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# Conceptualizing Factors of Adoption for Head Mounted Displays: Toward an Integrated Multi-Perspective Framework

**Ibrahim Halil Yucel & Robert Anthony Edgell**

State University of New York Polytechnic Institute, NY, USA

## Abstract

Recent developments in Head Mounted Displays (HMDs) offer radical new ways of exploring and interacting in three dimensional virtual or augmented spaces. However, the literature reveals a gap in terms of predictive adoption factors that address human usage and social constraints. Our investigation was guided by the question, "*What are the critical factors that predict HMD adoption?*" We used a literature review and discourse analysis approach to conduct exploratory research. As an outcome, our paper contributes a conceptual HMD framework which includes diverse adoption factors from each of three differing perspectives: producer firm-level, general product-level, and HMD-specific. We posit that all three perspectives are necessary for a comprehensive systemic framework that robustly predicts the successful adoption of HMDs in diverse settings. At the firm-level or producer-level, we explore business factors that might impact adoption by applying the Transparency Innovation Models (TIMs) typology. At the product-level, users' satisfaction with immersions into virtual realms depends on how engaged they become in "flow" states which is influenced by mechanics, dynamics, and aesthetics general design choices. At the HMD-specific level, visual strain, power arrangements, and haptic interaction are important considerations. Also, the paper contributes application case studies of two HMD firms: Oculus and Magic Leap. We argue that the meaningful-TIM approach when distributed across networks of key stakeholders offers greater advantages in terms of enabling open relationships and development processes among critical stakeholders, such as HMD producers, software developers, and potential users. The paper concludes with a discussion of possible future outcomes for HMDs.

*"Body proximate display applications give rise to a range of other issues which challenge the limits of the human being and our social sphere at varying scales." (Quigley & Grubert, 2015: 5)*

## 1. Introduction

For several years, game users and producers alike have been intrigued by the possibilities of visualization and three dimensional (3D) virtual spaces. However, interaction and immersion into 3D has been challenging since traditional "body proximate" devices are optimal for two dimensional (2D) representations (Pichlmair, 2015). Overtime game developers have learned how to represent 3D perspectives on 2D dimensional screens and how to best control virtual cameras to explore 3D virtual spaces, using combinations of computer mice, keyboards, and joysticks. Recent developments in virtual and augmented reality headset technology offer radical new ways of exploring and interacting in 3D virtual spaces such as those used in video games. Collectively we refer to these particular types of "body proximate" products as Head Mounted Displays or HMDs (Desai, Desai, Ajmera, & Mehta, 2014). Examples of recent HMD commercial developments include Oculus Rift (Desai, Desai, Ajmera, & Mehta, 2014) which aims to be the first of these headsets available to the general public in retail form (Sydell, Laura, 2015). This release will be closely followed by other products such as the CastAR, Microsoft Hololens, Sony's Project Morpheus, Magic Leap, and HTC Vive (Desai, Desai, Ajmera, & Mehta, 2014; Pichlmair, 2015; Sydell, Laura, 2015; Telosin, 2015).

While emergent HMD releases represent critical steps in the technology's adoption and the evolution of gaming, simple experimentation by early or select lead users alone, may not significantly contribute to developing adoption by diverse users (Genaro Motti & Caine, 2014). Despite recent enhancements, HMDs still induce hindrance stress in human users and, as such, risk not gaining widespread adoption by secondary users (Genaro Motti & Caine, 2014). Lacking a holistic and scientific approach, producers may be more likely to develop HMDs that increase user stress, reduce adoption, increase the likelihood of suboptimal resource utilization, and ultimately fail to develop socially instrumental HMD technologies. Accordingly, our research was guided by the question, "*What are the critical factors that predict HMD adoption?*" In response, we conducted exploratory research using a combined literature review and discourse analysis method. We used a discourse analysis approach, appropriate for exploratory research, with the intent to generate meanings and understandings useful for constructing aspects of a conceptual framework. Our method is consistent with those used by ethnographers, qualitative researchers, and discourse analysts (Ketokivi & Mantere, 2010; LeCompte & Schensul, 2013; Mantere & Ketokivi, 2013; Schensul, Schensul, & LeCompte, 2013).

As an outcome of this investigation, our paper contributes a conceptual HMD framework that includes diverse adoption factors from three differing perspectives: producer firm-level view, general product-level view, and HMD-specific view. We posit that all three perspectives are necessary for a comprehensive systemic framework that robustly predicts the successful adoption of HMDs in diverse settings from the home to the workplace. In addition, the paper provides application insights through case studies of two HMD firms.

## 2. Literature Review

Video games are forms of artistic expressions commercialized through complex business spaces. Creating software experiences that are both critical and commercial successes requires understandings of how to not only build content, but also manage the organizations that support creation and distribution of devices and game libraries. For these reasons, we propose that emergent interactive entertainment technologies be holistically conceived as systems consisting of hardware platforms, software libraries, and firm-level innovation models. Accordingly, we explore the future

potential of HMDs by analyzing firm-level or producer innovation factors as well as general and specific product-level design factors.

The literature on producers reveals that firms increasingly adopt forms of innovation strategies, managerial practices, techniques or useful processes to achieve successful innovations (Almirall & Casadesus-Masanell 2010, Brown and Kathleen M Eisenhardt 1995). Organizational researchers use the term, "innovation model", to identify any coded approach to innovation. Informed by models, innovators develop mental constructs that generally shape their cognitions and behaviors. In firm settings, these models contribute language that leaders and others may use to envision and implement specific innovation activities. Models typically have both explicit and implicit components and are either predictive or prescriptive (Edgell & Vogl 2013).

Edgell and Vogl (2013), in their Transparency Innovation Models (TIMs) typology, identified information transmission modality as critical to innovation success and delineated a typological continuum of innovation models anchored by two endpoints. Meaningful Transparency Innovation Models (m-TIMs) are those which guide firms to share information and power among diverse constituencies, especially those external stakeholders who may contribute to innovation processes or who will likely be most affected by the innovation. Guided by m-TIMs, firms deploy discursive practices with embedded stakeholder groups to construct shared meanings (i.e., common schemas and scripts), often with the aim of improving social and technological synthesis (Garud & Karnøe, 2003; Latour, 2005).

At the other end of the continuum, Selective Transparency Innovation Models (s-TIMs) encourage firms to tightly control power and information, often on the basis of competitiveness rationales. With s-TIMs, firms influence perceptions of value and firm-favorable meanings through careful and selective dissemination of information. Firms constrain discourse with stakeholders by selecting and withholding information pertinent to innovations and their social impacts. Guided by s-TIMs, firms strongly shape external perceptions of value, often with the aim of controlling stakeholders' propensity to accept and eventually adopt innovations while preserving adaptability for future uncertainties (Hargadon & Douglas, 2001).

At the product-level, the video game industry has been at the forefront of many innovations in computer visualization and body proximate devices. Given that many gamers wish to more fully immerse themselves into the virtual worlds of games, producers have been motivated to integrate and develop HMDs. Considerable literature reveals the factors by which successful games with traditional body proximate devices engage and motivate users (Csíkszentmihályi, 1990; Hunicke, LeBlanc, & Zubek, 2004; Chen, 2007; Oliver et al., 2015). In contrast, few authors have explored similar success factors for creating engaging game experiences with HMDs. However, various authors have proposed design frameworks for the development of games that may be used to shape and guide future development for HMDs.

The Mechanics, Dynamics, and Aesthetics (MDA) framework assists game developers with both conceptualizing their projects and fully understanding their software's capacity to engage audiences (Hunicke et al., 2004). The MDA framework guides designers to first develop systems of rules (Mechanics) which then lead to interactions (Dynamics) that in turn create forms of fun (Aesthetics) for players. The process is then reversed for gamers, as they first experience games through Aesthetics and then through play try to discern games' Dynamics and Mechanics. Hunicke, LeBlanc, and Zubek (2004) conceptualized eight types of aesthetics that video games afford as follows: Sensation (game as sense-pleasure); Fantasy (game as make-believe); Narrative (game as drama); Challenge (game as obstacle course); Fellowship (game as social framework); Discovery (game as uncharted territory); Expression (game as self-discovery); and Submission (game as pastime). These aesthetic goals are the means by which designers influence players' affects towards games by inducing states of engaged productivity, otherwise known as "flow".

Csíkszentmihályi (1990) first coined flow to describe states in which individuals performing activities are fully immersed in feelings of energized focus, full involvement, and enjoyment in the process of the activity. Later Chen (2007) applied this concept to game design by introducing the concept of Dynamic Difficulty Adjustment. Currently, developers use Chen's approach in their games to keep users in flow and, thus, engaged. Initially, game users may readily adopt HMDs due to the appeal of perceived novelty. However, after introductory phases gamers or other users may not continue to use or adopt HMDs long-term. Research suggest that HMDs are more likely to remain or become more accepted long-term if they afford users prolonged and meaningful engagement experiences similar to those achieved by extant video games (Oliver et al., 2015). As such, MDA and Chen's approach may be crucial considerations for designing HMDs that sustain highly favorable user affects.

HMDs utility and corresponding user adoption, as with most hardware, is to a certain degree dependent on software content appeal and integration with the hardware. Accordingly, designers often aim to create software that optimally fuses with particular hardware affordances and constraints. Without the robust support of software developers and a variety of applications, game users may view HMDs as short-term novelties. Based on the research above, it follows that software developers who apply existing frameworks such as MDA and Chen's approach (e.g., "flow") to their virtual reality gaming applications for HMDs will gain benefits in the form of better engaged audiences, larger user bases, stronger integration with HMDs, and higher revenues. However, these software developers, in turn, want access to hardware producers' information and tools for particular platforms. As such, hardware producers might be challenged by twin paradoxical pressures: the force to be open with porous boundaries that permit omnidirectional information flows and the force to maintain and develop competitive advantages often derived from proprietary information.

## 3. Framework Discussion

We propose an integrated framework as shown in Figure 1 which includes diverse adoption factors from each of three differing perspectives: producer firm-level view, general product-level view, and HMD-specific view. At the firm-level or producer-level, we explore business factors that might impact adoption by applying the TIMs typology. At the product-level, users' satisfaction with immersions into virtual realms depends on how engaged they become in "flow" states which is influenced by mechanics, dynamics, and aesthetics general design choices. At the HMD-specific level, visual strain, power arrangements, and haptic feedback interaction are important design considerations. Both the multi-level nature and emphasis on HMD-specific factors make this framework particularly instrumental for HMDs.
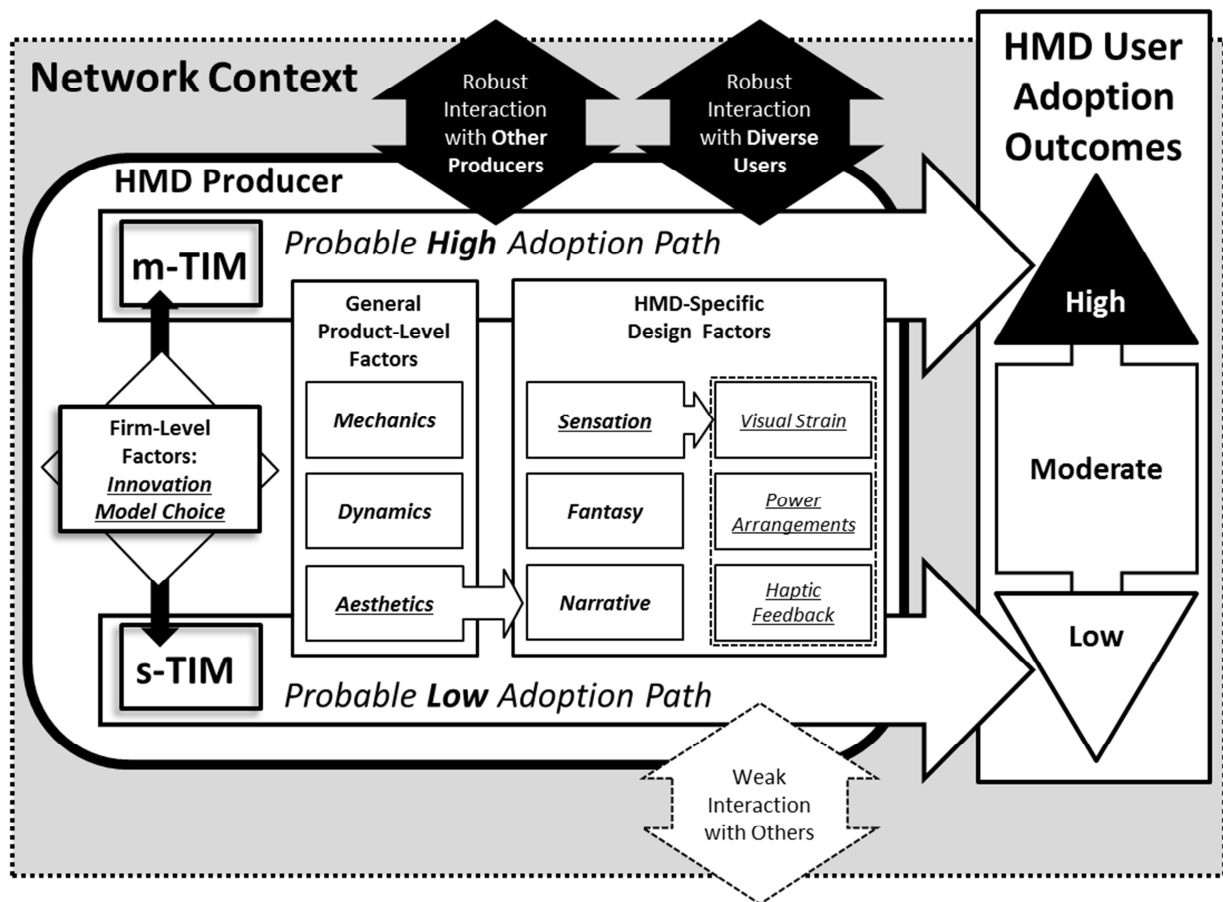
**Figure 1: Integrated Multi-Perspective Adoption Framework for HMDs**

At the firm- or producer-level, we explore business factors that might impact adoption by applying the **TIM framework** discussed above. We begin our investigation by briefly conducting a discourse analysis of publicly-available game developer comments (artifacts) with the aim of seeking insight about the prevalence of various TIM models (D4xframer, 2013). We use codes associated with each TIM variant, s- and m-. Our findings, although not generalizable due to sample size and other considerations, suggest a much higher prevalence of s-TIM deployment by game software developers and producers.

Moving to the general product-level, users' immersions into virtual reality realms generally depend on the aesthetics described in the **MDA approach** and keeping them in an engaged "flow" state. Chen's approach may be somewhat effective for enhancing HMD experiences and, as such, may need to be further tested and refined. At the specific product-level, the most powerful MDA aesthetic function that HMDs afford is the **Sensation** aesthetic which is favorably influenced by the art assets that games provide. By utilizing stereoscopic 3D, HMDs have the ability to make visualizations that appear to have depth and presence. Diverse technological innovations have enabled HMDs to achieve improved Sensation when compared to historical virtual reality attempts. One such example is the miniaturization of displays utilized by mobile technologies. Without these small displays, users might perceive HMDs as excessively heavy and lacking in terms of resolution or refresh rates and, thus, not have pleasurable Sensation experiences.

Furthermore, there are many relevant Sensation related factors that are highly likely to influence the utility and adoption of future HMD displays. In particular, **visual or eye strain** will limit the amount of time users will be able to enjoy HMDs (Desai, Desai, Ajmera, & Mehta, 2014).

Games and interfaces within HMDs will need to balance between desires to make visually complex and compelling experiences and to secure user comfort over long usage periods. In addition, usage periods are limited by **power arrangements**. Most current solutions enable power source tethering which limits mobility. On the other hand, batteries provide mobility but impose time usage limitations and increase device weight. Also, the means by which **haptic feedback** is integrated from other control devices will be relevant for Sensation development in certain HMD applications (Kangas et al., 2014).

Other MDA aesthetic design aspects are important. **Fantasy** and **Narrative** are also useful aesthetic factors for HMD adoption since together they contribute to HMDs capacity to replace or augment real world experiences. Games, relative to other entertainment and technology, afford perhaps the best non-normative and consequence-free experiences. This phenomenon should enhance initial HMD adoption given that gamers seek novel experiences. In addition, high levels of Challenge may be a difficult aesthetic to achieve since users may experience "disconnectedness" from interfaces and, as such, not be able to achieve satisfactory control of interactive experiences. Accordingly, early adoption may rely less on interaction and more on the Fantasy and Narratives aesthetics provided by HMD products.

To gain further insight about our integrated framework, we prepare case studies of two HMD firms: Oculus and Magic Leap. When observing various HMD producers through the TIMs lens, evidence suggests that Oculus's approach maps best to the m-TIM type whereas Magic Leap's model seems to represent an s-TIM type. Evidence that support our conclusions about Oculus includes its Kickstarter page which openly displays a timeline of news related to the device and comments (Oculus, 2012). Furthermore, Oculus's website appears to focus on community-building and encouraging discourse; it generously provides visitors with ample updates on innovation projects and with reasonable information about retail releases. It includes links to a community on Reddit which has over 50,000 registered subscribers (Telosin, 2015). Also, it allows anyone to buy developer kits unlike other producers. For example, HTC Vive provides only application pages; selection for development is not guaranteed (HTC, 2015). Lastly, Oculus provides developers with a robust "answers" section in which questions are responded to by the development team (Oculus, 2015a; Oculus, 2015b).

If Oculus's innovation approach is most aligned with the meaningful-TIM end of the continuum then TIMs would predict that Oculus might struggle to optimize initial or short-term adoption. However, Oculus could over longer periods experience greater adoption and loyalty since its products (e.g., Rift) should temporally come to meet or exceed expectations co-evolved with users and others. This may be especially true if users easily adopt HMDs upon introduction, due to novelty as well as Fantasy and Narrative aesthetics, but then require additional evolution of the overall interactive experience offered by HMDs. Oculus's deployment of an m-TIM might enable a more robust and engaged relationship with users who then are loyal and supportive of future product iterations. Also, this approach might lead to better anticipation of potential less-obvious harms.

In contrast, recent reports by news agencies have referred to Magic Leap as a "secretive" firm (Rusli & Barr, 2014) and a "mystery" startup (Ravikumar, 2014). Furthermore, a recent Reddit AMA ("ask me anything") session with CEO Abovitz elicited anonymous comments from participants which reveal disappointment with perceived vague answers to questions (Ronyabovitzofficial, 2015). Collectively this evidence suggests that Magic Leap's approach is focused on impression management and most closely aligned with the selective-TIM type. If true then TIMs would predict that Magic Leap might optimize initial or short-term adoption. However, it could, over longer periods, experience weaker adoption and retention since Magic Leap's products might not continue to meet or exceed users' emergent and evolving expectations. While the selective release of information might enhance initial adoption due to impression shaping, it might arrest the

development of insight needed to evolve highly engaged and immersive user experiences which in turn might negatively influence user loyalty. Expectations for future product iterations by the firm and by users may diverge. This could be especially problematic for the HMD market since research reveals that user factors, perhaps correlated with Sensation aesthetics, is an important acceptance variable (Genaro Motti & Caine, 2014). Game users report being skeptical (e.g., low levels of commitment) towards new innovations since they have experienced significant disappointment stemming from unrealized historical claims made by gaming firms (Sydell, Laura, 2015). Also, the s-TIM approach might lead to weaker anticipation of potential harms especially those arising from Sensation aesthetics.

## 4. Conclusion

We propose that the successful adoption of HMDs will depend upon not only software that instrumentally engages audiences and provides diverse libraries of applications, but also firm-level innovation model (TIMs) choices which yield HMDs with diverse and adaptable affordances and acceptable constraints.

Generally, both the m-TIM and s-TIM innovation approaches confer advantages and disadvantages. However, when applying these to HMD adoption, we argue that the m-TIM approach when distributed across networks of key stakeholders, offers greater advantages in terms of enabling open relationships and development processes among critical stakeholders such as HMD producers, software developers, haptic device producers, and potential diverse users. The use of m-TIMs may increase the likelihood of developing common schemas and scripts shared by key constituents. Although HMD producers are central to the development process, software developers are also essential since they support HMD adoption potential in two ways. First, they create and innovate uses for devices that could result in "killer apps" and encourage adoption by other gaming user groups as well as non-gaming user groups. Second, software developers act as early adopters; their acceptance can grant early market advantages to HMD devices.

However, producers' deployment of m-TIMs may not guarantee success given the evidence that many open development hardware projects are perceived as failures when they do not meet constituents' expectations. While not a HMD, the Android Ouya gaming platform exemplifies a project which had a highly successful Kickstarter campaign whose constituents ultimately perceived it as a failed hardware release due to not meeting firmware and library expectations (Kain, 2014; Marchand & Hennig-Thurau, 2013). In contrast, hardware innovated by producers using s-TIM models, as exemplified by the Nintendo Wii Motion Plus, might become commercial successes especially if they lack direct competitive offerings that provide comparable functionality (Marchand & Hennig-Thurau, 2013). We envision future studies after commercial HMD releases to further evaluate the TIMs used and corresponding user adoption metrics.

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