TECHNOLOGY STEERING: DRIVING TECHNOLOGY DEVELOPMENT BY ENVISIONING QUIESCENT MEANINGS

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ABSTRACT

In the past few decades, increasing attention has been paid to research and development expenditures. Indeed, the previous (and recent) literature has addressed this topic from a different perspective. On one hand, the Technology Future Analysis literature (Porter, 2004) has attempted to cluster the existing methods to identify the development processes of different technologies. On the other hand, there is a growing focus on Technology Epiphanies, which is defined as the unveiling of the quiescent meaning that resides in a given technology (Verganti, 2009). This attention has occurred because the technology is no longer considered in isolation but in relation to the competitive advantages that it can create; therefore, this paper aims to investigate those managerial practices that can enhance the development of a Technology Epiphany. As opposed to previous studies, the investigation revolves around two case studies in which the focus is trained on two technologies (video encoding and MotionX) instead of on the two commercialized products (GoPro and Jawbone UP). The paper identifies a two-phase process, consisting of the Explorative phase and the Selection phase, that can enrich managers' knowledge regarding the Technology Epiphanies concept.

INTRODUCTION

In recent years, growing attention has been paid to analyzing the effectiveness of R&D expenditures. Indeed, investing in new technologies is not easy for today's companies because they are facing economies characterized by crises in which every investment must be weighed carefully. This trend is immediately revealed in the data provided by Eurostat regarding European investments in research and development over the last decade. In 2013, R&D investments had risen less than 0,26% compared to the same indicators in 2004, signaling aversion to R&D expenditures. This statistic shows that major European companies have not increased their investments in research. Indeed, it is difficult for many to justify consistent investment in research and development—and ultimately in technology—before the application for the technology under study is clearly identified. To overcome this limitation, several companies have recently adopted two different strategies. Under one approach, some companies have involved other investors (foreigners or externals) in their research and development processes as co-financing entities. Alternatively, other companies have acquired technology and know-how from outside their company. The first approach is detailed in the open innovation literature (Chesbrough, 2006), whereas the second refers to the growing phenomenon of the acquisition of innovative start-ups by large companies, which is a trend that is largely diffused in the digital environment but is also a factor in other sectors. Thus, Facebook's 2014 acquisition of Oculus is a typical acquisition made by a large firm to enhance its knowledge of another technology, in this case of virtual reality technology.

Nevertheless, not all companies are ready or willing to rely solely on external sources to create value by developing technology. Indeed, when they want to gain competitive advantages by exploring new opportunities, companies often fear potential spillovers, which typically leads them to develop technology internally. In this case, a new perspective on how to effectively and profitably develop a technology is needed. Moreover, it is common knowledge among practitioners—as demonstrated in several real-world cases—that when companies develop new technological solutions internally, they attempt to internalize as much value as possible from the process mainly because companies can develop promising technologies only to obtain disappointing economic results from their application in end products, which is a fundamental problem for many companies. Indeed, it is unclear to these companies how they can find the more meaningful (i.e., more profitable and more valuable) applications for the technologies they develop. This question looms even larger if we consider the words of the semiologist Giampaolo Proni (2007): "*technologies offer opportunities which are of course not infinite, but are greater in number than those imagined by early developers*". Thus, this study strives to answer this question: how can a company imagine the opportunities offered by a technology during its development in order to understand its meaningful applications?

To answer this question, the paper will rely on the concept of Technology Epiphany, which is defined by Verganti (2009, 2011) as the discovery of a hidden and often more powerful meaning inside a particular technology. Considering this approach makes it clear that is not a matter of being the first but being the first to identify the real market potential of an analyzed technology (Verganti, 2011), which is what has occurred in several companies, such as Nintendo with the Wii or Apple with the iPod. Micro-electro-mechanical systems (MEMS) radically changed the approach toward console games several years after having

been used in many different fields, including white goods or automotive goods. STMicroelectronics, a supplier of MEMS, was looking for a more meaningful application field for its technology and was experimenting with different solutions but realized only after they approached Nintendo that they could best exploit their technology's potentiality in console games. Indeed, adding MEMS to console games radically changed the meaning of playing these games by allowing the shift from a deep immersion in virtual reality to a real experience of a game that you do not play alone but that you and another—or better that Wii (we)—play together. The real challenge we want to investigate is how to discover the most potential applications and envision new meanings within new or existing technologies, such as MEMS did in the console game market. Thus, the focus is more on the technology developer—the so-called material scientist actor—than on the companies that deliver the final products. To provide some suggestions, the investigation aims to mix research activities related to new technologies with studies of emerging lifestyles and societal values to introduce radical Design-Driven Innovations (Verganti, 2009). Thus, the paper aims at providing a methodology that can support companies in steering their technology development during its early stages. The main literature streams upon which it leverages include the Technology Future Analysis (TFA) and Technology Epiphanies (TEs) streams.

This paper is structured as follows. The next section details the relevant literature regarding TFA and TE, and a section addressing the methodology adopted follows. Then, the empirical results of the investigations conducted are assessed, and the final section will summarize the limitations and potential future research in connection with the study.

LITERATURE REVIEW

The literature review is divided into two sections. First, we summarize the principal contributions of the literature on Technology Future Analysis (TFA). Then, we briefly review the literature on the innovation of meanings, which represents the main research domain of this paper, focusing on Technology Epiphany (TE), in particular.

Technology Future Analysis

Before analyzing the Technology Future Analysis literature, it is important to detail some of the broader aspects of studies of technology. In particular, in studying technology, we must consider its maturity. As discussed above, new and old technologies must be considered differently because of certain peculiar aspects that affect the analysis (Bourreau, Cambini, and Doğan 2012). Moreover, practitioners have indicated that when a new technology emerges, companies (in typical myopic fashion) simply replace existing solutions with new solutions without considering the great number of opportunities and meanings that may be embedded in the technology (Verganti, 2009). This topic is also absent in the Technology Future Analysis literature. Indeed, a review of the literature reveals that TFA is more concerned with possible future developments than with strategic analysis. When these aspects are considered, the existing methods, practices, and processes of studying technology evolution radically change. Indeed, some TFA methodologies are more suited to new technologies, whereas other methodologies are preferable for old technologies; nonetheless, few are suited to scouting for new meanings embedded in technologies.

Talking about technology development means focusing on the Technology Future Analysis literature. This literature review is even more important when considering the recent scholarly emphasis on the impact that technologies have (or will have) in the economies of today and of the future (Porter et al. 2004). This field of study is consolidated, and several methods and technologies are grouped within it. Porter's work is a reference point in this literature because it collects all the existing practices and processes that are useful for making suggestions about possible future technological evolution (Porter et al. 2004). As an outcome of that study, TFA might be defined as any systematic process for making judgments about the characteristics, development pathways, and potential impacts of emerging technologies. Thus, the studies in this stream of research have the ultimate goal of outlining the possible future evolution of a new/old technology. Porter creates a detailed table in which he classifies all the methods into the following nine families based on the tools and skills required: Creativity, Descriptive and Matrices, Statistical, Expert Opinion, Monitoring and Intelligence, Modeling and Simulation, Scenarios, Trend Analyses, and Valuing/Decision/Economics. Researchers have identified these classes to better support decision-making processes in complex socio-cultural contexts based on private- and public-sector needs (Martino, 1972). In addition, practitioners can use the classification as a means of integrating and implementing the different instruments in a more systematic and continuous fashion. Nevertheless, no TFA methods directly address the complex topic of quiescent meanings embedded in technologies, although TFA attempts to facilitate the analysis of networks by examining whether they involve those who provide sources, those who arrange these instruments, or those who exploit the results derived from them. Moreover, considering the literature regarding technology (and particularly the TFA literature), forecasting and foresight must be distinguished (Cuhls, 2003). These two approaches are recognized by researchers as distinct when used to develop theories, concepts and methods. Some major differences are derived from the starting point, the inputs and the outputs of a study. On one hand, practitioners refer to forecasting as a means of formulating estimates in known situations (Armstrong and Yokum, 2001). Estimation connotes future orientation in which the area to be observed must be known in advance. Scholars have outlined the following four aspects that characterize the forecasting approach: time, forecasted technology, a statement of the characteristics of technology, and a statement of the probability associated with a forecast (Martino, 1993). All these characteristics outline how forecasting typically ends by identifying a single possible future for a technology (Armstrong and Yokum, 2001; Martino 1993; Jantsch, 1967). On the other hand, technology foresight refers to a systematic process that attempts to view the longer term. This technique is typically used to monitor evolving trends, particularly those with policy implications (Coates, 1985). Indeed, foresight is often conducted to acquire more knowledge about things to come and to identify probable desirable futures (Jungk and Müllert, 1996). Considering these differences, foresight could be used to select those areas that should be deeply analyzed in forecasting studies.

TFA researchers have also outlined the difference between the anticipatory approach and the exploratory approach. The former refers to a process that is need-oriented. The process begins from needs, which are assumed to be objectives for the future, and moves backwards to the present to evaluate the actual possibility of satisfying those needs. The latter is opportunity-oriented and begins with the present to evaluate possible solutions for the future. Porter (2004) proposes a structured framework of the major forces and elements

affecting the process (Figure 1) that summarizes the variety of methods and practices that are useful for conducting a TFA.

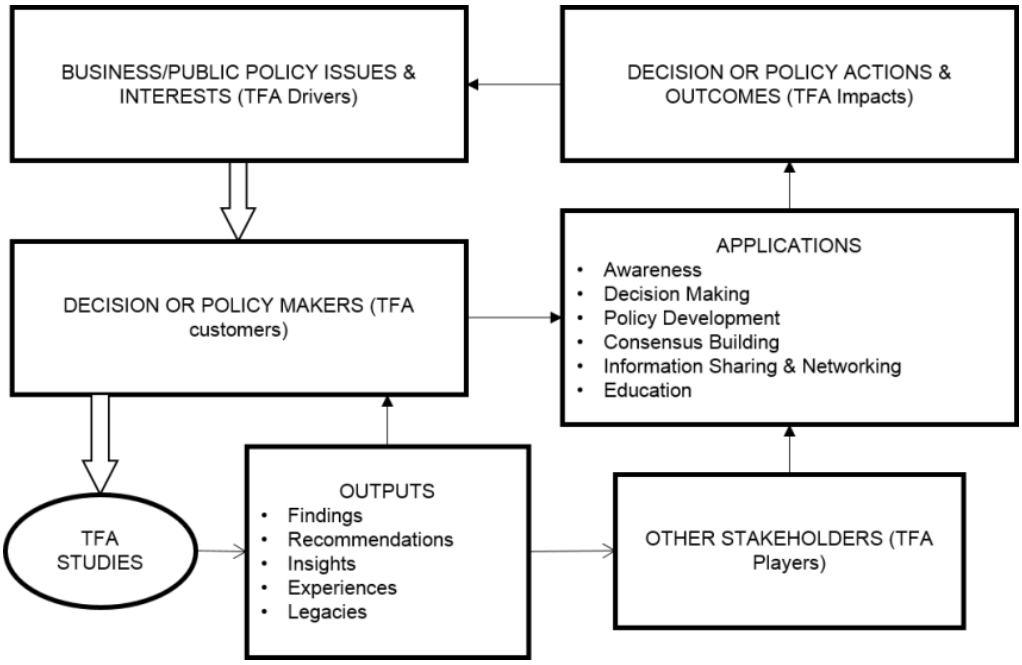

Figure 1. Framework for Technology Future Analysis (Source: Porter 2004).

Technology Epiphany

As discussed above, following Krippendorff (1989) and Heskett (2002), we interpret Design-Driven Innovation as innovations related to why people buy and use things, i.e., this paper focuses on the innovation of meanings. The meaningful dimension of design has been recognized and underscored by several design scholars and theorists (Margolin and Buchanen, 1995; Cooper and Press, 1995; Petrowski, 1996; Karjalainen, 2003; Lloyd and Snelders, 2003; Bayazit, 2004; Norman, 2004; Redström, 2005; Dell'Era and Verganti, 2007). Research in marketing, consumer behavior and the anthropology of consumption has also demonstrated that the affective/emotional and symbolic/socio-cultural dimensions of consumption are as important as the utilitarian perspective of classical economic models, even for industrial clients (Douglas and Isherwood, 1980; Csikszentmihalyi and Rochberg-Halton, 1981; Fournier, 1991; Sheth, Newman, and Gross, 1991; R. Kleine, S Kleine, and Kernan, 1993; Mano and Oliver, 1993; Brown, 1995; Du Gay, 1997; Holt, 1997, 2003; Bhat and Reddy, 1998; Schmitt, 1999; Pham et al. 2001; Oppenheimer, 2005; Shu-pei, 2005).

There are two types of strategies for innovating the meaning of things, User-Driven and Design-Driven strategies. User-Driven design has been popular over the last decade and has been in the spotlight thanks to the successes of major design firms such as IDEO (Kelley 2001) and Continuum (Lojacono and Zaccai, 2004). This approach implies that product development should begin with a deep analysis of user needs (Stein and Iansiti, 1995; Leonard and Rayport, 1997; Thomke and Von Hippel, 2002; Chayutsahakij and Poggenpohl, 2002). By using ethnographic methods and observation—and therefore by

becoming closer to users—firms may better understand those meanings and through creative problem-solving sessions, they may be able to address any mismatch between existing meanings and existing products (Verganti and Dell'Era, 2014). Importantly, radical innovation of meaning clearly requires a different process. Indeed, customers can barely help but anticipate possible radical changes in product meanings. The contemporary socio-cultural context in which customers are immersed makes them inclined to interpretations that are consistent with what is occurring today. However, radical changes in meanings instead ask for wholly new interpretations of what a product is meant for, which might be understood (and affected) only by looking at things from a broader perspective (Dell'Era, Marchesi, and Verganti, 2008; Verganti and Oberg, 2013; Verganti and Dell'Era, 2014). On some occasions, a particular type of Design-Driven innovation might be generated by deeply analyzing the possibilities offered by new or old technologies. Indeed, when the innovation comes from the revelation of quiescent meanings hidden in technologies, a Technology Epiphany occurs (Verganti, 2009). Indeed, as claimed by semiologist Giampaolo Proni, "Technologies offer opportunities which are of course not infinite, but are greater in number than those imagined by early developers" (Proni, 2007). In particular, in Verganti's view, Technology Epiphanies emerge from the interplay of two different radical innovation approaches: technology-push, on one hand, and design-push, on the other. Technology-push is an innovation attitude based on the discovery of new technologies that foster the emergence of revolutionary products on the market (Norman and Verganti, 2014). The new technology is typically embedded in new objects and gives rise to new usage of the latter. However, the design-push approach focuses on radical changes in meanings. The recent stream of Technology Epiphany literature provides additional insights into strategies that companies can adopt to extract value from applications based on new technologies (Verganti, 2009; Dell'Era, Marchesi, and Verganti, 2010; Buganza et al., 2015). In this vein, Swatch is an example of radical innovation based on technological discontinuity (Verganti, 2008). In the early 1980s, the Swiss watch industry was imploding, although until the mid-1970s, Swiss companies had led the watch industry with more than 40% of the world market. However, things changed dramatically with the advent of quartz movement and digital display watches. Although Swiss manufacturers invented quartz movement, they did not grasp its potential, shunning it instead as a technology unsuited to their core competence in precision mechanics and assembly. Japanese and Hong Kong manufacturers, however, exploited quartz movement, combining it with cheap labor to conquer the low end of the watch market. In the mid-1980s, Swatch completely changed what people meant by a "watch" to the extent that Swatch no longer represented timekeeping—although it still kept time from a functional perspective—but instead represented fashion. The company sold 1.1 million Swatches in 1983, 4 million in 1984, and 8 million in 1985; it has sold an increasing number of watches ever since.

Considering the two streams of literature and the objective of the paper previously discussed, our investigation aims at enhancing knowledge regarding both the managerial practices that can help develop Technology Epiphanies and the ways in which companies can steer technology development to create these events.

RESEARCH DESIGN

To fulfill the objectives of this study, the companies selected for this study are high-tech firms in which development is undertaken in the R&D department. In fact, the objective of this investigation is to enhance the existing theory explaining the concept of Technology Epiphany. Thus, as opposed to previous research, the perspective adopted by the present study is that of the technology developers and not of the companies that market the products to the end users. For this reason, this study investigates Ambarella and Fullpower as case studies. In particular, we refer specifically to those technologies developed for GoPro and Jawbone, respectively (Table 1). The sampling adopted is theoretical to establish the comparability of the results obtained by the two case studies (Easton, 1995; Eisenhardt, 1989; Dubois and Gadde, 2002; Halinen and Törnroos, 2005; Siggelkow, 2007). In particular, after having identified two Design-Driven Innovations in GoPro and Jawbone, we achieve this comparability using the definition established by Verganti 2009. Thus, we have built two explorative case studies (Yin, 2003). In doing so, the authors utilize both primary and secondary resources, collecting reports available on line, institutional web pages, articles and insights gathered during direct contact with the managers of the two companies. All this information was collected to create a history of the two technologies chosen. After collecting the data and the insights, a deep analysis of this information was developed. In particular, after having identified technology that gave rise to an epiphany, this study focused on the different application fields in which technologies were applied to understand which path was followed, as shown by the tech development and managerial decisions undertaken by the companies.

Company	Technology	Product	Description of the company
Ambarella Inc.	Video Encoding	GoPro	Ambarella Inc. is a developer of semiconductor processing solutions for video encoding. Its products enable the capturing, sharing and display of HD video contents. It was funded in January 2004 by Fend-Ming “Fermi” Wang, Les Kohl, John Ju and Didier LeGall, and it now provides the best processors for HD video that simultaneously capture high resolution still images. Since its funding, Ambarella has enjoyed continuous economic growth due to its ability to offer chips in the best sectors in terms of expected growth rates and expected future market size. Ambarella's operating activities are focused on its chip design, which is based on its proprietary architecture and software, whereas the rest of the production and delivery activities are outsourced.
Fullpower	MotionX (accelerometers)	Jawbone Up	Created in 2003 in California, Fullpower is fundamentally shaped by its co-founder, Philippe Kahn. His passion for sailing led him to create a prototype of a sleep tracker that used biosensors to optimize the sleep benefits of a 26-minute power nap during sail time. Fullpower has the declared mission to put

		motion-sensing into every mobile device. To meet this objective, Fullpower developed its MotionX technology platform.

Table 1: Case studies overview

EMPIRICAL RESULTS

The aim of this paper is to provide insights regarding technology development and particularly about the process that leads to the creation of what Verganti defines as Technology Epiphanies. To this end, two technologies that, in past years, have led to two notable epiphanies were taken into account, including the video encoding industrialized by Ambarella Inc. and the MotionX technology developed by Fullpower. This section will describe the epiphany, the story of the technology and how the two companies reached technology maturity.

Ambarella Inc.

As discussed above, the focus is not on Ambarella itself but on a specific technology developed by the company, i.e., its video-encoding technology. This technology allows a camera to capture, share and display video contents. The expertise of the companies derives from the material scientists that work in it, who have spent years of study on that peculiar technology. In particular, some of them came from C-cube, another company that engaged in video encoding years before Ambarella. Moreover, Ambarella's research center developed unique expertise in the system on chip (SoC) technology that allowed them to gain a significant leadership position on the market. The video encoding technology pioneered by the SoC technology fostered the development of radical innovative products such as the GoPro. Indeed, Chris Day, the VP of Marketing and Business Development for Ambarella, says that they saw an opportunity during the Consumer Electronic Show (CES) several years ago and decided to develop the GoPro idea together with Nick Woodman, founder and CEO of Ambarella, because they were sure that they would have the technological expertise to help him achieve his goal.

In particular, the video encoding technology gave rise to a Technology Epiphany in the GoPro. Indeed, if we look at Figure 2, i.e., the Verganti framework for Technology Epiphanies, it is clear that the technological evolution from the digital camera in which the encodings were realized on cassettes is radically different from the digital encoding on a flash drive memory. However, the meaning also evolved because in the digital camera, the recorded objects are those observed through the lens, while with GoPro, the recordings are those lived by the recorder. This shift of perspective leads to a radical change in meaning from a camera to record someone else's emotion to a camera that record's the personal emotions of the recorder. The slogan—"GoPro Be a Hero"—powerfully conveys this new meaning. A camera is no longer meant to record institutional events or ceremonies but instead records emotions, feelings and sensations.

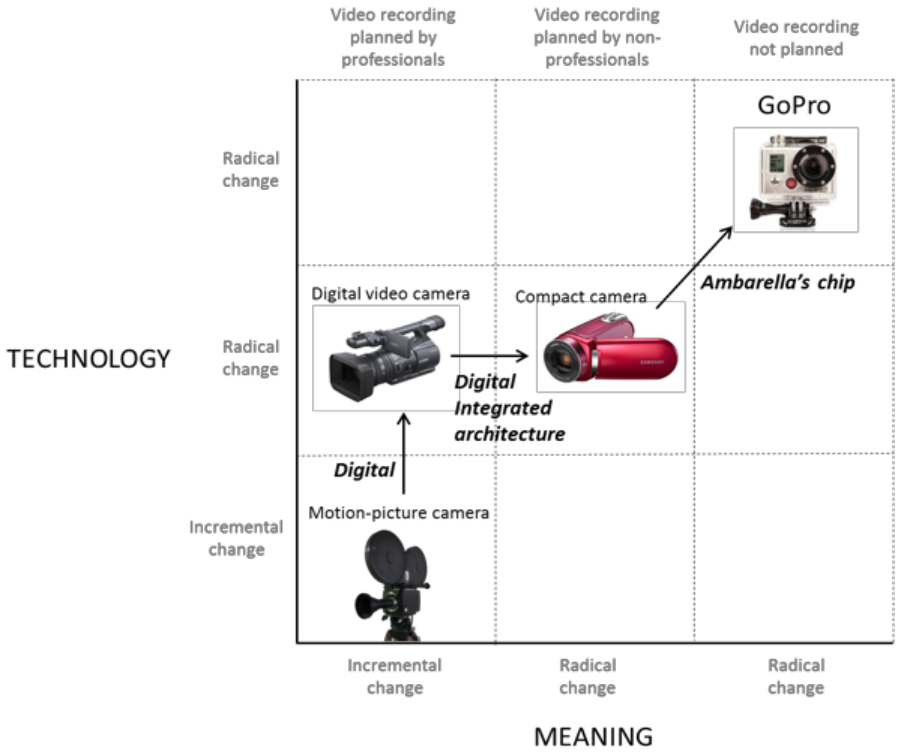

Figure 2: Technology Epiphany in the Video Encoding Market

Examining Ambarella reveals that the process that brought the company to address sports and wearable cameras was not linear. Indeed, leveraging on their growing knowledge regarding video encoding technology, the best seller in its portfolio, the company was able to address different markets or (as discussed above) different application fields. The conclusion that emerges is that this technology was used in other markets before being used in the action camera market. Figure 3 summarizes this evolutionary process.

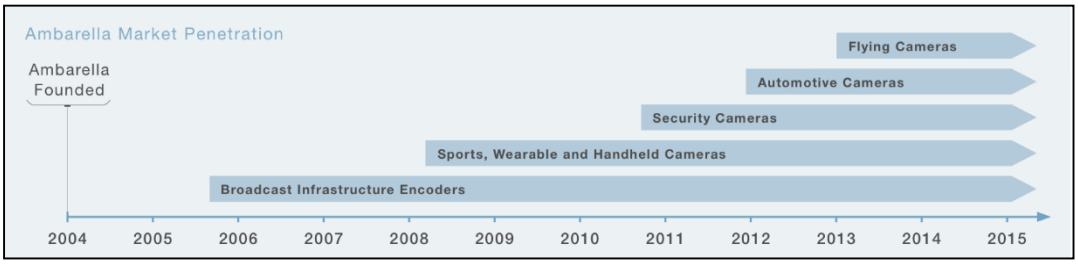

Figure 3: Ambarella market penetration

Considering market penetration, the first opportunity caught by Ambarella with its chip of video encoding was in the Broadcast Infrastructure Encoders market. Although the Broadcast Infrastructure market was not Ambarella's first choice (as reported in several interviews), the manufacturer became interested in this sector based on the performances given by the chip's architecture. The Broadcast Infrastructure Encoders are a fundamental part of broadcasting activities, and they are part of the chain that extends from creating to

delivering the video contents. Their purpose is to convert different video formats from different sources in the video format standard to broadcast the video content (the H.264). The demands of efficiency, rapidity and quality allowed Ambarella to achieve a competitive advantage based on its high-performing video encoding technology. Its expertise that had matured in the sector allowed Ambarella to enlarge its portfolio when new opportunities were identified.

In 2008, Ambarella moved upstream in the production process of digital content when it decided to develop video encoding chips for both consumer and professional-grade recorders but no longer for broadcasters, one of the last elements of the chain of distribution. This decision resulted because the market suffered the disruptive integration of high-resolution cameras in smartphones, and broadcast video encoding was significantly influenced. Nevertheless, the company did not approach the smartphone market but instead targeted a large segment of the more promising markets in which products require high-performing cameras, such as wearable cameras, action cameras, IP security cameras and flying (drones & UAVs) cameras. Considering the differences among the sectors, a shift in—or steering of—the technology was required. Indeed, the video encoding for the broadcaster market was different than that of the action or the wearable camera markets. After this explorative approach, in which Ambarella examined a completely different market (broadcaster vs action camera) and targeted a completely different customer (professional vs consumer), the market approaches that followed are more market-exploiting. Indeed, the application fields addressed after the first jump are closer to one another.

Fullpower

The second case study considered is Fullpower. Fullpower is considered among practitioners as the leader in developing technology for the Internet of Things and wearable sensors. The company principally developed its business around this second skill in the past and around the technology called MotionX, in particular. MotionX is a sensor that contains a highly accurate three-axis accelerometer. An accelerometer is a technology able to sense the physical acceleration experienced by an object due to the force of gravity, known as proper acceleration (9.81 m/s2 in rest, zero in free falling). Multi-axis accelerometers can detect the magnitude and direction of proper acceleration as a vector quantity and can be used to sense orientation because the direction of the weight changes.

Leveraging on this technology and on the explorative study made with mobile applications to test the algorithm that processes the data, Fullpower was able to foster a radical innovation (Figure 4). Indeed, after fully investigating how to exploit the data gathered by the MotionX technology, the company created Jawbone, the first fitness tracker able to measure the quality of sleep. Indeed, whereas MotionX was previously used to evaluate and measure the fitness activity in sports, i.e., similar to Nike+, the addition of the sleep tracker allowed Jawbone to change the meaning of tracking. In fact, Jawbone UP is used not only during sports activity but also throughout the day and at night. One of the most important features is its “wake-up” modality. Analyzing the movements and data from the sensor, the algorithm is able to understand whether the person who is wearing the bracelet is in REM or non-REM sleep, allowing it to wake up the person in the smoothest and most appropriate way by considering the sleep moment. This is a clear Technology Epiphany, as previously defined, in which the Motion X technology enables a radical change of

meaning by using tracking to measure fitness activity to improve wellness by choosing the wake-up moment.

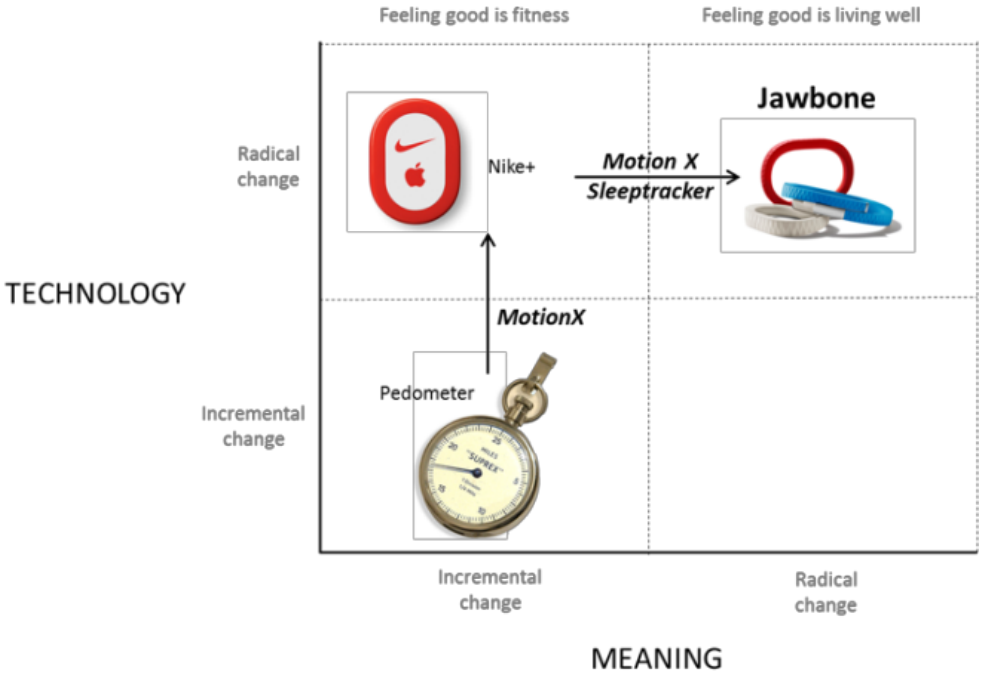

Figure 4: Technology Epiphany in an Activity Tracking Industry

The first application released was a mobile application for smartphones called MotionX-Poker based on a 3-D rendered dice. Considering the current technological level, the functioning of the app turns out to be simple: shaking the iPhone causes five dice to roll and generate numbers on the display. This action therefore creates a poker game versus the computer using three rolls. Instead of using a random number generator, the application captures the hand's motion thanks to the accelerometer in the smartphone and creates simulated collisions between virtual dice. The second type of exploratory application of MotionX was, Nike+, a sensor that communicates with a mobile application that launched on the market in 2010. Nike+ is an activity tracker device shaped like a button and placed under a user's insole. Using Nike's app, it measures and records the pace and distance of a walk or a run. After understanding the real potential of the MotionX platform (accelerometer plus algorithm), Jawbone was the first company to integrate sensors to enhance the usage experience of its products. In particular, the first application that enhanced the development of the technology was the Jawbone ERA, a headset able to detect natural movements and to respond by corresponding to determined actions. In particular, this innovation involved mainly the UX/UI of the headset by allowing the user to respond just by moving it—without pressing any buttons. Finally, MotionX was implemented by Jawbone in the so-called UP bracelet; with this application, the technology finally finds meaningful application. Indeed, after previous learning made using different

applications in different markets, the company glimpsed a new quiescent meaning for the technology.

DISCUSSION

The two case studies have common traits in their approaches to technology development. Indeed, after an initial phase in which the companies applied the technology in different fields to better understand it, they were able to steer the technology and gain competitive advantage from such intentionality. In describing the empirical results, the first phase is called the explorative phase . The purpose and the aim of this stage is a deeper understanding of the capabilities and potential of the technology. The outcomes gathered during the explorative phase turn into inputs for the second phase of the innovation process. The explorative phase opens the technology steering process and its outcome is identifying explorative applications. In particular, this phase concerns a creative and divergent process to generate solutions that is shared among practitioners; during this phase, a heterogeneous team of experts and the presence of both designers and material scientists can bring useful and valuable insight to technology development. The second phase is the selection phase and aims at transforming the opportunities identified into a selection of new application fields in which the technology can embrace potential new meanings. In this stage, the team should find more meaningful applications. The application in which so-called quiescent meaning can be unveiled and that can allow the company to achieve significant competitive advantage in the market or that can allow the firm to create a new market. A clear example is MEMS technology in Wii products. The purpose of the selection is a deeper understanding of whether the promising technology features can actually lead to unlocking new meaningful experiences by applying them to actual products. Compared to the exploration phase, the selection is more convergent and deterministic.

Explorative Phase

From the case study conducted, certain insights emerge regarding how to explore the opportunities offered by a technology. In particular, the figure reported below shows different approaches to the exploration phase.

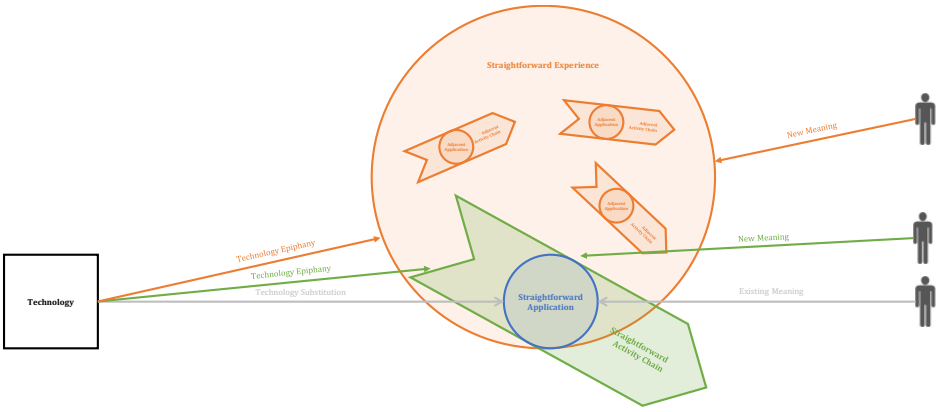

Figure 5: Framework Highlighting Technology Epiphany Approaches

Looking at Figure 5, the first more common way to exploit the technology appears to be the technology substitution approach in which the new invention is used in a straightforward application. In other words, an older technology is replaced by a new technology that is typically better performing. With this approach, no new meanings are brought to end users. This approach does not lead to an epiphany because no quiescent meaning is unveiled. An example of this methodology is the first application of the video encoding technology in the broadcasting industry. Indeed, the chip developed by Ambarella was a better performing chip for the reference market, but it did not change anything at the level of meaning. The second example involves the exploration of the Straightforward Activity Chain. By this denomination, we refer to all the types of activities strictly related to the previously addressed application field. Indeed, when a company engages in a market segment with a technology, it obtains insights and information on how the sector is managed and what the technological requirements are to outperform in it. When combined with appropriating the technology matured during the first application, this knowledge should be better exploited by the company. By exploring other situations in particular, products or services in the previous activity chain in which the technology was mastered can be applied and can create a competitive advantage, such as by exploring the moments that comprise the output creation and identifying the opportunities among them. With respect to MotionX, this approach allowed the company to move from an application that was made to play poker to the creation of an external sensor for fitness tracking. Indeed, the activity chain is the same—the smartphone infotainment—but the service provided is quite different. In addition, if we consider the exact point in the activity chain, we can outline the difference because it is in the end product, the mobile app, whereas the other exact point is in the sensor that populates the mobile app. The third approach is referred to as Experience Exploration. In this case, the shift is from the existing production or service process to the experience in which the previously existing application is inserted. In this case, the suggestion is to look to closer experiences that are somehow related to the previous experience of the company with the technology to determine whether there are similarities or opportunities to be exploited. If we consider Ambarella and video encoding, this approach is clear and immediate. Indeed, the company was present in the experience of creating video content with its broadcasting infrastructure encoder, a straightforward application for a video encoding chip, and the first shift was to create a chip for camcorders, a hybrid camera for shooting video, which was an application belonging to a different but linked activity chain. Then, they moved to a completely different activity chain within the same experience, i.e., the production of videos and self-made recordings with GoPro, in particular. These recordings involve different moments of the broader video creation experience. The probability of creating a Technology Epiphany in this case is higher because the company opens up the technology's boundaries and tries to find new application fields and new opportunities that are suited for the technology mastered because all are related to the same experience. The output of each approach is a set of different opportunities within the same activity chain or experience in which the technology can be applied (Table 2).

Technology Epiphany Approach	What should I study?	When is it more useful?	Probability of realizing a Technology Epiphany

Activity Chain Exploration	The output of the technology application	When the applications are well-known	Medium
Experience Exploration	The overall experience provided by the technology application	When many applications have been previously disclosed	High

Table 2: Different Technology Epiphany approaches

Selection Phase

The output of the exploratory phase is the input of the selection phase, and these two phases are iterative and not subsequent. The deep study of the case studies outlines that there are some drivers that can lead to the selection phase. In particular, once the study created the heterogeneous long list of possible new applications, the selection of the more promising studies is based on the following four criteria.

1. *Value for users (Will people love it?)*: This criterion is based on the appeal that the product has on final users;
2. *Differentiation (Will it make a difference in competition/current path?)*: This criterion represents the capability for generating competitive advantage;
3. *Appropriability (Can we "own" the meaning? Branding, technology, distribution)*: This criterion represents the ability of the company to retain the profits generated by its research activities and limit imitation by competitors;
4. *Feasibility (Is there any interesting product/service idea already?)*: This criterion represents the investigation if there are previous ideas and/or prototypes of the technology that have been studied in the market.

These four criteria emerge from the analysis conducted on the shift between different application fields explored by the two companies. If we consider the video encoding case, these criteria are evident. Indeed, choosing to steer the video encoding to foster the realization of the GoPro Ambarella took into account different aspects of the technology. After evaluating the potential value for the user, the company decided to follow the insights of the founder met at CES mainly because every Design-Driven Innovation leveraged on these emotional aspects of the purchasing process. Moreover, it was a differentiation choice because it opens action cameras to a new and different market segment. In addition, in terms of appropriability, this choice is interesting thanks to the brand awareness created through the slogans and communications. There were no other solutions on the market for the feasibility concerns at the time of development.

CONCLUSION

Considering that competitiveness is increasing and the cost of technology developments and investments are rising in today's market, a deeper knowledge about how to foster radical innovation is relevant for both practitioners and scholars. In line with the foregoing conclusion, this paper has enhanced knowledge around the concept of Technology Epiphanies. In particular, it has provided some insights regarding how managers can approach technological development to unveil the quiescent meanings of them. Unveiling the processes and the sub-criteria embodied in the two phases is useful for both practitioners and researchers to better comprehend how to create and approach Technology

Epiphanies. This step is particularly important with respect to exploration and gathering opportunities. In other words, companies and managers can truly exploit technological development through exploration. Considering the costs and efforts that a new technology development process requires, companies should be interested in being able to enhance the potentiality of the impact technological development. In particular, the exploration in this instance is not casual but guided, and the basic assumption is that the exploration can occur in two directions: either on a previously addressed activity chain or within the experience in which the first application was launched. In particular, it is important that after a first explorative application, the firm can enlarge its horizons by creating a list of different application fields in which the newly developed technology can be applied. All these opportunities are then evaluated with a structured approach during the selection phase and converged to the selection of a single application field. This convergent process helps leverage the four criteria and helps managers to choose one application field at a given time. Understanding the technology and exploring the opportunities offered are just two of the important things to examine when developing a new technology. The investigation also reveals the idea that managers must create a multidisciplinary team to address the development of the technology. Indeed, adding different perspectives in both the explorative and selection phases can lead to real insights in the progress of the technology. Bearing in mind that this is an exploratory study, the evidence and the clues outlined are not generalizable, which is one of the most relevant limitations in this investigation. Nevertheless, this growing attention to R&D effectiveness is an important factor in creating knowledge and consciousness around the Technology Epiphany concept because it can both help companies to create new markets and because it can help create more meaningful applications and—as a result—radical innovations. Thus, this area represents one of the most significant follow-ups for further research in the field. Technology Epiphanies are an under-researched topic that is relevant in several sectors—and not just in the digital technology sector—and in several nations. Finally, a more quantitative and more structured approach can be used to enhance the knowledge around the two-step process identified in this paper.

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