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Exploring barriers to adoption of Virtual Reality through Social Media Analytics and Machine Learning – An assessment of technology, network, price and trialability

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ABSTRACT

This paper aims to assess how diffusion of Virtual Reality (VR) technology is taking place and identify potential barriers to increased adoption. This is done by utilising Social Media Analytics to collect a data set covering an empirical material of 6044 user-generated content concerning the market-leading VR headsets Oculus Rift and HTC Vive, and machine learning to identify critical barriers to adoption. Our findings suggest that there is a lack of sufficient technological performance of these headsets and that more applications are required for this technology to take off. We contribute to literature on VR by providing a systematic assessment of current barriers to adoption while also pointing out implications for marketing.

1. Introduction

Virtual Reality (VR) technology is a medium designed to present media content in as immersive a way as possible (Berg & Vance, 2016). Recently, VR technology developers have made use of motion tracking to create handheld controls allowing the user to interact with objects in VR (Gronstedt, 2016; Oculus, 2016; Vive, 2017). This feature creates opportunities to create novel consumer experiences. Consequently, technology companies such as Facebook and HTC are currently developing high-end VR technology for the experience industry through their headset initiatives Oculus Rift and HTC Vive respectively.

Even though VR technology is much anticipated and has attracted significant investment (Gleasure & Feller, 2016), sales numbers are so far disappointing. Given that Facebook bought Oculus Rift for $2 billion in 2014 (Gleasure & Feller, 2016), and that the price of a headset is about $500, much remains to be done to achieve widespread adoption in key consumer markets. Understanding barriers to adoption of VR technology is therefore a critical issue, not only for suppliers of these sets, but also for related businesses and consumer groups.

This paper aims to assess ways in which diffusion of VR technology is taking place and identify potential barriers to adoption. Specifically, we explore whether barriers are related to the performance of VR headsets, the amount of available complements, the price point and/or the trialability of these products. We do this by employing Social Media Analytics (SMA) and machine learning (ML). Utilising SMA, a data set covering 6044 user-generated content concerning the market-leading VR headsets Oculus Rift and HTC Vive was first collected. By applying ML, central dimensions related to barriers to adoption for VR technologies were studied thereafter. Our data points at specific barriers to adoption and, in doing so, this paper adds to extant literature on VR technologies by providing a systematic assessment of VR's current state of diffusion and its associated implications for marketing.

The remainder of the paper is organised as follows. The next section delves deeper into literature on VR and relates it to literature on factors determining whether new technologies are adopted or not. Next, our method is presented in further detail, which is followed by our results and analysis. Eventually, a concluding remark is provided together with limitations and directions for future research.

2. Elements of the topic

This section provides a further introduction to VR technology, while also looking more into factors determining the adoption of new technologies. The final subsection elaborates, derives and justifies our

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research problem in further detail.

2.1. Virtual reality

VR technology is designed to present the senses with a computer-generated three-dimensional environment that can be explored and interacted with to some degree (Virtual Reality Society, 2017). The illusion is created by activating many of the senses, including vision, hearing and feel. Traditional ways to present media are also designed to immerse the user, but these technologies do not strive to create an ever-improving illusion of another reality. That is the ambition of VR technology (Virtual Reality Society, 2017).

In practice, the illusion of VR is created by presenting visual data on screens within a headset that completely obscures the user's vision. Headphones present the user with sound from the VR he or she is viewing in the headset. VR headsets are equipped with gyroscope technology that tracks head movement to create an illusion of looking around inside VR. High-end headsets make use of motion and touch controls to enable more interaction with VR (Oculus, 2016; Vive, 2017).

Today, Facebook and HTC invest heavily in developing their (relatively) advanced headsets Oculus Rift and HTC Vive respectively. Both of the headsets require a high-end personal computer to function and have a relatively high price. HTC Vive is the more expensive of the two, selling at around $600, while Oculus is sold at around $400 (Oculus, 2016; Vive, 2017). Sales amounted to 159,000 headsets (Oculus and HTC) in Q1 of 2017 and rose to 370,000 units for Q3 in 2017. Hence, the technology is presently growing, but from low levels.

While the gaming industry has shown the most significant interest in VR technology, the technology creates many new possibilities for innovation within other industries as well (Carr, 2016). Engineering and design-heavy industries (Amend, 2016), healthcare (Lee, 2017) and the defence industry (ClassVR, 2017) are examples of settings in which VR can be used to develop established businesses. Other examples are IKEA, which has developed an application allowing customers to design and experience kitchens in VR (IKEA, 2017), and some car manufacturers that now offer a VR feature allowing customers to 'sit' in and personalise car models as part of the purchasing process (BMW, 2017).

Within the specific domain of marketing, some early academic contributions have explored how VR can be applied to reach and engage customers in novel ways. VR offers a set of generic properties which makes it attractive for marketing purposes, e.g. the opportunity to create more vividness than two-dimensional videos (Van Kerrebroeck, Brengman, & Willems, 2017a, 2017b), particularly as the technology can stimulate more empathy through an individualised experience (Shin, 2018). Generally speaking, VR enables a richer experience as more senses are activated (Lin, 2017). In doing so, the technology provides new opportunities to analyse customer behaviour (Meißner, Pfeiffer, Pfeiffer, & Oppewal, 2017) and to potentially offer a more attractive consumer experience (Charron, 2017; Jung, tom Dieck, Lee, & Chung, 2016; Van Kerrebroeck et al., 2017a, 2017b). Other studies have investigated the relevance of VR to tourism and how it can positively affect the images of travel destinations (Griffin et al., 2017; Huang, Backman, Backman, & Chang, 2016) as well as future potential applications in other domains such as fashion marketing (Lau & Lee, 2016).

It is clear that VR holds considerable potential and may transform not only marketing and the customer experience but also the way firms organise themselves internally (O'Brien, 2016). Moreover, VR headsets may emerge as a novel platform similar to the smartphone, where application developers and customers create self-reinforcing network effects and an entirely new business ecosystem.

In contrast to this promising and exciting future for VR technology, current sales of headsets are, as previously stated, growing but from low levels. Hence, the VR market is presently characterised by uncertainty. Expectations have been high, but sales figures are slow to respond so progress has been slow. Given the potential of VR technology and its expected impact on several sectors of society, including marketing, research into barriers to adoption is critically important at this stage.

2.2. The value of new technology platforms

A large and well-established literature has concerned itself with how and why certain technologies are accepted. This research spans academic disciplines such as information systems, sociology and psychology (Taylor & Todd, 1995; Venkatesh & Davis, 2000; Venkatesh, Morris, Davis, & Davis, 2003) as well as more economic approaches assessing the utility of a technology against various performance dimensions (Christensen, 2013; Oskarsson & Sjöberg, 1994).

To understand barriers to adoption of a new platform technology and its associated ecosystem, the value of a technology platform needs to be assessed against several dimensions (Schilling, 2010). First, it can be evaluated on its stand-alone value. This value is based on the technological utility the innovation brings to the user. Examples of parameters upon which a user might evaluate the stand-alone value of a technology are how much fun it is to use, how simple it is or the image it conveys. As such, the functionality of the technology to the user forms the basis for this type of value.

Second, a new technology can be assessed on its network externalities' value. That is, the value of an innovation depends on its installed base and access to complementary goods. The installed base is the number of other customers that are using the technology. This value stems from the network effects phenomena. A large installed base increases the likelihood of products and services being developed for a particular platform (Arthur, 1996). For example, the value of an Android phone increases when other customers also choose to use Android, since this increases the probability of more applications becoming available. Also, a large installed base is likely to increase the pace of improvement of the focal technology as developers will put more effort into the technology. A large installed base is likely to increase access to complementary products. This access heightens the value of a product and its so-called network externalities' value.

Both types of network externalities' values stem from the network created by multiple users of the technology. As such, network externality value mostly concerns technology ecosystems or platforms, where interaction with the users and interaction with the developers add to the end performance of the technology (Magnusson & Nilsson, 2014). The resulting logic is that it is not always enough that a new technology has a great stand-alone value; in order to diffuse in a population, the new technology's value needs to exceed the combined value of technological utility, the installed base and the availability of complementary goods of the old technology.

The new technology ecosystem benefits if the customers have access to complementary products that add value to the ecosystem. In some cases, this access to complements is necessary for diffusion to occur. As such, even if the focal technology is fully developed and functioning, a low attraction for third-party developers can slow down the rate of adoption. Barriers that slow down the rate of adoption can be referred to as 'emergence challenges' (Adner & Kapoor, 2015). These are often challenges inherent in the ecosystem that are required to be solved in order for diffusion to take off.

The total value of the technology to the customer is the sum of the value attributed to the stand-alone product and the value attributed to the network externalities. In order to make a purchase decision, however, the customer will compare the perceived total value of the technology with the price. This comparison is done in the phase Rogers (2003) calls the 'decision phase'. Put differently, in this phase the customers will try to determine if the price of the product is less than the perceived total value it brings.

2.3. Synthesis and research problem

In light of the discussed literature on the emergence and technological properties of VR as well as the critical barriers to adoption identified above, to the authors' knowledge no direct attempt has yet been carried out to assess why VR technology is not attracting more consumers at this point. More specifically, taken together, studies conducted to date represent a helpful but incomplete body of knowledge regarding the current state of VR. Sluggish sales may be due to an insufficient level of technological performance and/or a lack of available complements. Also, the price point may at present be too high to motivate a purchase decision when compared to the combined value stemming from the technology and its associated complements. In this paper, we therefore set out to explore barriers to widespread adoption of VR technology. Specifically, we are interested in disentangling whether the technology as such is presently underperforming, whether complements are lacking and assess the influence of price and trialability.

3. Method

To assess how the diffusion of VR technology is taking place and potential barriers associated to widespread adoption, SMA was used for data collection and ML for the purpose of data analysis. Each step in this process is described in the following subsections.

3.1. Data collection through social media analytics

SMA is an interdisciplinary approach for the analysis of social media data (Stieglitz, Dang-Xuan, Bruns, & Neuberger, 2014). Social media an ideal context for studying how specific innovations are framed (Geissinger, Laurell, & Sandström, 2018; Laurell & Sandström, 2017; Laurell, Sandström, & Suseno, 2018) as social media data often contain combinations of text, links, images, videos and other media which entails that social media data tends to be rich in character (Brooker, Barnett, & Cribbin, 2016). However, social media data often contain a larger proportion of noise compared to traditional forms of data (Karpf, 2012) which represents a challenge. Another challenge is the lack of standardised access to user-generated content across social media platforms. More specifically, social media platforms' respective Application programming interfaces (APIs) tend to have different restrictions concerning data access (e.g. Stieglitz et al., 2014). As a result of this challenge, a sector of services offering structured access across platforms has emerged that manages changes in data access across platforms.

To assess how the diffusion of VR technology is taking place and potential barriers associated with that diffusion, the two market leaders of Oculus Rift and HTC Vive (Steam, 2017) were chosen as empirical cases. Utilising a service called Notified, a data set was collected covering all publicly posted user-generated content published in Swedish on the social media outlets of Twitter, Instagram, Facebook, blogs, forums and video platforms that included the keywords 'Oculus Rift' or 'HTC Vive' from 18 August 2016 to 23 August 2017 to capture ways in which potential and actual users associate meaning and value to the two respective headsets. Table 1 presents the distribution of collected social media data per social media platform.

Table 1
Collected and publicly posted user-generated content per social media platform.

Social media	Frequency	%
Blog	569	9.4
Facebook	276	4.6
Forum	2398	39.7
Instagram	341	5.6
Twitter	2381	39.4
Video	79	1.3
Total	6044	100.0

3.2. Data analysis through machine learning

ML algorithms are a set of computerised algorithms that use statistical tools to learn from examples, so-called 'training data', in order to predict new data (Stieglitz et al., 2014). This allows the algorithm to better capture complex data patterns, such as the nuanced meanings of human language (van Zoonen & Toni, 2016). ML has seen usage in a wide range of applications, including text classification, recommender systems and spam filtering (Kumar, Gao, Welch, & Mansoori, 2016). Different algorithms function in different ways and choosing the right one stems directly from the particular purpose of the research.

When initiating the development of an ML program, the programmer needs to consider both what properties the input data has and how the output data should be structured to address the program's purpose. Also, the structure of the output data is to an extent dependent on the properties of the input data. Thus, there is a triangular relationship between the input data, the output data and the algorithm, which makes program development a complex and iterative process.

The ML algorithm used in this study is supposed to emulate a manual content analysis of the data. That is, it should read each post in the data set and determine something about the content of the particular post. Therefore, the algorithm chosen in this study was a supervised binary discrete algorithm, due to this algorithm's ability to simulate how a human would classify text into discrete categories based on the contents' meaning. As such, the output data of the algorithm will in this study be an updated data set where each post is given a label based on what the meaning of the post is.

In order to study the two dimensions of value as well as the potential gap between the total value and the market price as discussed in Section 2.2, the algorithm was designed to label each post based on whether it contains information about either of the two dimensions of value, i.e. the stand-alone value or the network externalities' value, or the price–value gap. The price–value gap can be discussed in two ways: either the customers are interested in the price itself and, as such, discussing the price, or they are hesitant and discuss the value of trying the headsets before a purchase. Thus, the algorithm was designed to interpret the content of each post and assign to it one or more of the four labels below:

1. Technology: discussions about the stand-alone value of the headsets.
2. Network: discussions about the network externalities' value, that is the installed base of each headset type or the access to applications or other externalities.
3. Price: discussions about the price of the headsets or their associated applications.
4. Trialability: discussions about the value of trying the headsets before a purchase.

Whenever the algorithm was unable to assign one of the four labels to a specific post, the algorithm classified it in one of two separate ways. First, in cases where the algorithm could not identify a post as being related to discussions regarding VR technology, such posts were labelled as 'spam'. In total, 5035 publicly posted user-generated content were labelled as 'spam' which indicated that the total collected material contained high levels of noise, which is to be expected due to the character of social media compared to traditional forms of data (Karpf, 2012). Second, in cases where the algorithm identified a post as being related to specific discussions regarding VR but could not distinguish it in relation to the four labels as presented above, no label was assigned to the post by the algorithm. As a result, posts labelled as spam were excluded from the data set while non-labelled posts became subject to manual analysis.

Subsequent to having assessed the extent of the four labels in the collected data set, both through the categorisation carried out by the algorithm as well as manual analysis, ways in which barriers to adoption were discussed among potential and actual users vis-à-vis the four

Table 2
Distribution of identified user-generated content per analysed dimension.

Dimension	Frequency	%
Technology	355	35.2
Network	394	39.0
Price	143	14.2
Trialability	117	11.6
Total	1009	100.0

labels were thereafter analysed in further detail. This analysis was conducted by manually reviewing the identified material per analysed dimension to verify the classification of individual user-generated content as well as identifying shared characteristics of the manner in which discussions about barriers of adoption within the four respective labels manifested.

4. Results and analysis

Table 2 presents the distribution of posts per analysed dimension. As illustrated in the table, the majority of entries were labelled in the technology dimension and the network dimension. In contrast, discussions regarding price and trialability were, in relative terms, less common.

The technology dimension concerns discussions about the stand-alone value of the headsets. As such, discussions tend to revolve around technical specifications, and the following example is illustrative of the material:

> The HTC Vive headset has an OLED-panel with 2160 × 1200 pixel resolution (1080 × 1200 per eye) and 110 degrees field of vision. The headset has 32 motion sensors, a gyroscope and an acceleration meter that renders your motions with extreme precision. The headset has straps that can be adjusted around the user's head and interchangeable soft padding around the eyes that ensures that it is comfortable to wear. Additionally, it can be adjusted so it fits to have glasses on inside the headset.

However, not all posts relate to the technology dimension by discussing specific technical attributes. Discussions also concern problems associated with usage. The following examples illustrate how this discussion takes place:

> I used HTC Vive and quickly got sea-sick.

> Just played Dirt Rally with Oculus Rift. Pretty cool but damn, became really 'carsick'. I never become that otherwise.

> Just tested VR for the first time and is completely sold. Applications like The Lab, Google Earth VR, Arizona Sunshine etc. Feel a strong must-have-craving. However, got a bit nauseous, so I took a break, had some food, etc. Used it again for like 30–40min and felt sick again. Became a bit more doubtful if I will buy HTC Vive or not, maybe nothing for me if I do not manage to use it for more than 40 min.

The network dimension includes discussions about the network externalities' value and one of the most discussed aspects is related to available applications. The following example is illustrative of the material:

> There are 354 VR games and John Wick is on the first page before it has even been released so it looks really bright. There are not all too many that own an HTC Vive set but it is increasing all the time.

As in the case of the technology dimension, discussions taking place in the network dimension also specifically cover problems associated to network externalities' value. The following two examples posted by one potential VR user as well as one actual VR user are illustrative of such discussions:

> I want there to be more games before I purchase.

> I bought the Oculus Rift and realized that there are not many games.

In terms of the price dimension in which discussions regarding the price of the headsets or their associated applications take place, discussions concerning the high price of the headsets in particular are common. Two illustrative examples state:

> I had my first VR experience in 2016, and although it left me deeply hopeful for the future of the technology, I did not feel an immediate need to spend 5,000 [SEK] on my own headset.

> The only thing the stops it right now is the price. I and many others that are positive to it but have not yet bought it have not done so precisely due to the price. When I can get a new HTC Vive (version 2?) for max 6000 [SEK] I will close the deal. 6k is not something most have just lying around for fun.

In terms of trialability, i.e. discussions about the value of trying the headsets before a purchase, the material is primarily characterised by statements posted shortly after the headsets were tried. The following examples are illustrative:

> Went and tested HTC Vive for the first time and was completely sold! This will be this year's Christmas present.

> I've finally tested HTC Vive (Virtual Reality). The controls are strange. But they worked well for VR!

Similar to the price dimension, where users are expressing hesitation about buying VR headsets, the trialability dimension also exhibits hesitation. One illustrative example stated:

> I have just tested PS VR on Mediamarkt. Feel absolutely certain that it's a fun accessory for the PS4, but I have not reached a purchase. I think it feels a bit too early for that yet. […] Would also like to test the Oculus Rift and HTC Vive before I decide what headset I want.

In view of these results, the two dimensions of stand-alone value as well as network externalities' value amount to 74.2% of entries and, together, suggest that these are the most critical obstacle for widespread adoption. Discussions related to price or the possibility of trying the technology before a full purchase are less frequent (25.8%) but nonetheless represent obstacles for adoption as well. Hesitation that stems from the gap between the perceived total value of the technology and the market price is, arguably, an important factor.

While VR offers the potential to transform marketing and create novel interactions between customers and firms (Lau & Lee, 2016; Meißner et al., 2017; Van Kerrebroeck et al., 2017a, 2017b), our findings illustrate underlying reasons as to why diffusion has not really taken off yet and, consequently, why VR still does not represent a platform that allows firms to reach consumers on a larger scale. This platform may become strategically important in the coming years but attempts at using it for marketing purposes right now face the risk of not meeting expectations as, presently, VR offers too little stand-alone value, too low network externalities and seems to exhibit a gap between the perceived total value of the technology and the market price.

Both stand-alone value and network externalities are, however, subject to increasing returns and exponential improvements (Arthur, 1996). Hence, the ways in which VR enables richer and more attractive experiences (Charron, 2017; Jung et al., 2016; Lin, 2017; Van Kerrebroeck et al., 2017a, 2017b) still have the potential to be highly beneficial for marketing as reported across a wide range of sectors such as tourism, destination development, fashion and museums (Griffin et al., 2017; Huang et al., 2016; Jung et al., 2016; Lau & Lee, 2016). Our results concerning the present state of the technology would nevertheless indicate that a cautious approach is preferable due to current hesitation among potential users.

5. Concluding remark, limitations and directions for future research

This paper has assessed current discourse in social media concerning VR technology and, by doing so, has identified barriers to widespread adoption. Utilising SMA for the purpose of data collection and ML for the analysis of ways in which users associate meaning and value vis-à-vis VR technologies, the presented results have illustrated that the stand-alone value of the market-leading headsets Oculus Rift and HTC Vive as well as their associated network externalities' value are the most frequently discussed aspects among consumers. Even though discussions regarding price and trialability are less frequent, the nature of these discussions suggests that the price and trialability dimensions also represent obstacles for widespread adoption. In conclusion, both the technological performance and the amount of complements available constitute barriers to adoption at present. Price point also seems to play a role, but less attention is devoted to this parameter.

By illustrating where specific barriers associated to adoption are situated for VR technologies, this paper adds to extant literature on VR technologies as we provide a systematic assessment of VR's current state in the marketplace and the associated implications for marketing. Our results indicate that a cautious approach is presently to be preferred given limited adoption and the fact that the technology doesn't seem entirely ready at this point. Given exponential improvements in performance and availability of complementary goods, we do not exclude the possibility that this phenomenon will evolve positively in the coming years.

We acknowledge two main limitations of our study. The collected data set contains user-generated content published in Swedish which means that this study is limited to the ways in which VR technologies are perceived in the social media landscape of Sweden. Therefore, the empirical focus of the data set imposes constraints upon generalisations from this data to other national contexts. Second, the data concerns perceptions among users posting in social media. These perceptions are by definition not objective but rather indicative of how users are currently relating to VR.

Given VR's current state of diffusion and its associated barriers, much remains to be done in assessing how this technology's development unfolds. Concerning the specific headsets currently dominating the market, it would be of great interest to look further into whether one of the two competitors is gaining momentum and the associated consequences of such a development for barriers of diffusion identified in this study. Also, we see a general need for knowledge concerning how consumers and firms should choose to implement the technology at hand given its currently uncertain future. SMA enables novel ways to study these issues due to its unobtrusive character; we therefore welcome further empirical research utilising this approach. ML offers considerable potential, especially for larger data sets, but may require researchers to adopt new skills, especially regarding programming. We welcome further enquiries into how ML may affect both SMA research and the social sciences more generally.

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Declarations of interest

None.

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