(Page de garde)

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L'expérience de la stimulation haptique dans un contexte cinématique : l'effet des caractéristiques audiovisuelles et haptiques

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Résumé

Les technologies haptiques sont de plus en plus utilisées dans le divertissement multimédia pour améliorer et renforcer l'immersion des spectateurs de cinéma. Des études nous montrent que la technologie haptique telle que le siège vibrocinétique améliore l'expérience immersive de ces utilisateurs lors d'un visionnement d'un film. Cependant, un écart entre le type de film/environnement narratif et l'expérience immersive haptique reste inexploré. La technologie haptique est utilisée pour ajouter une composante tactile pour intensifier l'immersion, mais elle peut ne pas être nécessaire pour tout type de films ou champs narratifs dans un film. Certains extraits ne peuvent pas être représentés par cette technologie. De plus, se concentrer seul sur l'expérience visuelle et auditive peut transmettre le même sentiment de manière immersive. Un autre écart qui reste à être exploré est le mécanisme neurophysiologique par lequel les haptiques peuvent augmenter l'immersion et reste à être précisé. Ce mémoire vise à comprendre quel type d'extrait de film sont plus immersifs avec la technologie haptique. On cherche aussi à connaître l'effet de la technologie haptique sur l'activité cérébrale en association de l'immersion pendant le visionnement de différents extraits de film. Pour pouvoir répondre à ces objectifs, une étude expérimentale à été menée pour répondre à ces questions : *Existe-t-il un effet immersif ressenti par la technologie haute fidélité haptique dans un contexte cinématique sur l'immersion de l'utilisateur? Est-ce qu'il y a une différence dans l'effet immersif en fonction des caractéristiques audiovisuelles que le HFVK* (vibrocinétique de haute fidélité) *a été conçu à soutenir ?* Cette étude actuelle fait appel à des groupes intermédiaires utilisant l'électroencéphalographie (EEG) tout en employant la localisation des sources pour mieux identifier et localiser l'activité électrique dans le cerveau. De plus, l'étude a analysé les effets de la stimulation HFVK sur l'activité cérébrale corticale et l'immersion autodéclarée lors de la visualisation cinématographique. Trois regroupements d'activité cérébrale significatifs ont été identifiés comme présentant une activité corticale plus élevée que le groupe témoin lors de l'analyse des données EEG. Les résultats de l'étude suggèrent une relation partielle entre l'immersion et les régions cérébrales identifiées dans le mécanisme sous-jacent de l'effet de la HFVK sur l'immersion dans les expériences multimédias. Les résultats de l'analyse de l’immersion par catégorie d’extrait montrent que les extraits d’un film à haute intensité sont encore plus immersifs lors de la présence de la technologie haptique.

Mots clés : Haptique, vibrocinétique, EEG, cinématique, activité cérébrale, audiovisuelle, multimédia

Table des matières

Liste des tableaux et des figures 14

Liste des abréviation 15

Avant-propos 16

Remerciement 19

Chapitre 1: Introduction 21

1.2 Construits clés du mémoire 22

1.2.1 L'immersion dans le contexte cinématographique 22

1.2.2 L'amélioration de l'immersion cinématographique grâce à l'haptique 23

1.3 Question de recherche 23

1.4 Présentation sommaire du premier article 25

1.5 Présentation sommaire du deuxième article 25

1.6 Objectif et contribution 26

1.7 Contribution et reponsabilité individuelle 26

Chapitre 2: Haptic Technology, Cinematic Immersion, and Brain Activity: A Literature Review 32

1.0 Introduction 33

2.0 Methodology 35

3.0 Results 35

3.1 Immersion 36

3.2 Measuring Immersion 36

3.2.1 Subjective Immersion 37

3.2.2 Objective Immersion 38

3.3 Haptic Technology and Immersion 40

3.3.1 Audiovisual Immersion 41

3.3.2 Tactile Immersion with the Integration of Haptics 42

3.3.3 Vestibular and Somatosensory Immersion with Haptics 45

3.4 Movie-Related Antecedents of Immersion 46

3.4.1 Movie Characteristics: Action vs. Non-Action Scenes 47

3.4.2 Movie Characteristics: Music vs. Non-Music Scenes 48

3.4.3 Movie Characteristics: Riding vs. not Riding 50

3.4.4 Movie Characteristics: Low vs. High Scene Intensity 50

4.0 Consequence of Immersion: Temporal Distortion/Characteristics 51

5.0 Discussion 52

Chapitre 3: Deuxième Article: The Effect of High-Fidelity Vibrokinetic (HFVK) Stimulation by Movie Characteristics in a Cinematic Context 67

Abstract 67

1. Introduction 68

2.0 Movie Characteristics Categorization 70

2.1 Immersion 70

2.2 The Relationship between Movie Characteristics/Design and Immersion 71

3.0 Previous Movie Characteristics/Design Research 72
3.1 Action vs. Non-Action Scene Difference with Haptics 73
3.2 Riding vs. Not Riding Scene Difference with Haptics 75
3.3 Music vs. Non-Music Scenes Differences with Haptics 76
3.4 Low-Intensity vs. High-Intensity Scene Difference with Haptics 77
4.0 Haptic Touch to Immersion 78
5.0 Measuring Immersion in Relation to the Context of Cinematics and Haptics 79
5.1 Consequence of Haptic Enhanced Immersion 81
6.0 Hypothesis Development 83
7.0 Methods 84
7.1 Experimental Design 84
7.1.1 Participants 85
7.1.2 Procedure 85
7.1.3 Stimuli (Audiovisual and HFVK Stimuli) 86
7.2 Measures 87
7.2.1 Electroencephalography (EEG) 87
7.2.2 Measurement Scale 87
7.2.3 Movie Clip Categorization 88
8.0 EEG Analysis 90
8.1 EEG Recording and Pre-Processing 90
9.0 Statistical Analysis 92
9.1.1 Immersion Score 92
9.1.2 Immersion and Movie Characteristics 92
9.1.3 Cortical Activity Analysis 92
10.0 Results 93
10.1 Immersion 93
10.2 Immersion and Movie Characteristics 95
10.3 Cortical Activity Results 98
10.3.1 Cortical Activity Results: Theta 99
10.3.2 Cortical Activity Results: Beta 102
11.0 Discussion 108
12.0 Limitations of the Study 111
13.0 Conclusion 112
Chapitre 4: Chapitre de Conclusion 128
1.0 Rappel du contexte 128
2.0 Défis méthodologique du projet 129
3.0 Rappel des questions de recherche et résultats 129
4.0 Contribution du mémoire 130
5.0 Limites et recherche futurs 131
Appendix 1 **136**
Appendix 2 **137**

Liste des tableaux et des figures

Chapitre 1: Introduction

Tableau 1 : Contribution dans le projet de recherche et rédaction d’article 27

Table 1: Movie clip classification table of the fifteen clips from 8 movies shown to participants between the four movie categories. 89

Figure 1: EEG segments in between movie scenes. 91

Figure 2: Mean difference between control and HFVK groups. 93

Figure 3: Temporal characteristics mean per group. 94

Figure 4: Non-temporal characteristics mean per group. 95

Figure 5. Movie characteristics by immersion score per groups. 97

Figure 6: Beta cortical activity results 98

Figure 7: Theta cortical activity results 98

Figure 8: Theta cortical activity by action vs. non-action characteristics. 99

Figure 9: Theta cortical activity by low vs. high-intensity characteristic. 100

Figure 10: Theta cortical activity by riding vs. not riding characteristic. 101

Figure 11: Theta cortical activity by music vs. no music characteristics. 102

Figure 12:Beta activity for action vs. non-action for the left cluster (on the left) and for the right cluster (on the right). 103

Figure 13:Beta activity for the low-intensity vs. high-intensity scene characteristics for the left cluster (on the left) for the right cluster (on the right). 104

Figure 14:Beta activity for the riding vs. not riding scene characteristics for the left cluster (on the left) for the right cluster (on the right). 105

Figure 15: Beta activity for music vs. no music scene characteristics for the left cluster (on the left) for the right cluster (on the right). 106

Table 3: Summary of results. 107

Liste des abréviations

HFVK: High Fidelity Vibrokinetic

VK: Vibrokinetic

UX: User Expérience/ Expérience utilisateur

EEG: Électroencéphalographie/ Electroencéphalography

AV: Audiovisual

POV : Point of View

Avant-Propos

Ce mémoire en Expérience utilisateur en contexte d’affaires a été soumis avec l’autorisation de la direction administrative du programme de la Maîtrise ès Science en Gestion.

Le projet de recherche lié à ce mémoire a été approuvé par le comité d’éthique de la recherche (CER) de HEC Montréal. Deux articles issus du projet sont compris dans le mémoire avec le consentement des coauteurs.

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Chapitre 1 : Introduction

1.1 Mise en contexte de l'étude

La conception et la réalisation de films sont un art à multiples facettes qui combine des éléments visuels, auditifs, narratifs et technologiques pour créer des expériences cinématographiques captivantes (Agrawal et al., 2020; Rasheed & Shah, 2002). L'un des objectifs de la conception des films est de créer le sentiment d'immersion, c'est-à-dire la capacité de transporter le public dans l'univers du film, où il est un observateur, un participant dans le narratif du film où il devient émotionnellement investi dans le film (Douglas & Hargadon, 2000). L'immersion dans les films va au-delà du simple divertissement; elle favorise une connexion profonde entre le public et le récit, les personnages et les émotions représentés à l'écran. Pour atteindre ce niveau d'immersion, il faut une compréhension et une synchronisation parfaite de divers éléments de conception (Salselas et al., 2019; Salselas et al., 2021). Parmi ceux-ci, l'esthétique visuelle, les paysages sonores, la structure narrative et les innovations technologiques jouent un rôle essentiel. Dans cette exploration, nous nous penchons sur la relation complexe entre la conception d'un film et l'immersion dans un contexte cinématique, en soulignant comment chaque élément contribue à créer des expériences cinématographiques captivantes et mémorables.

D'après un sondage effectué en 2021 sur le temps consacré au visionnement, des films et des films au Québec montrent qu'en moyenne une personne passe 28 heures par semaine à regarder des films et des émissions de télévision (Fortier, 2021). Les entreprises travaillent continuellement à améliorer l'expérience de visionnement de films, dans le but de proposer au public des avancées uniques et des innovations (Eid & Osman, 2016; Gibbs et al., 2022). Avec des spectateurs qui sont maintenant devenus plus sophistiqués et technologiquement plus compétents, ils s'attendent à une narration plus innovante qui dépasse les attentes cinématographiques traditionnelles (Giggs et al., 2022). Ceci permet au cinéaste de repenser, répondre et capter l'attention des spectateurs aux nouvelles attentes.

Une des technologies récemment en hausse concernant l'amélioration de l'expérience utilisateur est la technologie haptique. L'haptique n'est pas une technologie très connue, mais elle est de plus en plus utilisée pour augmenter les expériences immersives des utilisateurs dans différents contextes tels que les films, les jeux vidéo et les parcs d'attractions (Boasen et al., 2020). Il est important de comprendre comment l'utilisation de la stimulation haptique avec la stimulation audiovisuelle permet d'améliorer le sentiment d'immersion de l'utilisateur. Des études relatives au retour haptique ont suggéré que la présence d'une stimulation haptique peut induire un plus grand sentiment de présence par rapport à l'audiovisuel seul (Eid & Osman, 2016; Giroux et al., 2019). Le retour haptique c'est ce qui fournit l'utilisateur avec des sensations physiques ou des vibrations qui simulent le toucher ou des textures en fonction de la sensation qui doit être stimulée en conservant la sensation et la texture appropriées (Eldeeb et al., 2020). Ceci aide l'utilisateur à avoir une expérience avec les sensations de manière plus réaliste qui rend l'expérience plus immersive (Gibbs et al., 2022). L'expérience subjective dépend de l'intensité et de la fluctuation de la sensation haptique et des stimuli visuels qui fonctionnent de manière synchrone pour être perçus de manière holistique. Si la stimulation haptique n'était pas synchronisée avec les autres indices audiovisuels, la sensation subjective de réalisme se dégraderait (Douglas & Hargadon, 2000; Hammond et al., 2023).

Les progrès technologiques ont considérablement élargi les possibilités d'immersion (Danieau et al., 2014). Des techniques telles que le cinéma en 3D, la réalité virtuelle (VR) et la réalité augmentée (AR) ont repoussé les limites de l'expérience cinématographique. La technologie haptique à haute fidélité, en particulier, immerse les spectateurs dans l'environnement du film, leur permettant d'interagir et d'explorer la narration (Eid & Osman, 2015; Danieau et al., 2014). Ces innovations permettent aux cinéastes de se rapprocher de la frontière entre la réalité et la fiction, permettant au public de s'engager dans l'histoire à un niveau plus personnel et sensoriel.

1.2 Construits clés de mémoire

1.2.1 L'immersion dans le contexte cinématographique

Dans le contexte cinématique, l'immersion est la capacité de pouvoir engager les spectateurs dans l'univers du récit narratif pleinement de manière que les l'audience ressentent une profonde connexion cognitive ainsi qu'émotionnellement avec les personnages, les aventures, et l'environnement au cinéma (Alsuradi & Eid, 2021). En outre, l'immersion est une expérience qui dépasse le simple phénomène de l'observation passive (Agrawal et al., 2020). Elle met le public dans une expérience où ils peuvent s'identifier avec les protagonistes, ressent les émotions ainsi que les enjeux dans le récit narratif. Dans le but d'atteindre un niveau d'immersion plus élevé, les films font l'utilisation de stimulations visuelles, auditives, narratives et technologiques (Eid & Osman,2016; Agrawal et al., 2020). Des éléments tels que la cinématographie immersive, les effets sonores évocateurs, les récits bien construits, les performances d'acteurs convaincantes et, dans certaines situations, des technologies comme la réalité virtuelle ou le son ambiophonique, contribuent à créer une expérience cinématographique où les spectateurs se sentent véritablement partie prenante de l'histoire (Giroux et al., 2019).

1.2.2 L'amélioration de l'immersion cinématographique grâce à l'haptique

L'utilisation de la technologie haptique dans le contexte cinématique donne l'opportunité d'augmenter le caractère immersif des expériences audiovisuelles en ajoutant deux nouvelles dimensions sensorielles: le sens du toucher (somatosensoriel) et le sens du mouvement (vestibulaire) (Eid & Osman, 2016; Eldeeb et al., 2020). Ce domaine n'a pas été bien exploré jusqu'à présent, mais il pourrait jouer un rôle essentiel dans l'expérience immersive pour plonger les spectateurs dans les émotions et les actions du film. L'intégration de cette technologie crée une expérience sensorielle complète dans l'expérience de son utilisateur (Venkatesan & Wang, 2023). Elle donne la chance à son spectateur de vivre l' événement de manière physique et ceci provoque une réponse émotionnelle et un sentiment d'immersion plus profond dans ces utilisateurs. Ces technologies sont observées dans l'utilisation des fauteuils vibrants, les gilets haptiques et d'autres dispositifs utilisés pour générer des sensations (Giroux et al., 2019; Lemmens et al., 2009). Ces dispositifs sont ensuite programmés pour répondre aux éléments comme les effets sonores, musicaux et les effets spéciaux/mouvement de caméra pour créer l'effet de l'immersion (Yilmaz et al., 2023). Il faut aussi s'assurer que l'utilisation de cette technologie est bien équilibrée, car trop de sensation pourrait aussi rendre l'expérience cinématique distrayante et perturber l'expérience immersive du spectateur.

1.3 Questions de recherche

On souhaite déterminer si l'emploi des stimulations haotiques présentant des caractéristiques de film/design variées dans un contexte cinématographiques de flims/design variées dans un contexte cinématographique peut accroître l'immersion lors de stimuli audiovisuels. Cette question sera répondue par l'utilisation des stimuli haptiques qui seront synchronisés avec des extraits de film en les comparant avec des utilisateurs qui n'auraient jamais eu d'expérience avec les stimuli haptiques.

Le premier article est une revue de littérature qui porte sur l'effet de l'immersion en lien avec la stimulation haptique. L'article permettra de définir les lacunes dans la recherche sur l'immersion dans un contexte cinématographique en lien avec les caractéristiques de film et design, ainsi que l'activité cérébrale qu'on utilise pour adresser ces problèmes. De plus, elle couvre les concepts clés et explique les liens entre les concepts importants.

Le deuxième article porte sur l'effet de la stimulation haptique pour affecter l'immersion perçue des utilisateurs, dans l'objectif de mieux comprendre comment l'haptique améliore l'immersion à la fois d'un point de vue cognitif et en fonction des caractéristiques audiovisuelles pour lesquelles l'haptique est conçue pour apporter un soutien. Dans ce mémoire, nous mesurons l'activité cérébrale du cerveau lors de l'utilisation de la stimulation haptique par un siège vibrocinétique pendant une expérience cinématographique. De plus, on cherche à comprendre l'expérience immersive par caractéristique de film perçue par l'audience en utilisant un questionnaire psychométrique. Ceci nous permettra de comprendre si la simulation haptique pendant le visionnement des films peut avoir un effet sur le type d'extrait ou le genre de film utilisé lors d'une expérience immersive. Elle permettra de mieux comprendre l'expérience immersive entre un groupe contrôle et expérimentale (haptique) afin d'identifier les régions du cerveau affectées. De plus cet article permet aussi de répondre aux questions de recherche suivantes :

QR1*:Dans quelle mesure la technologie haptique haute fidélité dans un contexte cinématographique a-t-elle un effet sur l'immersion ?*

QR2*: Dans quelle mesure le phénomène de l'immersion a-t-il un effet en fontions des caractéristiques audiovisuelles en cinématique pour lesquelles le HFVK a été conçu ?*

1.4 Présentation sommaire du premier article

Cette littérature explore l'intersection de l'immersion cinématographique et de la technologie haptique, dans le but de comprendre les réponses neurologiques et comportementales des utilisateurs. L'industrie cinématographique cherche à développer des technologies innovantes pour améliorer l'expérience des utilisateurs. La technologie haptique utilise des actuateurs pour simuler des mouvements et des vibrations, ceci est une avenue prometteuse dans la contribution de l’expérience immersive. Cependant, l'impact de cette technologie repose principalement sur des données subjectives, car il manque de la recherche sur la perception et le phénomène d'immersion de manière objective. Cette revue de littérature définit l'immersion, explore les méthodes de mesure, identifie les antécédents et les conséquences, et examine la relation entre la technologie haptique et l'immersion. Deux questions de recherche guident ce chapitre en se concentrant sur l'impact général de la technologie vibrocinétique haute fidélité (HFVK) sur l'immersion et les variations basées sur les caractéristiques audiovisuelles. Les résultats de la revue de littérature montrent qu'une relation significative existe entre la technologie haptique et l'immersion, en améliorant principalement les stimuli audiovisuels. Ainsi, ce chapitre contribue à une compréhension plus approfondie de l'expérience utilisateur et oriente les futures recherches empiriques dans le contexte cinématographique.

1.5 Présentation sommaire du deuxième article

Les technologies haptiques sont de plus en plus utilisées dans le divertissement multimédia pour améliorer et augmenter l'immersion des cinéphiles. Il existe des études sur les effets neuropsychologiques des haptiques lors du divertissement audiovisuel (AV).Cependant, le mécanisme neurophysiologique par lequel les haptiques peuvent accroître l'immersion reste à clarifier. De plus, il reste à préciser comment la technologie vibrocinétique haute fidélité (HFVK) a un effet sur différentes catégories de films/caractéristiques audiovisuelles telles que : action vs non-action, chevaucher vs. sans chevaucher, intensité faible vs élevée et scènes de musique ou sans musique. L'objectif de cette étude était d'investiguer s'il existe un effet général de la technologie haptique haute fidélité dans un contexte cinématographique sur l'immersion ? et s'il existe une différence dans l'effet immersif en fonction des caractéristiques audiovisuelles que la HFVK a été conçue pour soutenir ? Nous avons formulé l'hypothèse que les personnes du groupe HFVK auront un haut niveau d'immersion ainsi qu'une haute activité corticale dans les régions associées au traitement tactile et à l'attention. Nous avons invité quinze participants à regarder 15 extraits de film en les assignant au hasard, soit au groupe HFVK, soit au groupe témoin.

1.6 Objectifs et contributions

La contribution principale de la revue littérature présentée est la reconnaissance que l'immersion dans le contexte cinématographique va au-delà de la simple observation passive. De plus, la littérature met en évidence que pour atteindre un niveau d'immersion plus élevé, il est nécessaire d'explorer la relation complexe entre l'immersion cinématographique et les diverses caractéristiques cinématographiques, en mettant l'accent sur le rôle de la technologie haptique. Le deuxième article souligne l'impact de la technologie haptique sur l'amélioration des expériences cinématographiques ainsi que le potentiel immersif de la technologie haptique en relation avec les scènes avec de la musique vs. sans musique, action vs. non-action, scène avec chevauchement vs. sans chevauchement et faible intensité vs. forte intensité. La recherche haptique permet d'intégrer une dimension tactile à l'expérience cinématographique et contribue à enrichir l'expérience sensorielle globalement. La technologie haptique peut susciter des réponses émotionnelles, d'engagement et d'immersion plus fortes, favorisant ainsi une connexion plus profonde avec les contenus de films. La recherche en haptique dans le cinéma encourage le développement de nouvelles technologies et techniques pour créer des expériences cinématographiques plus immersives et innovatrices.

1.7 Contribution et responsabilité individuelles

La contribution et les responsabilités personnelles liées à ce projet de recherche et à la mémoire sont définies dans le tableau suivant (voir Tableau 1). Cette table décrit chacune des étapes de ce projet de mémoire. Les tâches présentées décrivent la contribution que l'auteur à effectuer lors de ce mémoire.

Tableau 1 : *Table de contribution dans le projet de recherche et rédaction d'article*

Revue de littérature	Identifier des points de recherche inexploré qui sont pertinent à l'activation corticale dans le contexte cinétique et d'immersion et aussi d'un siège - 100%
Conception du design expérimental	Compléter le formulaire de demande au CER (F8) – 100% ● Un membre de l'équipe du Tech3Lab s'est assuré que les formulaires étaient adéquats. Le protocole d'expérimentation à été élaboré et rédigé. Modifier le scripts Python afin de pouvoir présenter et permettre l'automatisation de la présentation du stimulus - 0% Organiser et préparer la salle de collecte de données – 50% ● L'équipe de recherche a contribué à l'organisation de la salle i.e l'installation de la chaise, rideaux, ordinateur, caméra et de l'équipement EEG) ● L'auteur de ce mémoire s'est occupé de différente étape lors de l'organisation de la salle.
Recrutement des participants	Élaborer et rédiger le questionnaire de pré-sélection pour le recrutement – 60% ● Recruter les participants et planifier leurs créneaux

	● Une assistante de recherche avait la charge de faire des échanges par courriel et appels pour confirmer la présence des participants
Prétest et collecte de données	Prendre en charge des opérations lors des collectes de données – 33% ● Un(e) assistant(e) de recherche était présent et contribuait à la collecte de données i.e installation des outils neurophysiologiques, lecture du verbatim, enregistrement des outils, administration du questionnaire) ● L'auteur de ce mémoire a été présent pour toutes les collectes de données pour la deuxième phase de l'étude. La première phase a été collectée par un autre étudiant en 2021. ● L'auteur de ce mémoire à principalement à la pose des outils (ex :la pose du casque EEG) l'explication des questionnaires et la présentation du stimulus.
Extraction et transformation des données	Extraire et mettre en forme des données neurophysiologiques (EEG) - 100% ● Pré-traitement des données EEG sur Matlab et Brainstorm
Analyses des données	Préparer les données EEG et les données qualitatif du questionnaire Réaliser les analyses statistiques du mémoire - 80% ● Interprétation des résultats à l'aide du logiciel statistique SPSS.

	● Avec l'aide d'un chercheur postdoctorant on fait l'utilisation du test statistique approprié sur le logiciel statistique SPSS (IBM). ● SPM12 à été utilisé pour l'analyse de l'activité corticale cérébrale
Rédaction des articles	Rédaction de la revue littérature et de l'article présenter dans ce mémoire - 100% ● La revue littérature et l'article ont été peaufiné à l'aide de commentaire ainsi que de suggestion à l'aide des superviseurs de recherche.

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Chapitre 2: Literature Review

Haptic Technology, Cinematic Immersion, and Brain Activity: A Literature Review[1]

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Abstract

This literature explores the intersection of cinematic immersion and haptic technology, aiming to understand the neurological and behavioural responses of users. The film industry seeks to make innovative technologies to enhance the viewer's experience. Haptics is a technology that makes use of actuators to simulate motions and vibrations and has shown to be a promising avenue in the contribution of immersion. However, the impact of this technology relies majoritarily on subjective evidence as it lacks to show how the audiences experience the phenomenon of immersion objectively. This literature review defines immersion, explores measurement methods, identifies antecedents and consequences and looks at the relationship between haptics and immersion. Two research questions guide this chapter while keeping the focus on the impact of high-fidelity vibrokinetic (HFVK) on immersion and variations that are based on audio-visual characteristics. The results of the literature review show that a significant relationship exists between haptic technology and immersion in enhancing mainly audiovisual stimuli. Thus, this chapter contributes to a deeper understanding of user experience and future empirical research in the cinematic context.

Keywords: Cinematic immersion, haptic technology, subjective, objective, audiovisual characteristic

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[1] This article is in preparation for submission to the Journal of Frontiers Neuroergonomics.

1.0 Introduction

In the past few decades, cognitive sciences and neuroscience research have delved into the intricacies of cinematic immersion (Levin & Baker, 2017; Visch et al., 2009). This realm of research studies how viewers process, perceive, and understand films by examining key constructs such as attention, memory, emotion, immersion, or comprehension. With a staggering 84% of the Canadian population engaging in regular movie consumption, filmmakers and companies have been challenged to create an elevating viewing and engaging experience for their audience (Astrinaki, 2012; Lankinen et al., 2016). This spurred the movie industry to pursue newer technologies to enhance film immersiveness (Salselas et al., 2021). Among these technologies, one such technology is haptics (Visch et al., 2009; Danieau et al., 2013). Haptic technology uses actuators to impart a sense of motion, vibration, and the application of force on the user (Danieau et al., 2013). Haptic feedback is achieved when the application of opposite force is along the axes x, y and z (Hwang & Hwang, 2011). Moreover, recent findings on integration and human senses have proposed that adding haptics may heighten the immersive quality during movie viewing (Lemmens et al., 2009; Venkatesan & Wang, 2023). Consequently, companies have come to adopt haptic technology to stimulate proprioception, enhancing users' experience during their cinematic experience. When employing haptic technology, research emphasizes the significance of considering communication and interaction with our physical environment (Danieau et al., 2013: Visch et al., 2010).

Surprisingly, while haptics has been able to make its way through different multimedia entertainment such as cinemas, music, and gaming; research concerning the impact of these technologies has little knowledge concerning the consumers' neurophysiological and behavioural responses (Boasen et al., 2020; Branje et al., 2014). Despite haptics being intertwined with human interaction, immersion, and emotion, most of the research relies solely on subjective evidence (Tsetesrukou et al., 2009). Consequently, there is a pressing need to further investigate the neurophysiological (i.e. cortical activation) effects of haptic technology on its users (Boasen et al., 2020). The knowledge gained from doing so could improve the user experience and create more immersive and realistic encounters (Kim et al., 2017). Exploring the untapped potentials of haptic technology in relation to immersion remains an open avenue for further investigation.

This led us to question how haptic technology could influence the impact of the immersive journey of its users (Flavián et al., 2019). To address this question a comprehensive literature review was conducted on various fields that are relevant to this study: Immersion, a method for measuring immersion, the antecedents and consequences of immersion and the intricate relationship between haptics and immersion. This literature review was conducted to better understand the connection between cinematic immersion and haptics technology in a broader manner to determine which type of movie design has an impact on one's immersion during movie viewing.

This literature review assesses existing knowledge of the concepts and fields relating to the research question and has six sections to address these points. The main point of this paper is to review the immersive experience concerning haptics technology and to link its relationship to cortical activity. These will be addressed by the following sections: 1) define immersion in relation to cinematics 2) define how to measure immersion: subjectively and objectively 3) define the antecedents of immersion 4) define the consequence of immersion and 5) define haptics 6) make the link between immersion and haptic technology 7) summarize and discuss the literature review 8) highlight the important research gaps 9) identify the limitations 10) conclude the literature review. The following questions will help us guide the literature review:

RQ 1: To what extent does high-fidelity haptic technology in a cinematic context have an effect on immersion?

RQ 2: To what extent does the phenomenon of immersion have a effect depending on the audiovisual characteristics in the cinematics context for which HFVK has been designed to support?

By reviewing these concepts and relationships, through a review of existing empirical research, this paper aims to enhance comprehension of user experience (UX) and clarify the fundamental underlying mechanisms of immersion. Furthermore, it seeks to understand how we can effectively study immersion within the context of cinematic viewing and immersive technology (Suh & Prophet, 2018). It will conclude by stating the existing gap in the literature and the hypothesis underpinning this study thereby, providing a comprehensive overview of the research landscape.

2.0 Methodology

To address the research questions and present a comprehensive overview of the current knowledge, this literature review starts by identifying articles that define immersion and research articles that relate immersive technology to cortical activity (Park et al., 2022; Alsuradi & Eid, 2016). The literature was conducted in two stages; one in relation to immersion and movie design and the second one consisted of advancing the literature search into neurophysiological measures. The first search employed a broad set of keywords including "immersion," "immersive technology," "haptics", "vibrokinetics", "vestibular", "somatosensory", "cortical activity", "electroencephalogram" and "sustained attention" to understand immersion, subjective and objective measures. The second stage. consisted of using keywords such as "sound design", "movie design", "narrative engagement", "multimedia" and "spatial presence" were used to have a deeper understanding of movie design. After identifying immersion as the key work at the initial stage of the search a more rigorous inclusion and exclusion process was applied during article selection. Focusing on peer-reviewed and academic publications from high-impact journals to ensure source credibility. Articles were chosen according to the following criteria: Publication date, relevance, peer-review and methodology. Notably, the keyword "cinema" was excluded to maintain precision, as the literature primarily centered around immersion and haptic experiences or technologies. Moreover, this approach allowed to increase the precision of our search as it is not a phenomenon that is widely studied. Instead, it focused on the exploration of various environments where haptics and immersion intersected, making their relationship clearer.

The literature search utilized Google Scholar, IEEE Xplore, and Elsevier Journal Finder. Exclusions were made for papers involving population patients, non-English articles, inadequate sample representativeness and outdated information.

3.0 Results

The literature findings suggest an association between immersion and haptics across various forms of multimedia and interactive technologies (Agrawal et al., 2020; Venkatesan & Wang, 2023). Haptic has been shown to play a crucial role in enhancing immersion by providing users or viewers with a more lifelike and engaging sensory experience (Astrinaki, 2012; Gardé et al., 2018). Overall in a cinematic context, haptics can enhance immersion through several factors:

audiovisual immersion, tactile realism/ tactile immersion, vestibular stimulation and movie design (Friese et al., 2016; Haegens et al., 2012).

The subsequent sections of this paper will be dedicated to past research on immersion, methods of measuring immersion, the antecedents and consequences of immersion, haptics and the interplay between them. Understanding and exploring how these three interact it will enable us to identify the gap in multisensory research in association with immersion (Ferrè et al., 2015; Burns & Fairclough, 2015).

3.1 Immersion

Immersion is a phenomenon that can be quite complex to define since it can be experienced across different contexts (Salselas et al., 2021). Whether we are captivated by a book or movie, storytelling possesses the capacity to transport individuals into a fictional realm (Visch & Tan, 2009; Visch et al., 2010). Immersion is often associated or synonymous with other terms such as realism, naturalness, and presence. Nevertheless, emerging literature suggests immersion to be a state where individuals dissociate from their surroundings shifting their attentional focus to an engaged state (Agrawal et al., 2019; Friese et al., 2016; Liu et al., 2007). This definition of immersion is not constrained to a single domain, it can be applied to gaming, films, movies, and virtual environments (Salselas et al., 2021). These can manifest in a real-life situation or can be facilitated through a virtual environment and technology. Furthermore, the use of immersive technology in user research can take different perspectives such as the technological perspective, the psychological perspective, the user-centered perspective or the narrative/storytelling perspective (Suh & Prophet, 2018). Considering different perspectives allows us to understand the capabilities and limitations of immersive tools (Cannavò et al., 2023; Choi et al., 2022). This helps understand the user's needs, preference and overall satisfaction (Fornerino et al., 2008). Moreover, the examination of immersive technology from a narrative perspective can contribute to the development of engaging content or quality content.

3.2 Measuring Immersion

The sense of immersion has sparked numerous debates among researchers, challenging the definition and the identification of influencing factors (Bouchard et al., 2012). Thus far the existing literature has suggested that there are two approaches in which we can use to measure immersion in users: Subjectively and objectively (Choi et al., 2022). The subject method involves gathering the self-reported experience and perceptions. Participants are typically asked to give feedback, rate their immersion level or express their feelings during their experience (Agrawal et al., 2021). In contrast, objective measures make use of direct observations and physiological or behavioural indicators to measure immersion.

3.2.1 Subjective Immersion

The subjective method of measuring immersion involves assessing it through self-reported means (Agrawal et al., 2020). They are majoritarily given at the end of the study and makes use of the person's memory and feeling. Researchers commonly use subjective feedback that describes the sense of immersion, emotional engagement and people's overall sense of engagement during a movie (Lonne et al., 2023; Visch et al., 2010). Thus, these self-reported measures are able to convey how users feel about their experience, however, there are some challenges to this method. Some of the challenges to consider when measuring immersion are subjectivity and recall bias (Lonne et al., 2023). Immersion is considered to be a phenomenon that is highly subjective and can constitute a varying perspective which can introduce bias into results (Schneider, 2017). Second, recall bias required participants to recall about their experience after the event which can be influenced by time since it may not be possible to capture the immediate emotions or reactions (Schneider et al., 2017). However, despite these challenges, self-reported measurement scales are valuable for studying immersion. They cover a broad spectrum of immersion-related questions, including emotional engagement and understanding design components (Jennett et al., 2008; Schneider, 2017). Furthermore, addressing these issues involves employing validated scales and cross-referencing self-reported data with other data types, such as physiological or behavioural data, to achieve a more comprehensive understanding of immersion (Yeongmi et al., 2010; Wang et al., 2013; Meer et al., 2020). Previous research has investigated the quality of experience and subjectivity during immersive experiences. Jennett et al. (2008) conducted experiments in the field of gaming and virtual reality in order to understand immersion in multimedia contexts by creating a single scale. The results of the study showed that immersion could be quantified into subjective measures allowing researchers to gain a comprehensive approach to immersion. It allowed them to measure the feeling of presence, engagement, emotional response and the overall perceived immersion. In this context, subjective testing is really important because it describes, characterizes and understands the audiovisual experience and interprets the influence of the physical properties of the stimuli and how individuals perceive things (Agrawal et al., 2021; Visch & Tan, 2009; Waltl et al., 2010).

3.2.2 Objective Immersion

While numerous studies have explored immersion using subjective measures, there has been comparatively less research done employing objective measures (Schneider, 2017; Yeongmi et al., 2010). The human body perceives through the different senses (i.e. skin, eye and ear) in the body and each of these modalities is associated with generating corresponding perceptions in our brain (Abromavicius et al., 2017; Alsuradi & Eid, 2016). The brain not only extends beyond perception but also allows us to form an understanding and form a connection with the physical environment (Astrinaki, 2012; Ga et al., 2015). To comprehend the complexity of immersion and the neural correlates, neurological measures can be promising in exploring the phenomenon of immersion (Maksimenko et al., 2018; Choi et al., 2023).

Technological advancement in neurophysiological imaging has allowed the use of better tools (i.e. electroencephalography (EEG), functional magnetic resonance imaging (fMRI), electrocardiogram (ECG) and electromyography (EMG), galvanic skin response (GSR)) for experiments and not only for the purpose of medical diagnosis (Xue et al., 2010). Among these tools, EEG has been preferred due to its low cost, high temporal resolution, non-invasive and more natural environmental method of data collection as opposed to other neuroimaging tools. In the past few years, a great amount of advancement has been made in understanding and applying EEG (Reaves et al., 2021). Addressing a common challenge faced in user experience studies, which often rely on subjective self-reports, the integration of neurophysiological measures facilitates a more profound understanding of the underlying mechanism (Park et al., 2022; Reaves et al., 2021; Tauscher et al., 2019). Studies exploring the differences between immersion and concentration have shown that both phenomena can be differentiated after analyzing their brain oscillations (Lim et al., 2019; Baceviciute et al., 2021). EEG has the ability to measure neural oscillations while allowing researchers to investigate frequencies that are associated with different brain functions (Quandt et al., 2013).

Different brain frequencies have been associated with different cognitive functions (Haegens et al., 2012). In the context of immersion research, the association of theta oscillations (5 -7Hz) with sensory processing has become particularly relevant (Abromavicius et al., 2017; Baceviciute et al., 2021). Research further indicates that synchronized theta oscillations are linked to conveying specific information about stimuli in the visual cortex (Liu et al., 2007). This connection between theta oscillations and visual processing could play an important role in understanding how individuals immerse themselves in audiovisual content (Danieau et al., 2013). Furthermore, given that theta oscillations are also associated with working memory performance, their role in immersive experience might extend to retention and recall, overall contributing to a more comprehensive understanding of the cognitive processes during immersion (Rostamian et al., 2022; Schaefer et al., 2006; Sreelakshmi & Subash, 2017).

Alpha band activity (8-12 Hz) has been associated with voluntary and involuntary attentional shifts and engagement (Souza & Naves, 2021). This means that when individuals are immersed in an experience, whether it be movies or another form of multimedia, the alpha band activity reflects the modulation of attention (Souza & Naves, 2021; Van Diepen et al., 2019). These involuntary attention shifts may show the brain responsiveness to the presented stimuli in the immersive environment. Since, in this case, alpha bands reflect the brain’s ability to respond to stimuli without conscious efforts it would mean that the viewer's attention is captured which contributes to the overall immersive experience (Van Diepen et al., 2019). This suggests that the link between alpha and immersive experiences may lie in studying the consciousness and engagement of the brain while presenting a compelling stimulus.

Beta oscillation (15-29 Hz) dominates our normal waking state of consciousness when attention is directed toward cognitive tasks and the outside world (Lim et al., 2019). Beta is a ‘fast’ activity, present when we are alert, attentive, engaged in problem-solving, judgment, decision-making, or focused mental activity (Biau & Kotz, 2018). Similarly to alpha being able to understand the role of beta in immersion may help understand the role of our attention and engagement (Biau & Kotz, 2018; Quandt et al., 2013; Kang et al., 2015). The increase in beta activity may indicate the state of being focused in different multimedia contexts. Therefore, it would be important to also consider beta oscillation in the underlying immersive experiences (Kang et al., 2015).

Subjective measures such as those collected through questionnaires, can be used with neurological measures like electroencephalogram (EEG) to understand the nuances of immersive experiences and various cognitive processes (Reaves et al., 2021; Visch et al., 2010). Researchers, who are exploring the feasibility of measuring subjective immersion within the realm of virtual reality, have looked for neuroanatomical correlates in this domain (Bouchard et al., 2012). Moreover, EEG can be effectively combined with subjective measures, to provide comprehension and understanding of the interplay between neural responses and subjective experiences. Researchers strategically stimulate users' senses by using audiovisual stimuli to manipulate immersion, now more often in conjunction with haptics. Immersive experiences have been also shown to create a phenomenon called cognitive distancing (perceived realism) which decreases the cognitive bias in participants' responses or judgment of the movie (Visch et al., 2010). These differences are noticed after evaluating the responses of viewers' ratings through questionnaires after viewing movie clips. Although realism has been often studied in terms of subjectiveness showing that individuals enhance immersiveness and emotions it remains that their subjective experience should be reflective of their objective performance while performing those tasks (Bouchard et al., 2012). The integration of EEG may be valuable to gain insights into the aspect of immersion.

3.3 Haptic Technology and Immersion

Haptic technology makes use of different types of stimulation to enhance the experience of its users (Petersen, 2019). It works by the use of tactile, vibrations and motion on users to simulate sensations that would be felt if they interacted with these objects directly. One of the technologies that use haptics to enhance immersiveness is high-fidelity vibrokinetic (HFVK) technology in the context of entertainment by integrating the technology into movie seats (Boasen et al., 2020). It incorporated vibration and kinetic stimuli to enhance the immersiveness of the audiovisual stimuli presented in multimedia entertainment. Typically, multimedia/movie content uses a video and audio component which engages the audio and visual senses in humans

(Rasheed & Shah, 2002; Boasen et al., 2020). Studies on visual and auditory modalities have been extensively studied in terms of cognitive and perceptual research (Alsuradi et al., 2020). However, multimedia content has tried to create an immersive feeling in individuals by creating a sensorial experience for its users. These sensations are created by synchronizing vibration, motion, sound, and visual stimuli together to produce a realistic environment during the experience. Haptic stimulation works by applying different forces such as vibration and motion using actuators to create a sensation in its users (Hwan & Hwang, 2017; Ideguchi & Muranaka, 2007; Pauna et al., 2017). In more recent years, there has been an increase in the use of haptics in a cinematic context. The inclusion of haptic technology in movies is mostly to represent physical events that occur in the movie (Danieau et al., 2013). Haptics is often separated into two categories: tactile and kinesthetic feedback. Tactile feedback refers to the use of touch sensation to provide them with sensory information that allows the perception of touch of objects or different surfaces (Israr et al., 2014; Iosifyan & Korolkova, 2019). On the other hand, kinesthetic feedback allows the body to know the sense of movement, position or orientation of the body or limbs. This allows the body to have spatial awareness without solely relying on visual cues (Poeschl et al., 2013; Angelika et al., 2009). Recent research on haptic technology and its effect has shown that the different stimuli used in haptics (motion, vibration and force) during audiovisual cues enhance the other senses (Gavazzi et al., 2013; Hwang & Hwang, 2011; Ideguchi & Muranaka, 2007). Thus, it is important to explore how haptic technology during audiovisual cues can affect the user neurophysiologically (Choi et al., 2023).

3.3.1 Audiovisual Immersion

Over the past decade, there has been significant progress in audiovisual technology (Agrawal et al., 2020). The progression of technology such as the appearance/display of virtual reality, augmented reality (AR) and haptic technology are reshaping the way audiovisual stimuli are designed. Previously, immersion had been used to mostly refer to and describe audiovisual experiences; however, the precise idea was not well understood (Waltl & Hellwagner, 2010). Research surrounding audiovisual immersion explores how the combination of auditory and visual elements can create a sense of immersion in different multimedia environments including movies, video games, virtual reality and other forms of multimedia (Baceviciute et al., 2021).

The characteristics and aspects of visual modalities allow immersion in individuals when there is a change in image content and complexity in the sequence (Liu et al., 2020). Similar to the auditory modality when there is a sudden change in high volume or quick pace sounds.

Neurological evidence suggests a relationship between immersion and audiovisual stimuli (Burns et al., 2015; Abromavicius et al., 2017). First, the evidence suggests an increased activation in regions related to sensory processing such as the auditory, somatosensory and visual regions of the brain, when individuals are exposed to audiovisual stimuli in an immersive setting (Haegens et al., 2012; Keller et al., 2017; Abromavicius et al., 2017). Moreover, the findings show when audio and visual stimuli are well synchronized it enhances the multisensory integration while poorly synchronized clips show less effective integration (Abromavicius et al., 2017). The evaluation of immersion in this study involved exposing participants to audiovisual stimuli with various degrees of synchronization and assessing their immersive experience using a self-rating scale. Results suggest that an optimal synchronization significantly improved the participants' immersive experience. To add to this, Abromavicius and colleagues (2017) investigated regions of the brain that get stimulated by audiovisual stimuli. The study revealed a significant difference in alpha (8-12 Hz) band activity in the frontal, parietal, right temporal, occipital and central lobes. Additionally, significant differences were also found in the beta band in the right frontal region and parietal and temporal lobes. These increases in beta (13-29 Hz) activity have been associated with high levels of arousal and cognitive exhaustion (Biau & Kotz, 2018; Friese et al., 2016). However, no significant differences were observed in the theta (4-8 Hz) band. Existing literature suggests that audiovisual stimuli may modulate regions related to cognitive processing and spatial processing (Abromavicis et al., 2017; Venkatesan & Wang, 2023). These regions of the brain have been identified to be the frontal, parietal, temporal and occipital lobes.

Other studies evaluating immersive experiences through audiovisual stimuli propose a link between attention and immersion (Hammond et al., 2023; Lim et al., 2019). When viewers experience immersion their attention shifts toward the media, and the narrative leads them to designate some of their cognitive resources to depict the characters and events in the movie (Hammond et al., 2023). Moreover, participants paid more attention when they found the content engaging regardless of whether they’ve seen it before or not. This might allow us to understand how attention while viewing a movie is of an immersive nature and engaging content.

3.3.2 Tactile Immersion with the Integration of Haptics

The sense of touch plays a fundamental role in our everyday life and experiences (Schaefer et al., 2006). Touch, also known as tactile perception or somatosensation, allows us to communicate and interact with our physical environment (Quandt et al., 2013). Additionally, somatosensation allows the body and brain to detect different sensations such as pressure, temperature, texture, vibration, pain and other types of tactile cues (Vickery et al., 2020; Schaefer et al., 2006; Rostamian et al., 2022). The recognition and processing of these sensations are important to provide feedback about our environment by communicating, interacting, and forming emotional connections (Ravaja et al., 2017).

Individuals working in the field of haptic feedback have been trying to understand how our senses work and how it impacts their cognitive experience (Alsuradi et al., 2020; Quandt et al., 2013). Haptics is increasingly recognized as an important component to consider in designing immersive systems, necessitating careful consideration of various factors such as shape, texture and intensity (Rostamian et al., 2022). Recent findings have shown the connection of touch sensation to be linked by networks of nerves throughout our bodies, including the somatosensory system (Alsuradi et al., 2020; Rostamian et al., 2022). Thus, when designing multimedia sensory devices, designers now need to consider and map all the senses (Nesbitt, 2005). Given that each sense can perceive various amounts of properties, designers must make informed decisions about which sense and property they want to stimulate (Salselas & Penha, 2019; Saarinen et al., 2021; Nesbitt, 2005). This involves the consideration of whether the multi-sensory experiences created can produce a sensory bias or sensory conflict (Radianti et al., 2019). Research evaluating the experience of a multi-touch environment has shown that participants are more engaged, in control, to relate to other people and to be more immersed compared to environments that do not let participants use their sense of touch (Watson et al., 2013). Thus, this further shows how the use of multimedia experience may have an important role in fostering immersion.

In the past decades, there has been critical research done in order to understand how important timing is in vibrotactile frequency (Vickery et al., 2020). It is suggested to play a role in the manner in which the senses integrate information from different receptors that respond to a variety of temporal and spatial stimulation patterns (Luo & Poeppel, 2012). Given the fact that sound is a multimodal component that is sensed through vibrations and sonically it is possible to create haptic designs that suit movies, musicals and other forms of entertainment (Venkatesan & Wang, 2023; Luo & Poeppel, 2012). Increased beta activity in the temporal region has been also associated with an increased level of immersiveness. Beta rhythms originate from the precentral region in the motor gyrus (Quandt et al,. 2013). Other studies also suggest that the sensorimotor cortex is involved in processing immediate somatosensorial information such as tactile and proprioceptive input. This hypothesis suggests that theta oscillations may be implicated in various functions related to multisensory divided attention, such as audio-visual integration and cognitive control (Cavanagh & Frank, 2014; Cavanagh et al., 2010). Therefore using EEG would allow us to relate the ongoing brain/oscillations of participants when experiencing stimuli.

Somatosensory interaction has become an important topic to study as researchers have tried to create better experiences by integrating more senses (Liu & Shen, 2022). This region has been long known to play an important role in the processing of sensory information from multiple/various regions in the body (Kim et al., 2021). Researching the literature for the past decade surrounding EEG and touch suggests that the underlying neural mechanism of touch and cognitive perception seems to be associated. The somatosensory region is involved in the processing of haptic technology and uses tactile sensation to stimulate the sense of touch (Kim et al., 2021; Liu et al., 2020; Alsuradi et al., 2020). This system is composed of a different peripheral nerve that detects different sensory modalities such as pressure, pain, temperature, and touch (Liu & Shen, 2022). Sensations are processed and integrated into the central nervous system to help individuals interpret and interact with their environmental stimuli. The somatosensory is not only involved in processing sensations from our own body but also responds to visible contact with other people or inanimate objects even without physical touch (Kim et al., 2021). This phenomenon is known as “mirror neuron”, neuroimaging techniques such as EEG have shown that when individuals observe touch the somatosensory gets stimulated. Moreover, Lim and colleagues (2019) demonstrated that participants experiencing immersion have significantly higher alpha waves compared to other phenomena that require attention such as increased concentration. Interestingly, previous studies on attentional alpha have shown attention to be decreased in tactile stimulation when alpha activity occurs in the contralateral hemisphere of the stimuli location (Shen et al., 2022). The modulation of alpha waves may be associated with increased immersion and engagement in the virtual environment (Hagens et al., 2012). This also may have been suggested to be an indicator of spatial attention which allows the facilitation of visual processing to the location of sounds. Thus, it appears that during bottom-up processing of visual attention by the salient auditory stimulus is a phenomenon that can occur regardless of the engagement and attention.

3.3.3 Vestibular and Somatosensory Stimulation on Immersion with Haptics

The relationship between vestibular stimulation and audiovisual stimulation in combination with haptics suggests that it may contribute to enhanced immersion (Danieau et al., 2013). The vestibular system provides information about the orientation and balance based on the pattern of motion of the organism (Day & Fitzpatrick, 2005; Quandt et al., 2013). The integration of these processes from other sensory channels (i.e. vision, touch, audition) is essential in the overall perception and adaptability of our environment (James et al., 2007; Ferrè et al., 2015). Individuals can have a sense of perception and awareness of their spatial orientation (i.e., body position and movement) because of visual, tactile and postural modalities (Volkening et al., 2014). The effect on the vestibular system can be initially seen through the motion or movement of the camera technique to create immersive experiences. In the context of cinema, the use of haptics can help the audience develop a sense of spatial awareness (Lankinen et al., 2016).

Devices and technologies that are equipped with vibration and motion such as vibrokinetic chairs can have an impact on the vestibular system (James et al., 2007). The vibration and motion are detected from the inner ear which is part of the vestibular system and detects the changes ahead of the movement or acceleration. Moreover, these interactions have been suggested to be reflected in the neurological evidence showing the regions that are activated when the vestibular system is stimulated (Haegens et al., 2012; Schaefer et al., 2006). Although researchers have not pinpointed a singular region associated with vestibular stimulation there are a few regions that are associated with the processing of vestibular information (Haegens et al., 2012). Regions such as the parieto-insular vestibular cortex and the posterior insula are areas that integrate vestibular information (Espenhahn et al., 2020; James et al., 2007). Moreover, other regions that are involved in processing sensory information (i.e visual, vestibular and vestibular inputs) namely the posterior parietal cortex and the supramarginal gyrus may have additional roles in the body position in space, multisensory integration and spatial processing (Angelaki et al., 2009). Angelaki and colleagues (2009) suggest the presence of haptic feedback to enhance the perception of motion and spatial presence. Additionally, during audiovisual stimuli, vibration and motion appear to boost activity in the vestibular system which is connected to the increase of theta activity.

Other processes should be considered in the processing of spatial processing as they have been linked to attention. Frank (2007) show that attention networks play a role in regulating the vestibular system when visual processing is processing what we see. However, sensory conflict is a factor that should be kept in mind when stimulating the vestibular system (Ng et al., 2020). A sensory conflict arises when information from different modalities is inconsistent with each other (Marshall et al., 2019). An instance where sensory conflict may be observed and disadvantageous in the context of haptics is when the sensory input from the visual and the vestibular are not aligned properly with each other. For example, stimulating motion allows one to perceive motion while sitting down (Ng et al., 2020). Studies show that when these conflicts happen it can reduce the effect of immersion due to the inability to engage in the environment.

Combining objective and subjective measures can allow us to have a more comprehensive and holistic understanding of immersion (Agrawal et al., 2020; Jennett et al., 2008). Overall, the literature seems to suggest that touch and motion are essential components to consider in the cinematic context as well as other domains such as gaming.

3.4 Movie-Related Antecedents of Immersion

Some aspects of a movie can play a crucial role in contributing to the audience's level of immersiveness in the story (Cannavò et al., 2023). As aforementioned immersion is the feeling of being fully absorbed in the narrative world presented to us. To be able to influence one’s level of immersiveness in the context of movies we need to take into account different characteristics such as action vs non-action scenes, music vs non-music scenes, riding vs not riding effects, low low-intensity vs high-intensity scenes (Liu et al., 2020; Cannavò et al., 2023; Rasheed & Shah, 2002; Kataria & Kumar, 2016). These characteristics should be taken into account because they can significantly influence the manner in which the narrative, content and style convey information or feelings to the audience. Additionally, exploring the role of haptics technology in the context of cinema may add another layer to the immersive experience thus allowing audiences to feel immersed in their narrative world, thereby enhancing overall immersion (Jackman, 2015).

3.4.1 Movie Characteristics: Action vs Non-Action Scenes

The relationship between the genre of a movie and the level of immersion experienced by the audience is a subject of substantial interest in contemporary cinema studies (Visch & Tan, 2009). The distinction between action and non-action scenes has become a prominent area of investigation, as each genre employs distinct narrative, visual, and auditory elements to engage viewers (Alma et al., 2021). This literature review explores the existing research on how action and non-action scenes affect immersion, focusing on how the dynamic elements of action films and the introspective qualities of non-action scenes contribute to the overall immersive experience (Lankinen et al., 2016). Action scenes are renowned for their fast-paced sequences, high-stakes scenarios, and adrenaline-inducing narratives. Thus, when the addition of haptics is used in these movie sequences they are often characterized by intense vibration or rumbling to make the audience feel the force of the action (Gaffary & Lécuyer, 2018; Alma et al., 2021). For example, haptic feedback can be used to simulate a car accelerating, braking and crashing by replicating the force and tactile sensations that are associated with the actions. To create the impact of a crash, designers will use shards and sudden jolts and vibrations to mimic the sensation (Alma et al., 2021). Whereas, the feeling of acceleration will be generated by using a forward force which would leave the audience the feeling of being pushed into their seat. Finally, the sensation of braking can be replicated by using an opposing force to simulate the feeling of deceleration (Giordano et al., 2015). These can be applied and catered to different scenes depending on the sensation that needs to be stimulated by designing the proper sensation and texture (Eldeeb et al., 2020). On the other hand, scenes that are less intense and non-action-related use haptics to convey subtle cues (Kim et al., 2019). For example, to convey the feeling of a gentle breeze designers would use a low frequency or gentle rhythmic vibrations resembling the movement of air (Dalsgaard et al., 2022). These haptic designs allow users to be more easily immersed because it attempts to replicate real experiences in a virtual environment.

Research suggests that the intense visual and auditory stimuli present in action sequences often lead to heightened levels of immersion (Naef et al., 2022). The dynamic camera movements, rapid editing, and explosive special effects are believed to draw audiences into the heart of the action, creating a visceral experience where viewers feel closely connected to the characters and events. Moreover, studies have shown that physiological responses, such as increased heart rate and pupil dilation, are more pronounced in viewers of action films, indicating a deeper physiological engagement (Hammond et al., 2023). Conversely, non-action sequences, which encompass genres like drama, romance, and art-house films, emphasize character development, introspection, and emotional resonance. While the sensory intensity may be lower compared to action films, the focus on character psychology and relatable emotions can lead to a different kind of immersion (Alma et al., 2021). Research suggests that viewers of non-action scenes often experience a sense of emotional immersion, where they empathize with characters' dilemmas and internal struggles (Yilmaz et al., 2023). This emotional identification can lead to a profound connection, causing viewers to lose themselves in the character's emotional journeys.

3.4.2 Movie Characteristics: Music Scenes vs. Non-Music Scenes

Sound design is an essential audiovisual element in entertainment and a fundamental component in storytelling in movies (Choi et al., 2023; Salselas et al., 2019). Background music, dialogues, ambient sounds and sound effects in movie scenes are essential to the narrative (Choi et al., 2023). It has the ability to give the illusion of being present to the viewer in a specific perspective during movie watching (Salselas et al., 2021; Giroux et al., 2019). Moreover, there has been a shift in the technological development of immersive media in terms of the sensory information available to viewers (Salselas et al., 2021). The emergence of these technologies gives the potential to change the way in which we can manipulate sound design and subliminal perception (Turchet et al., 2021). Sounds in movies are designed while considering the tempo to create different feelings (Venkatesan & Wang, 2023). For example, scenes with high tension or action will make use of fast music. On the other hand, scenes needing a softer atmosphere will have calmer and lower-paced music (Gorbman, 1980). Sounds made by objects in the background of movies are important because they give a sense of being part of the environment and increase the sense of realism which contributes to immersion.

The literature suggests that audiences will be more immersed in the scenes when the rhythm of the narrative matches the music in the movie (Turchet et al., 2021; Mazzoni & Bryan-Kinns, 2015). Poeschi and colleagues investigated the subjective level of immersion in conditions using no-sound and sound-using visual displays while manipulating the synchronization level of the audio component (2013). The audio components used for this study were music and ambient background sound. An increased level of immersion was found in individuals when sound was synchronized perfectly to the visual stimuli while maintaining a medium to large audio level. This suggests that the inclusion of music and ambience in immersive environments may lead to higher levels of immersion. Moreover, the integration of haptic with the audiovisual input will yield a better immersive experience (Venkatesan & Wang, 2023). But, if audiovisual sensory information is not properly aligned it will contribute to poor attentional focus and lead to ambiguous interpretation which will not allow viewers to experience immersion. The consideration of sound design with haptic technology has allowed designers to consider various aspects such as the physical and psychological dimensions of sound to produce emotion and wanted reaction in their listeners (Salselas et al., 2021). As it is clear how sound may increase immersion level in someone's experience it is important to consider how the addition of haptics may also contribute to further enhancement of audiovisual cues (Turchet et al., 2021). To explore how this may be an important factor to take into consideration Venkatesan and Wang (2023) have created an experiment to understand tactile experiences in the context of music experiences. Touch is a component that may be important to music due to sound being a component that is both felt through vibrations and sonically (Turchet et al.,2021; Venkatesan et al., 2023). Moreover, there is evidence supporting that listening to music without feeling vibrotactile feedback is not as engaging and rich of an experience (Ideguchi & Muranaka, 2007). There are a few papers regarding the impact of haptic music players suggesting haptic devices to increase levels of enjoyment of people's music listening experiences. For instance, the paper by Giroux et al. (2019) found that people listening to music in a chair with vibrokinetic feedback synchronized with music increased psychological arousal and greater subjective appreciation for music. However, there is not enough research to support that evidence regarding neurological or physiological findings to show how vibrotactile feedback may influence sound and its sensibility to musical components (Venkatesan & Wang, 2023).

3.4.3 Movie Characteristics: Riding vs not Riding

While limited research delves into the effect of characters riding or not riding, existing literature shows that the character’s mode of transportation can significantly influence both the narrative and the overall cinematic experience (Marshall et al., 2019). The effect of riding can be used to ride a vehicle, or animals to reach a location, escape danger or achieve a mission. When considering these effects haptic designers need to consider the type of vehicle and try to replicate the sensation and forces that are associated with the type of vehicle chosen. They need to consider the vibration, acceleration, deceleration, turning, leaning, the type of surface (bumpy, flat, uphill, downhill) and the type of texture (pavement, gravel, sand) the character is going through (Eldeeb, 2020). These elements allow the narrative to move forward and create feelings of excitement or suspense (Karafotias et al., 2017). Additionally, these can influence the visuals and the dynamic of the overall cinematic scene. Filmmakers often use a camera angle known as point of view (POV) to make the audience feel like they are seeing the movie from the character's perspective. This gives the impression that the character is riding something that can make the viewer feel like they are experiencing the event while enhancing their immersion. Moreover, the addition of haptics can enhance the effect of riding by simulating the physical sensations that are associated with riding (Marshall et al., 2019; Freeman et al., 2014). Adding this dimension of realistic sensations can deepen the audience's immersion by making them feel as though they are part of the journey of the movie character physically. However, this still remains to be explored as it is a characteristic that is not popularly studied (Zika, 2019).

3.4.4 Movie Characteristics: Low vs. High Scene Intensity

The intensity in movies is understood as the level of excitement or refers to the activity in a scene; they are characterized by action, emotion, and audiovisual stimulation (Kataria & Kumar, 2016). In high-intensity scenes, there are elements that are more dramatic moments, high or fast-paced moments, and dynamic camera work which contributes to immersion (Tikka & Laitinen, 2006). A high-intensity scene can overlap with characteristics of action scenes but they are not necessarily the same (Karafotias et al., 2017). A high-intensity scene generates heightened tension and tries to engage the audience more emotionally as opposed to an action scene which is more action-oriented (Iosifyan & Korolkova, 2019; Karafotias et al., 2017).

Whereas, low-intensity movies contain a focus on character development or the connection of the characters. Moreover, Slow and contemplative scenes can be immersive by contributing to the overall narrative pacing.

The literature indicates that both high and low scene intensity contribute to immersion but through different mechanisms (Karafotias et al., 2017). High-intensity scenes engage viewers emotionally and physically, while low-intensity scenes facilitate intellectual and emotional immersion by providing context and depth. Filmmakers can strategically balance these elements to optimize the viewer's immersive experience. A study investigating the complexity of movie narrative and immersion suggests that more complex movies are more immersive than those that are less complex (Cutting et al., 2016). Participants in this study were asked to watch movies with varying levels of narrative: simple plots vs intricate plots. Complex narratives allowed viewers to be more engaged and perceived movies as being more immersive because they were trying to actively piece the narrative together. However, literature also suggests how haptic designs that are overly intense or overwhelming can potentially disrupt immersion during cinematic viewing (Gaffary & Lécuyer, 2018). Coming back to our example of the car explosion, if haptic simulates a car explosion that has strong vibration, it may become a distraction rather than an immersive experience (Alma et al., 2021). Moreover, knowing when to reduce, vary or stop vibrations or motion is important because the continuous vibration may become redundant and reduce the effectiveness of HFVK.

4.0 Consequences of Immersion: Temporal Dimension/ Characteristic

Immersion in a cinematic context can have a significant impact on various aspects of our perception which includes time, cognitive and emotional perception (Visch & Tan, 2009). Oftentimes, immersive storytelling of events can lead to a distorted perception of time where the audience loses track of time and loses their awareness of the real world (Eagleman, 2004). This distortion causes viewers to perceive events as being faster or slower (Gavazzi et al., 2013). Distortions are created by filmmakers who have made use of different techniques in order to manipulate time perception for artistic and storytelling purposes in movies by the use of different technologies. such as haptic technology (Gil, 2009; Kovarski et al., 2022). Compared to traditional movie viewing haptic technology makes use of sensation which allows one to feel as if they are present. This amplifies the perception of speed or weightlessness (Gavazzi et al., 2013). Some of the distortions that can be experienced include the distortion of velocity, temporal frequency, and visibility. Moreover, the literature suggests that there is no specific organ that seems to be involved in the measure of time perception/passage of time instead these have been suggested to be evaluated subjectively using the several sensations and the perception of change (Jennett et al., 2008; James et al., 2007). Interestingly, our senses rely on speed and different cortical regions to provide information on time measurements therefore these may cause distorted perception (Gavassi et al., 2013; Haegens et al., 2012; Kropf et al., 2019). Exploring this phenomenon can help provide further comprehension of immersive experience as opposed to satisfaction or enjoyment since it goes beyond the surface level. It delves into how sensory inputs influence our perception and may be able to provide more concrete evidence.

5.0 Discussion

In conclusion, this literature review has provided valuable insight into the multifaceted relationship of immersion within cinematic experiences (Hale & Stanney, 2004). The main finding of the literature suggests immersion is influenced by different movie characteristics and the manner in which storytelling happens (Kovarski et al., 2022; Israr et al., 2014). Additionally, a critical observation from the literature review is to acknowledge haptics as a significant influencer of cinematic immersion particularly with HFVK technology (Agrawal et al., 2020; Alsuradi & Eid, 2016; Astrinaki, 2012). HFVK is a promising avenue for the enhancement of cinematic experiences; moreover, the findings suggest it plays a role in shaping the audience's perception (James et al., 2007).

Immersion as a subjective experience, has been explored and measured through different methods encompassing subjective measures such as scales and questionnaires and objective measures such as neurophysiological makers like brain activation patterns (Hale & Stanney, 2004; James et al., 2007). However, the interplay and progression in understanding haptics and immersion have shown to have notable gaps in the literature due to some areas still being understudied (Alsuradi & Eid, 2016; Angelaki et al., 2009; Astrinaki, 2012). One notable gap is the need for a more comprehensive exploration of the neurological mechanism underlying the haptics on immersion (Boasen et al., 2020). Moreover, these are also impacted by different characteristics of movies. While the literature has already touched on the broad effect of haptic technology, the more effective and targeted approach may help further the impact on cinematic immersion (Peterson, 2019).

In conclusion, there exists a gap in our understanding of the neurological underpinning of immersion with haptics. By addressing this gap, future research can advance our knowledge in haptics.

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Chapitre 3: Deuxième article

The effects of high-fidelity vibrokinetic (HFVK) stimulation by characteristics in a cinematic context[2]

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Abstract

Haptic technologies are increasingly being used in multimedia entertainment to enhance and increase immersion in moviegoers. There are studies regarding the neuropsychological effects of haptics during audiovisual (AV) entertainment; however, the neurophysiological mechanism where the haptics may increase immersion remains to be clarified. Moreover, it remains that it should be clarified how high-fidelity vibrokinetic technology (HFVK) has an effect on different movie categories/audiovisual characteristics such as: action vs non-action, riding vs not riding, low vs high movie intensity and music vs non-music scenes. The purpose of this study is to investigate: To what extent does high-fidelity haptic technology in a cinematic context have an impact on immersion? and To what extent does the phenomenon of immersion have an effect depending on the audiovisual characteristics in the cinematics context for which HFVK has been designed to support? It was hypothesized that individuals in the HFVK group would have an increased level of immersion as well as increased cortical activity in the regions associated with tactile and attention processing. We invited fifteen participants to watch 15 movie clips by randomly assigning them to either the HFVK or control group. This present study made use of a between-group design using electroencephalography (EEG) while using source localization to better identify and localize the electrical activity in the brain. Moreover, the study analyzed the effects of HFVK stimulation on cortical brain activity and self-perceived immersion during cinematic viewing. A cluster in the inferior parietal cortex and two clusters in the inferior temporal gyrus were significant. They were identified as having higher cortical activity than the control group during the analysis of the EEG data. Additionally, the characteristics of a movie

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[2] This article is in preparation for submission to the Journal of Frontiers Neuroergonomics.

appear to influence theta brain activity, while no significant effect was found in the beta band frequency.

Keywords: Immersion, Haptic, EEG, Audiovisual, Vibrokinetic, Attention, Multimedia, Non-action, Action, Movie Characteristics

1. Introduction

As movies remain a popular form of entertainment filmmakers and companies have been challenged to create a more immersive and engaging viewing experience for their audience (Astrinaki, 2012). Movies are a form of multimedia that blends many aspects such as music, sounds, dialogues, and moving pictures to tell a story while creating a viewing experience for its users (Mazzoni & Bryan-Kinns, 2016). Previous research on cinematic realism has shown to be dependent on the narrative form to have an influence on its users (Astrinaki, 2012). This led the movie industry to rely on newer technologies to enhance the immersiveness of its users (Levin & Baker, 2017). However, the film indistry wanted to further investigate how users' experience can enhance immersion by playing with their other senses and cinematic components (Visch et al., 2010). The effective use of haptic design is important for achieving heightened levels of immersion (Wang et al., 2019). Additionally, incorporating sensory components aligns with how humans perceive their environment resulting in an overall immersive experience. Traditionally, designers and engineers have primarily targeted the sense of sight and hearing stimulating visual images such as depth perception and auditory content (offering a multidirectional perspective with stereos) (Sigrist et al., 2013). However, haptic technology introduces a new dimension, extending its influences to various multimedia technologies such as cinema, music, and gaming to enhance the immersive experience by applying different forces and vibrations on the user (Boasen et al., 2020; Giroux et al., 2019). Recent findings on integration and human senses underscore the impact of haptic technology, revealing noticeably the increased immersion and enjoyability significance during movie viewing of users (Mazzoni & Bryan-Kinns, 2016; Astrinaki, 2012).

High-fidelity vibrokinetic (HFVK) technology stands out as a haptic innovation aimed at elevating immersiveness, in particular within the entertainment realm by integrating haptic elements into movie seats (Gardé et al., 2018). While extensive studies have been conducted on the cognitive and perceptual aspects of visual and auditory modalities (Alsuradi et al., 2020), the domain of multisensorial multimedia focuses on the cognitive immersive feeling in individuals by creating a sensorial experience for their users (Giroux et al., 2019; Mazzoni & Bryan-Kinns, 2016). These immersive sensations are created by synchronizing vibration, motion, sound, and visual stimuli together to craft a realistic environment during the experience. Creating immersive movies also involves various factors in the design and narrative construction (Agrawal et al., 2020; Venkatesan & Wang, 2023).

Designing immersive movies involves nuances considerations in areas such as sound design/music, movie genre and the emotional intensity of scenes (Venkatesan & Wang, 2023). While existing research demonstrates the efficacy of HFVK in enhancing immersion in multimedia or audiovisual (AV) contexts, a compelling and unexplored domain remains to be further investigated: cognitive sciences (Tikka & Laitinen, 2006). Thus, this led researchers into trying to understand the mechanisms underlying HFVK technology which have an effect on immersion in the brain (Boasen et al., 2020, Giroux et al., 2019). Moreover, the substantial industrial impact haptic technology has in an audiovisual context is significant and remains an understudied facet (Tikka & Laitinen, 2006). Current research and technological advancement in haptics primarily centers on improving audiovisual entertainment, while predominantly focusing on improving image and sound (Danieau et al., 2013). These technological advancements in haptic technology prompted researchers to investigate the neurological impacts of such differences on one's cinematic experience (Van Wegen et al., 2023).

This study addresses the following research questions:

RQ 1: To what extent does high-fidelity haptic technology in a cinematic context has an effect on immersion?

RQ 2: To what extent does the phenomenon of immersion have an effect depending on the audiovisual characteristics in the cinematics context for which HFVK has been designed to support?

To answer these questions, this study categorized fifteen movie clips from eight different movies into different characteristic groups, such as action vs. non-action, low vs. high movie intensity, riding vs. not riding and finally music vs. non-music sequences (Visch & Tan, 2010; Rasheed & Shah, 2002). These categories were assessed based on characteristics known to influence design and immersion according to the literature. Additionally, cortical activity was measured using electroencephalography (EEG) to reveal the neural mechanisms that may be influenced by high-fidelity haptic technology in a cinematic context (Abromavicius et al., 2017; Burns & Fairclough,2015; Alsuradi et al.,2016).

2.0 Movie Characteristics Categorization

Classifying movies according to different scenes or environments can provide valuable insights into researching movie design (Liu et al., 2020). This approach enables the evaluation of design choices within different genres and styles of storytelling to see how design can significantly impact the experience of a user (Hale & Stanney, 2004; Nesbitt, 2005; Schneider et al., 2017). The categorization of movies by design not only highlights instances of innovation and its influence on the film industry but also facilitates the examination of how films have shaped subsequent generations of filmmakers (Rasheed & Shah, 2002). Furthermore, this allows researchers to explore how diverse design choices can impact audience reception and immersion by studying specific genres, styles or musical components (Agrawal et al., 2020; Salselas et al., 2021).

2.1 Immersion

Immersion is a pivotal component to consider in the cinematic experience, allowing the audience to transport themselves to the world of the film (Agrawal et al., 2020). In this context, immersion is defined as a profound involvement with something that causes someone to forget their surroundings (Lim et al. 2019; Peterson, 2019; Visch et al., 2010). Research on cinematic immersion provides valuable insights on how individuals engage with and become immersed in movies. Furthermore, immersion is a multifaceted phenomenon influenced by various factors, encompassing the design characteristics of the movie, audiovisual stimuli, storytelling, and additional influences on perception such as haptics (Visch et al., 2010; Peterson, 2019). Movie designers and researchers in the industry recognize the importance of manipulating different sensory components to enhance immersive experiences.

2.2 The Relationship between Movie Characteristics/Design and Immersion

The relationship between movie design and immersion is quite intricate due to the involvement of many components such as visual, auditory and the combination of narrative components that can collectively influence the perception and cognitive experience of the audience (Fornerino et al., 2008). Moreover, design elements such as cinematography contribute to the immersive environment because they shape the sensory and emotional experience of the audience (Baños et al., 2004; Nowak & Biocca, 2003). It also plays an important role in enhancing immersion by shaping the visual elements of the film.

Studies suggest that merging of various cinematic elements with audiovisual stimulation heightens immersion through cohesive audiovisual design (Cutting, 2016). The visual design of movies uses cinematography and special effects to craft stimulating environments close to reality (Giordano et al., 2015). Researchers showed consistency and visual coherence style are important to keep an audience immersed and reduce confusion (Ydewalle & Rensbergen, 1989; Mittell, 2006). Moreover, the inclusion of auditory stimuli such as music, soundtracks, dialogues and sound effects contribute overall to immersion in the context of cinema (Turchet et al., 2021; Ideguchi & Muranaka, 2007). The combination of both stimuli are auditory stimuli are key elements to deeply immersive environments due to thoughtful design and shaping how viewers perceive during movie viewing (Nowak & Biocca, 2003). Therefore, it is crucial to consider how the overall design, space, visual and audio work to make a movie feel immersive (Giordano et al., 2015). Lastly, the addition of haptic technology to these existing movies may further enhance immersion in users by adding a tactile dimension to sensory engagement (Levin & Baker, 2017). When tactile feedback is incorporated; the feeling of vibrations, motions and textures can deepen the connection between the user and the movie content (Visch et al., 2009; Danieau et al., 2013). The integration of all these sensory components can create a more impactful and immersive experience by allowing viewers to feel physical sensations that correspond to events or elements within the movie (Eid & Osman, 2015). For example, a scene with a character experiencing an earthquake would mean that the audience can experience the vibration of the earthquake with the intensity increasing according to the scene while hearing a loud noise and seeing movement in the movie. These allow for a more captivating and engaging experience that connects with the audience on a deeper level than if they were shown only audiovisual cues (Eid & Osman, 2015).

Moreover, when integrating haptic technology, there should be consideration of how tactile sensations complement the visual and auditory components of the movie (Nesbitt, 2005). When tactile stimuli are well integrated they can foster engagement, immersion, realism and emotional resonance as opposed to when these stimuli are poorly synchronized (Karafotias et al., 2017).

3.0 Previous Movie Characteristics/Design Research

Films do not mirror the real world; even the sounds and the effects are elements that are only mimicked and crafted by movie designers rather than direct replicas (Knight-Hill, 2019). The narrative of a movie and its design are two independent components that work together to create an immersive cinematic experience (Levin & Baker, 2017). Key elements that contribute to the overall impact of the film include themes/genre, emotional resonance and sound design. To bridge the gap between cinematic representation and reality, there needs to be a balance in communicating actions and effects while keeping in line with the subjective experience of the audience (Schneider, 2017).

The notion that films, irrespective of their genre, consist of various types of scenes and understanding the structure of these scenes helps understand the dynamic of the movie (Liu et al., 2020). A movie encompasses a wide range of scenes where each scene is designed to accomplish a role within its own narrative (Israr et al., 2014). These can include but are not limited to action, musicals, horror, comedy, flashback and more. Recognizing that a film can encompass diverse scene types not only ensures scene diversity but also contributes to an engaging cinematic experience (Visch & Tan, 2009). Existing literature proposes that action scenes are well suited for haptic technology, primarily due to action sequences being characterized by fast-paced movement (Liu et al., 2007). Implying action movies to be the most optimal candidate for leveraging haptic technology. Nevertheless, the application of this technology has other potential beyond simply action movies. It holds the potential to enhance the viewer's immersion in crucial scenes that try to convey more depth or nuance in non-action movie contexts, creating an immersive feeling in its users. Despite current research indicating that haptics do enhance movie immersion, there exists a research gap focused on identifying which scenes are best optimized for haptic technology (Lemmens et al., 2009; Lankinen et al., 2016). Moreover, there is a lack of research investigating the design elements that contribute to enhancing immersive experience. Considering different movie characteristics would allow filmmakers and designers to explore how there are diverse elements including haptic cues to contribute to immersion (Liu et al., 2020; Kataria & Kumar, 2016). It would also provide insight into the techniques that are effective for specific genres and help optimize the cinematic experience of the audience. These could also allow movie designers to know how they could put emphasis on certain features when integrating haptics into their audiences' cinematic experience (Israr et al., 2014). This presents an opportunity for further investigation, offering filmmaker insights and new techniques to enhance viewer immersion across a very broad spectrum of scenes.

3.1 Action vs. Non-action Scenes Differences with Haptics

Action scene narratives are accompanied by fast-sequence, high-energy and intense visuals that have a role in the sensory dimension of a moviegoer's experience (Liu et al., 2007). The audience experiences a feeling of adrenaline and excitement as a result of these fast-paced sequences (Gasselseder, 2014). Whereas non-action scenes encompass a larger range of genres such as drama, comedy, romance, science fiction fantasy focusing on emotional storytelling. The narrative of action sequences can be represented by the intensity, vibration or motion corresponding to the scene sequence (Gaffary & Lécuyer, 2018). Whereas, non-action scenes focus on the cinematographic and storytelling techniques to convey the emotion or atmosphere of the story (Gasselseder, 2014). These are also depicted in nuanced performances that evoke immersion in their audience in a deeper engagement.

Haptic technology has the potential to convey feelings by using stimuli that are sensations depicted in non-action movies (Petersen, 2019). Tactile stimulation has also been shown to play a role in the perception of the user such as the perception of vibration, pressure and temperature felt by users (Espenhahn et al., 2020). Not only that researchers are interested in knowing if this type of technology can increase immersion but they are also interested in knowing if the pairing of this technology could alter the viewer's perception of the narrative (Barrass, 2006).

Passive movies can be represented in different ways with haptics to represent the environment or elements within the fictional world within the narrative (Barrass, 2006). Moreover, haptic technology has the potential to convey passive feelings in non-action movies by producing haptic feedback that corresponds to the emotion or sensations that are depicted in movies (Venkatesan & Wang, 2023; Viswanathan et al., 2011). These elements can be represented by haptics in three different ways: temperature sensations, texture stimulation, and pressure or weight vibrational feedback (Barrass,2006). It can simulate different temperature sensations by trying to convey feelings of warmth, coolness, or breeze (Dalsgaard et al., 2022). It can be quite tricky since haptic technology makes sure to use tactile and motions to convey this feeling, however, there is one way this can be approached. The vibration patterns can be used to represent different concepts of temperature for instance, gentle motion can be associated with breeze while rapid vibration could convey heat (Viswanathan et al., 2011; Dalsgaard et al., 2022). Visual and audio cues help enhance the realism and the viewer's understanding of temperature (Gonçalves et al., 2022). To represent speed and different textures can be conveyed by haptics simulating different tactile sensations by increasing or decreasing the intensity or frequency of movements that carry the sense of movement and velocity (Gaffary & Lécuyer, 2018; Alma et al., 2021; Giordano et al., 2015). These are also achieved by creating a rhythmic vibration or movement that mimics speed such as sliding or gliding and by the use of a visual element which corresponds to the user's perceived speed in a fast-paced sequence (Lankinen et al., 2016). The integration of sound allows cues for fast-moving or slow-paced motions to enhance the viewer's perception of speed. Moreover, the texture and visuals of the movie sequence can convey the feeling of smoothness or roughness (Cavdan et al., 2021). In order to convey pressure or weight to the audience it needs to apply pressure or resistance to the viewer experience (Liu & Shen, 2022). Vibrations in higher or lower intensities can portray the feeling of heaviness or lightness of objects.

There has been research conducted on the effects of action movies in relation to haptic technology that suggests increased immersion and emotional reactivity (Alma et al., 2021; Yilmaz et al., 2023). Most studies make use of subjective measures (i.e. questionnaires) or physiological measures to measure heart rate or skin conductance (Hammoond et al., 2023). However, studies in this area are very limited so far, showing how haptic technology can enhance a user's emotional engagement and immersion in non-action movies (Alma et al., 2021). Yilmaz and colleagues (2023) for instance have found that non-action movies or sequences can lead to feelings of emotional resonance, immersion or connection with characters. Moreover, there has not been much haptic technology that has been able to properly convey passive sensations to moviegoers due to the challenge of conveying abstract concepts and the subtle nuances of storytelling (Israr et al., 2014; Astrinaki, 2012). Additionally, most studies have made use of subjective measures and lack neurophysiological evidence to suggest how users experience immersion when haptic technology is involved (Agrawal et al., 2019). This led us to question how haptic technology could be used to impact the immersive journey of its users in non-action movies (Cannavò et., 2023).

3.2 Riding vs. Not Riding Scenes Differences with Haptics

The difference between a character riding something and not riding something may have an impact on the immersiveness of the audience during movie watching (Marshall et al., 2019). While exploring literature on filmmaking, optimizing haptic feedback is suggested to be done according to scene characteristics and uses the advantage of the unique sensory dimensions provided by haptics (Wang et al., 2019). It relies on tactile and motion sensations to match the mood or content of the narrative rather than relying on traditional camera work (Yilmaz et al., 2023; Branje et al., 2014). Traditional camera work in movies uses a passive observation of the audience which offers only a visual and auditory perspective. In the realm of haptic design, it becomes imperative for designers to meticulously consider the chosen vehicle type, seeking to replicate the corresponding sensation and forces (Gaffary & Lécuyer, 2018). For example, when a character is riding something like a vehicle it may give the sensation of movement or physical engagement that contributes to the sense of immersion. This involves a nuanced approached encompassing factors like vibration, acceleration, deceleration, turning, leaning, surface texture (i.e. bumby, flat, uphill, downhill), and material (i.e. pavement, gravel, sand) through which the character traverses (Eldeeb, 2020). These elements not only propel the narrative but also evoke feelings such as emotion, immersion and suspense which profoundly impacts to visual and dynamic of cinematics (Karafotias et al., 2017). Moreover, haptic feedback can extend beyond the camera work and allow viewers to sense actions and events that are outside their visual field (Zika, 2019). Moreover, the change in speed or movement can stimulate a visceral experience in viewers which in return can evoke the feeling of excitement or engagement (Eldeeb, 2020; Zika, 2019).

There is limited knowledge on how the effect of riding vs. not riding can have an impact on the audience's level of immersiveness (Zika, 2019; Marshall et al., 2019). Moreover, they do not provide a comprehensive understanding of how haptic technology may contribute further to immersion however, there is potential for it. Haptic feedback may create distinct sensory experiences such as riding, and vibration in riding scenarios compared to non-riding scenarios which would potentially enhance immersion.

3.3 Music vs. Non Music Scenes Differences with Haptics

Sound design plays an important role in cinematic storytelling, influencing the viewer's perception and immersion in movie scenes (Choi et al., 2023; Salselas et al., 2019). Moreover, sounds in movies are designed with considering the tempo to create different feelings (Venkatesan & Wang, 2023). Music, dialogues, ambient sounds and sound effects in movie scenes are integral to the narrative, creating the illusion of viewer presence and perspective (Choi et al., 2023; Salselas et al., 2021; Giroux et al., 2019).

Music, as a fondamental component of movies, has demonstrated its positive impact on enhancing attention and viewer immersion (Choi et al., 2023). Additionally, the incorporation of music into immersive environments has been a subject of research, seeking to understand design strategies and the utilisation of sound components to capture the attention of the audience (Zhang & Fu, 2015; Choi et al., 2022). Existing literature suggests the significance of synchronizing sounds, such as music and ambient background noise, with visuals to augment immersion (Poeschi et al., 2013). Poeschi and colleagues, found that maintaining perfect synchronization of sound at medium to large audio levels with visuals led to increased immersion levels. The integration of haptic technology with sound design enables designers to explore diverse aspects, including the physical and psychological dimensions of sound. This versatility allows designers to evoke immersion, specific emotions, and elicit desired reactions from the audience (Salselas et al., 2012). Overall, the integration of haptic technology with audiovisual input has further enhanced immersive experiences, but proper alignment is crucial for optimal results (Gibbs et al., 2022). Studies, like Venkatesan and Wang (2023), have explored tactile experiences in musical contexts, emphasizing the importance of thoughtful integration necessary for enhancing immersion.

Using music in movie scenes is a unique way to convey information compared to non-music scenes because they focus their attention on different components in the narrative (Poeschi et al., 2013). Scenes using music typically integrate songs, dances or fast/slow tempo into the narrative and create a distinctive immersion for the viewers (Turchet et al., 2021; Mazzoni & Bryan-Kinns, 2015). Scenes using music have been suggested to trigger multisensory responses because they combine visual and auditory components (music and vocals) and choreography that can deeply immerse viewers into the story. Music scenes or operatic music have the ability to evoke immersion, emotions and feelings that cannot be captured with words alone (Herget, 2021). This contributes to the overall intended emotional immersion context in a narrative and benefits the auditory perception (Ross et al., 2022). Literature looking at the narrative between music scenes and non-music scenes has shown that movies with music sequences have a more dynamic transition and a smoother narrative flow between scenes (Ma et al., 2021; Gasselseder, 2014). Moreover, scenes making use of music have the ability to grab the attention and encourage the audience to participate through the use of catchy tunes and memorable lyrics (Gasselseder, 2014). Non-music movies can also achieve immersiveness through different cinematic techniques and storytelling approaches. Instead of using music to enhance the user's experience, filmmakers have tried to rely on different aspects like visuals and realism to enhance the user's experience (Poeschi et al., 2013; Salselas et al., 2012).. In non-music films the narrative often prioritizes realism and authenticity and creating a more believable environment helps to create a more immersive narrative. Both types of scenes seem to have different strategies to captivate and involve the audience in different manners (Ma et al., 2021).

The use of music and cinematic experience helps create a vivid and more engaging immersive world as opposed to non-music sequences (Gasselseder, 2014). Instead, they make use of different storytelling techniques to give the audience an immersive experience. The literature seems to suggest that music and non-music sequences have their own potential ways to be immersive however it still remains that not a lot is known about whether music with the use of haptics will elicit higher levels of immersion as opposed to non-music scenes (Gibbs et al., 2022).

3.4 High-Intensity vs. Low-Intensity Scene Differences with Haptics

Movie scenes that have high intensity can be more immersive than low-intensity scenes because they stimulate more sensory and emotional components thereby shaping the viewer's experience (Kataria & Kumar, 2016; Tikka & Laitinen, 2006). These different types of movie scene intensity contribute to immersion in different manners. High-intensity scenes are characterized by tension, strong emotions such as fear, excitement or empathy, suspense and action. Moreover, intense scenes often make use of dynamic visuals, rapid camera movements, impactful sound effects, and heightened emotions (Iosifyan & Korolkova, 2019; Karafotias et al., 2017). This engages multiple senses therefore increasing the immersion towards the movie scenes. However, haptics may not always be optimal in certain movie scenes (Kataria & Kumar, 2016; Cutting et al., 2016). In some scenes, it is already emotionally or visually intense the use of haptics can overwhelm the user's sensory perception and distract their attention away from the storyline (Israr et al., 2014). Despite this technology holding great potential to create an immersive experience it may need to be used more selectively depending on the content since it may not be optimal for movie watching (Israr et al., 2014, Tikka & Laitinen, 2006).

4.0. Haptic Touch to Immersion

Using haptics allows us to have a closer connection to our movie-viewing experience as opposed to having a cinematic experience that is distant and purely audiovisual (Horton, 2017). Cinematic tactility in a cinematic context refers to the viewer's engagement with different elements in storytelling (Turchet et al., 2021). Haptics involves the use of vibration, and motion to stimulate the sense of touch by adding a tactile dimension (Eid &Osman, 2015; Eldeeb et al., 2020). It adds a sense of realism to our virtual experiences by creating the feel of textures and enhances the illusion of interacting with the environment or object which makes our experience more immersive (Tikka & Laitinen, 2006). The relationship between haptics, immersion and design are interconnected because they impact the storytelling in a movie (Israr et al., 2014). The visual cues in a movie are made to create an atmosphere or mood therefore enhancing the overall cinematic experience (Sigrist et al., 2013). The incorporation of haptic technology enhances the overall design by integrating tactile and textural elements that harmonize with the visual aspects of the movie (Turchet et al., 2021; Israr et al., 2014). This use of haptic technology adds a new layer to sensory engagement.

5.0 Measuring Immersion in Relation to the Context of Cinematics and Haptics

Measuring immersion can be done through two different approaches: Subjective and Objective (Choi et al., 2022). To begin with, both methods allow you to measure the immersive level of the audience because it can be measured by self-report tools as well as neurophysiological tools (Agrawal et al., 2021; Reaves et al., 2021). In order to understand how these can be measured some literature had to be done to support which methods would be the most appropriate to use to do so.

The assessment of immersion in the context of cinematic experiences can involve both subjective and objective measures (Choi et al., 2022). Subjective methods, primarily questionnaires used post-study, rely on participants' memory and feelings to measure the user's sense of immersion, emotional engagement and overall experience during a movie (Agrawal et al., 2020; Lønne et al., 2023; Visch et al, 2010). While self-reported surveys provide insights into users' feelings about their experience, challenges such as subjectivity and recall bias need consideration (Lonne et al., 2023). Subjective testing remains valuable, covering a spectrum of immersion-related aspects and helping in the understanding of design components (Schneider, 2017). Studies investigating the relationship between immersion and movies subjectively have shown that there is an existing link between both (Visch et al., 2010). Research suggests that engaging multiple senses during movie-watching enhances cinematic immersion and contributes to the overall experience (Visch et al., 2010; Galloso et al., 2016). They propose that the increase in immersion may be due to immersion influencing the participant's sensory dimension related to the intensity of the movie and elements thus affecting factors such as the emotional and arousal dimensions. Visch and colleagues (2010) demonstrated that manipulating different sensory and environmental features positively increases the user's emotional and scene subjectiveness during movie viewing. Additionally, the integration of different components (i.e. olfaction, tactile, visual) of 3D movies can be shown to positively influence the immersive experience. Despite these challenges, researchers, like Jennett and colleagues (2008) have shown how immersion can be measured using subjective measures, encompassing feelings of presence, engagement, emotional responses, and overall perceived immersion.

In contrast, objective measures of immersion have received less exploration but offer a promising avenue for a deeper understanding of the underlying mechanism of immersion (Schneider, 2017; Yeongmi et al., 2010). Neurophysiological measures, particularly electroencephalography (EEG), have gained prominence for their low cost, high temporal resolution, and non-invasiveness. Electroencephalography (EEG) is a non-invasive method that allows the investigation of brain activity at a low cost (Xue et al., 2010; Reaves et al., 2021). Another advantage that the EEG offers is the ability to measure the changes in the brain in real-time as it has great temporal resolution compared to other neuroimaging tools (Lim et al., 2019; Reaves et al., 2021). EEG is beneficial to studies involving immersion and haptics because EEG provides an objective measurement of brain activity and it allows the real-time monitoring of brain activity as opposed to other brain imaging tools (Lim et al., 2019; Baceviciute et al., 2021). EEG is also a tool that allows the assessment of cognitive assessment such as attention, engagement and emotional responses which is a phenomenon suggested to be linked with immersion (Hofmann et al., 2021). Moreover, it will provide an objective measure of the underlying mechanism related to immersion while relying on subjective measures (Park et al., 2022; Reaves et al., 2021; Kang et al., 2015). Various frequency bands in EEG are used to represent distinct brain activities: Delta (1-4 Hz), theta (5-7 Hz), alpha (8-12 Hz), beta (15-29 Hz), and gamma (30-40 Hz) (Haegens et al., 2012). As this study is not intended for individuals with sleep disorders or neurological disorders, the study will focus on theta, alpha and beta waves and exclude delta and gamma from the EEG analysis (Lim et al., 2019). Recent work on immersion demonstrates that EEG can be used to record brain activity, enabling researchers to observe cortical changes (Abromavicius et al., 2017; Baceviciute et al., 2021). Moreover, given the association between cognitive immersion, engagement and directed attention it is feasible to use neuroimaging tools to investigate this phenomenon (Lim et al., 2019; Baceviciute et al., 2021).

Moreover, EEG studies have explored brain oscillation such as theta, alpha and beta to understand how these are influenced in the cinematic context (Abromavicius et al., 2017; Baceviciute et al., 2021; Danieau et al., 2013). Theta so far has been associated with sensory processing, alpha with attentional shifts and engagements. Additionally, beta oscillations have been associated with focused mental activity (Friese et al., 2016). The integration of subjective measures, like questionnaires, with neurological measures provides a comprehensive understanding of immersive experiences and cognitive processes (Park et al., 2022; Reaves et al., 2021). Researchers have been studying the neuroanatomical associations of subjective immersion while manipulating users' senses through audiovisual stimuli and now newly integrating haptics (Bouchard et al., 2012;Van Diepen et al., 2019).

The evidence behind the subjective enhancement of immersion experiences has prompted researchers to investigate the effects of HFVK technology on the brain (Venkatesan & Wang, 2023; Boasen et al., 2020). While the exact effects are still unknown, researchers have tried to investigate the neurological mechanism underlying immersion, given that haptic technology stimulates the vestibular and somatosensory systems (Peterson, 2019). There is evidence suggesting that HFVK/vibrotactile stimulation can influence cortical activity during the viewing of audiovisual content (James et al., 2007; Angelaki et al., 2009). The use of neurological tools can help provide insights into neural processing as well as the cognitive process users have when they are engaged in immersive experiences (Kang et al., 2015). Moreover, this will provide an insight into whether some characteristics can better enhance immersion than others (Perterson et al., 2022).

5.1 Consequence of Haptic Enhanced Immersion

Theta activity has been known to be commonly linked to memory and emotion regulation nevertheless, studies have revealed that theta is also involved in encoding information during spatial navigation and exploratory movement (Abromavicius et al., 2017; Baceviciute et al., 2021). The use of HFVK and audiovisual stimuli triggers the sensory processing system, engaging the bottom-up processing mechanism. Theta synchronization has been associated with the bottom-up system during the processing of auditory and visual stimuli (Abromavicius et al., 2017). The observed theta-related evidence indicates a potential association between these changes and sensory processing in the context of haptic sensory stimulation. Studies aligned with sensory processing research propose the involvement of the sensorimotor cortex in handling immediate somatosensorial information, including tactile and proprioceptive input. This is underscored by the implication of the theta oscillation in various functions that are related to multisensory experiences, divided attention and cognitive control (Cavanagh &Frank, 2014;

Cavanagh et al., 2010). Theta oscillations have been implicated in various functions in the context of multisensory divided attention, such as audio-visual integration and cognitive control (Cavanagh et al., 2010). Furthermore, theta activity in the occipital lobe is suggested to be associated with visualization and the processing of mental imagery.

Alpha is one of the most dominant oscillations observed during EEG (Van Diepen et al., 2019). It has been shown to be involved in the process of attention as the power of alpha has been shown to be modulated by different attention tasks (Souza & Naves, 2021; Van Diepen et al., 2019). Desynchronized alpha has been linked to visual and auditory attention (Klimesch et al., 1998). Studies have suggested that alpha has a significant role in attention and perception (Shen et al., 2022). A large body of literature in line with current studies suggests that alpha desynchronization during externally directed attention is observed in parieto-occipital regions (Souza & Naves, 2021; Van Diepen et al., 2019). Moreover, decreases in alpha are observed in the sensorimotor region during sensorimotor tasks and movement (Mann et al., 1996).

Beta oscillations (15- 29 Hz) are dominant when attention is directed toward cognitive tasks and the external environment (Quandt et al., 2013; Quandt et al., 2014). Moreover, these are reflected in a state of alertness, attentiveness and during mental effort. It is important to consider beta oscillations in the context of haptics because the use of motion and vibration are associated with engagement and focused attention (Biau & Kotz, 2018; Quandt et al., 2013; Kang et al., 2015). Additionally, beta oscillations are one of the most studied frequency bands when it comes to sensorimotor activity. According to the literature, it is important to consider regions of the brain that involve the integration of sensory information, motor execution or planning (Liu & Shen, 2022). One of the regions involved in processing tactile sensations is the primary somatosensory region (Kim et al., 2021; Liu & Shen, 2022; Alsuradi et al., 2020). Although the exact neural mechanisms can vary depending on the nature of haptics there is also literature suggesting this area to be involved in the processing of haptic stimuli (Ng et al., 2020). There are suggestions that changes in beta can be experienced due to the tactile input.

Haptic technology involves the stimulation of different senses by using the sense of vibration, tactile feedback and motion (Petersen, 2019; Petersen et al., 2022). Moreover, it involves the somatosensory system which is involved in the processing of touch as well as proprioceptive information. This has been shown to be associated with the somatosensory cortex and the parietal lobe which have been shown to have a role in processing information related to the sense of touch (Gharabaghi et al., 2014; Danieau et al., 2014). These regions help distinguish the different aspects of touch such as texture, shape and the level of pressure applied on the skin (James et al., 2007). Moreover, literature on touch perception has suggested that when other modalities such as sight and hearing are combined it allows a unified and holistic multisensory experience (Schaefer et al., 2006; Rostamian et al., 2022). Thus, the integration of haptic allows to further enhance the perception of realism (Tikka &Laitinen, 2006). Further, research in this field may help with the combination of audio and visual may help better understand how the integration of tactile stimuli with other sensory modalities works (Venkatesan & Wang, 2023; Luo & Poeppel, 2012). It would allow them to further develop haptic technology that could create more realistic and immersive designs for their users.

Finally, experiencing immersion in movies can significantly influence how we perceive time, impacting the cognitive, immersive and emotional dimensions (Visch & Tan, 2009). In a cinematic narrative, the audience may lose track of time, as well as their awareness of the real world can diminish and create a distorted sense of time passage (Gavazzi et al., 2013). Filmmakers use various techniques, including haptic technology to manipulate time perception for their artistic purposes. Unlike traditional methods of viewing it adds a sensation of presence, thus intensifying the feeling that the movie is trying to convey such as speed or weightlessness (Gavassi et al., 2013; Haegens et al., 2012; Kropf et al., 2019). Moreover, the perception of time distortion includes changes in velocity, temporal frequency, and visibility (Gavazzi et al., 2013).

6.0 Hypotheses Development

The present study aims to better understand how haptics can convey the narrative in non-action movies. Since the integration of haptic feedback in non-action movies has the potential to enhance the immersive experience of the audience, it may be beneficial to understand to what extent these could be felt. Moreover, it would be important to identify the underlying neurophysiological mechanism of these HFVK stimulations during cinematic (AV) immersive experiences by using neurophysiological measures.

Thus, it is hypothesized that :

H1: HFVK stimulation, compared to no HFVK stimulation, will psychologically increase immersion.

H2: HFVK stimulation, compared to no HFVK stimulation, will increase neurophysiological attention and sensory integration processing.

H3: The neuropsychophysiological effects of HFVK stimulation will differ according to the characteristics of the movie scene for which they were designed.

It is hypothesized that those in the HFVK group will experience increased perceived immersion as opposed to those in the control group. It is also hypothesized that individuals in the HFVK group would have increased activity in the underlying neurological mechanism associated with attentional processing and tactile stimuli. To test these hypotheses this study will make use of EEG to investigate the neurological mechanism that may be influenced by HFVK stimulation. This research is important because the incorporation of haptics in immersive experiences can provide users with increased customer satisfaction. Moreover, these would allow us to enable user experience in different aspects such as realism, emotional impact, innovation and further research development.

7.0 Methods

7.1 Experimental Design

This study made use of a between-group design using a one-factor experimental design. Moreover, participants were randomly assigned into either a group that received HFVK stimulation (HFVK group; F: 5, M:2; mean age: 24.9 ± 6.0 years) or a group that did not HFVK stimulation (Control group; F:6, M:3; mean age: 29.6 ± 5.1 years). Participants were separated into either the control or the experimental group and were asked to answer questionnaires. There were no significant differences in the baseline characteristic levels of the HFVK group compared to the control group.

7.1.1 Participants

Participants were recruited via advertisements on social media (Facebook and Instagram) and by our institution's research participant pool with our lab for recruitment. Participants who were interested in the study had to complete a questionnaire to confirm their eligibility for the study.

The pre-screening questionnaire consisted of demographic questions such as age, sex, and contact information. The exclusion criteria of this study consisted of individuals who previously experienced a vibrokinetic experience (HFVK) or left-handed people. Moreover, individuals who have neurological disorders, hearing impairment and recently dyed their hair were excluded from the study. Individuals who had viewed any of the movies (AV stimuli) more than two times were excluded from the study to eliminate the effects of priming/learning. Once participants were found to be eligible to the study, they were contacted to be scheduled for the experiment at our lab. The study has been ethically approved by the Counsel for Ethics in Research of our institution and in accordance with the declaration of Helsinki. Written informed consent was obtained by all participants in the study before beginning the experiment. After screening out the questionnaires, a total of fifteen right-handed participants were recruited to participate in this ongoing study

7.1.2 Procedure

Participants interested and eligible for the study were contacted and invited to come to our lab to participate in the experiment. They were welcomed in front of the lab and seated in the room where the experiment took place. Research assistants were on the other side of the room separated by a tinted glass to give instructions and describe the study to the participants via the microphone. Participants in the HFVK group were told that the seat would vibrate and produce motions during the viewing of each clip whereas the control group was told that they would watch clips on a standard seat. Once done, they were then asked to read and sign the consent form. The participant’s head circumference was measured to select the proper electroencephalography (EEG) cap. Before installing the EEG on the participant's head, electrodes to measure the electrical activity of the heart (ECG) and electrodermal activity (EDA) were placed on the participant's left-hand and chest and lower abdomen respectively. The EEG cap was remeasured to verify the proper position and conductive EEG gel was then applied to the 32 electrode channels (actiCAP, BrainProducts, GmbH, Munich, Germany) using an applicator and impedance was checked. Captrack (BrainProducts, GmbH, Munich, Germany) was then used to digitize the position of the electrodes for each participant’s head. They were then seated in the HFVK seat which was installed in a room with blackened curtains around the HFVK seat. The research assistant went to the other side of the room to calibrate the tools used for the data collection. Once the calibration was done participants were asked to sit still for ninety seconds to get a baseline. Participants were then instructed to sit as still as possible with their eyes open facing the TV during the viewing of each movie clip and were reminded about how to complete the questionnaires after each viewed clip. All the participants in the study watched the same clips in the same order and answered the same validated immersion questionnaire after each of them. Participants in the Control group, at the end of the viewing of the clips, were made aware that there were two groups that the seat they were sitting on produced vibration and motions. They were then asked to choose two clips of their preference to view with the HFVK stimuli and were given the final questionnaire regarding their movie-watching experience to answer.

Once the participant was done the research assistant entered the experiment room to remove the electrodes and EEG equipment from the participant, and they were led to wash out the electrode gel. When participants were done washing their hair, they were asked to complete the compensation form to receive 30$ via e-transfer. They were thanked for their participation and escorted out. The total duration of the experiment was 2h30.

7.1.3 Stimuli (Audiovisual and HFVK Stimuli)

Fifteen different clips were selected from eight different movies (Arrival (2), The Secret Life of Walter Mitty (3), La La Land (2), The Shape of Water (2), A Star is Born (2), Shallows (1), Get Out (1), The Grand Budapest Hotel (2)) that were already available designed with HFVK stimuli by D-BOX (D-BOX Technologies Inc., Longueuil, Canada). This baseline period was named the "vanilla baseline". Movie clips ranged in different duration (from 103 seconds to 288 seconds) in length. Each clip was separated into three different periods: pre-stimuli, stimuli and post-stimuli period. The pre-stimuli period was a 20-second-long period in which no HFVK stimuli were placed before the stimuli period. The same applied to the post-stimuli period however, this period occurred right after the presentation of the stimuli period.Moreover, the stimuli period which was the middle section of the clip had either a stimulus or no stimuli period depending on the group (HFVK or Control). The HFVK stimuli were produced by actuators equipped with the D-BOX chair. The actuators can produce different types of motion that can replicate and coincide with the physical environment and action of the characters in the viewed clip. The clips ran with a Python script that played the selected clips on a media player on a Dell Windows 8 laptop. The laptop was connected with an HDMI to a 70 × 120 cm high-definition Samsung TV that displayed the videos. The audio was projected by Pioneer VSX-324 AV receiver and played in 5.1 surround sound on Mission 761 speakers.The audio audio markers from the speaker went straight from the receiver to the EEG trigger box. The trigger box is then directly sent and recorded as an event in the EEG recording.

7.2 Measures

7.2.1 Electroencephalography (EEG)

A 32-electrode montage was used for the purpose of this study. The EEG montage (actiCAP, BrainProducts, GmbH, Munich, Germany) was installed according to the 32ch Standard Cap layout made for the actiCAP. Conductive EEG gel was used for all participants. Moreover, electrode positions were digitized using CapTrak (BrainProducts, GmbH, Munich, Germany).

7.2.2 Measurement scales

Two different questionnaires on immersion were given after each clip to the participants: a validated immersion scale, and a new immersion scale.

Self-perceived immersiveness was assessed after each movie clip using a validated immersion questionnaire by Jennett al. (2008) by adapting the language of the questionnaire to fit the present experimental study. The original questionnaire contained 31 items on different dimensions of immersion, 11 of those items were selected to use in the present immersion questionnaire (see Appendix 1). The 11 selected items covered the following dimensions: motivation, and presence. The scale for each item went from 1 (being not at all) to 5 (being very much so). The total score of each clip was then averaged across all the clips by averaging the score between the scores of participants in the HFVK group and the control group.

The second scale contained questions regarding participants' perceived immersion of the viewed clip (see Appendix 2). This scale was used to observe if there are differences in perceived immersion between both groups to address our first hypothesis. They had to answer how they perceived the scene with the multiple choice given to them. These questions were separated into temporal and non-temporal characteristics categories. The non-temporal characteristics are elements that do not correspond to characteristics associated with the passage of time. For example, a question “Estimate the maximum speed reached by helicopter during the scene

(100km/h = 62.13 mph)” and they were given different options about the speed could select from 5 to 15 km/h, 15 to 25 km/h, 25km/h to 35km/h, 35 to 45 km/h, 45 to 55 km/h, 55 to 65 km/h. Temporal characteristics are elements that are related to the passage of time in the story or the manner in which time is depicted on screen. For example, questions on the perceived time were asked to participants “Estimate the length of time the helicopter flew over the military camp facilities.” and they were given a couple of options about time to select from 0 to 15 seconds, 15 to 30 seconds, 30 to 45 seconds, 45 to 60 seconds, 60 to 75 seconds, 75 seconds to 90 seconds.

7.2.3 Movie clip categorization

To gain insight into the design and how immersion is impacted by the audience, four different categories were used to gain insight into how it impacts the user experience in the context of cinematics and haptics. Moreover, each movie clip was separated into binary categories to compare how different components in a movie’s narrative can impact the audience's level of immersion. Four categories were used to do this: “Music vs. Non-Music”, “High-Intensity Movie Scenes vs Low-Intensity Movie Scenes”, “Action vs Non-Action, and “Riding and Not Riding” (see Table 1).

Movie clips	Arrival (Clip 1)	Arrival (Clip 2)	Walter Mitter (Clip 3)	Walter Mitter (Clip 4)	Walter Mitter (Clip 5)	La La Land (Clip 6)	La La Land (Clip 7)	Shape of Water (Clip 8)	Shape of Water (Clip 9)	Star is Born (Clip 10)	Star is Born (Clip 11)	Get Out (Clip 12)	Shallow (Clip 13)	Budapest Hotel (Clip 14)	Budapest Hotel (Clip 15)
Movie scene	Helicopter	Alien arrival	Skateboard ride	Car ride and volcano	Wind	Dancing in the museum	Dancing in the planetarium	Creature scare	Dancing with creature	song performanice	car ride	chair sinking	wave motion	train ride	sled ride
Action/Non action	🟩	🟩	🟩	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟩
Riding/No Riding	🟩	🟥	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟩	🟩
Music/No music	🟥	🟩	🟥	🟥	🟥	🟩	🟩	🟥	🟩	🟩	🟥	🟩	🟥	🟥	🟥
Low Intensity/High Intensity	🟥	🟩	🟩	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟩	🟥	🟥	🟩

Table 1. *Movie clip classification table of the fifteen clips from 8 movies shown to participants between the four movie categories. The green indicates the first option in the table and the red indicates the second option of the table per clip.*

8.0 EEG Analysis

8.1 EEG Recording and Pre-Processing

The EEG analysis of the raw EEG data consists of preprocessing the signals such as filtering, removal of artifacts and a spectral analysis to look at the activation of each frequency band. EEG gets affected by noise by physical and non-physiological artifacts such as muscular movement, large sources of noise, blinks and movement and objects that may have electrical interference. EEGs were recorded raw at a 500 Hz sampling rate using BrainVision recorder (Brain ProductsGmbH, Munich, Germany) and processed using an open-source application made for the analysis EEG, MEG, sEEG, ECog data called Brainstorm. Brainstorm was run via MATLAB 22a (MathWorks, Natick, MA, USA). Before starting the EEG analysis, the data had to be pre-processed by removing any unnecessary signals and dead or noisy electrodes manually removed through independent component analysis (ICA). ICA allows the separation of the independent component contained within a signal to remove noise. Additionally, ICA is used to remove EOG and ECG components using the typography of the ICA components. Then, pre-processed by running an independent ICA to separate independent signal sources such as blinks and heartbeat artifacts that may interfere with EEG data. In order to preprocess the signals a low-pass and high-pass filter (1-40Hz) needed to be added to cut out frequencies below 1 Hz and frequencies above 40 Hz. The event markers of each pre-stimuli and post-stimuli period were marked for each clip. The baseline and post-stimuli periods were marked at three-second intervals and epoched at -1000 to -4000 ms relative to each marker by using a MATLAB script. This allowed for the period before and after the vibrokinetic (VK) stimulation to be separated into smaller time segments for the analysis. One baseline period was collected before the presentation of the movie clip (see Figure 1). The baseline had a duration of 90 seconds and resulted in 30 epochs of three-second duration for the analysis. As for the post-stimuli period, each clip had a duration of 20 seconds and was separated into three-second epochs meaning that on average six epochs were produced per clip for the post-period period. Thus, in total the post-period resulted in 86 epochs. The baseline and post-stimuli epochs were then visually inspected, and epochs were rejected if EEG amplitudes exceeded -/+ 100 microvolts. A noise covariance matrix, which is a 60-second noise-free period, was created from their baseline period where participants are shown no stimuli for each participant. Then, using the digitized position of the electrodes from Captrack (Brain Products GmbH, Munich, Germany), the position of each electrode was registered on a brain model/template for each participant. The EEG model excluded rejected electrodes during the pre-processing. Then, sources were computed to create an inverse kernel for each participant using minimum-norm imaging, density map option and an unconstrained model. This allowed us to run a source-level time-frequency decomposition for each epoch on each participant in the theta (5-7 Hz), alpha (8-12 Hz), and beta (15-29 Hz) bands via Hilbert transform. The time-frequency envelopes for each band were averaged across epochs for each participant for baseline and post-stimulus periods separately. The envelopes for the amplitude of the time-frequency envelopes for each signal were standardized across participants. Finally, mean post-stimulus cortical activity was normalized as a percent deviation of mean baseline cortical activity by using the following formula $Xstd = x-\mu / \mu \times 100$. Here, x stands for the amplitude of the time-frequency envelope for each timepoint and μ for the time average over the baseline period. The standardized time frequency was then used to average each time three second period across brain areas for each subject to be used for statistical analysis.

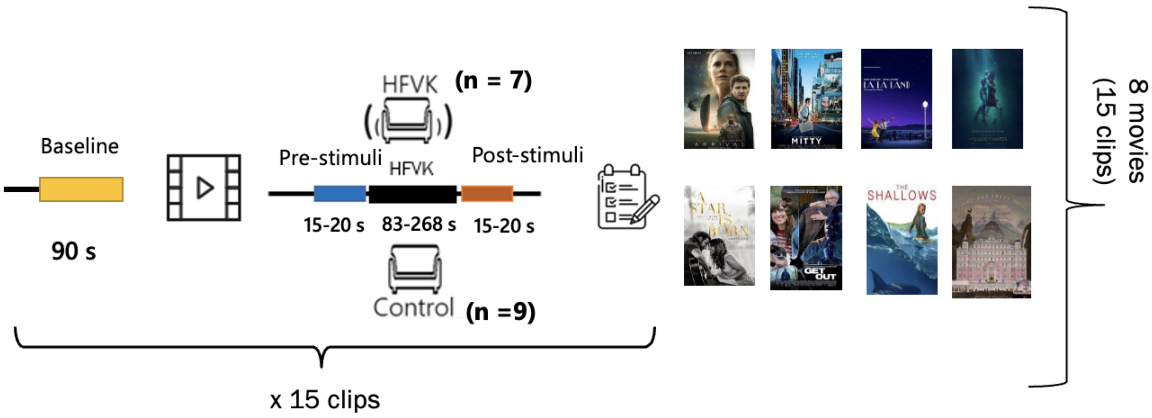

Figure 1. *EEG segments in between movie scenes.*

9.0 Statistical Analysis

9.1.1 Immersion Score

The total score across the 11 items was calculated by adding the value of each item for each clip. The total score of each clip was then averaged across all the clips by averaging the score between the scores of participants in the HFVK group and the control group. Then, an independent t-test was done using SPSS by using a script (version 22, IBM, Armonk, NY, USA) by using the total average score from the immersion questionnaire. A significance level of $p \leq 0.05$ was used for the statistical test.

The second unique immersion questionnaire on participants' perceived physical characteristics of the viewed clip total was calculated by attributing a number to each option. Each option was listed in ascending order and was numbered from one to six. These were then separated into temporal and non temporal characteristic categories and an independent t-test was conducted.

9.1.2 Immersion and Movie Characteristics

Statistical analyses were performed using SPSS version 26 (IBM, NY, USA) to analyze the effects of different movie characteristics on the level of immersiveness between the experimental and the control group. A comparison of means between immersion levels was conducted to observe the difference between four different categories: Music vs. Non-Music, High-Intensity Movie Scenes vs Low-Intensity Movie Scenes, Action vs Non-Action, and Riding and Not Riding between the HFVK and the control group. A significance level of $p \leq 0.05$ was used for the statistical test.

9.1.3 Cortical Activity Analysis

The effect of HFVK on cortical activity was tested by comparing cortical activity between groups using a voxel-wise independent t-test performed in SPM12 for each frequency band separately using a height threshold of $p < .05$ (uncorrected), and a cluster defining threshold of $p < .001$(uncorrected) with an extent threshold of 50 voxels and clusterwise significance determined at $p < .05$ (FWE corrected). One participant's EEG data had to be excluded due to noisy EEG data.

In the event of significant clusters, posthoc repeated measures analyses of variance were conducted using SPSS (IBM, Armonk, NY, USA) to compare with the different frequency band activity (i.e theta, alpha and beta) in each cluster between groups according to each two-level movie characteristics factor separately (i.e., Music vs. Non-Music, High-Intensity Movie Scenes vs Low-Intensity Movie Scenes, Action vs Non-Action, and Riding and Not Riding. A significance level of $p \leq 0.05$ was used for main factors and $p \leq .1$ was used for interaction effects. In the event of a significant interaction, pairwise comparisons were performed with p values corrected via Bonferroni correction.

10.0 Results

10.1 Immersion

The HFVK group exhibited significantly higher immersion levels in the self perceived validated immersion scale (M = 38.18, SD = 0.74) compared to the control group (M = 29.95, SD =2.08), with a p-value of 0.004 (see Figure 2). Thus, supporting hypothesis H1, suggesting that HFVK technology exhibit higher levels of immersion compared to those in the control group.

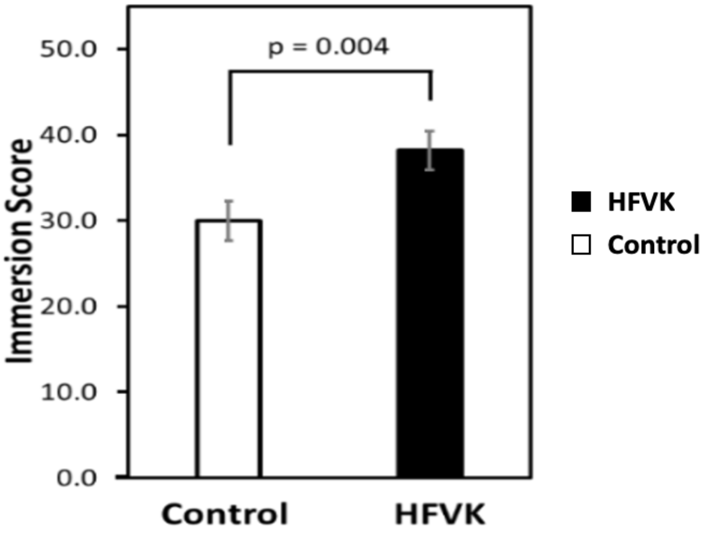

Figure 2. *The mean difference between control ($n_{control}=9$) and HFVK ($n_{HFVK}=7$) groups.*

The second unique immersion questionnaire on perceived physical characteristics on temporal and non-temporal characteristics (see Figures 3 & 4, respectively) shows individuals in the HFVK group to have higher perceived temporal characteristics (M = 3.42, SD = 0.56) than individuals in the control group (M =3.10, SD = 0.74). The results show that there is statistical significance p = 0.05. Moreover, the HFVK group (M= 4.42, SD = 0.77) showed a greater level of perceived non-temporal characteristics than the control group (M = 3.86, SD = 0.76) but no statistical significance with a p-value = 0.194. Thus, further supports the H1 hypothesis suggesting that HFVK technology will exhibit higher levels of immersion.

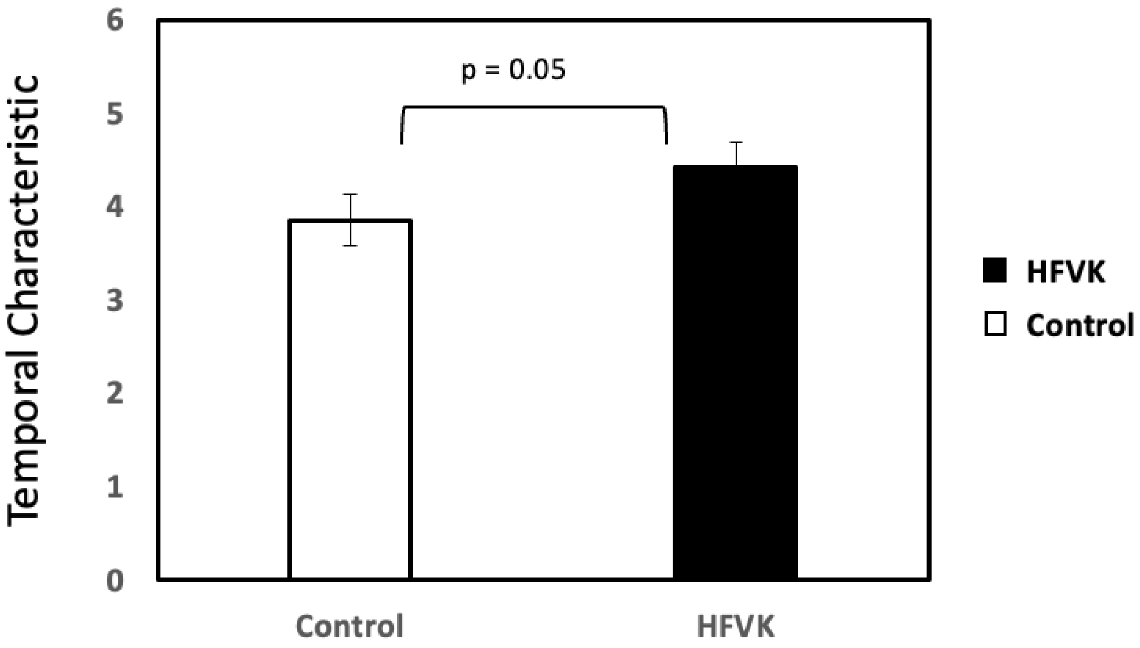

Figure 3. *Temporal characteristics mean per group ($n_{control}$=9, n_{HFVK}=7).*

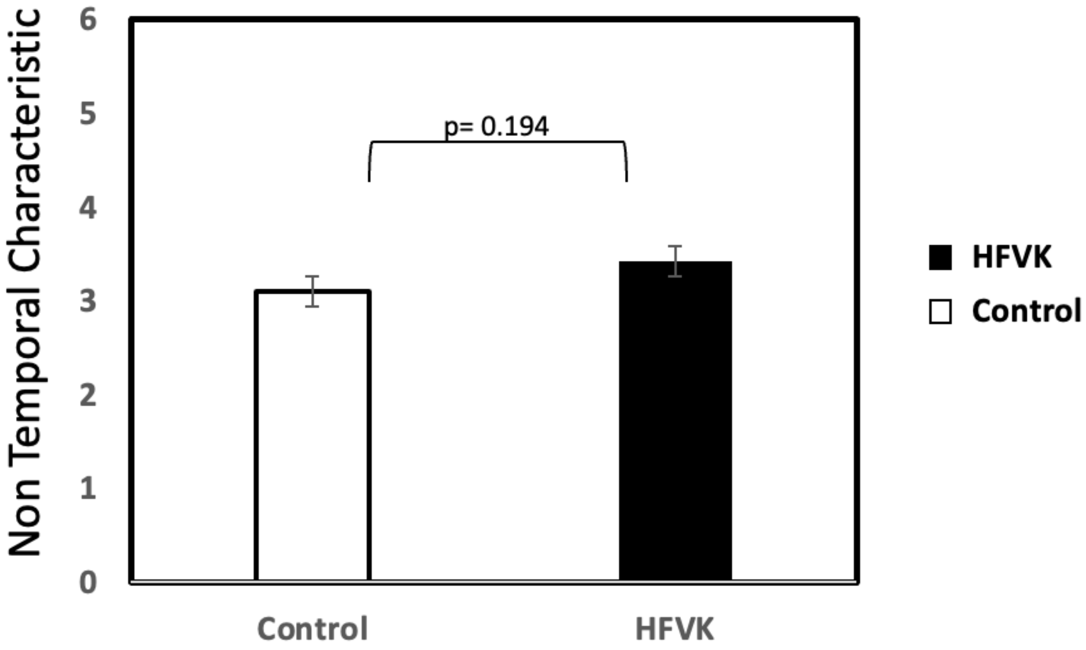

Figure 4. *Non-temporal characteristics mean per group ($n_{control}$=9, n_{HFVK}=7).*

10.2 Immersion and Movie Characteristics

In order to test for the H3 hypothesis, the mean immersion score by clip characteristics (i.e. action vs. no action, music vs. nomusic, riding vs no riding, low vs high intensity) and a repeated measure ANOVA had to be conducted to compare within subjects factors and between subjects factor of group.

Action vs. Non-Action

The results of action vs. non-action showed a significant main effect of characteristics on immersion (F $(_{1,14})$= 7.482, p = 0.016, ηp2 = 0.348). Moreover, the main effect of the group (i.e. HFVK vs. control) was observed to be marginally significant (F $(_{1,14})$ = 4.490, p = 0.052, ηp2= 0.24). The interaction between movie characteristics (action vs. non-action) and the group was not statistically significant (F$(_{1,14})$ = 1.115, p = 0.309, ηp2 = 0.074) suggesting that the relationship between characteristics and immersion did not significantly differ across groups (see figure 5).

Low Intensity vs. High Intensity

The results comparing low vs. high intensity characteristics revealed a substantial impact on immersion ($F(_{1,14}) = 129.277$, $p < 0.001$, $\eta 2 = 0.902$). The main effect for group (HFVK and control) did not reach statistical significance ($F(_{1,14}) = 3.073$, $p = 0.101$, $\eta 2 = 0.180$). Furthermore, the interaction between characteristics and groups ($F(_{1,14}) = 7.815$, $p = 0.014$, $\eta 2 = 0.358$) indicated a statistically significant relationship between these variables. In a pairwise comparison, a mean difference of -.3492 was observed between the control and HFVK groups. Specifically, there was a significant difference in the high-intensity characteristics and group (i.e., HFVK and control) ($\beta = -5.163$, $p = 0.034$), while no statistical significance was found for the low-intensity group ($\beta = -1.821$, $p = 0.034$) (see Figure 5).

Music vs. No Music

The results regarding music vs. no music demonstrated a significant main effect ($F(_{1,14}) = 7.184$, $p = 0.018$, $\eta p2 = 0.339$). Additionally, there was a significant main effect observed for groups ($F(_{1,14}) = 4.779$, $p = 0.046$, $\eta p2 = 0.254$). However, the interaction between music vs. no music and groups was not found to be significant ($F(_{1,14}) = 0.001$, $p = 0.977$, $\eta p2 = 0.000$), suggesting that the impact of music vs. no music did not significantly differ across groups.

Riding vs No Riding

The main effect of characteristic (i.e. riding vs no riding) is statistically significant on immersion ($F(_{1,14}) = .324$, $p = 0.021$, $\eta 2 = 0.324$). The main effect of the group has shown to be statistically significant at ($F(_{1,14}) = 4.674$, $p = 0.048$, $\eta 2 = 0.250$). The interaction effect between riding vs. no riding and groups is not significant ($F(_{1,14}) = .0.181$, $p = 0.677$, $\eta 2 = 0.013$).

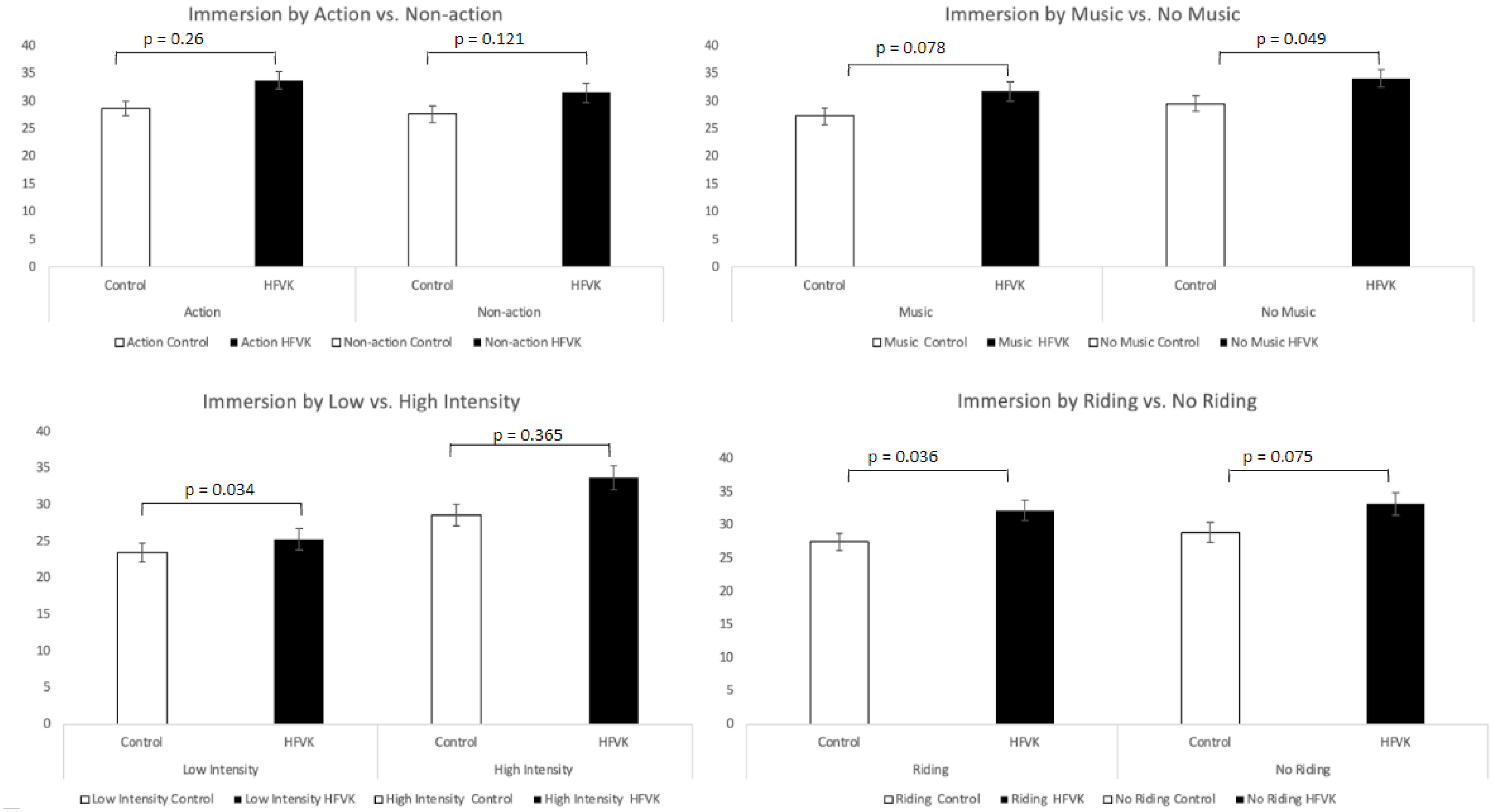

Figure 5. *Movie characteristics by immersion score per groups* ($n_{control}$=9, n_{HFVK}=7).

10.3 Cortical Activity Results

To test hypotheses H2 and H3 a SPM12 by voxel-wise analysis was conducted to investigate the relationship between cortical activation patterns associated with movie characteristics (see Figures 6 & 7). Notable regions such as the inferior temporal cortex for beta and one region for the inferior parietal cortex for theta were significant; all significant clusters surpassed a voxel-wise threshold of $p < 0.001$ and FWE (family-wise error corrected) of $p < 0.05$. This results partially supports H2 as increased activity was found in the inferior regions associated with sensory integration. However, no increased activity was found to be associated with the inferior temporal cortex. The coordinates of the significant brain activity in the cluster were then used to test H3 to see whether the neuropsychophysiological effects of HFVK stimulation will differ according to the characteristics of the movie scene for which they were designed. Moreover, theta and beta activity were extracted from clusters which were significantly different between the HFVK and Control groups. The overall cluster activities mean and overall movie characteristics mean (i.e. action vs. no action, riding vs. no riding, music vs. no music, low and high intensity). One participant from the HFVK group was excluded due to noisy EEG data.

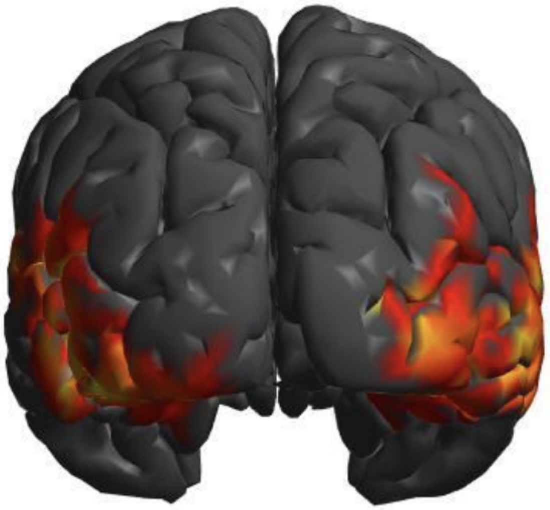

Figure 6. *Beta cortical activity: Two clusters were identified in the inferior temporal cortex ($n_{control}=8$, $n_{HFVK}=7$).*

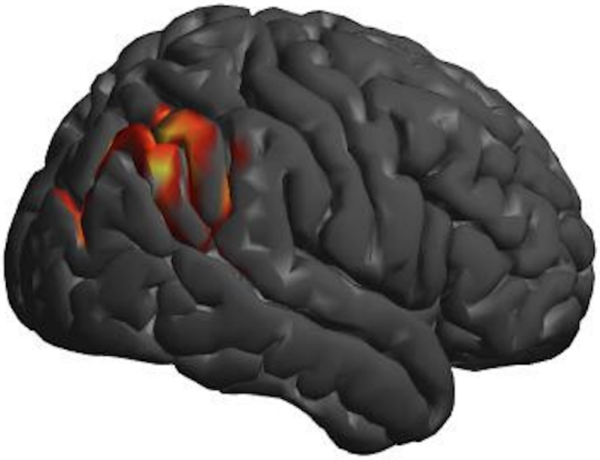

Figure 7. *Theta cortical activity: One significant cluster was found in the inferior parietal cortex ($n_{control}=8$, $n_{HFVK}=7$).*

10.3.1 Cortical Activity Results: Theta (5-7Hz)

Theta cluster was found to be significant in the posterior region of the brain; cluster one (Coordinate 1: -47, -80, -13; $_p$FWE = 1.000). In the action scenes, the mean action for the control group was mean = -39.59, (SD = 33.35) while the HFVK group mean was = 5.92, (SD = 62.62). The non-action scenes theta activity in the control group mean was =-51.35, (SD = 28.56) and the HFVK group showed was M = -20.99 (SD = 39.69). The effect of action vs. non-action characteristics and HFVK stimulation vs. control on theta activity in one identified cluster, RM ANOVA revealed a statistically significant main effect for action vs. non-action on theta activity (F($_{1,13}$) = 8.115, p=0.014). Moreover, the main effect for groups (HFVK vs. Control) has shown to be non-significant (F($_{1,13}$) = 3.325, p = 0.091). Likewise, the interaction effect between action vs. non-action and groups was found to be not significant (F($_{1,13}$) = 1.247, p= 0.284) (see Figure 8). Consequently, these results fail to support hypothesis H3, which suggested different level of cortical activity based on the movie characteristic of action vs. non-action.

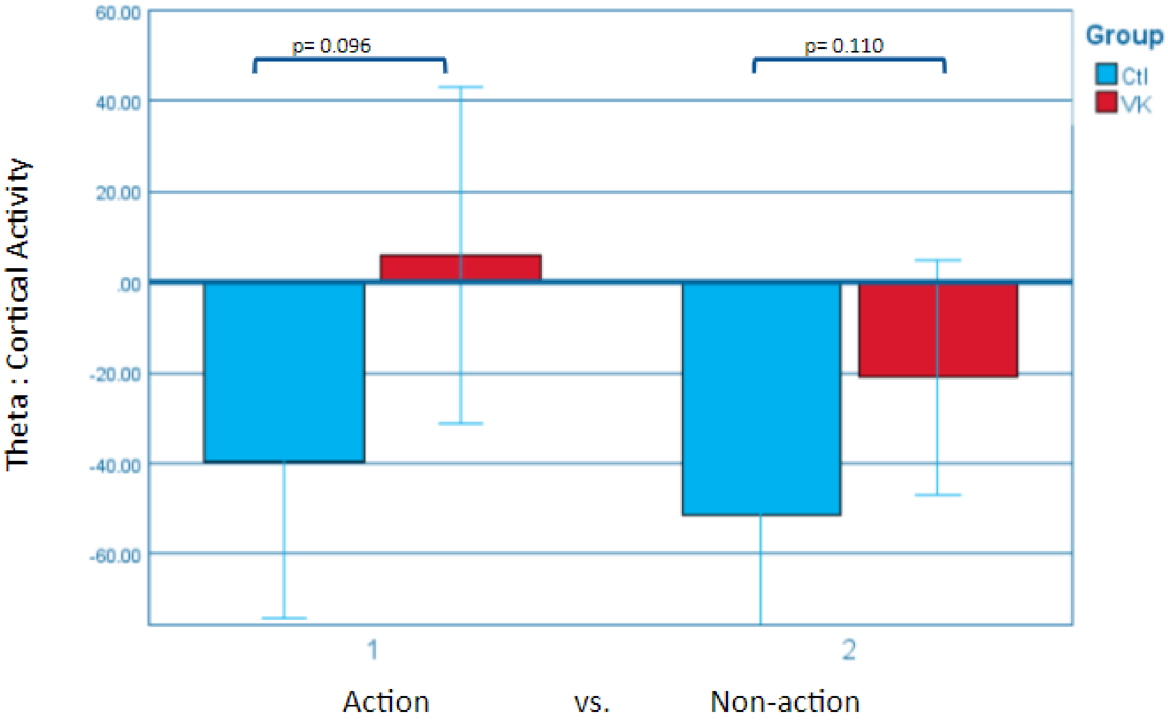

Figure 8. *Theta cortical activity by action vs. non-action characteristics ($n_{control}$=8, n_{HFVK}=7).*

In the low vs. high-intensity movie scenes, the mean high intensity for the control group was mean = -46.53, (SD = 31.10) while the HFVK group mean was = 0.932, (SD = 60.397). The low-intensity scenes theta activity in the control group mean was = -43.422, (SD = 30.489) and the HFVK group showed was = -15.293 (SD = 40.25). For high intensity vs. low intensity, no statistical significance was observed for the main effects (F($_{1,13}$) = 1.544, p= 0.236). The main effects for groups were shown to be non-significant (F($_{1,13}$) = 3.281, p = 0.93). The post hoc pairwise comparison results of theta brain activity indicate the relationship between HFVK and the control group to be non-significant (see Figure 9). Therefore not supporting hypothesis H3.

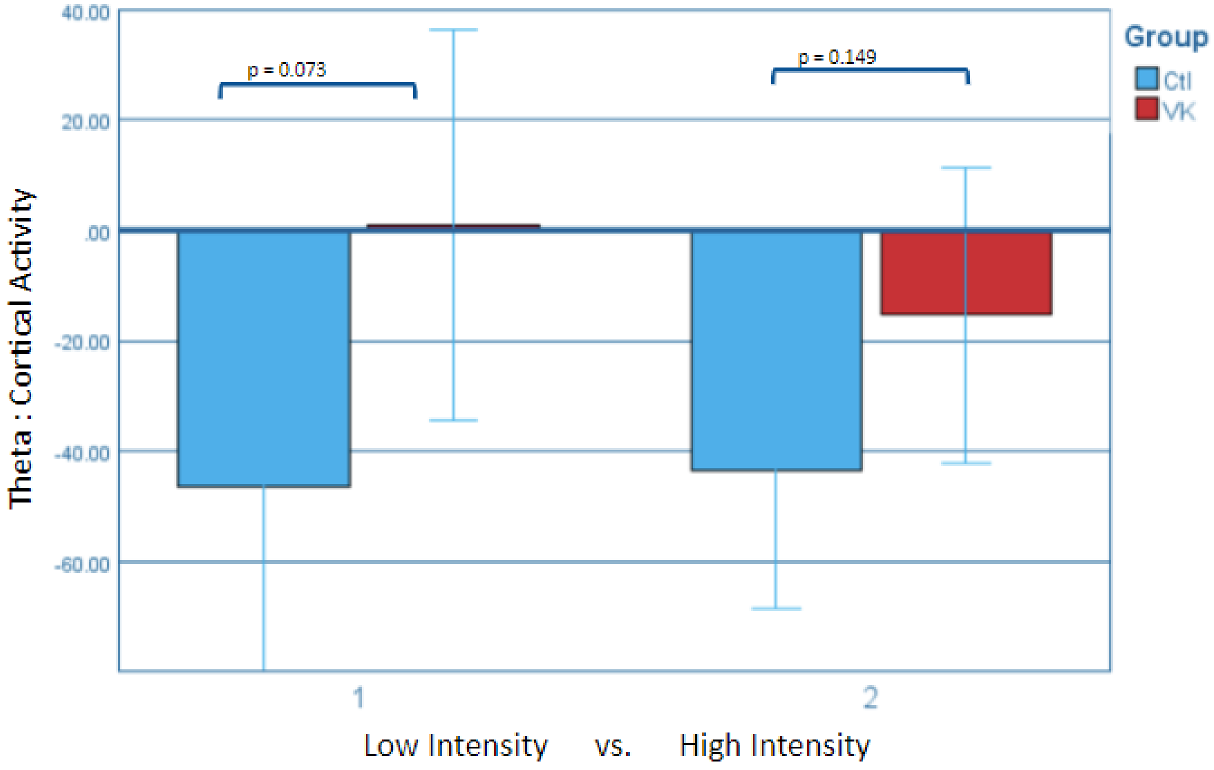

Figure 9. *Theta cortical activity by low vs. high-intensity characteristic ($n_{control}$=8, n_{HFVK}=7).*

The mean for riding in the control group was M=-40.48 (SD= 33.227) and for the HFVK group was M = -11.426 (SD= 37.278). The mean for the no riding in the control group is M = -48.145 (SD= 29.285) and the HFVK group mean is M = -3.449 (SD=59.134). For riding vs. not riding the within-subject effect shows non-significant results the the main effect of riding vs. not riding (F($_{1,13}$) = 0.001, p = 0.974). The main effect for the group showed to be non-significant (F($_{1,13}$) =

3.233, p = 0.95)(see figure 10). Moreover, the interaction between riding vs not riding and groups also showed to be non-significant ($F_{(1,13)}$ = 2.673, p = 0.126), these results fail to support hypothesis H3, which suggested different level of cortical activity based on the movie characteristic of riding vs no riding.

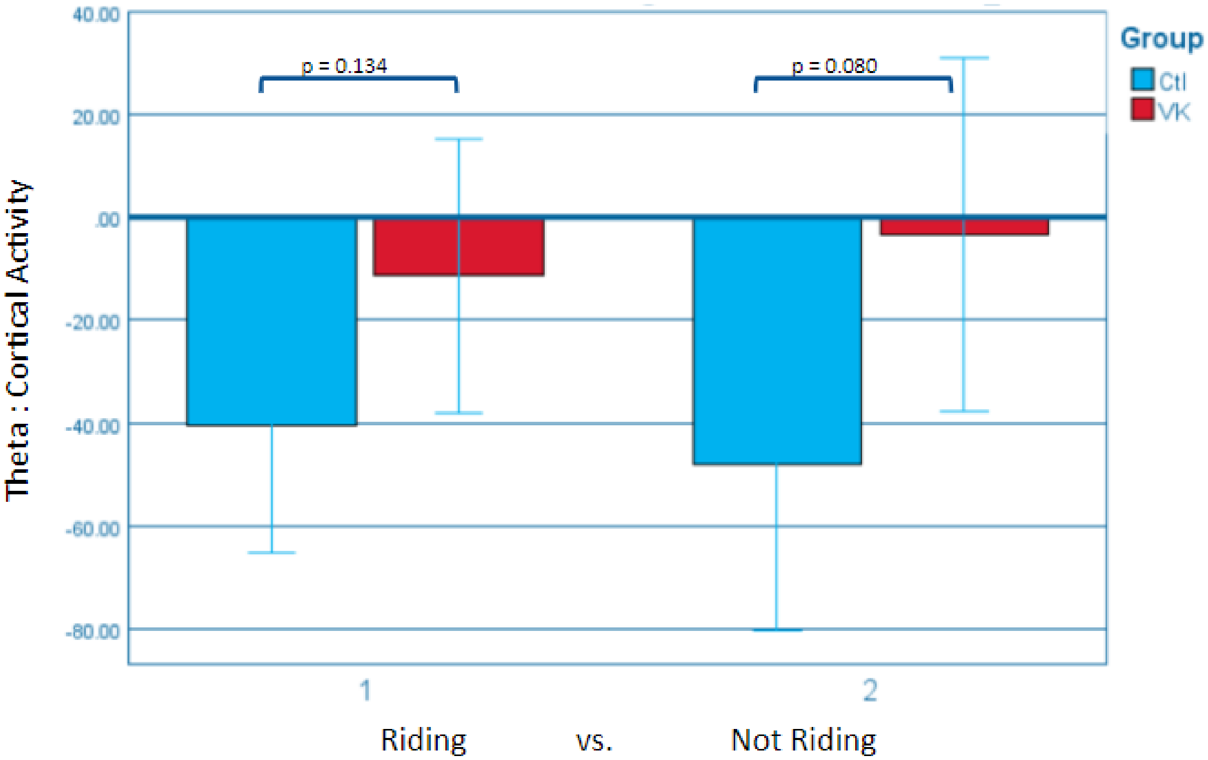

Figure 10. *Theta cortical activity by riding vs. not riding characteristic ($n_{control}$=8, n_{HFVK}=7).*

In the music vs no music movie characteristics, the mean high intensity for the control group was mean = 28.429 (SD= 1.367) while the HFVK group mean was = 32.948 (SD= 1.550). The music scenes theta activity in the control group mean was = -44.756 , (SD = 13.723) and the HFVK group showed was = -7.808, (SD = 14.670). For music vs. no music, no statistical significance was observed for the main effects ($F_{(1,13)}$ = 0.369, p= 0.554). The main effects for groups were shown to be non-significant ($F_{(1,13)}$ = 3.383, p = 0.089). However, the interaction between music vs. no music the results revealed a statistically significant effect ($F_{(1,13)}$ = 1.147, p = 0.304). The post hoc pairwise comparison results of theta brain activity indicate the relationship between HFVK and the control group to be non-significant (see Figure 9), these results fail to support hypothesis H3, which suggested increased level of cortical activity based on the movie characteristic of music vs. no music.

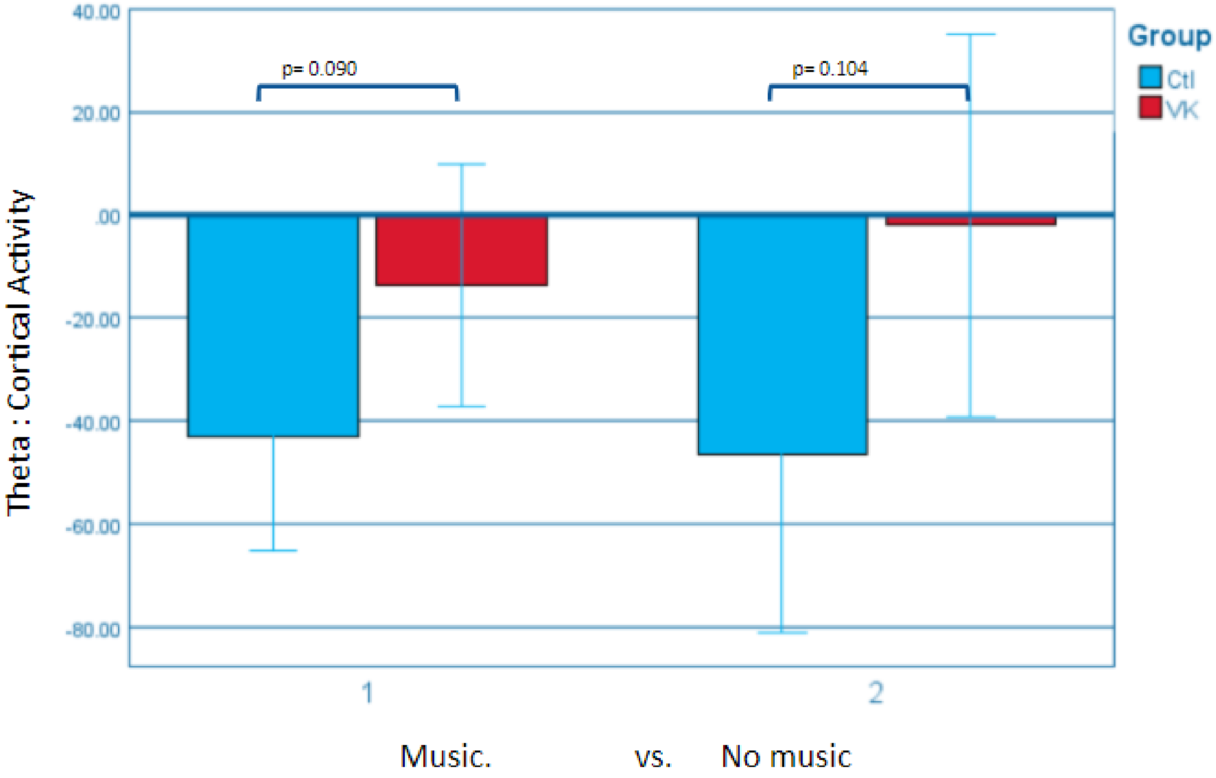

Figure 11. *Theta cortical activity by music vs. no music characteristics* ($n_{control}$*=8,* n_{HFVK}*=7).*

10.3.2 Cortical Activity Results: Beta (15-29 Hz)

The analysis of the left and right beta cluster were conducted to assess the observe the difference between the movie characteristics (Coordinate 1: -52, -68, -14; $_p$FWE = 1.000 and Coordinate 2: 54, -67, -13; $_p$FWE = 1.000).

The mean for the beta activity for action for control was M = .769 (SD = 63.115) and M = 174.815 (SD = 209.088) for the HFVK for the left cluster. For the non-action scenes, the left cluster mean was M = 2.512 (SD = 74.521) for the control group and M =199.959 (SD = 322.653) for the HFVK group. As for the right cluster, the action scenes have shown the mean for the control group to be M=86.556 (SD = 257.985) and for the HFVK group to be M = 189.838 (SD = 183.915). For non-action scenes, the mean for the control group was M = 60.539 (SD = 240.574) and for the HFVK to be M = 205.596 (SD = 283.115). For action vs. non-action, the analysis showed a non-significant effect for characteristics ($F(_{1,13})$ = 0.027, p = 0.871).The main effect for the cluster was not significant ($F(_{1,13})$ = .849, p = .374) and non-significant for groups $F(_{1,13})$=2.344,p=0.150). The interaction between characteristics and cluster was shown to be not significant ($F(_{1,13})$=1.563, p= 0.233) (see Figure 12). Moreover, non-significant interactions indicate influence on the combined effect of characteristics and groups ($F(_{1,13})$ = 0.421,p = 0.527) . The interaction effect of group and cluster was non-significant ($F(_{1,13})$= 0.476, p=0.502). The three-way interaction effect of cluster, characteristic and group was also shown to be non-significant ($F(_{1,13})$ = 0.383, p=0.547). Consequently, these results fail to support hypothesis H3, which suggested level of cortical activity to differ based on the movie characteristic of action vs. non-action

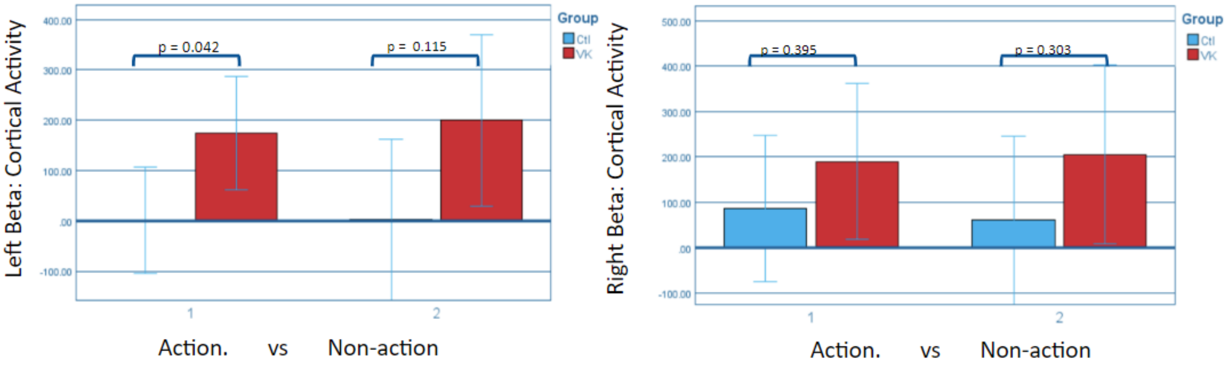

Figure 12. *Beta activity for action vs. non-action for the left cluster (on the left) and for the right cluster (on the right) ($n_{control}$=8, n_{HFVK}=7).*

For the left beta cluster, the mean for high-intensity scenes in the control group was M= -3.672 (SD = 61.995) and for the HFVK group, it was M = 172.636 (SD = 229.470). For the low-intensity scene, the mean for the control group was M = 7.588 (72.487) and for the HFVK group, it was M= 202.449 (SD = 298.054). For the left cluster, the high-intensity scenes in the control group were M = 72.844 (SD = 245.822) and for the HFVK group to be M = 185.544. As for the low-intensity scenes, the control group showed a mean of M=76.210 (SD = 251.0848) and for the HFVK group, the mean was M = 210.5038 (SD=277.121). For high intensity vs. low intensity, the analysis showed a non-significant main effect for the cluster (F($_{1,13}$) = .865, p = 369), characteristics (F($_{1,13}$) = 0.378), and for the group (F($_{1,13}$) = 2.339, p= .150). Moreover, the interaction effect between the movie characteristic (low vs. high intensity) and the cluster was non-significant (F($_{1,13}$)=0.484, p = 0.369). It was also found to be non-significant between the characteristics and group (F($_{1,13}$) = 0.279, p = 0.606) and between the cluster and group interaction (F($_{1,13}$)= 0.223, p=0.644). It was also found to be non-significant for the interaction between movie characteristics (low vs high intensity), cluster and groups (F($_{1,13}$)=0.014, p = 0.912) (see Figure 13).These do not support hypothesis H3, which suggested cortical activity to differ based on the movie characteristics of low vs. high intensity.

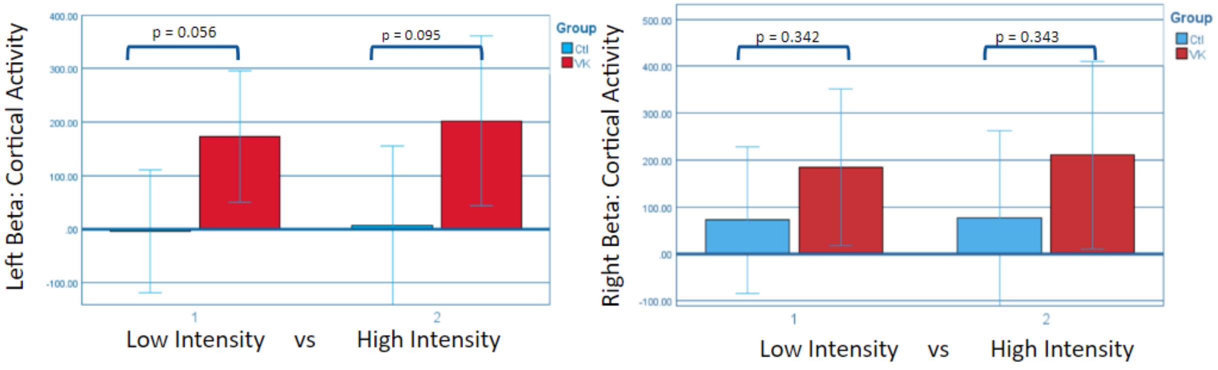

Figure 13. *Beta activity for the low-intensity vs. high-intensity scene characteristics for the left cluster (on the left) for the right cluster (on the right) (*$n_{control}$*=8,* n_{HFVK}*=7).*

For the left cluster for riding characteristics, the mean for the control group was M = -7.914 (SD = 58.131) and for the HFVK group it was M = 148.599 (SD = 177.796) as for the not riding group for the control the mean was M=7.914 (SD = 73.110) and M = 211.848 (SD = 329.058) for the HFVK group. In the right cluster for riding characteristics, the mean for the control group was M = 68.4301 (SD = 249.66) and M = 125.161 (SD = 107.675) for the HFVK group. As for the not-riding characteristic for the right cluster, the mean for the control group was M = 79.404 (SD = 247.446) and for the group, it was M = 245.212 (SD = 311.460). For riding vs. not riding the analysis showed a non-significant main effect on characteristics (F($_{1,13}$)=1.901, p=0.191), cluster (F($_{1,13}$) = 0.748, p = 403), group (F($_{1,13}$) = 2.391, p= 0.146). Moreover, no statistical significance was found between the interaction of characteristics and cluster (F($_{1,13}$)= 3.819, p = 0.73) or cluster and group interaction (F($_{1,13}$) = 0.570, p = 0.464) and characteristics and group (F($_{1,13}$) =1.079, p=0.318). Finally, no statistical significance was found between the interaction of characteristics, cluster and group (F($_{1,13}$) = 5.775, p = 0.73) (see Figure 14). Hypothesis H3, which suggested cortical activity to differ based on the movie characteristic of riding vs no riding.

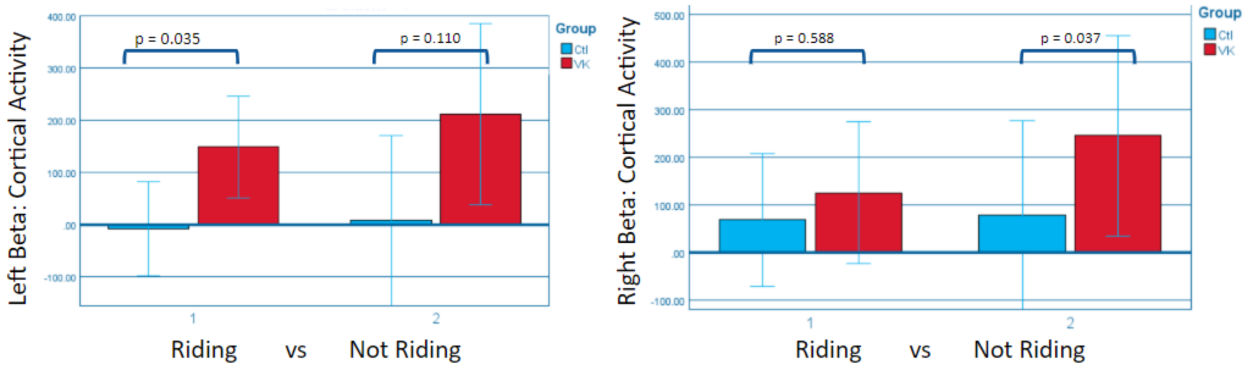

Figure 14. *Beta activity for the riding vs. not riding scene characteristics for the left cluster (on the left) for the right cluster (on the right)* ($n_{control}$=8, n_{HFVK}=7).

The left cluster for music vs. no music showed the mean to be M = 7.766 (SD=74.942) for the control group and to the HFVK group to be M = 157.6454 (SD=199.869). For the no music scenes the control showed to have a mean of M = -2.539 (SD=62.290) and for the HFVK group to be M = 205.818 (SD = 304.386). The right cluster the mean for the music group, the control group showed a mean of M=88.948 (SD=273.417) and the HFVK showed a mean of M=167.031 (SD = 159.406). As for the no music characteristics, the control group showed to have an M=64.726 (SD = 231.644) and HFVK to have a mean of M=217.299 (SD = 273.644). Moreover, when tested for statistical significance for the main effects of the cluster (F($_{1,13}$) = 0.904, p = 0.359), characteristics (F($_{1,13}$) =0.448, p =0.515) and group (F($_{1,13}$) = 2.266, p = 0.156) was non statistically significant. As for the interaction effects for cluster and group (F($_{1,13}$)=0.513, p = 0.486), characteristic and group (F($_{1,13}$)=1.938, p=0.187) and for cluster and characteristics

(F($_{1,13}$)=0.159,p=0.697) to non-statistically significant. Lastly, the interaction between cluster, characteristic, group and cluster is non statistically significant (F($_{1,13}$) = 0.291, p = 0.599) (see figure 15). H3, which suggested cortical activity to differ based on the movie characteristic of music vs. no music.

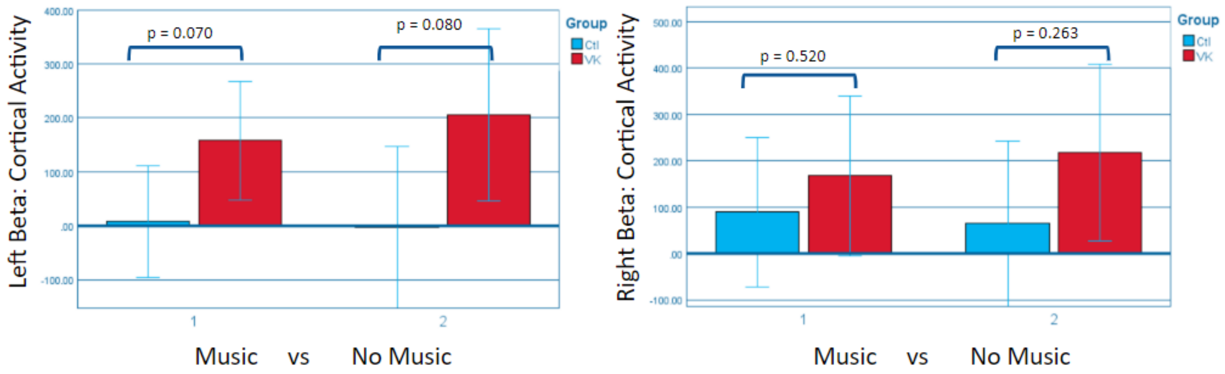

Figure 15. *Beta activity for music vs. no music scene characteristics for the left cluster (on the left) for the right cluster (on the right) ($n_{control}$=8, n_{HFVK}=7).*

Hypotheses	**Results**
H1: Individuals exposed to HFVK technology will exhibit higher levels of immersion, compared to those in the control group.	
Immersion scale	Supported (p <0.004)
Temporal immersion	Supported (p <0.05)
Non-temporal immersion	Not supported (p>0.194)
H2: This will occur in association with neurophysiological changes in attention and sensory integration processing.	Partially supported
Inferior parietal cortex (associated with sensory integration and attention processing)	(p <0.05)
Posterior temporal cortex (not associated with sensory integration and attention processing)	(p <0.05)
H3: The neuropsychophysiological effects of HFVK stimulation will differ according to the characteristics of the movie scene for which they were designed.	Not supported
Theta (5-7 Hz)	Not supported (p >0.284)
Action vs. No action	Not supported (p >0.93)
Low vs. High Intensity	Not supported (p >0.304)
Music vs. No music	Not supported (p >0.126)
Riding vs. No riding	
Beta (15-29Hz)	
Action vs. No action	Not supported (p>0.233)
Low vs. High Intensity	Not supported (p>0.912)
Music vs. No music	Not supported (p>0.73)
Riding vs. No riding	Not supported (p>0.599)

Table 3. *Summary of results.*

11.0 Discussion

The study aimed to investigate the impact of HFVK on immersion across different movie characteristics. Prior research and literature on haptics have suggested that HFVK does have an effect on the immersion level of individuals. Thus, our research question was “To what extent does the phenomenon of immersion have an effect depending on the audiovisual characteristics in the cinematics context for which HFVK has been designed to support?” The results indicated that HFVK had a perceptible impact across certain movie characteristics such as low vs. high intensity, music vs. no-music and partially on action vs. no action scenes. Moreover, this may indicate the applicability and versatility of HFVK in contributing to the viewers immersion (Hwang & Hwang, 2011). Moreover, it was observed that individuals in the HFVK group have higher levels of perceived immersion as opposed to those in the control group. This further shows that haptic technology does indeed play a role in enhancing immersion in a cinematic context.

Therefore, these findings in enhancing immersion and how different movie characteristics contribute to the varying level of immersion in individuals underscores the role of haptic technology. Our results align with the existing literature supporting the notion that HFVK enhances immersion. The literature regarding action vs. non-action have shown HFVK to enhance sensory experiences, making action scenes more immersion. While a main effect on the characteristics of music is consistent with audiovisual stimulation studies, the lack of significance in HFVK interaction effect suggest that music alone may evoke immersion, but the integration of HFVK may not significantly alter the experience as shown in Danieau (2013). Moreover, the variation in HFVK across different movie characteristics could be attributed to the complexity concerning sensory integration. A study by Wang et al. (2021) may explain the intricate relationship between HFVK and audiovisual features that the effectiveness of haptic technology may vary depending on the nature of movie scenes or stimulus. Moreover, studies also suggest that the effectiveness of HFVK with complex audiovisual stimuli may diminish due to sensory overload (Ng et al., 2020). This could explain the reason why the characteristic of no music had higher levels of immersion compared to the music characteristic in the HFVK group. Therefore, understanding the potential of these characteristics can help future research of design and improve the development and implementation of haptic technologies for enhanced cinematic experiences.

Moreover, further explain “To what extent does high-fidelity haptic technology in a cinematic context have an effect on immersion?” the observation made on perceived temporal characteristics suggests it may be influenced by HFVK. Moreover, individuals in the HFVK perceived heightened temporal characteristics compared to the control group. They perceived time and speed to be longer or quicker depending on the scenes. HFVK can influence temporal characteristics due to the changes in patterns, intensities or frequencies that are synchronized with the narrative which creates the sense of time distortion. These indicators may reflect the depth of immersion in a cinematic experience which contribute to understanding the general impact of HFVK on immersion. Individuals in the HFVK group did not perceive heightened non-temporal characteristics (i.e. being more lighter, heavier or colder) than the control group. These results may be explained by the fact HFVK may not be sufficiently detailed to convey non-temporal characteristics (Flavian et al., 2019).

The current study investigated whether the mechanism underlying immersion can be identified by evaluating differences in the cortical activation in the HFVK group opposed to those in the control group. This helps us adresse the first research question “To what extent does high-fidelity haptic technology in a cinematic context have a general impact on immersion?”. The results of the study suggest that individuals in the HFVK group are more immersed compared to those in the control group. Results were able to partially demonstrate that there is a difference between a no-stimuli viewing experience and an HFVK experience. There were no significant clusters that were identified in the alpha band frequency for this study. However, significant clusters were identified for the theta and the beta band. Moreover, these findings help us test our second hypothesis (**H2**): Individuals in the HFVK group will have increased activity in areas associated with attention or sensory integration processing. This has shown to support our findings partially. Although, the literature suggest that the regions involved in vestibular processing are associated with the somatosensory cortex, parieto insular vestibular cortex and the posterior insula; the results of the study only showed significance in the inferior parietal regions. This result is in line with the literature as this region play a role in processing spatial and non-spatial attention and shifting attention between stimuli (Espenhahn et al., 2020; James et al., 2007). Additionally, this region also plays a role in integration visual, auditory and somatosensory information to create a cohesive perception of the environment (Ferrè et al., 2015). The second significant clusters found in the inferior temporal cortex was found to not be in line with the proposed research and literature. In contrast to the existing literature, our study uncovered significance in the inferior temporal region which is not traditionally associated with attention processing or sensory integration. Moreover, this brain area has been found to be involved in visual perception, object recognition, face processing and scene recognition (Guo & Meng, 2015; Schweinberger et al., 2002; Chelazzi et al., 1993). This may have been engaged through the content depicted in movies. Moreover, since, the neural mechanism of underlying immersion is complex, it can involve the interaction among multiple brain areas (Stilla & Sathian, 2008) . The integration of haptics may be attributed to complex sensory processing as it may contribute to the integration of visual information (Sathian, 2016). Therefore, HFVK may influence areas that extend beyond traditional areas linked to vestibular or somatosensory processing areas thus multisensory experiences may engage in a network that involves the inferior temporal cortex (Stilla & Sathian, 2008).

As for the results concerning theta activity (5-7Hz) a cluster was found in the inferior parietal cortex (Hasson et al., 2008). The increase of theta activity in that region has shown to be associated with various cognitive functions and other brain processes. In the cinematics context this can be linked to two different processes: cognitive and spatial or perception processing (Hofmann et al., 2021; Hyafil et al., 2015). Theta oscillation in these regions according to previous studies show that they play a role in spatial navigation, awareness of body position and other aspects of spatial cognition. This increase in activity is expected since haptic stimulation provides vibration and motion feedback which stimulates the vestibular system by creating a sense of movement, acceleration or orientation (Huisman, 2017). Moreover, increased theta activity was observed while comparing immersion score between the movie characteristic action vs. non action in contrast to all the other movie categories.

For the result concerning beta activity (15-29 Hz), two non-significant clusters were found in the right and left inferior temporal gyrus. While it is not fully understood why these regions have shown an increase in beta activity the potential explanations based on existing literature suggest these results to be due to multisensory processing (Gonçalves, 2008; Stilla & Sathian, 2008). The inferior temporal gyrus has previously shown to be implicated in the visual processing of object, face and scene perception but the addition of haptics may have led to a more comprehensive processing of the overall sensory experience (Guo & Meng, 2015; Schweinberger et al., 2002).

The results showed an unexpected absence in significance in the regions that are commonly associated with vestibular processing like the somatosensory cortex which prompts further explorations. The neural mechanisms that underlie immersion with the integration of haptics are complex and involve the interaction of many regions of the brain. Moreover, significance was observed in the inferior temporal region aligns with the literature on multiple sensory integration (Chelazzi et al., 1993). While visual processing has mostly been associated with visual processing with the inferior temporal area, the processing of visual and tactile information has been implicated as well. This may indicate that the neural correlates of immersion with the association of haptics involve more sensory modalities than what has been previously thought (James et al., 2007). The literature so far has shown to have limitations in understanding the full extent of the neural correlate of HFVK induced immersion.

12.0 Limitations of the study

The limitation of this study is that the sample size is relatively low. It is observed that there was an insufficient sample size to interpret the results due to data loss. Consequently, the insufficient number of participants created uneven groups as a comparison for the control group. The findings in this study should be interpreted with caution. Additionally, after conducting an a priori power analysis in G*Power a sample total sample size of 60 (HFVK = 30, Control = 30) is suggested. Therefore, a sample size of 60 participants with a $p = .95$ ($\alpha = .05$) is recommended to reduce the probability of committing a Type II error. Moreover, studies conducted by (Fornerino et al., 2008) made use of 20 participants in the experimental group and 20 individuals in the control group to observe the difference in an immersive experience. Suggesting that an insufficient sample was used for the interpretation of the results. Second, since HFVK stimulation/design have limitations in the type of movements and motion that can be produced some clips may have more trouble having an immersive influence on the user (Haegens et al., 2012). Therefore, HFVK stimulation created by the HFVK is part of a subjective process that needs to be carefully interpreted. The use of subjective measure is also limited in the ability to measure immersion (Jennett et al., 2008). Since immersion was measured at the end of each movie sequence it made use of the user's feeling and memory to assess immersion. We should also consider that the interpretation of neural activity is complex, and can vary based on the nuances of each study. Additionally, the duration of each movie clip was short and may have reduced the immersive state of the user as opposed to individually who would experience the movie fully with haptics.Moreover, the study has a semi-ecological validated value due to its unnatural environment to perform the study. The experiment is performed in a darkened room to replicate a cinematic environment; however, wearing an EEG takes away the naturalistic behaviour of the participants. Moreover, we should also consider that some movement and tactile vibration cannot be emulated by the chair as it has some limitations in the movement. Finally, it is important to consider that when conducting immersion research, the experience is user research that relies on the appreciation of the user. Thus, it would be important to be able to validate the emotion elicited during the movie clips to investigate which specific emotions are induced in its users.

13.0 Conclusion

As hypothesized, the study suggests that HFVK stimulation during movie-watching has an effect on brain activity but these were only observed to be partially present. The future direction to this study will hopefully contribute to seeing haptic as a field where both the artistic and scientific processes can be explored. This may further understand how haptic technology is involved in the neurocognitive processes associated with immersion. It could contribute to knowing the ecological values that this technology may have on its users and how it may be manipulated to offer a better experience. Moreover, it can be interesting to explore how haptic technology can be differentiated from the sense of touch and be mediated only by sensation (Culbertson et al., 2018). This could contribute to the collaboration between industries and research in academia to improve technology and create better immersive experiences.

The design of haptic movies may play a pivotal role in shaping the user experience and enhancing immersion (Yeongmi et al., 2010). Moreover, by the incorporation of haptic technology in movies, designers have the opportunity to engage users on a multisensory level, that goes beyond audio and visual stimuli (Waltl et al., 2010; Venkatesan & Wang, 2023). Since haptics which tactiles sensations and vibrations, adds a tangible dimension to the audience's viewing experience (Wang et al., 2013). The use of vibration and tactile cues corresponding and synchronized with the environment, characters movement or music may create a deeper connection between the film and the viewer. Additionally, the stimulation of different sensory components in association to the narrative can immerse viewers into the narrative.

It would be interesting to test this technology (haptics) on individuals who are hearing impaired because it could potentially enhance and give a more enriching experience while watching a movie (Ma et al., 2021; Meer et al., 2020; Nesbitt, 2005). It is also to note that understanding of specific neural processes related to haptics is still an ongoing area of research. Moreover, the brain is a complex and interconnected organ and there may be variations in neural responses that may exist, and further research is needed to provide more understanding to these underlying mechanisms.

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Chapitre 4: Conclusion

1.0 Rappel du contexte

En conclusion, la littérature sur concernant l'intégration de la technologie haptique dans la recherche sur l'immersion cinématographique nous montre qu'elle ouvre de nouvelles perspectives pour améliorer l'expérience des utilisateurs. L'ajout de la technologie haptique aux films crée une expérience multisensorielle qui est plus complète et aussi captivante. De plus, cette inclusion permet la stimulation audiovisuelle traditionnelle permettant aux spectateurs de sentir les sensations physique correspondant aux évènements à l'écran (Rasheed & Shah, 2002). Elle permet d'introduire une nouvelle dimension narrative pour les cinéastes pour transmettre des éléments narratifs, de designs et des conditions environnementales, ceci offre une manière innovante de s'immerser dans l'histoire (Danieau et al., 2014). La technologie haptique implique la stimulation de différents sens, contribuant au traitement de l'information tactile et proprioceptive. Cette intégration améliore la perception du réalisme et offre une expérience multisensorielle unifiée (Lemmens et al., 2009; Salselas & Penha, 2019). De plus, l'utilisation de l'haptique dans les films peut influencer significativement la perception du temps, impactant les dimensions cognitives, immersives et émotionnelles. Dans une narration cinématographique, le public peut perdre la notion du temps, et sa conscience du monde réel peut diminuer, créant une perception déformée de l'écoulement du temps (Gavazzi et al., 2013). Les cinéastes utilisent diverses techniques, y compris la technologie haptique, pour manipuler la perception du temps à des fins artistiques.

Bien que l'expérience immersive ait été explorée à travers diverses méthodes, tant subjectives (échelles, questionnaires) qu'objectives (mesures neurophysiologiques), des lacunes significatives subsistent (Jennett et al., 2008; Wang et al., 2013; Hammond et al., 2023). Notamment, une exploration approfondie des mécanismes neurologiques liés à l'impact des retours haptiques sur l'immersion, en tenant compte des différentes caractéristiques des films, reste nécessaire (Israr et al., 2014). Comprendre ces nuances pourrait affiner l'impact de la technologie haptique sur l'expérience cinématographique. La mesure de l'immersion dans le contexte des expériences cinématographiques implique des approches subjectives et objectives (Astrinaki, 2012; Argawal et., 2020). Les méthodes subjectives, telles que les questionnaires post-étude, reposent sur les sentiments des participants pour évaluer le sentiment d'immersion et l'expérience globale lors d'un film (Jennett et al., 2008). Bien que cette méthode est précieuse, la méthode subjective nous présente des défis tels que la subjectivité. Malgré cela, la recherche indique un lien entre l'immersion et les films, la stimulation haptique et l'amélioration de l'immersion cinématographique (Salselas et al., 2021). De plus, les mesures objectives, en particulier l'EEG, offrent une avenue qui est prometteuse pour une compréhension approfondie sur les mécanismes sous-jacents de l'immersion (Yeongmi et al., 2010).

2.0 Défis méthodologiques du projet

On reconnaît qu'il y a un défi avec la taille de l'échantillon qui est relativement faible, ceci entraîne une puissance statistique insuffisante ainsi que des tailles inégales pour la comparaison de données. Il aurait dû avoir une taille d'échantillon de 60 pour une interprétation plus robustes des données. De plus, les limitations dans le type de mouvements et de sensations que la stimulation haptique entraîne une variabilité dans son influence immersive.

3.0 Rappel des questions de recherche et résultats

L'étude dans le troisième chapitre visait à évaluer l'impact de la stimulation HFVK dans différents types de films. Les données collectées pour ce mémoire ont permis de répondre à ses questions de recherche à travers les articles. Les questions de recherche suivantes ont étés répondu dans le deuxième article du mémoire.

QR1: Dans quelle mesure la technologie haptique haute fidélité dans un contexte cinématographique a-t-elle un impact sur l'immersion ?

QR2: Dans quelle mesure le phénomène de l'immersion a-t-il un effet en fonction des caractéristiques audiovisuelles pour lesquelles le HFVK a été conçu ?

L'étude visait à explorer l'impact de la technologie haptique haute fidélité (HFVK) sur l'immersion dans un contexte cinématographique. La première question de recherche nous as permis d'observé que les individus du groupe HFVK ont des niveaux d'immersion perçus plus élevés par rapport à ceux du groupe contrôle. Cela démontre davantage que la technologie haptique joue effectivement un rôle dans l'amélioration de l'immersion dans un contexte cinématographique. Le HFVK peut influencer les caractéristiques temporelles en raison des changements de motifs, d'intensités ou de fréquences synchronisés avec le récit, créant ainsi une sensation de distorsion temporelle. Ces indicateurs peuvent refléter la profondeur de l'immersion dans une expérience cinématographique, contribuant à la compréhension de l'impact général du HFVK sur l'immersion. Les individus du groupe HFVK n'ont pas perçu de caractéristiques non temporelles accrues (c'est-à-dire être plus léger, plus lourd ou plus froid) par rapport au groupe témoin. Ces résultats peuvent s'expliquer par le fait que le HFVK pourrait ne pas être suffisamment détaillé pour transmettre des caractéristiques non temporelles (Flavian et al., 2019). La deuxième question de recherche (QR 2) portait sur l'impact de la HFVK sur l'immersion à travers différentes caractéristiques de films. Les effets de la HFVK sur les scènes d'action vs. non-action, les scènes à haute intensité vs. faible intensité, les scènes avec musique et sans musique, les scènes de chevauchement vs. sans chevauchement. Les résultats ont confirmé pour les scènes à haute intensité vs. faible intensité et les scènes de chevauchement vs. sans chevauchement, démontrant que la HFVK améliore l'immersion à travers ces caractéristiques de films. Bien que des effets significatifs aient été identifiés pour l'activité thêta dans les scènes d'action par rapport aux scènes non d'action et dans les scènes à haute intensité par rapport aux scènes à basse intensité, l'impact de la stimulation HFVK n'a pas atteint de signification statistique à travers ces caractéristiques cinématographiques. Cela suggère que bien que des caractéristiques spécifiques du film aient influencé l'activité thêta, l'effet global anticipé de la stimulation HFVK sur l'activité corticale n'a pas été fortement soutenu par ces résultats. L'étude a montré une activité accrue dans le lobule pariétal inférieur, spécifiquement dans la bande de fréquence thêta (5-7 Hz), associée à des fonctions cognitives et au traitement spatial. Cependant, aucune activité significative n'a été observée dans les régions traditionnellement liées au traitement vestibulaire ou somatosensoriel, suggérant une complexité dans les mécanismes neuronaux sous-jacents à l'immersion avec HFVK (Espenhahn et al., 2020; James et al., 2007). De plus, une augmentation de l'activité bêta a été observée dans le gyrus temporal inférieur, indiquant une intégration multisensorielle potentielle (Chelazzi et al., 1993).

4.0 Contributions du mémoire

Le premier article est la revue littéraire sur l'immersion. Le design et la technologie haptique peuvent apporter plusieurs contributions significatives dans la recherche. Premièrement, elle permet de synthétiser les connaissances existantes sur l'immersion, le design et l'haptique. Cela permettrait aux chercheurs une vue d’ensemble des avancées, des tendances et aussi des lacunes dans le domaine de la recherche. La revue de littérature permet aussi d’analyser les différentes méthodologies de recherche qui sont employées dans le domaine de la recherche, du design de la technologie haptique et audiovisuelle ainsi que dans le domaine de la cinématographie. Cela aide les chercheurs à comprendre les approches expérimentales, les outils de collecte de données et les métriques (i.e questionnaire) utilisés par d’autres chercheurs. En examinant les études antérieures, elle aide à comprendre les approches expérimentales, les outils de collecte de données et les métriques utilisées par d’autres chercheurs.

Le deuxième article à permis de voir si le si le mécanisme sous-jacent à l'immersion pouvait être identifié en évaluant les différences d'activation corticale dans le groupe HFVK par rapport au groupe contrôle. Les résultats soulignent la nécessité de futures recherches pour mieux comprendre les corrélats neuronaux de l'immersion induite par HFVK, notamment les interactions complexes entre les différentes régions cérébrales impliquées dans le traitement sensoriel et cognitif. Les résultats contribuent à la compréhension de l'impact du HFVK sur l'immersion cinématographique, mettant en évidence son potentiel pour améliorer les expériences utilisateur (Boasen et al., 2020). Ces conclusions offrent des perspectives importantes pour les concepteurs de technologies haptiques, suggérant que la connaissance approfondie des mécanismes sous-jacents peut guider le développement de technologies plus efficaces et immergées.Bien que des amas significatifs aient été trouvés dans le lobule pariétal inférieur et le lobule temporal inférieur, certains résultats contredisaient la recherche et la littérature proposées. Ceci nous suggère que le mécanisme neuronal complexe de l'immersion avec l'intégration haptique implique plusieurs zones cérébrales, suggérant que le HFVK pourrait engager un réseau au-delà des zones traditionnelles de traitement vestibulaire ou somatosensoriel.

5.0 Limites et recherche futures

Le domaine de l’haptique cinématographique présente quelques limites. Premièrement, la précision des retours haptiques, la synchronisation parfaite entre les stimuli audiovisuels à l’écran et l’haptique doivent être précis pour ne pas mélanger l’utilisateur. De plus, la technologie haptique à des limites dans les motions et vibrations qui sont possible avec la chaise vibrocinétique.

La lacune identifiée dans notre compréhension concerne les mécanismes neurologiques de l'immersion avec la technologie haptique. En comblant cette lacune, la recherche future peut enrichir notre connaissance de l'haptique. Cela pourrait contribuer à optimiser l'application de la technologie haptique pour améliorer de manière ciblée l'expérience cinématographique globale. L'étude suggère que la stimulation HFVK pendant le visionnage de films a un impact partiel sur l'activité cérébrale. La direction future de la recherche vise à explorer conjointement les aspects artistiques et scientifiques de l'haptique, notamment son rôle dans les processus neurocognitifs liés à l'immersion. Cette exploration pourrait également révéler les valeurs écologiques de la technologie haptique sur les utilisateurs et comment elle peut être optimisée pour une expérience améliorée. De plus, la différenciation de la technologie haptique par rapport au sens du toucher, médiée uniquement par la sensation, est un aspect intéressant à explorer, tout en encourageant la collaboration entre l'industrie et la recherche académique pour des expériences immersives de qualité supérieure (Eid & Osman, 2016; Eldeeb et al., 2020). Tester la technologie haptique sur des individus malentendants est également envisagé pour une expérience cinématographique enrichissante (Eid & Osman, 2016; Alsuradi & Eid, 2020). La compréhension des processus neuronaux spécifiques liés à l'haptique reste un domaine de recherche en évolution, soulignant la nécessité de recherches supplémentaires pour approfondir ces mécanismes sous-jacents complexes du cerveau (Alsuradi & Eid, 2020).

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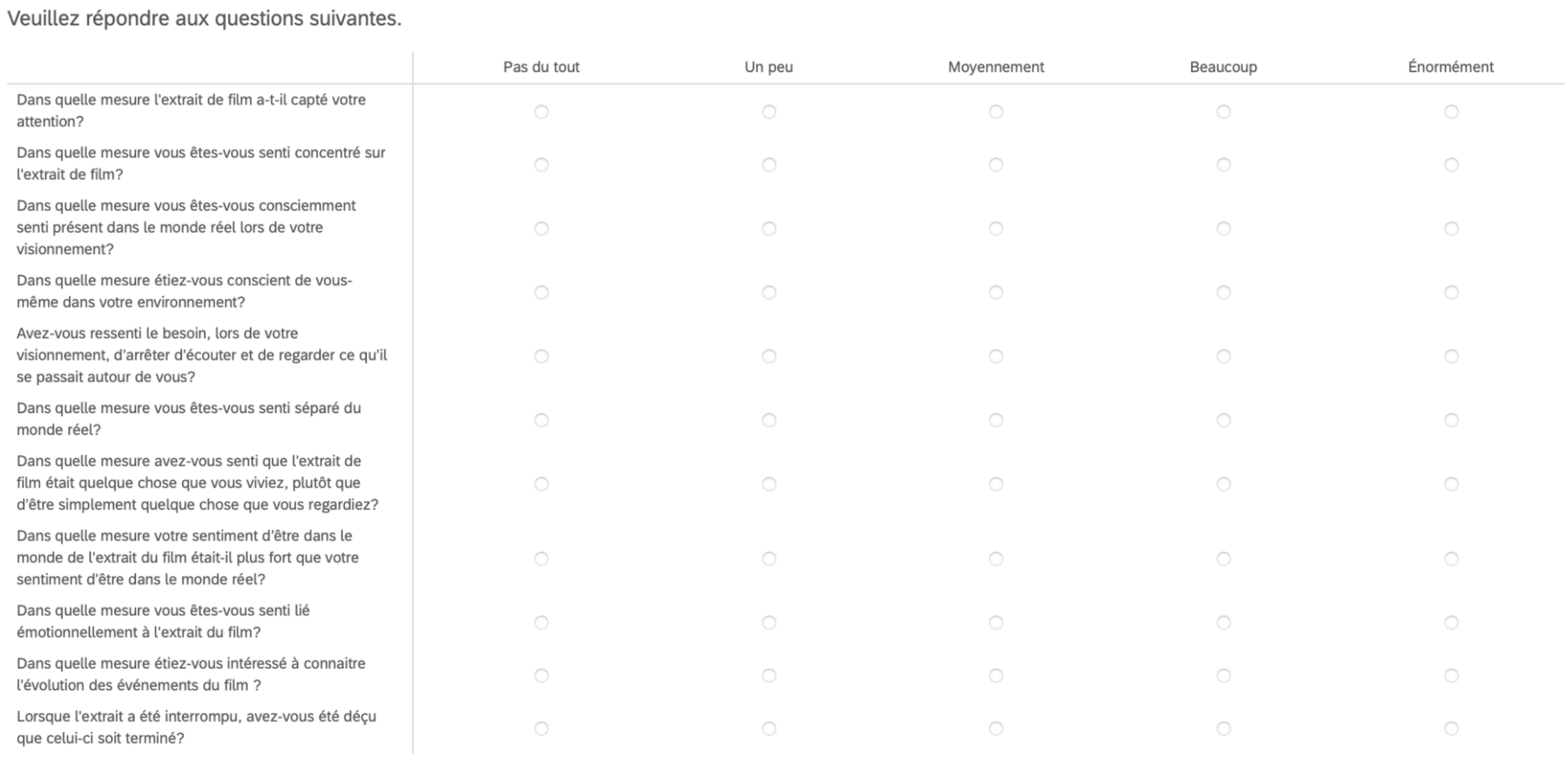
Appendix 1



Veuillez répondre aux questions suivantes.

	Pas du tout	Un peu	Moyennement	Beaucoup	Énormément
Dans quelle mesure l'extrait de film a-t-il capté votre attention?	○	○	○	○	○
Dans quelle mesure vous êtes-vous senti concentré sur l'extrait de film?	○	○	○	○	○
Dans quelle mesure vous êtes-vous consciemment senti présent dans le monde réel lors de votre visionnement?	○	○	○	○	○
Dans quelle mesure étiez-vous conscient de vous-même dans votre environnement?	○	○	○	○	○
Avez-vous ressenti le besoin, lors de votre visionnement, d'arrêter d'écouter et de regarder ce qu'il se passait autour de vous?	○	○	○	○	○
Dans quelle mesure vous êtes-vous senti séparé du monde réel?	○	○	○	○	○
Dans quelle mesure avez-vous senti que l'extrait de film était quelque chose que vous viviez, plutôt que d'être simplement quelque chose que vous regardiez?	○	○	○	○	○
Dans quelle mesure votre sentiment d'être dans le monde de l'extrait du film était-il plus fort que votre sentiment d'être dans le monde réel?	○	○	○	○	○
Dans quelle mesure vous êtes-vous senti lié émotionnellement à l'extrait du film?	○	○	○	○	○
Dans quelle mesure étiez-vous intéressé à connaitre l'évolution des événements du film ?	○	○	○	○	○
Lorsque l'extrait a été interrompu, avez-vous été déçu que celui-ci soit terminé?	○	○	○	○	○

Appendix 2

Clip 1

Estimez la vitesse maximale atteinte par l'hélicoptère durant la scène (100km/h = 62,13 mph).

- 5 à 15km/h
- 15 à 25km/h
- 25 à 35km/h
- 35 à 45km/h
- 45 à 55km/h
- 55 à 65km/h

Estimez la durée de temps pour laquelle l'hélicoptère a survolée les installations du camp militaire.

- 0 à 15 sec
- 15 à 30 sec
- 30 à 45 sec
- 45 à 60 sec
- 60 à 75 sec

75 à 90 sec

Clip 2

Estimez le poids d'un extra-terrestre. (1Kg = 2.2 lbs)

- 0 à 200Kg
- 200 à 400Kg
- 400 à 600Kg
- 600 à 800Kg
- 800 à 1000Kg
- 1000 à 1200Kg

Estimez, à partir du début de la scène, la durée pour laquelle les protagonistes ont été dans le vaisseau des extra-terrestres.

- 0 à 15 sec
- 15 à 30 sec
- 30 à 45 sec
- 45 à 60 sec
- 60 à 75 sec
- 75 à 90 sec

Clip 3

Estimez la vitesse maximale atteinte par le protagoniste en planche à roulette. (100km/h = 62,13 mph)

- 30 à 50km/h
- 50 à 70km/h
- 70 à 90km/h
- 90 à 110km/h
- 110 à 130km/
- 130 à 150km/h

Estimez la durée de la descente du protagoniste en planche à roulette.

- 0 à 30 sec
- 30 à 60 sec
- 60 à 90 sec
- 90 à 120 sec
- 120 à 150 sec
- 150 à 180 sec

Clip 4

Estimez la vitesse maximale atteinte par la voiture lorsque les personnages s'échappent de l'éruption volcanique en km/h. (100km/h = 62,13 mph)

- 30 à 50km/h
- 50 à 70km/h
- 70 à 90km/h
- 90 à 110km/h
- 110 à 130km/h
- 130 à 150km/h

Estimez la durée de la fuite des protagonistes en voiture jusqu'à leur arrivée à la pizzeria.

- 0 à 30 sec
- 30 à 60 sec
- 60 à 90 sec
- 90 à 120 sec
- 120 à 150 sec
- 150 à 180 sec

Clip 5

Estimez la température ressentie dans la montagne lorsque le protagoniste interagit avec les sherpas.

- 0 à 10°C
- -10 à 0°C
- -20 à -10°C
- -30 à -20°C
- -40 à -30°C
- -50 à -40°C

Estimez la durée de la conversation (muette) entre le protagoniste et les sherpas.

- 0 à 15 sec
- 15 à 30 sec
- 30 à 45 sec
- 45 à 60 sec
- 60 à 75 sec
- 75 à 90 sec

Clip 6

Estimez le poids de la protagoniste figurant dans la scène. (1Kg = 2,2lbs)

- 45 à 50Kg
- 50 à 55Kg
- 55 à 60Kg
- 60 à 65Kg
- 65 à 70Kg
- 70 à 75Kg

Estimez la durée du trajet du couple dans le musée, de leur entrée jusqu'au moment où ils arrivent dans la salle du télescope.

- 0 à 30 sec
- 30 à 60 sec
- 60 à 90 sec
- 90 à 120 sec
- 120 à 150 sec
- 150 à 180 sec

Clip 7

Estimez le poids du protagoniste figurant dans la scène. (1Kg = 2,2lbs)

- 55 à 60Kg
- 60 à 65Kg
- 65 à 70Kg
- 70 à 75Kg
- 75 à 80Kg
- 80 à 85Kg

Estimez la durée de la danse du couple dans « l'espace ».

- 0 à 15 sec
- 15 à 30 sec
- 30à 45 sec
- 45 à 60 sec
- 60 à 75 sec
- 75 à 90 sec

Clip 8

Estimez le poids du monstre dans la cage.

- 75 à 80Kg
- 80 à 85Kg
- 85 à 90Kg
- 90 à 95Kg
- 95 à 100Kg
- 100 à 105Kg

Estimez pendant combien de temps la protagoniste (dame qui observe dans la cage) a été dans la même pièce que le monstre en cage.

- 0 à 15 sec
- 15 à 30 sec
- 30 à 45 sec
- 45 à 60 sec
- 60 à 75 sec
- 75 à 90 sec

Clip 9

Estimez le poids de la protagoniste (la dame) figurant dans la scène.

- 45 à 50Kg
- 50 à 55Kg
- 55 à 60Kg
- 60 à 65Kg
- 65 à 70Kg
- 70 à 75Kg

Estimez la durée de la chanson jouée sur la scène.

- 0 à 15 sec
- 15 à 30 sec
- 30 à 45 sec
- 45 à 60 sec
- 60 à 75 sec
- 75 à 90 sec

Clip 10

Estimez la quantité de spectateurs présents dans le stade.

- 0 à 5000
- 5000 à 10 000
- 10 000 à 15 000
- 15 000 à 20 000
- 20 000 à 25 000
- 25 000 à 30 000

Estimez la durée de la chanson.

- 0 à 30 sec
- 30 à 60 sec
- 60 à 90 sec
- 90 à 120 sec
- 120 à 150 sec
- 150 à 180 sec

Clip 11

Estimez la vitesse maximale atteinte par la voiture durant le trajet. (100km/h = 62,13 mph)

- 5 à 15km/h
- 15 à 25km/h
- 25 à 35km/h
- 35 à 45km/h
- 45 à 55km/h
- 55 à 65km/h

Estimez la durée du trajet du protagoniste en voiture

- 0 à 30 sec
- 30 à 60 sec
- 60 à 90 sec
- 90 à 120 sec
- 120 à 150 sec
- 150 à 180 sec

Clip 12

Estimez la distance de la chute du protagoniste dans l'endroit sombre.

- 0 à 5 mètres
- 5 à 10 mètres
- 10 à 15 mètres
- 15 à 20 mètres
- 20 à 25 mètres
- 25 à 30 mètres

Estimez la durée de la chute du protagoniste dans l'endroit sombre.

- 0 à 5 sec
- 5 à 10 sec
- 10 à 15 sec
- 15 à 20 sec
- 20 à 25 sec
- 25 à 30 sec

Clip 13

Estimez la température de l'eau de la mer dans la scène.

- 0 à 5°C
- 5 à 10°C
- 10 à 15°C
- 15 à 20°C
- 20 à 25°C
- 25 à 30°C

Estimez la durée de temps pour laquelle la protagoniste est restée dans l'eau de la mer.

- 0 à 15 sec
- 15 à 30 sec
- 30 à 45 sec
- 45 à 60 sec
- 60 à 75 sec
- 75 à 90 sec

Clip 14

Estimez la vitesse maximale atteinte par le train durant la scène. (100km/h = 62,13 mph)

- 5 à 15km/h
- 15 à 25km/h
- 25 à 35km/h
- 35 à 45km/h
- 45 à 55km/h
- 55 à 65km/h

Estimez la durée de la conversation dans le train présentée dans la scène jusqu'au moment où les gardes entrent dans la cabine.

- 0 à 15 sec
- 15 à 30 sec
- 30 à 45 sec
- 45 à 60 sec
- 60 à 75 sec
- 75 à 90 sec

Clip 15

Estimez la vitesse maximale atteinte par les protagonistes durant la descente. (100km/h = 62,13 mph)

- 30 à 50km/h
- 50 à 70km/h
- 70 à 90km/h
- 90 à 110km/h
- 110 à 130km/h
- 130 à 150km/h

Estimez la durée de la descente des protagonistes dans la montagne.

- 0 à 15 sec
- 15 à 30 sec
- 30 à 45 sec
- 45 à 60 sec
- 60 à 75 sec
- 75 à 90 sec