# Improving Digital Experience Through Modeling the Human Experience The Resurgence of Virtual (and Augmented and Mixed) Reality

# Improving digital experience through modeling the human experience: The resurgence of 'Virtual'- (& 'Augmented'- & 'Mixed'-) Reality[1]

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VR, broadly conceived, has existed in concept and occasional practice for over sixty years – with concepts dating back to science fiction, and implementations including the mechanical, multisensory, 3-D "Sensorama" system introduced as an entertainment novelty in 1956. Over the last decade, many applications of VR have been created, including some, such as *Second Life*, that reached mass popularity. However, VR has only recently achieved a stage of democratization – in the last several years mass-market, low-cost, high performance hardware and complementary VR development software has become widely available. (See Blade, et *al*. 2014, for a discussion of the history of VR in detail.)

## 1. Virtual Reality - A Broad View

We interact with digital information constantly. The aim of virtual reality (VR) is to improve the digital experience and enable people to interact with information in ways that they perceive as real. More precisely "virtual reality", in its broad sense, denotes a set of computer-human-interface methods, related technologies, and environments created by these methods that render information in the form of simulated objects, presenting these objects to the user through sensory stimuli, and offer physical modes of interaction. (Blade et al. 2014; Bailenson et al. 2008) This definition is intentionally broad, and encompasses not only binocular 3-dimensional visualization methods (such as those provided by VR headsets), but also 'augmented reality' such as the Microsoft Hololens, 'mixed reality', 'virtual environments' , and even realistic video games.

In the last year, building on decades of research and experimentation, effective tools that support VR have become widely available and affordable. For example low cost hardware offers surprisingly rich stereoscopic information visualization, head and body tracking, and environmental sensing and imaging. Further, the current generation of the now ubiquitous smartphone now offers some form of all of these. Whether they recognize it or not, people all over the world are increasingly encountering the methods of VR in games, work, and in 'third places' such as libraries and museums.

This new generation of tools shows substantial promise. With thoughtful design and implementation, VR tools and methods can be used to to enhance how people interact with computers, with information, and with each other other. VR methods can be used to make interactions easier, richer, more immersive, and more realistic -- and ultimately increase the engagement, efficiency, and satisfaction of these interactions.

This essay is designed generally to introduce information professionals and researchers to the topic of VR, to characterize its potential to enhance human experiences, and to identify the concepts that are critical to its application. The essay is also intended specifically for professional librarians, and applied library information science researchers, who aim to integrate new interface technologies and design concepts into library systems.

### 1.2 Pokémon are (Literally) Everywhere!: The spread of Augmented Reality

Pokémon GO was released by Niantic Labs in July 2016. Users downloaded this game to their mobile devices and attempted to find, catch, and train Pokémon. The first Pokémon game was originally released in 1996 for the Game Boy. Since then the Pokémon franchise released more electronic games, card games, and anime series. Pokémon GO revolved around the same concept as the rest of the franchise, to find, catch, and train Pokémon to become the best Pokémon trainer. The difference in Pokémon GO is that the game utilizes player's GPS systems on their phone to find Pokémon in the real world. These Pokémon could be found in parks, stores, libraries, and other public places around the world. Instead of staying in one place, the game forced players to walk around their neighborhoods to find new Pokémon to capture. When a player came across a Pokémon, they could see an image of the monster in front of them through their phones (Thier, 2016).


**Figure 1: Image from** PokémonGo Augmented reality game

Libraries embraced the Pokémon GO phenomenon. Many libraries created Pokémon related programs and displays. Some libraries even became pokéstops. Pokéstops are landmarks that users must visit to collect objects in order to continue with the game. They allow users to interact with each other and the pokéstop itself. The New York Public Library wrote a blog explaining the game and showing where to find Pokémon around the library. The Skokie Public Library in Skokie, IL created Pokémon GO Safaris for K-5 patrons. (Spina, 2016).

Pokémon GO utilizes a form of VR called augmented reality. Augmented reality combines the real world with virtual objects (van Krevelen & Poelman, 2010). There are many ways to experience augmented reality. With recent technology advancements, mobile devices are one of the easiest ways to utilize augmented reality technology. In Pokémon GO, for example, the Pokémon will only appear in the player's environment if they are looking at it through their phones or other devices. Augmented reality allows users to interact with their real world environment in new ways.

## 2. Design Principles for Applying VR

### 2.1 Enhance emotional experiences

Libraries act as places that inspire the people who visit them in addition to providing information. Often inspiration can be provided by innovative architecture that encourages exploration, thinking, collaboration. In a similar way, carefully designed use of VR can support richer and more positive emotional experiences.

For an example of how VR can heighten emotion, consider the work "Man on Spire" from the New York Times VR (Chin & Solomon, 2017). Even experienced on a smartphone, using an inexpensive viewer, such as Google Cardboard, this work can induce awe. The 4:34 video depicts Jimmy Chin, a professional mountaineer and filmmaker as he climbs to the top of the spire atop the newly built One World Trade Center in New York City. The title of the video makes reference to the 2008 documentary, "Man on Wire," about Philippe Petit's 1974 high wire walk between the twin towers of the former World Trade Center. We see Chin climb the needle-like spire of the new World Trade center along with Jameson Walsh, the person certified to conduct the annual inspection of the site. Chin refers to the skyscrapers of New York as the mountains of the city, with the World Trade Center as the tallest mountain. Upon reaching a platform at the top of the building, we see Chin slowly ascend the ladder-like tower that reaches another 408 feet into the sky. Entering the last portion of the spire, Chin clips the carabineer from his harness to the ladder, and leans out to take pictures of the skyline. We look out, up, and down with him.

Looking down at the buildings and the water below induces awe – and perhaps a little anxiety. Chin comments: "It's a very intense feeling to be up there. There you are on the top of this needle above eight million, ten million people. You get that very visceral experience of feeling insignificant. It was really just beautiful and almost lonely. I think that is what makes it special."

Although these emotions are cognitive phenomenon, they are often triggered, in part, by specific sensory experiences and visual designs. VR technologies offer new opportunities to incorporate richer sensory experiences into how patrons and visitors interact with digital material and data.

VR affordances are often employed with the goal of inducing a sense of *presence*. Informally presence is the feeling that one is really within a virtual environment, and interacting with it. Presence is often promoted by increasing *immersion*, or sensory fidelity, of the experience. Immersion is most often enhanced through visual elements, such as field of view; display resolution; stereoscopy; graphics rendering (image synthesis) features (e.g. shading, lighting, texture, reflection, depth of field) ; and head based rendering. (Bowman and McCahan 2007; Cummings and Bailenson 2015) Immersion can also be increased through elements of the virtual auditory interface including spatial auditory displays, cross-mode interactions, and selective auditory attention (Vorlander and Cunningham, 2014).

More formally, presence might be broadly conceived as part of a holistic experience that integrates sensory, cognitive, affective, active (personal) and relational (social) interaction together in order to increase the sense that a person is really in a particular place, the accuracy of the experience, and it's memorability. (Chertoff & Schatz 2014)

Nor is presence the only emotion that VR promotes. For example, VR is commonly employed in games with the aim of enhancing enjoyment. And although pleasure and enjoyment are often underrated in information system design, there is evidence to suggest that pleasure can be supported as an integral part of information of information seeking (see M. Dork, et.al 2011 for a review, and for examples see Hudt, et al 2012; Cauchard et. al 2006), This may, in turn, promote higher engagement, flow, and more effective learning.

Thoughtful use of VR affordances can even enhance not only interactions with systems, but with other people. Recent research suggests that VR may be useful to promote empathy and support pro-social behavior. Some approaches to enhancing empathy and pro-social behavior include enhancing social signals through capturing facial expressions and other behaviors (see Bailenson et. al 2008); simulating the perspective of others (Oh, et al. 2016); providing interaction methods that prime behaviors (see, Rosenbuerg et al., 2013), in which participants were given 'superpowers'.

There are even suggestions that VR may, through the induction of perceptions such as "vastness", may be able to promote profound emotional experiences such as awe (Rauhoeft et al. 2015). Although for thousands of years, many civilizations have recognized awe as an unexpected and overwhelming emotion that is tied to epiphanic experience, it is only recently that researchers have begun to study the emotion systematically. According to Dachner Keltner and J. Haidt, awe is defined, "as the emotion that arises when one encounters something so strikingly vast that it provokes a need to update one's mental schemas" (2003). Various studies on awe show that the emotion corresponds with feelings of well-being, of engagement, and benevolence (Rudd, et al. 2012) as well as increasing subjects willingness to "modify mental structures" (Shiota, Keltner, Mossman, 2007; Silvia et al. 2015) and change attitudes.

Awe is induced by two cognitive properties: vastness and accommodation. Vastness or so-called "perceived vastness" can literally mean the impression of a vast or large space such as a galaxy of stars or a city skyline. Vastness can also be interpreted on a metaphorical level where it, "describes any stimulus that challenges one's accustomed frame of reference in some dimension" (Shiota, Keltner, Mossman, 2007). This is to say that a speech by an exceptional orator could be perceived as vast as could a mind-altering or innovative novel.

In response to a vast event that is beyond one's usual frame of reference, the brain must accommodate or shift in order to assimilate this new experience into their worldview. Accommodation is the name of this reaction that occurs in the reaction to an awe-inducing event. Accommodation is both, "an inability to assimilate an experience into current mental structures" as well as the, "willingness to modify mental structures" in order to integrate the new experience into an evolved worldview (Keltner and Haidt, 2003; Shiota, Keltner, Mossman, 2007).

Psychological research on creativity shows that experiencing events or imagery that is "outside of habitual thought patterns can lead to enhanced cognitive flexibility and creativity."[3] In their 2012 article, scientists from UC Davis and Radboud University Nijmegen, hypothesized that students who experienced an "unusual or unexpected experience" would demonstrate greater, "flexible and creative thinking." To test this process, students watched events in VR that violated the laws of physics. For example a bottle knocked over from a table started to float or levitate in the air instead of falling to the ground. After viewing this imagery, students were asked to answer the question "What is sound?" by generating as many answers as possible. The scientists found that, "actively (but not vicariously) experiencing unusual and unexpected events enhances people's cognitive flexibility"(Ritter et al. 2012). Simone M. Ritter defines cognitive flexibility as, "the ability to break old cognitive patterns...and thus, make novel (creative) associations between concepts"(2012). Therefore, it is possible that brainstorming techniques or exploration in VR, which alters patrons' self-schema can promote greater creativity as well as innovation in the research and learning process.

In 2016, David B. Yaden and Jonathan Iwry and several other scientists completed a study on the so-called, "overview effect," which is the term created by Frank White for the epiphanic, euphoric, and self-transcendent feeling astronauts experience when seeing the earth from space. In writing about the overview effect, Yaden et al. note that the experience corresponds with, "changes to the observer's 'self-schema'—the particular framework through which they imagine themselves in relation to the world" (Yaden 2016). As a next step, Yaden would like to try to replicate the overview effect through VR technology as way to, "foster that feeling of connectedness" that is generated by awe-inspiring overview effect.[4]

[3] P. 93, *Wired to Create: Unraveling the Mysteries of the Human Mind*, Scott Barry Kaufman and Carolyn Gregoire (2015)

[4] Jordan Rosenfeld in New York Magazine, 26 May 2016. "Scientists are trying to solve the mystery of awe."

In sum, VR enables one to create experiences that are emotional as well as informative. By thoughtfully designing the sensory affordance in VR to enhance the intellectual and psychological interactions, one can create a substantial impact.

### 2.2 Designing interfaces to enhance engagement

One of the most prevalent functions of VR technology is the ability to feel "present" in a different environment through sensory immersion. These immersive experiences increase user engagement in these environments. There are three different types of engagement, behavioral, emotional, and cognitive. Behavioral engagement focuses on participation. Emotional engagement includes positive and negative reactions to those around them and willingness to do the work. Cognitive engagement incorporates thoughtfulness and willingness to put forth the necessary effort to understand complex ideas. While there are distinctions between the three types of engagement, they come together to form a single multidimensional process (Fredricks, Blumenfeld, & Paris, 2004).

Using immersion can enhance engagement through situated learning. Situated learning is rarely used in the classroom because it is difficult to re-enact a real life setting in a structured classroom. However, immersion can use situated learning by allowing users to experience real life situations through the digital environment (Dede, 2009). There are two types of immersion that helps students to engage in learning and develop better problem solving skills. 'Actional' immersion allows for users to experience actions that would otherwise be impossible to experience in the real world. For example, being able to fly around like a bird would increase the level of concentration (Dede, 2009). Symbolic immersion uses experience to trigger psychological associations with the user. For example, someone may have an increased sense of fear if they were to face a virtual monster even though their physical environment is unchanged and safe. These two types of immersion creates a new environment for students to build their academic abilities by allowing students to move away from their real world identities (Dede, 2009).

One example of a virtual environment that enhanced engagement was Second Life. Second Life was a 3-dimensional, desktop based virtual world created in 2003 by Linden Labs and was for adults who were 18 years old or older. It allowed users to create avatars and interact with other users in a virtual environment. Avatars could imitate the real world by purchasing clothes, constructing buildings, and meeting new people. Second Life offered people with a space where they could collaborate together in the virtual world (Inman, Wright & Hartman, 2010).

Universities explored Second Life's potential to create virtual immersive learning environments for students. The School of Library and Information Science at San José State University created a sixteen-acre virtual campus modeled after their physical campus. The faculty at San José State

University were encouraged to move their classes to their new virtual campus on Second Life. Some professors embraced the idea of hosting classes on Second Life. Faculty found that there was less geographic or physical constraints by hosting classes through Second Life which allowed for freedom to create experiences that were difficult to achieve in real life. For example, one professor created simulations so students could practice skills such as interviewing (Luo & Kemp, 2008). Creating these virtual immersive learning environments on Second Life helped achieve a situated learning environment and increase the engagement of online students who may be missing the experience of in person classes.

### 2.3 Designing systems to support collaboration

Virtual worlds like Second Life allowed for people all over the world to collaborate and create a shared task space in a virtual environment. For example, virtual conferences created a new way for avatars to come together in the virtual world. Creating a shared task space in VR gives people the ability to meet and collaborate in a virtual environment without the limitations of needing a physical space.

There are many features that would create a virtual collaborative environment that could emulate face to face collaboration. Allowing for a shared task space and shared manipulation gives users the opportunity to collaborate together in the same environment and to create with each other. Web-based word processors such as Google Docs allow for this type of collaboration. In Google Docs, users can add content into a shared document and see each other's edits in real time without needing to download it to a computer (Karpova, Correia, & Baran, 2009**).** Collaboration in VR could take this a step further and incorporate more elements of face to face interactions. Other ways collaboration can be enhanced is by allowing users to see where someone else is looking or by being able to view, manipulate, and annotate a physical object in a virtual space.

Mixed reality, a subclass of VR, provides a different way for people to collaborate virtually. Mixed reality is a form of VR which mixes real and virtual worlds within the same experience (Milgram & Kishino, 1994). Carnegie Mellon University and Microsoft teamed together to work on a method to utilize mixed reality without requiring every participant to have a mixed reality device such as Microsoft's Hololens. They envisioned a method utilizing Skype where a single user would have a head mounted display to allow others to see and annotate the primary user's space (Lee, Swift, Tang & Chen, 2015).

The article gave the example of a student participating in an exploration of a cave. Using this method, if the professor could not accompany the student, the student could use a Hololens device to allow the professor to see exactly what the student is seeing by using Skype from their office. Then the professor could annotate the student's environment and the student would be able to see the professor's annotations in real time (Lee et al., 2015). While the consumer version of the Hololens has yet to be released, this method could have a great impact on virtual collaboration among education and other fields alike.

### 2.4 Support physically richer modes of interacting with systems/content

Creating a realistic environment goes beyond the visual aspects of a virtual world. It is also important to consider how the user interacts with the environment. There are many ways that VR can support richer modes of interacting with an environment by creating methods that are similar to how users interact with the real world. Gaze tracking follows where a user focuses their attention. Body motions can be tracked allowing for a user to walk around in the virtual world while physically walking in the real world. Hand tracking would allow users to interact with the world in a realistic way instead of using a game controller. These movement tracking methods enhance the VR experience by creating a deeper level of immersion for the user (Lee, Lin, Tung, Wang, & Valstar, 2015).

Hand tracking systems in VR help to create a life-like environment for those using VR technologies. These systems allow users to use hand gestures to interact with objects or manipulate the virtual environment. There are various proposed methods to tracking hand gestures. Many hand tracking systems require some device on the hand itself to track motions due to the difficulty of tracking the bare hand. The bare hand is hard to track by itself since it is a highly articulated flexible object (Pan et al., 2010). One proposed method that tracked the bare hand used a multi-cue hand tracking algorithm based on velocity weighted features and color cues in the hand (Pan et al., 2010).

Other methods track the hand by using devices on the hand. Wang and Popović (2009) utilizes a multi colored glove and a single camera to track the motions. They demonstrated the applications of this method in three ways. They demonstrated the ability to control a character's walking motions, interact with building blocks to create a virtual 3-D structure, and recognize the American Sign Language alphabet to create a fingerspelling application (Wang & Popović, 2009). Frati and Prattichizzo (2011) proposed a method using Microsoft Kinect and sensors on the fingers to track user's hand motions. They presented an algorithm to allow for the animation of the hand in the virtual environment (Frati & Prattichizzo, 2011). While there are various methods for hand tracking systems, these three show the variation in achieving accurate hand tracking.

There are many possible benefits to creating realistic forms of interaction. These elements allow for users to be further immersed in their environment by being able to realistically interact with the virtual world. However, there are benefits beyond creating these immersive experiences.

These forms of interacting are also helpful for medical purposes by allowing patients to use realistic hand movements while playing a game.

In a study, a leap motion controller was utilized to aid elderly patients affected with subacute stroke (Iosa et al., 2015). A leap motion controller captures the motions of the hands to control a virtual environment without the need of markers while playing video games designed to help improve the patient's hand functions. Four elderly patients participated in the study and their hand ability and grasp force were measured. At the end of the study, patients showed significantly higher improved hand ability and grasp force. The sample size for this study is small due to the fact it served as a pilot study to provide a proof of concept that a leap motion controller can be suitable for elderly patients with subacute stroke. Despite the sample size, this study does show how hand tracking, such as with the leap motion controller, can be utilized to simulate real life hand motions and allow users to interact with these systems in realistic ways.

### 2.5 Incorporate elements of user environment/content

Augmented reality, a form of mixed reality, allows for digital elements to be incorporated into the real world. Augmented reality was first prototyped in the 1960s by a computer graphics professor, Ivan Sutherland and his students at Harvard University and the University of Utah. In the 1970s and 1980s research continued with a small group of people from the U.S. Air Force's Armstrong Laboratory, the NASA Ames Research Center, the Massachusetts Institute of Technology, and the University of North Carolina at Chapel Hill. Augmented reality was a distinct field of research by the late 1990s after several conferences began presenting on the topic (van Krevelen & Poelman, 2010).

Augmented reality aids users in incorporating elements into the user's environment. Pokémon GO, as mentioned earlier, helped the general public understand how augmented reality could be used to create this concept. However, Pokémon GO is not the only way augmented reality can be used to enhance the user's environment.

Libraries could help patrons receive book reviews by creating a book display of augmented reality enabled covers accessible through an app on their phones (Goerner, 2016). Posters hung around a classroom or library can trigger videos and come to life when viewed through a tablet or mobile device (Baird, 2016).

There are many key components needed to create an augmented reality system. Essential components including displays, sensors and tracking user position, and orientation are necessary to combine the virtual world with the real world. Also, graphic computers and software technologies are key components to allow for real-time, 3D interactions (van Krevelen & Poelman, 2010).

Estapa and Nadolny (2015) assessed the achievement and motivation of high school students after utilizing augmented reality for a mathematics activity. In this study, students solved mathematics problems surrounding a similar theme, a spring break trip to Mexico. Half of the students solved the problems using print documents enhanced by augmented reality and the other students accessed the same information on a website. While they found both groups increased their overall achievement, the group using augmented reality demonstrated higher motivation. Estapa and Nadolny (2015) stated, "Augmented reality within and across content areas has the potential to produce interactive, real-world learning opportunities for students" (p. 46).

## 3. Developing a strategy to enhance digital interactions with (and within) Libraries

### 3.1 Targeting Library Interactions and Audiences

For librarians the discussion above may raise questions about how the affordances of these new technologies may be applied in libraries -- for example to increase inclusion and access: Could VR be used to increase engagement and attention by using immersion to convey a sense of place of being in an historic archive? Could we reduce the barriers to those seeking library instruction and reference by using avatars to enhance social communication? Could we enhance discovery and interaction with library collections by using physical interaction to make navigation of information spaces seamless?

The conceptual diagram below illustrates the conceptual connections between areas of library services, the enhancements to interaction that VR can possibly provide; the interaction features that promote those enhancements; and the current technologies that support these features.

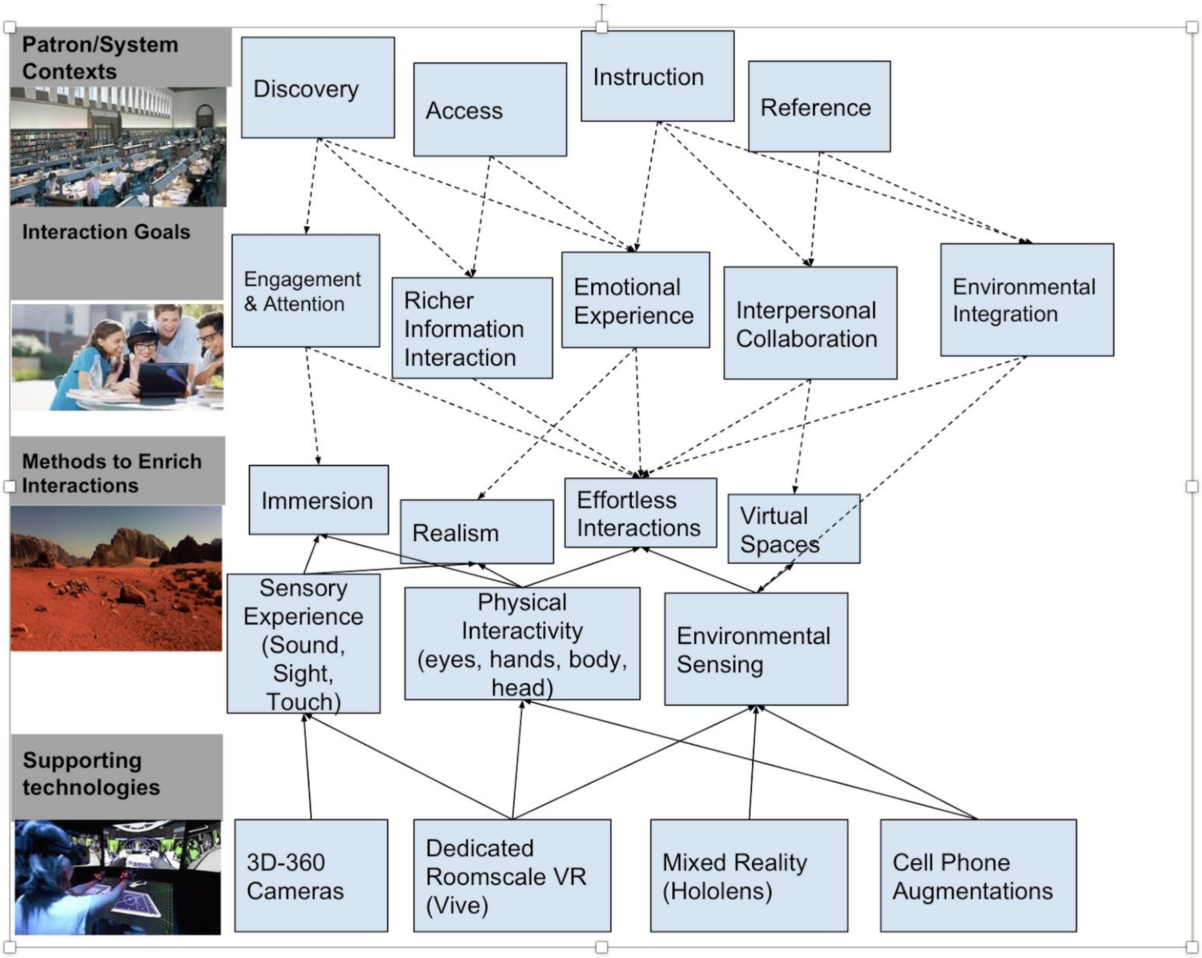


**Figure 2:** Links between library interaction scenarios, interaction goals, methods, and technologies

VR may potentially be used to enhance any of the major areas in which patrons interact with libraries and collections: discovery, access, reference and instruction. VR technologies can enhance interactions with information and with other people in a variety of ways through enhancing emotional experiences such as presence, curiosity, pleasure, empathy, and awe; enhancing engagement through forms of immersion; supporting collaboration by reducing barriers to communication, and by providing shared task spaces; providing richer modes of interacting with information; and by incorporating elements of the user's environment in the experience.

However, VR experiences must be carefully designed -- as the various VR affordances (and supporting technologies) target different parts of the interaction experience. And each area of library services may use VR in different ways -- in pursuit of different interaction goals. When libraries move to pilot a VR experience they should carefully consider how the target audience and interaction might benefit from selected enhancements; which areas of enhancement to target; and thus which VR features to support.

For example, library discovery may benefit from the use of VR to improve engagement, offer richer information interaction, and induce emotional experiences such as “flow”  -- whereas library instruction may benefit more from VR’s potential to facilitate more seamless interpersonal interaction, and to incorporate elements of the user’s environment into the interaction. As a library prepares to engage with VR it should carefully consider which area of interactions it is targeting, what current or additional audiences it intends to reach, and how these audiences can be better served.

Once a target audience, area of interaction, and enhancement goal has been selected,  one should target the features of VR that are most closely associated with that enhancement goal. For example, sense of presence is strongly enhanced by the ability to direct the direction of gaze (e.g. through 360-degree video), by binocular video, and by head tracking; while collaboration is more strongly promoted by shared task spaces, and facial tracking. Select specific technologies only once the most important interface features have been identified.

### 3.2 Exploring strategies: Four ways of looking at Medieval manuscripts

When a library has a particular need for their collection, one that is difficult to solve with staffing, current collections technology, or funding, one place to turn may be VR. VR can allow access to certain library materials and spaces without the constraints of time, space, staffing, and perhaps most importantly, physical availability of the collections or item in question. VR may also help libraries raise the profile of certain collections and make them available to the entire internet enabled world.

While VR technology at the level of a VIVE or similar device is not yet entirely common, YouTube is available on every internet connected device. 360 degree videos are supported by YouTube and can be used on desktops or mobile devices. 360 degree videos can also be watched via VR devices and are relatively inexpensive to create and produce. For example, if one wanted to give patrons a more immersive experience, they could create a 360 degree video tour of a special collection. This will allow patrons to feel immersed in the environment. The University of Adelaide Libraries in Australia created a VR project to explore two key forms of VR. They used the GoPro 360 Heros rig to shoot three short videos around and outside of the library. (Weatherall, Miller, & Thomas, n.d.)

VR experiences such as these may allow for remote browsing, cut down on wear and tear on specific items, and make the collections available to a wider audience. The library may want to allow for anyone to view, for instance, their manuscripts as well as allow patrons to interact with the manuscripts by being able to add comments or tags to the images or take screenshots. Items may available for online browsing, and patrons may be able get a better feel of a rare or fragile item by allowing the entire item to be scanned and manipulated in VR.

These immersive experiences may also allow patrons the magic of serendipity. It may make finding different or unknown items easier and assist with better searching and suggestions based on previous searches. This type of experience should also, ideally, allow patrons to take screenshots or download the entire text and provide an easy way for patrons to access and ask questions about the material. They can create digitized books of manuscripts like an ebook. A VR tour can achieve these goals by having all the texts live on a virtual bookshelf. It can be hosted on the library's own website via a virtual reference desk interface.

If patrons want to use a manuscript in the special collections room for heavy research, a program could be created for use on a desktop computer with high resolution. The library could put aside one or two computers that contain the program. This would allow patrons to write notes in their own notebooks and people could potentially work together if they wanted to look at the same thing. However, this experience is not immersive. If patrons want to use this option for educational purposes or just to explore, the institution could create a program that is supported on a high end VR device such as Oculus Rift to create an immersive experience. If both seem like a good option then both could be created so patrons can use whichever method is best for them. A social platform in VR, Altspace VR, allows users to interact with each other in an immersive environment. While Altspace VR is intended for use with VR devices, users can also access the social platform on mobile devices or computers ("Altspace VR", 2017).

The library may want to enhance the experience of browsing the physical collection. Patrons could see comments, annotations and tags on physical items created by other patrons as well as add in their own. Patrons can use their own mobile devices for this purpose. The library can utilize an app that will allow patrons to do this by hovering over a book cover or a certain page and the other comments or annotations will appear. This app will also assist patrons in their search for items or topics within a collections.  They could search for a topic on their phones or tablet and then find an item and select it. They could hold their mobile device up to the shelves or the room and it will show on the screen where their item is located and, possibly, where other similar items are. Such an app could also help orient patrons around special collections as well. Such a patron oriented app could also function as a map -  patrons could hold their mobile device up at eye level and look at the screen and subject areas will highlight. This could help patrons discover the materials around them and enhance the magic of serendipity.

The library could create an app that uses augmented reality to achieve these goals. For example, media experience designer, Pradeep Siddappa, created an app called LibrARi that allows patrons to locate books on the shelf by utilizing augmented reality. The app is designed to enhance information discovery and make it easier for patrons to find books (Siddappa, 2014).

These are just a few examples of how a library could enhance various interactions utilizing VR. There are many more ways that VR could help solve a need in the library. Critically evaluating the needs of the library can help to decide how VR can be used to enhance patron experiences.

### 3.3 Negative Design Considerations

VR technology imposes costs for equipment, development, and maintenance; and can impose burdens on ease of use. For example, the need to use expensive, bulky VR equipment might well be justified in the experience of exploring a volcano– but would be counterproductive if used to reproduce the experience of sitting in an ordinary classroom. To avoid being seduced by novel features or becoming lost in technical choices, it is useful to consider past design misuses (also known as "anti-patterns").

*Avoid technology demos*. VR is a new technology, and many applications of VR function more as demonstrations of the technology, than as well-designed solutions to particular interface problems. While some of these demos may be initially attractive, they will not sustain user engagement unless they serve a purpose and provide a benefit. To avoid being entranced by technology experience identify the specific audience you intend to target, the specific ways in which you expect VR technologies to enhance the user-interface experience, and estimate the extent to which costs and barriers to use are justified by potential gains.

*Avoid creating new barriers to interaction.* The aim of VR is to make interactions richer and easier, however naïve application of new technologies can often have the reverse effects. Cutting edge VR technologies are often expensive -- thus requiring the use of these technologies for interaction with a system may create economic barriers to use. Further, even when equipment is supplied, or widely available, bulky VR equipment may limit some interactions while enabling others: cords restrict movement, goggles obscure vision (and may prevent interaction with people in the same space), and specialized controls may interfere with use of keyboards.

Moreover, use of VR may create new cognitive barriers to interaction -- resulting in a "steep learning curve". (See for example, Luo and Kempo 2008). While it may be natural for a user to perform direct physical manipulation of a physical model of information within a virtual environment, interacting with VR equipment and within virtual environments is not yet standardized. Thus VR environments may not support affordances (such as zooming in on an image) that users have come to expect, or may find the mechanism for non-physical UI interactions, such as displaying a menu, puzzling or non-intuitive. Further, even experiences based on physical manipulation may be more tiring, or induce motion-sickness in a virtual environment. (Fox et al. 2009) Finally, although the new affordances offered by VR offers the potential to create new interfaces that are more accessible to neurodivergent and disabled users, many current VR systems are not developed with accessibility in mind.

*Avoid indiscriminate realism.* Reality is sometimes boring, unpleasant or even dangerous. Thus when creating a virtual environment it is important to consider both which aspects of reality one should and should not reproduce. For example, some early approaches by Universities (and even libraries) to developing a presence in second life was to essentially duplicate the institutions physical environment – a campus, building, or lecture hall (for a partial review, see Jennings and Collins 2007) Although this approach may be useful for an architectural walkthrough – for most students a better approach (such as that taken by San Jose State University, discussed above) would be to have the virtual environment not duplicate the classroom experience but take an opportunity to provide a more authentic experience of the object of study.

## 4. Launching VR in Libraries

### 4.1 Planning for VR Implementation

There are many components to consider when thinking about implementing VR in libraries or other settings. A fully developed plan will be helpful to make decisions for the entire process. First, deciding what type of experience the users of the VR pilot will participate in will inform the rest of the process. It is first important to decide on a set goal or outcome for the VR experience. There are other questions to ask at this point to help guide this decision. These questions may include, what interaction elements are most influential in achieving the goal? What experience will be improved, for whom, and in what way? There are many other aspects to consider at this point as well. Deciding on a set budget is critical before getting too far in the process. It will help inform many other aspects implementing a VR experience. Other considerations at this point should include timeline, space available in the library, and staffing.

Another important component of this process is to decide how the pilot will be developed. There may be programs already produced that can be used for a VR pilot. This would be one of the simplest method of implementation. It would not require much development and the production cost could be lower. However, it may be harder to have a personalized experience. If the pilot needs to be produced from scratch then there will be more questions to answer. Some question to be considered could include, who will develop the program? Will someone need to be hired to develop it? What would be the added cost? Does that fit in with the budget allotted for the pilot? Answering all of these questions is critical before making decisions on VR devices.

The final stage of planning would be to consider what technologies are affordable and feasible for the pilot being planned. There are many different VR devices that vary in cost and functionality. Carefully considering which device would be appropriate for the pilot will be critical for success. Designing an assessment plan would also be a consideration at this stage. Having some quantifying information that can be reported could be critical for the further implementation of a VR pilot.

Even at the pilot stage, one should consider how the new technology will integrate with existing library systems. Although some technologies, such as 360 video are relatively standardized and interoperate with a range of hardware and software, standards in other areas, such as body tracking are still evolving.  Thus VR hardware and software may be tied to particular hardware and software platforms.

Finally consider if there are any safety considerations before implementation. VR hardware is often accompanied by a long list of cautions -- however most risks are minor. For example, some lower to medium end devices are not ideal for long sessions as they induce motion sickness: Users can start to feel a bit sick after long stretches with the device (Grush, 2016). Other common potential safety considerations include obscured vision from wearing goggles; collisions and falls when a person is physically moving their body in space -- especially if cords and goggles are involved. Finally, a potentially serious risk for those who have photo-sensitive epilepsy (which may be undiagnosed) is that full field-of-view visualizations could trigger seizures.  Considering these concerns before implementation would not only inform decisions but to plan ahead for when patrons begin use the devices.

### 4.2 Options for a VR Pilot

There are many different options to pilot a VR experience at a library or other institution. These options could range from being relatively inexpensive and easy to put together all the way to options that are costly and would be more complicated to produce. However, starting off with a smaller, less costly pilot could be helpful to introduce VR into a library to assess interest and future success.

An augmented reality pilot could be achieved with very low cost but it could take some time to produce. There are many programs and apps, including free programs, on the internet that allow users to create their own augmented reality experience. For example, one app called Aurasma allowed teacher, Maria Baird, to create an easy way for documents to be read aloud to students through their tablets. She even found a way to allow students to create their own experiences using the program (Baird, 2016). This option could be free to pilot if there are already smart phones or tablets available to use once the product is completed.

Another option for a VR pilot is to create 360-degree videos. Creating 360-degree videos could potentially have a low production cost. One of the benefits to creating 360-degree videos is that while users should use a VR headset to get the full experience, they can also view the video on a mobile device or computer. 360-degree videos are used for a wide range of purposes. For example, colleges and universities use these videos to provide tours of the campus. It provides students with the opportunity to get chance to look around campus and to get a feel of what it would be like to be there (Joly, 2016). Creating a 360-degree video would require the purchase of a special camera that supports 360-degree video recording. These cameras can cost around $200. These videos can be viewed with low end VR devices such as Google cardboard.

These two pilots are examples of smaller scale projects that could help introduce VR into a library setting. After a pilot is implemented, it is important to assess the program to see if a larger scale project could be successful. Some questions to ask could include, what could be learned from the pilot? How might it be improved for the future? What would a successful, larger scale project for the library look like? What new experiences would the users want to explore in a new project? Asking these questions could help improve the smaller pilot and inform the design of the larger project.

### 4.3 Scaling out a VR pilot

Once a successful pilot has been implemented, libraries may be interested in scaling out the VR experience to a larger project. This project would most likely have a specific goal in mind based on a specific need of the library. The same questions that were asked before implementing a pilot should be asked when looking to scale out. However, there may be some new aspects to consider. It would be important to decide how a VR project would help this need. Once a specific goal is in mind, the next step would be to decide on specific design elements that will be highlighted in the program. For example, is creating an immersive environment important to the goal of the project?

It is also important to understand what types of VR devices are on the market and which ones would be best to achieve the goal of the project. There are varying levels of VR devices. These devices cover a wide range in cost. Devices such as Google Cardboard are among the least expensive. People can even build their own headset by using plans and designs available for free on the Google Cardboard website (Moorefield-Lang, 2015). These devices are compatible with most mobile devices (W. Powell, V. Powell, Brown, Cook & Uddin, 2016). In the middle, there are devices such as the Gear VR and Google Daydream. Similar to Google Cardboard, these devices require the use of mobile devices to create the VR experience. However, unlike Google Cardboard, there are only a few mobile devices that are compatible with the Gear VR or Google Daydream. The highest level of VR include devices such as the Oculus Rift and HTC Vive. Both of these devices requires the equipment to be connected to a high powered computer. Connecting the device to a computer instead of a smartphone allows for higher quality images (Swider, 2017).

Each of these devices can be useful for various tasks that can be accomplished with VR. Every device allows for head tracking which gives the users the ability to look around the virtual environment in 360-degree views. For Google cardboard, one of the main functions of these devices are viewing 360-degree videos and photos. These videos allow for semi immersive experiences since most of these videos either do not allow users to move around or put them on a fixed path (W. Powell et al., 2016). Higher end devices such as Oculus Rift or HTC Vive would be better for creating physically richer modes of interacting with the environment. These devices can support various technologies to allow for this functionality. For example, hand tracking systems would be able to be incorporated in this higher end devices and provide users with a more immersive VR experience (Lee et al., 2015). Lower end devices may not be able to support these added systems.

After looking into various devices, limitations, and challenges, safety issues should be considered. Each device may have its own sets of limitations that would be important to know before purchasing and implementing the technology. For example, it is difficult to provide interactivity with the Google Cardboard. Some of these devices have a button built in allowing the user to click but the interactivity is limited (W. Powell et al., 2016). Also, heavy use of the phone inside device such as Google Cardboard, Gear VR or Google Daydream can cause the phone to potentially overheat (Grush, 2016).

Devices and programs may also have system integration considerations. For example, with high end devices such as Oculus Rift and HTC Vive, the user must have a high powered computer in order to run VR programs. The devices require a high amount of processing power to run without any issues (Eadicicco, 2016). Some computer companies sell computers that are ready to run these devices however they are relatively expensive. Standard desktop computers will not be able to support these devices.

Considering all of these elements when wanting to scale out will help the success of the VR project and careful consideration before any equipment is purchased will allow for easy implementation and may help there to be fewer issues later. Thinking about how this project will fit into the library and how it will fulfill a need in the library will not only allow users to have an interesting VR experience but also to create a meaningful experience for the community.

## Summary

VR is a collection of different tools and methods for enhancing interactions with digital systems and content. Although VR technologies have existed for decades, they are now improved and readily available to libraries. VR could improve browsing, access, reference, and instruction. To do this requires careful design to incorporate the key mechanisms and principles of VR such as creating immersive experiences to enhance engagement in virtual environments, enhancing the ability to collaborate virtually, to emulate face to face collaboration, enhance emotional communication, supporting physically richer modes of interacting with the environment, and incorporating virtual objects in the user's environment. Each of these design principles, whether taken separately or combined can create a VR experience for a wide range of users.

VR may potentially be used to enhance any of the major areas in which patrons interact with libraries and collections: discovery, access, reference, and instruction. As a library prepares to engage with VR it should carefully consider which area of interactions it is targeting, what current or additional audiences it intends to reach, and how these audiences can be better served. VR technologies can enhance interactions with information and with other people in a variety of ways. Thus, when libraries move to pilot a VR experience they should carefully consider how the target audience and interaction might benefit from selected enhancements; which areas of enhancement to target; and thus which VR features to support. Select specific technologies only once the most important interface features have been identified.

There are many key questions that should be asked when thinking about implementing VR in a library. These considerations include deciding on specific goals or a set outcome for the VR experience. Other considerations include target audience, budget, timeline, space available, and staffing. Another important aspect is to look into who would be developing the program and what added production costs might be. All of these components should be planned out and carefully considered before deciding on devices or equipment. These questions will help inform what would be appropriate for the desired outcome.

Starting off with a smaller pilot project is helpful for learning about the technology and how it will be received by users before implementing a larger scale project. Once deciding to scale out to a larger VR project there are more aspects to consider. It is important to have a specific goal in mind and think about the design elements that should be focused on in the project. Once these decisions are made then it is important to look at the types of devices that are currently on the market and which ones would be appropriate for the project. Each of these devices can accomplish different goals. Some design elements that may be featured in the project may not be available in every device. Limitations, challenges, safety issues, and system integration considerations should be evaluated before any final decision is made to ensure easy implementation. Implementing VR into a library can bring meaningful experience for patrons. VR is not only for gaming, it can enhance people's lives in new previously unachieveable ways, and libraries can bring that experience to them.

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