggest no would be anything that invades my sense of self. Like the gloves that make me feel things would be cool, but if it was a whole body suit that's just way too much. And smells would be cool for cooking games, but if it made me smell the rotting corpse of a zombie that would be an immediate no. And if I could choose to taste something I would be okay with that, but random tastes wouldn't be enjoyable to me. So in general as long as I have some sort of choice to experience something or not I will most likely have fun with it. Especially the ability to turn off or remove certain sensory inputs. When too many things happen at once it can really throw me for a loop.
- Personally I don't like vibration a lot, so that would make it overwhelming fast. Flickering make me feel nauseous ...
- I think more than 2-3 cues happening simultaneously, depending on the combination, is where it would start to get overwhelming.
- I think the only helpful ones are the ones I'm used to, while others would require mental faculties to adjust to.

- When too much thing is happening at once where you are lost best example is apex. But some people like hard games like that so itâ€™s more of what people you are targeting I think.
- I draw the line at touch, there are some things I would rather just look at instead of feeling them.
- when it goes from helping emersion to being uncomfortable. smelling grass in a field sounds nice, smelling wet stone or iron could add to an errie feeling, bit anything to unpleasant would be distracting
- More then 3 at once. Also it depends on which are "main" sensorh cues. If you have 2 mains ones and one complementary, then it wouldnt be so bad.
- Helpful cues are more subtle and easier to ignore when not required. Overwhelming cues demand attention and are harder to ignore.
- Playtest the games before launch. And adjust accordingly. But then again, most aren't used to new senses so a few risks need to be taken if we want to go in that direction. People might come to appreciate things over time. I'd probably limit smells and how far they could be accurate. I would add some stylization to them to make them more pleasurable and engaging. I probably won't add taste or temperature changing, atleast for the time being.
- Any extra sensory cue has to be subdue compared to visual and sound input. I would expect the visual and sound input to be enough to understand my surroundings.
- The line would be drawn at haptic vests and traditional items such as keyboard mouse and controller
- It depends on the game. For competitive fps, none of this would be helpful. In everything else it would be very cool. Letting user control the intensity of senses
- When I feel overwhelmed
- I feel like it's a pretty subjective thing. I think after a certain point, stuff can just get to be too weird, or too extra? I've done VR and it's interesting. Those theater seats that move, sometimes those are laughable. I haven't done any of the 4dx ones yet, none available in my area yet.

Appendix 5: Survey Scenarios

- Scenario 1: Your typical game - you are immersed in a game where your experience is guided by visual and audio cues. You observe the environment around you while also hearing key sounds such as footsteps, alerts or distant action. (Audio + Visual cues) 80
- Scenario 2: Now imagine you're wearing gloves that let you feel the objects and textures in the game. You can physically move your hands to interact: picking up weapons, tools or objects. The gloves provide vibrations when you take damage or touch different surfaces, adding a layer of physical feedback to the experience. (Audio + Visual + Touch cues)
- Scenario 3: Imagine you're now playing a game where you're preparing a meal. In addition to seeing and hearing the cooking sounds, you can also smell the aroma of the food you're making. For example you can smell the spices as you stir a pot of stew or the rich scent of grilled meat.
- Scenario 4: Now imagine you can taste what you've just prepared in the game. After completing your recipe, you experience the taste: sweet, savory, or spicy, just as you would in real life. This sensory feedback adds a new layer to your gaming experience.
- Scenario 5: In this scenario, you are receiving multiple sensory inputs: visual alerts on the screen, audio warnings (such as sirens or enemy footsteps), and continuous vibrations from your controller. However, these cues sometimes don't match, alerts may flash when there's no immediate danger, or vibrations occur with no visual signal, causing confusion.