INCREMENTAL AND RADICAL INNOVATION: DESIGN RESEARCH VERSUS TECHNOLOGY AND MEANING CHANGE

Donald A. Norman* and Roberto Verganti**
* Nielsen Norman Group
** Politecnico di Milano and Mälardalen University

Donald A. Norman – Bio

Don Norman is cofounder of the Nielsen Norman Group, an IDEO fellow, Trustee of IIT's Institute of Design (Chicago), and former Vice President of Apple. He is a member of the National Academy of Engineering and a fellow of the American Academy of Arts and Sciences. He is professor emeritus of Computer Science and Design at Northwestern University and professor emeritus of Psychology and Cognitive Science at the University of California, San Diego. He has been Distinguished Visiting Professor of Industrial Design at Korea's Advanced Institute of Science & Technology (KAIST). He was awarded the Benjamin Franklin medal in Computer and Cognitive Science, has honorary degrees from the University of Padua (Italy) and the Delft University of Technology (Netherlands). He is author of numerous books, including "Design of Everyday Things," "Emotional Design," and "Living with Complexity." He can be found at www.jnd.org.

Roberto Verganti - Bio

Roberto Verganti is Professor of Management of Innovation at Politecnico di Milano, where he directs MaDe In Lab, the laboratory for executive education on the Management of Design and Innovation, and is visiting professor at Mälardalen University, Sweden. He has been a visiting scholar at the Harvard Business School twice, and at the Copenhagen Business School. Roberto serves on the European Design Innovation Leadership Board of the European Commission, and on the Board of the EIASM – the European Institute for Advanced Studies in Management. His research on management of design and design clusters has been awarded the Compasso d'Oro (the most prestigious design award in Italy). He has issued more than 150 publications, which lie at the intersection of strategy, design and technology management. His most recent book is "Design-Driven Innovation: Changing the Rules of Competition by Radically Innovating What Things Mean" published by Harvard Business Press, nominated by the Academy of Management for the George R. Terry Book Award as one of the best 6 books published in 2008 and 2009 that have made the most outstanding contribution to the advancement of management knowledge. He can be found at www.verganti.com

Manuscript submitted to *Design Issues*. Based on a talk by Norman and Verganti (2011) at the Designing Pleasurable Products and Interfaces conference in Milan, 2011. The authors can be reached at norman@nngroup.com and oberto.verganti@polimi.it .

ABSTRACT

We discuss the differences between incremental and radical innovation and argue that each results from different processes. We present several methods of viewing incremental and radical innovation. One is by examining the quality of product space, envisioning each product opportunity as a hill in that space where the higher one is, the better. Under this view, human-centered design methods are a form of hill climbing, extremely well suited for continuous incremental improvements but incapable of radical innovation. Radical innovation requires finding a different hill, and this comes about only through meaning or technology change. A second approach is to consider the dimensions of meaning and technology change as two dimensions and examining how products move through the resulting space. Finally, we show how innovation might be viewed as lying in the space formed by the dimension of research aimed at enhancing general knowledge and the dimension of application to practice.

We conclude that human-centered design, with its emphasis on iterated observation, ideation, and testing is ideally suited for incremental innovation and unlikely to lead to radical innovation. Radical innovation comes from changes in either technology or meaning. Technology-driven innovation often comes from inventors and tinkerers. Meaning-driven innovation, however, has the potential to be driven through design research, but only if the research addresses fundamental questions of new meanings and their interpretation.

BACKGROUND

Our work began independently. Norman was one of the originators of the class of design exploration now commonly known as "User-Centered" or "Human-Centered" Design (Norman and Draper 1986; Norman 1998). All of these methods have a common framework: an iterative cycle of investigation, usually characterized by observations, ideation phase, and rapid prototype and testing. Each iteration builds upon the lessons learned form the previous cycle, and the process terminates either when the results are appropriate or the allotted time has run out.

Norman realized that this continual process of checking with the intended users would indeed lead to incremental enhancements of the product, but that it actually was a form of hill-climbing, a well-known mathematical procedure for finding local optimization. In the application to design, consider a multi-dimensional hill where one dimension, height along the vertical axis, represents product quality and position along the other dimensions represents choices among various design parameters. This is usually illustrated with just two axes: product quality along the vertical axis and design parameters along the horizontal, as we do in Figure 1. Hill climbing is used in situations such as design where the shape of the hill cannot be known in advance. Therefore, one makes tiny movements along all the design dimensions and selects the one that yields an increase in height, repeating until satisfied. This is precisely what the repeated rapid prototyping and testing is doing in human-centered design. Think of a

blindfolded person trying to reach the top of a hill by feeling the ground in all directions around the current position and then moving to the highest position, repeating until all directions are lower than the current one: this would be the top of the hill.

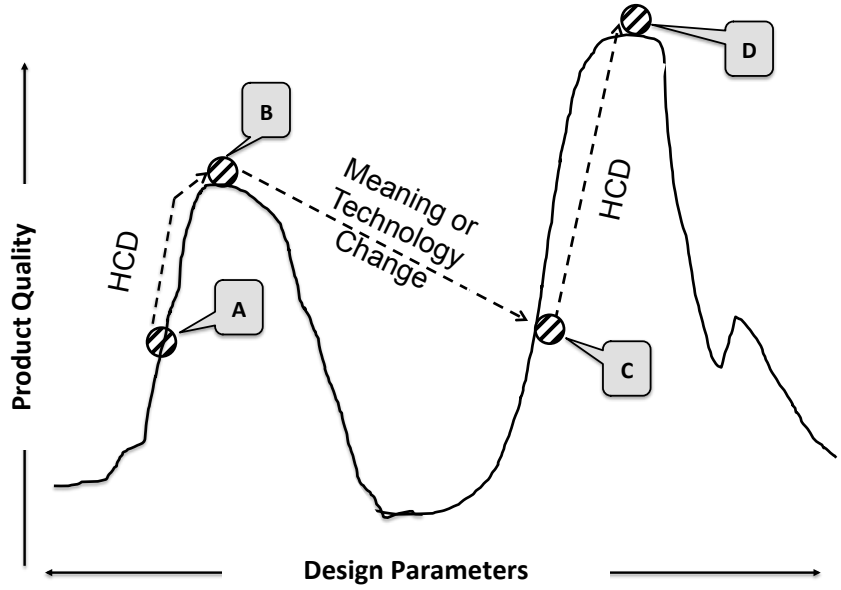

Figure 1. The hill-climbing paradigm applied to incremental and radical innovation. A given product might start off at "A." Through Human-Centered Design and Design Research (HCD & DR), the product undergoes a series of incremental innovations, eventually bringing it to its maximum quality for this part of the design space, point "B." To move to a different hill, one with a higher potential, requires radical innovation, and this comes about through either technology or meaning change, leading to point "C" on a larger hill. Note that the initial outcome is often inferior to that previously reached ("B"), and so HCD and DR are required to make the necessary incremental innovations to reach maximum potential. To make matters more complex, when the product is at point "C," there is no way of knowing if indeed there is a superior level ("D") or if this is an inferior spot in the design space.

Although the hill-climbing procedure guarantees continual improvement with eventual termination at the peak of the hill, it has a well-known limit: there is no way to know whether there might be even higher hills in some other part of the design space. Hill-climbing methods get trapped in local maxima. Incremental innovation attempts to reach the highest point on the current hill. Radical innovation seeks the highest hill. The implication for design is clear: because human-centered design is a form of hill climbing, it is only suited for incremental innovation.

Norman was bothered by his analysis and tried to find examples that refuted this conclusion: he failed. Every radical innovation he investigated was done without design research, without careful analysis of a person's or even a society's needs. The list of such innovations starts out long before design research existed with such technologies as indoor plumbing, electric lighting in homes, the automobile and airplane, radio and television. But even today, radical innovations such as Facebook's and Twitter's development of social networks have come about simply because their inventors thought they were interesting things to try. Videophone calls is an example that has persisted (and is

now finally gathering traction) despite multiple studies and multiple product failures warning against deployment. Norman was unable to find any example of radical innovation that resulted from the HCD process. HCD, he stated, was only suitable for incremental innovation. Norman argued that radical innovations were driven by technology changes, without any design research or formal analysis of needs. Once the radical innovation had been developed, however, then HCD was invaluable as a way of improving the product and enhancing its appeal, a good example being the way that both Facebook and Twitter have modified themselves since their initial introduction.

Norman presented his results at the IASDR conference in Hong Kong (Norman 2009), at IIT's Design Research Conference, DRC 2010 (Norman 2010a) and in the ACM magazine "Interactions" (Norman 2010b). During this process, Norman came across Verganti's book *Design-Driven Innovation* and his Harvard Business School blog (Verganti 2009, 2010), which made very similar arguments. As a result, it seemed clear that these two lines of thought should be combined, something Norman did in his DRC 2010 conference presentation.

Verganti, a scholar of innovation management, had come to design after conducting research on the management of technological innovation. In the search of a definition of design that could clarify and distinguish its contribution to innovation from other drivers such as technology or market, he has rooted his investigation on the definition of design as "making sense of things", as described by Klaus Krippendorf and John Heskett:

> "The etymology of design goes back to the Latin *de* + *signare* and means making something, distinguishing it by a sign, giving it significance, designating its relation to other things, owners, users or gods. Based on this original meaning, one could say: *design is making sense (of things)*" (Krippendorff 1989).
>
> Design: The deliberate and reasoned shaping and making of our environment in ways that satisfy our needs and give meaning to our lives. (Heskett 2002, Also personal communication with D. Norman, 2002).

Verganti's views were similar to those of Norman. Both agreed about the importance of human-centered design for incremental innovation and its weakness in radical innovation. Both agreed about the importance of technology change in driving radical innovation. But Verganti went one step more: he demonstrated that radical innovation could also come about through meaning change. Once the two discovered one another's works, they collaborated on a talk for the "Designing Pleasurable Products and Interactions" conference in Milan, 2011 (Norman and Verganti 2011), much to the dismay of the audience who expected the two to battle one another about the importance of human-centered design. This paper grew out of that talk.

Our observations convince us that there is a need for a better understanding of design research and design innovation and how they

are linked. In our discussion we consider design as the process of "making sense of things." Hence, our questions turn more precisely into the following ones: what type of research is conducted on the meaning of things? And what types of innovative output can this lead to? How are the two concepts, design research and design innovation, related?

TYPES OF DESIGN RESEARCH

The concept "research" takes two different forms in design. One perspective sees research as exploration and experimentation that leads to the advancement of knowledge, the development of theories and the application of theories. This perspective has been the subject of reflections, definitions and effective classifications by design theorists, for example Frayling's well-known three-part classification of design research: research into design, research through design, and research for design (Frayling 1993). See also Cross (1999), Friedman (2003), and Feast and Melles (2010). These definitions all share an epistemological base aimed at advancing knowledge.

The other perspective sees research as any activity of collection and analysis of data for a better understanding of a topic (which therefore includes the research a student at an elementary school conducts to write a paper on what tigers eat). This perspective is used by practitioners to indicate their activities such as ethnographic research or observations on people's activities to understand user needs, product research on possible solutions, market research on the kinds of products people would buy and price sensitivity, and usability research on the interaction between people and products.

In this second perspective, design research focuses upon how to improve both products and sales. In this paper we concentrate upon this second perspective of design research.

TWO TYPES OF INNOVATION: INCREMENTAL AND RADICAL

There are many kinds of innovation. Classification may vary according to the object of innovation, for example innovation of socio-cultural systems, of ecosystems, of business models, of products, of services, of processes, of organizations, of institutional arrangements, etc., to the drivers of innovation (technologies, markets, design, users, etc.), or to the intensity of innovation. In this paper we focus upon two categories of innovation for products or services: incremental and radical.

1. Incremental innovation: Improvements within a given frame of solutions ("doing better what we already do");

2. Radical innovation: A change of frame ("doing what we did not do before").

Most of the writing on innovation within the design community focuses upon radical innovation. It is often characterized as disruptive,

competence destroying, or breakthrough, with all these labels sharing the same concept that radical innovation implies a discontinuity with the past (Garcia and Calantone 2002). Radical innovation is the center of attention of design studies, where it is taught in design schools, and advocated by people discussing innovation and "design thinking." It is what everyone wants, but in fact, successful radical innovation is surprisingly rare. Most attempts at radical innovation fail (Sandberg 2011) Larry Keeley, President of the Doblin Group estimates that 96% fail (Bloomberg Business Week 2005, August 1). Successful radical innovation occurs infrequently within any particular area, perhaps once every 5 – 10 years.

Most radical innovations take considerable time to become accepted. For example, one of today's radical innovations is Apple's development of multi-touch interfaces and their associated gestures to control hand-held and desktop systems. Apple, however, did not invent either multi-touch interfaces or gestural control. Multi-touch systems have been in computer and design laboratories for over 20 years and gestures also have a long history. Moreover, several other companies had products on the market using multi-touch before Apple (Buxton 2007). Although Apple's ideas were not radical to the scientific community, they did come as a radical, major shift in the world of products and how people interact with them and give meaning to them. Similarly, Edison's development of the electric light bulb resulted in a radical, major revolution in home and business, but he did not invent the light bulb. Edison improved the existing bulbs, extending bulb life, and equally importantly, recognized the importance of providing all of the necessary infrastructure: the entire system requirements of generation plants, distribution systems, and even indoor wiring and sockets to hold the bulbs. Thus, his efforts did revolutionize the product space and the living and working patterns of households and businesses.

Incremental product innovation refers to the small changes in a product that helps improve its performance, lower its costs, and enhance its desirability or simply to announce a new model release. Most successful products undergo continual incremental innovation, lowering their costs, and enhancing effectiveness. This, by far, is the dominant form of innovation and even though it is not as exciting as radical innovation, it is just as important. Radical innovations seldom live up to their potential when first introduced. At first, they are often difficult to use, expensive, and limited in capability. Incremental innovation is necessary to transform the radical idea into a form that is acceptable to those beyond early adopters. The bottom line is that both forms of innovation are necessary. Radical innovation brings new domains, new paradigms, and creates a potential for major changes. Incremental innovation is how the value of that potential is captured. Without radical innovation, incremental innovation reaches a limit. Without incremental innovation, the potential enabled by radical change is not captured.

TECHNOLOGY AND MEANING DRIVEN INNOVATION

Having introduced some basic concepts of design, research, and innovation, we can now connect these concepts. We start by mapping the relationships between technology, meaning, and innovation, both incremental and radical. We examine how the two drivers of innovation, technology change and meaning change combine to track

innovation. We illustrate the movement of products in the space defined by the two dimensions of technology and meaning for two different domains: video game consoles and watches.

Video games

Figure 2 shows how the two independent dimensions of technology and meaning change track innovation. Early commercial video games were deployed on specialized game consoles and home computers. In this example, we focus only on specialized consoles. Our story starts with the successful introduction of game consoles for the home, dominated by three major players: Sony with its Play Station, Microsoft with its Xbox, and Nintendo with its GameCube. Playing with a game console provided the opportunity to enter into a new, virtual world, but one for which entrance was a privilege granted only to those who were adept. The user interface required expertise, which took considerable time and practice to acquire. The purpose (meaning) was to allow gamers to enter into a virtual world into which they would have never lived otherwise (a car racing track, a mythical battleground, or a complex maze of paths fraught with dangers, with magical objects and spells). Because reviewers and players of the games all expressed a desire for even better graphics and faster response times, product innovation was directed toward the creation of faster processors and higher quality graphics.

When technical advances in computer chips became capable of providing the requisite compute power, the huge expense of providing this technology led to a technological battle for supremacy between the two largest companies, Microsoft and Sony. The introduction of the Sony PlayStation and the Microsoft Xbox was a radical innovation in technology that was sufficiently powerful to make possible an entire new gamut of games and to enable these two companies to dominate the market for video game consoles. This is illustrated in Figure 2 by the movement of the early games in the lower left-hand corner upwards along the technology change dimension, where the change was the development of faster processors and better displays. Nintendo, as we will soon see, decided to follow a different path.

A related change was the introduction of massive numbers of simultaneous players, connected via the Internet, for example, the genres known as Massively Multiplayer Online Games (MMOLG) and Massively Multiplayer Role-Playing Online Games (MMORPG). These games, with huge numbers of players, where the game continued even when an individual player logged off the system, constituted a meaning change, shown by the shift rightward in Figure 2. Although multiple player games had already existed, this shift to massive numbers of simultaneous players (up to hundreds of thousands of simultaneous players) constituted a major change in the nature of computer game playing.

Nintendo declined to engage in the battle along the technology dimension but instead focused upon the meaning dimension, developing games that were more playable and enjoyable for less expert players. Nintendo took advantage of the arrival of inexpensive sensors, both for acceleration and infra-red imaging and used these simple, inexpensive technologies to launch a major meaning change: games for everyone. The introduction of the Nintendo Wii opened up console games outside

the normal small niche segment of skilled experts and let the entire family play sports, exercise, and play with one another without requiring expert skills. The Wii redefined the playing field by combining a simple technology shift with a massive meaning shift. Sony and Microsoft struggled to catch up. It took a few years for Microsoft to respond with its technology advance, the Kinect, which allows complete control of the game environment by body movement and gestures, dispensing with the need for the hand-held wands required by Nintendo's Wii.

An interesting back-story to Nintendo's success in redefining the meaning of a video game is that the technology that made this possible was rejected by the other major video console companies. They were so focused upon their audience of skilled, expert players, that they dismissed these sensors as too primitive and irrelevant.

The success of the Nintendo Wii was the clever application of MEMS accelerometers and infrared sensors. These components allow the console to sense the speed and orientation of the controller, therefore creating a completely new experience for game players, who for example can serve tennis balls by moving their arms and body to mimic the real serve of a tennis player. Before the launch of the Wii, MEMS accelerometers were already known to all manufacturers of game consoles, but Microsoft and Sony disregarded their potential because they were not helpful in targeting existing user needs. Their design research showed that the niche of expert gamers wanted more sophisticated virtual realities, so Microsoft and Sony invested significant resources to develop even more powerful processors. Nintendo instead challenged the existing meaning and produced a breakthrough experience from passive immersion in a virtual world into active physical engagement within the real world. It didn't matter that Wii used inferior processors and relatively low-quality graphics. They completely changed the dynamics of the game, attracting a large audience consisting of expert gamers as well as people of all ages who did not consider themselves game players.

Now that this meaning has become dominant, competitors are investing in the same direction. The Kinect by Microsoft for example enables even more advanced active playing through gesture recognition. The evolution of innovation has again turned back to the technology dimension, whereas the meaning has remained unchanged. Figure 2 provides a necessarily simplified view of the progress of video game consoles upwards through changes in technology and rightwardds through changes in meaning.

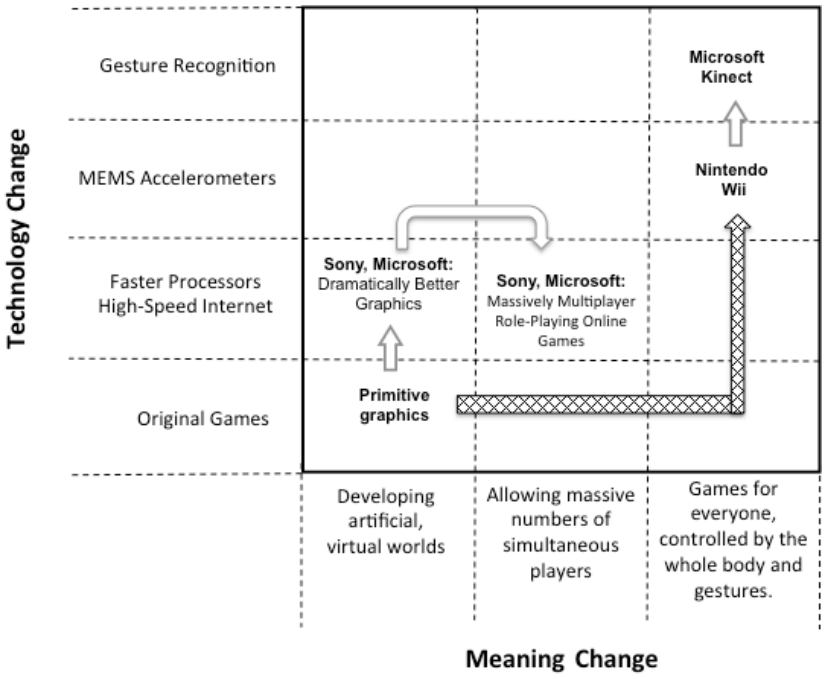

Figure 2. Viewing innovation in Video Game Consoles along the axes of Technology and Meaning change. The early games were played by small numbers of people at a time clustered around a game console. The graphics were crude. Sony and Microsoft followed the technology changes to introduce powerful processors with dramatically enhanced graphics, causing them to dominate the industry. Then, as high-speed internet became possible, they migrated to multi-player games, where up to a million people could be playing the same game even though located all across the world. Nintendo leveraged new sensor technology -- accelerometers and infrared imaging --to change the meaning from games for experts to games for everyone, controlled by whole body movements. This revolutionized the video game market Eventually both Sony and Microsoft were forced to follow along, with Microsoft's Kinect being the most successful.

Watches

Before the advent of the electronic watch in the 1970s, watches were considered jewelry, mainly sold in jewelry stores, and primarily made in Switzerland. When digital technology emerged, early applications attempted to substitute the mechanical movements with the new components, without changing the meaning.

A small number of Japanese companies (primarily Seiko, Citizen, and Casio) used the new electronic technology to transform the watch from an item of jewelry to that of a tool, developing inexpensive watches that kept accurate time (usually even better than the more expensive mechanical ones), coupled with the addition of multiple additional functions such as timers, stop watches, alarms, games, and calculators. By this meaning change, the Japanese became the world leader moving the center of watch production from Switzerland to Japan. The traditional, old-fashioned watchmakers in Switzerland suffered enormously. See Figure 3.

The Japanese dominated the watch industry until the Swatch watch company revitalized the Swiss industry through yet another radical meaning change: Watches as emotion, watches as fashion. Swatch was marketed as a fashion accessory. Whereas people used to own only a single watch, Swatch encouraged them to own multiple watches just as they owned multiple shoes, belts, ties, and scarves. They encouraged their customers to change their watches to match their clothes. Although the major change brought about by Swatch was the change in meaning of a watch, this was also accompanied by technological changes, especially in the manufacturing process. Swatch reduced the parts count of watches, used new, inexpensive materials, and developed automated factories for watch assembly, allowing them to create movements at a very low cost. Within ten years, the Swatch Group became the world's leading manufacturer of watches. The success of Swatch's redefinition of the meaning of a watch propelled the Swiss watch industry to recovery.

Today, yet another meaning shift is occurring within the watch industry: the luxury brands are marketing their expensive, hand-made mechanical watches as status symbols, precious in concept and symbolic connections to lifestyle.

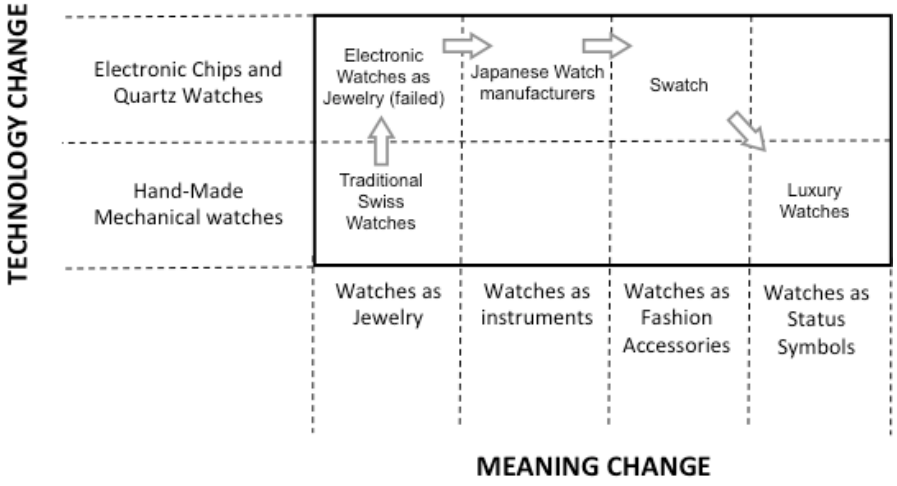

Figure 3. The dynamics of innovation in the watch industry. Watches were thought of as jewelry, purchased in the jewelry store and passed along the family to sons and daughters. A technology change took place when electronic circuits made it possible to forgo the complex, hand-made mechanical assembly of watches. The first attempts to reproduce watches as jewelry, but using electronics, did not succeed. Then Japanese manufacturers redefined the watch as an instrument for telling time: relatively inexpensive but very accurate and with numerous subsidiary functions. This moved the center for the industry from Switzerland to japan. Swatch, however, brought watchmaking back to Switzerland by redefining the watch as a fashion accessory. Today, luxury Swiss watchmakers are bringing back the expensive hand-made watch, but defining it as a status symbol.

HUMAN-CENTERED DESIGN

The two stories of video games and watches provide examples of radical innovations that do not seem to come from users. All these companies were of course concerned with the development of products that people would love and purchase, but the innovations did not come from design research. This poses a significant challenge to the philosophy of human-centered design.

Human- or user-centered design is a philosophy, not a precise set of methods, but one that assumes that innovation should start by getting close to users and observing their activities. We base this simplification on several sources: as previously noted, one of us (Norman) is one of the developers of HCD; the description is consistent with the International Standards Organization's definition (Human-centered design for interactive systems (ISO 2010); it is nicely described on the website of the Usability Professionals organization. The critical components of HCD are:

1. HCD starts by analyzing user needs and then searches for technologies (or methods) that can better satisfy them or updates product language to respond to existing trends.

2. HCD then goes through an iterative process of rapid prototyping and testing, each cycle developing a more refined, more complete prototype. This cycle guarantees that the needs are met and that the resulting product is usable and understandable.

Step 1 starts with extensive design research to determine user needs. This process, however, unwittingly restricts the potential solutions to incremental innovations because by its very nature, it focuses upon things people know already about. The results illuminate the difficulties and problems of existing products. These are important points, but addressing them leads to incremental enhancements. Not only do the users of products have difficulty in envisioning radical new meanings because of their total immersion in the current context and cultural paradigm, but the more that design researchers immerse themselves in the existing context, the more they too are trapped within the current paradigms.

Step 2 is a method of iterative testing, evaluation, and refinement. As such, it is hill climbing, and as we have already noted, this guarantees continual improvement to the top of the current local hill, but it can never lead one to the highest hill. Step 2, therefore, is fundamentally restricted to incremental change: it cannot lead to radical change.

THE RELATIONSHIP BETWEEN INCREMENTAL AND RADICAL INNOVATION

We have now introduced two ways of understanding innovation. One is to think of HCD as a method of hill climbing, showing how incremental innovation can lead to product improvement (incremental) but that jumping to a new and potentially higher hill comes about through technology or meaning change, as shown in Figure 1.

The second way of looking at innovation is through the two dimensions of technology and meaning change, as shown in Figure 4.

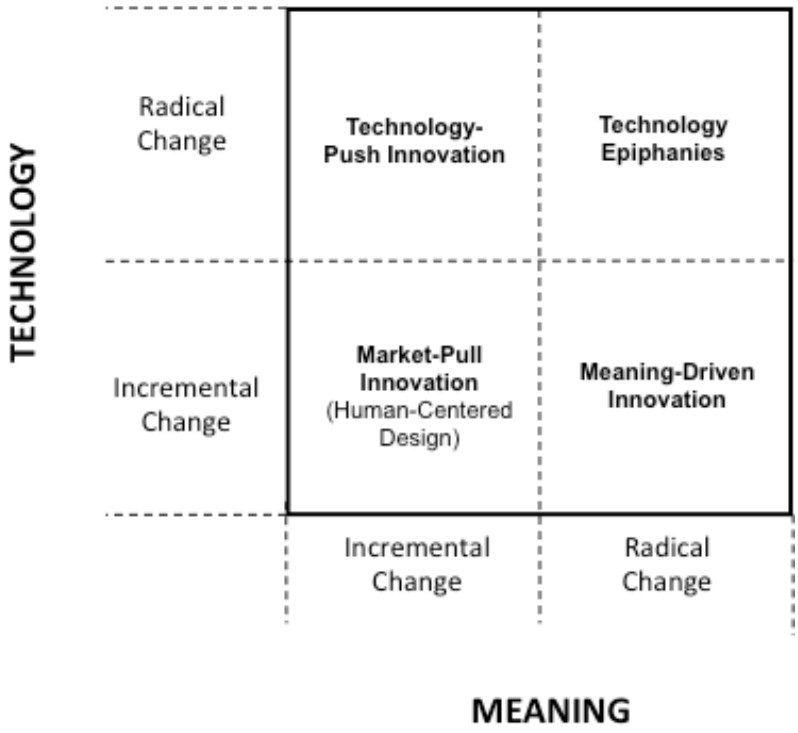

Figure 4: The two dimensions and four types of innovation. HCD leads to incremental change, and although it allows for local, linear changes in technology and meaning, basically it keeps the product within the lower left quadrant. Radical changes in technology can lead to radical technology-driven innovation: for example, the introduction of color TV. Radical changes in meaning can lead to radical meaning-driven innovation, as in the switch from watch as tool to watch as fashion accessory. The biggest change comes about when both the technology and meaning change, as when Wii used new technology and new meaning to radically change the space of video games. This dual change is rare and more dangerous: consumers tend to resist massive changes.

The framework of Figure 4 connects the two dimensions of innovation (technology and meaning) with the drivers: technology, design, and users (the market). We can use these two dimensions to define four types of innovations (Verganti 2008, 2009): technology-push, meaning-driven, technology epiphanies, and market-pull:

1. *Technology-push innovation* comes from radical changes in technology without any change in the meaning of products. The invention of color TV sets (on top of the existing black and white TV sets) is an example. Technology Push innovation definitely does not come from users (Christensen 1997; Dosi 1982).

2. *Meaning-driven innovation* starts from the comprehension of subtle and unspoken dynamics in socio-cultural models and results in radically new meanings and languages, often implying a change in socio-cultural regimes. The invention of the mini-skirt in the 1960s is an example: not simply a different skirt, but a radically new symbol of women's freedom that recognize a radical change in society. No new technology was involved.

3. *Technology Epiphanies* that bring a radical change in meaning enabled by the emergence of new technologies or the use of existing technologies in totally new contexts. The Wii video game console and the Swatch watch are examples of this type of innovation. The term "epiphany" is to be interpreted as "a meaning that stands in a superior position" and "a perception of the essential nature or meaning of something." This superior application of a technology is often not visible at first, because it does not satisfy existing needs. It does not come from users. Rather it is a quiescent meaning that is revealed only when a design challenges the dominant interpretation of what a product is and creates new, unsolicited products that people are not currently seeking (Verganti 2011; Verganti and Öberg 2012, forthcoming).

4. *Market-pull innovation* that starts from an analysis of user needs and then develops products to satisfy them. We put both Human-Centered Design and traditional market-pull methods here: both start from users to identify directions for innovation.

We are not claiming here that any of the above modes of innovation is unaware of the others (Dosi 1982). Technology-push innovation requires a deep understanding of market dynamics, and meaning-driven innovation implies analyzing people's aspirations and exploring new technologies. All successful projects have some aspects of all these dimensions. What is different however is the driver, the starting point.

THE DESIGN RESEARCH QUADRANGLE

We have seen that radical innovation may be associated with a change in either technology or meaning. What is the role of design research to lead to these types of innovation? In the classic study of the relationship between pure and applied research, Donald Stokes (1997) argued that research could be characterized along the two dimensions of the quest for understanding and considerations of use. In a similar spirit, we can view product research along the two dimensions of the

quest for a novel interpretation of meaning, the other consideration of practicality (Figure 5).

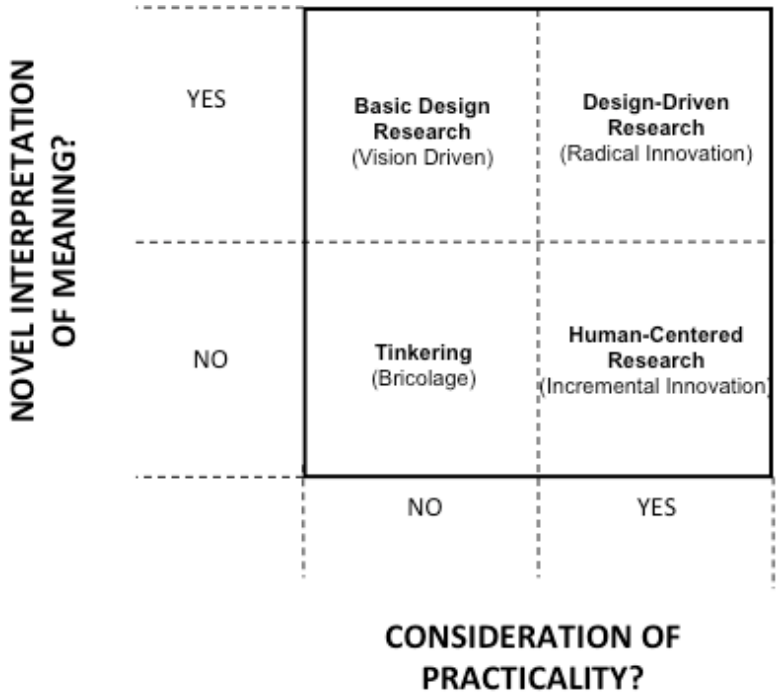

Figure 5. The Design Research Quadrangle. We can view product research along two dimensions: One is the quest for a novel interpretation of meaning, the other is a consideration of practicality. This analysis is inspired by that of Donald Stokes (1997) who argued that research could be characterized along the two dimensions of the quest for understanding and considerations of use. When someone plays around with a product or a technology with no goal, neither for enhancement of meaning nor for practicality, we call it tinkering. Tinkering, however, can often lead to brilliant insights and new products, but when this happens it is completely accidental.

In Figure 5 we use the two dimensions of product research to divide the space of design research into four quadrants: basic design research, design-driven research, human-centered research, and tinkering:

1. *Basic Design Research*. *R*esearch aimed at exploring new meanings, without specific consideration for use in products. A significant design example is the basic research conducted by Memphis, a collective founded by architect Ettore Sottsass in Milan In 1981, joining with emerging talents such as Michele De Lucchi, Matteo Thun, Javier Mariscal, and Aldo Cibic. The vision of the new collective was to challenge the institutional culture and dominant connotations of "good design", especially in furniture. They pioneered the exploration of post-modern philosophies and languages applied to experimental artifacts. In 7 years of experiments the circle acted as a laboratory that produced roughly 40 pieces characterized by a light-hearted and ironic language meant to make an emotional rather than a rational, utilitarian appeal. This was pure basic research, as the pieces were not meant for the mass market: they were arguments for discussion by other interpreters. And indeed, eventually its output, vision and understanding influenced

designers and firms in their developments, and post-modernism, with its emotional drive and its language of symbolic objects, made its way into mainstream markets. Note also that these experiments were developed through the deep and slow dynamics of basic research. Sottsass and his brethren did not consider themselves as a playful creative team, but as radicals engaged challenging current paradigms. They were not conducting fast brainstorming (which may perhaps be useful for incremental innovation). They went in depth to explore, for seven years, the vision of postmodernism in products.

2. *Design-Driven Research*. This is the process aimed at envisioning new meanings that are intended to be applied in products (Verganti 2009). An example is the research project "Family Follows Fiction" conducted by Alessi in the early 1990s. This project was aimed at creating new knowledge about meanings. It aimed a deep understanding of why people buy products, and how one could transform kitchenware into items that people buy for their emotional, playful and symbolic components as much as for their functional usage. The result redefined the meaning of kitchenware from tools to objects of affection that had the dual value of adding to our theoretical understanding while also delivering a new family of products for Alessi. These products were extremely effective, enabling the company to grow 70% in sales in just three years. They are still on the market today. Alessi leveraged the results of their research collaborations with Sottsass on postmodernism and emotion as well as basic research on meaning conducted by others (in particular, studies of Donald Winnicott, a pediatrician and psychoanalyst, who investigated the role that objects have in the psychological development of children).

3. *Human-Centered Research*. This is research that explores people's current meanings of products aimed at detecting existing meanings and needs in order to design products that fit those meanings and needs. Because of the focus on current meanings and needs combined with the iterative, hill-climbing nature of the process, this approach serves to enhance the values of existing categories of products, not to derive entire new categories. Applied ethnography and user-centered observation are prime research methods for this approach;

4. *Tinkering*. When someone plays around with a product or a technology with no goal, neither for enhancement of meaning nor for practicality, we call it tinkering. Tinkering can lead to brilliant insights and new products, but when this happens it is completely accidental. Given the lack of a deeper understanding of patterns and models, these ideas are extemporaneous, often not recognized, and difficult to replicate. It is the "shotgun" strategy followed by Sony's competitors in the 1980s, when they tried to launch products to compete with the Walkman. They tried everything, almost in a random process. Sometimes they even succeeded with some specific models, but they could never duplicate Sony's success (Sanderson and Uzumeri 1995).

The 4 types of research are connected to each other. In particular, there is often a pattern from Basic Design Research (e.g., the research on post-modern products conducted by Ettore Sottsass in the 1980s), to Design-Driven Research (the "Family Follows Fiction" project conducted by Alessi in the early 1990s), to Human-Centered Design (the continuous and improved launch of new products every year by Alessi within the "Family Follows Fiction" family, based on feedback from earlier products).

CAN DESIGN RESEARCH LEAD TO RADICAL PRODUCT INNOVATION?

Can design research ever lead to radical product innovation? Yes, but this is unlikely to occur through the methods of human-centered design. The generation of technology-driven radical innovation differs from that of meaning-driven innovation. Design research has far more potential in the space of meaning.

Radical innovation driven by technology often results from the explorations and dreams of inventors, engineers, and others who have an inner vision, often driven through self-observation, of what might be possible. They are not driven by formal studies or analyses. They usually do capture a need identified by the inventor, but the need might be real or imagined. Moreover, the potential utility of the idea is seldom examined, but the work is pursued simply because it can be pursued, or because it is an attractive challenge that puzzles the mind of inventors in the science commons (Kuhn 1962). Norman described this as "Technology first, needs last" (Norman 2010b). Note that this refusal to do market research is usually a good thing: many very successful radical innovations are known to have been rejected by marketing experts. (Examples are common: two examples are Chester Carlson's invention of the Xerographic copier that was turned down by multiple companies but that today is known as the Xerox copier and HP's development of the electronic calculator which was rejected by the marketing experts at HP, but was built only because Hewitt and Packard, the H and P of HP, wanted it.)

The more that researchers study existing human behavior, activities, and products, the more they get trapped into existing paradigms. These studies lead to incremental improvements, enabling people to do better what they already do, but not to radical change that would enable them to do what they currently do not do.

Radical innovation driven by meaning change can be design driven through better understanding of potential patterns of meanings. This can occur through research and observations rooted in more general socio-cultural changes as an understanding of how society and culture are changing. The search of new breakthrough meaning must avoid becoming trapped by the prevalence of existing products and usage.

Of course, innovation often results from unpredictable events. So, it might be that sometimes user-led innovation, sometime called "lead user" innovation (von Hippel 1988), or watching the results of the Do-it-Yourself (DIY) or hacking community can be used as an insightful research tool to lead the designer to radical innovation, or simply watching the workarounds and "hacks" that people employ to make

sense of their existing world (Norman 2008). Accidental developments and findings can lead designers to explore radical new areas of the design space, occasionally thereby leading to radical product innovation. This may also happen accidentally by tinkering or by user-centered innovation. But to really build a new paradigm, "a new hill" in the space of solutions with a breakthrough result, requires a vision that comes from a deep re-interpretation of the meaning of a product. This should be the goal of design research.

One promising direction towards the development of radical innovation is to modify the human-centered design process to require simultaneous development of multiple ideas and prototypes. By forcing the design team to simultaneously diverge into multiple directions, this enhances the chance of having some of these attempts start off in a different design space, one that might possibly allow for a successful, novel new product. In the words of hill climbing, this might lead one to a higher, more productive hill. (This is a standard technique used in computer hill climbing searches: starting off at random locations to see if the hills encountered there are different or higher than the one currently under study). See "Parallel prototyping leads to better design results" (Dow et al. 2010). Of course, having found a unique new product niche does not mean that it will be recognized as fruitful: witness the struggles of Carlson to get his xerographic copier accepted. Again, in order to recognize the potential for a new higher hill, what is needed is an explicit act of interpretation of patterns, rather than just random creativity.

Hence, the answer to our question is that Design-Driven Research can lead to radical innovation of meanings. To do this, the research must be directed towards new interpretations of what could be meaningful to people. Traditional ideation processes and other creative methods fail to emphasize the importance of interpretation processes, although it is possible that the procedures could be modified appropriately. Research based on interpretation processes is capable of leading to radical change that is recognizable and replicable (Verganti and Öberg 2012, forthcoming).

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