Invention and Innovation

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"The first person to make a novel and prospectively useful product or process is an inventor and the first person or enterprise to exploit that invention in a commercially viable product or service is an innovator" (Schmookler 1966.)

"Economic leadership in particular must hence be distinguished from "invention." As long as they are not carried into practice, inventions are economically irrelevant. To carry an improvement into effect is a task entirely different from the inventing of it, and a task, moreover, requiring entirely different kinds of aptitudes. Although entrepreneurs of course may be inventors just as they may be capitalists, they are inventors not by nature of their function but by coincidence and vice versa" (Schumpter 1934.)

These two quotes contain the essence of most of what will be discovered in this chapter. To begin that exploration, we will start with some established historical cases.

The Steam Engine: Watt and Boulton (*cf.* Scherer 1984)

According to his own account, in an afternoon in the winter of 1764–1765, James Watt, the mathematical instrument maker to Glasgow University, strolled around the grounds to work out a problem. Earlier he had been given a Newcomen engine to repair, a type of engine invented in 1712. During his walk he became conscious of a change that would significantly improve the efficiency of the machine by using a separate condensing vessel. Apparently, the time it took for him to come up with this concept was very short – a matter of hours – and it was dwarfed by the time it took before his insight led to a workable machine in 1780. He may not, in that afternoon, have appreciated the future contributions of John Roebuck, who went bankrupt, and then Matthew Boulton, who played the roles of unsuccessful and successful innovators, respectively. In the development of the Watt-Boulton steam engine neither of them could have seen that their machine would be the overture to the Industrial Revolution when large industrial cities were built far from rivers, reducing reliance on hydropower. By way of contrast to the real potential of their technology, Watt and particularly Boulton were focused on solving a contemporary problem with business potential – getting water out of flooded copper mines.

Two lessons derive from the steam engine story. The first is that the skills of both participants were required. James Watt provided the technical knowledge and the motivation to create a technical improvement and Matthew Boulton encouraged and funded Watt through years of development and resolved a serious patent roadblock. By 1780 they had a commercial product. The second lesson is that many successful products or services extend far beyond the vision of their creators but they all must have at least one sustainable application to get them started, such as extending the life of flooded mines.

Nike: Bowerman and Knight (*cf.* Moore 2006)

A modern example of the Watt-Bolton story is the development of Nike with the addition that the company branched out into adjacent categories. Bill Bowerman, coach of the University of Oregon track team, is known for producing numerous Olympic champions and world record holders and was also a cofounder of Nike. Bowerman liked to make running shoes for his athletes as he was dissatisfied with shoe design in the 1960s and early 1970s. He founded Blue Ribbon Sports (BRS) with Phil Knight and they had Bowerman's designs for running shoes manufactured by Onitsuka in Japan. Bowerman, in search of a light shoe with traction for his track athletes, invented a "waffle" sole using a waffle iron in his home. This invention became the basis for the waffle trainer, the first really successful shoe sold by BRS before the company became Nike. When Frank Shorter won the Olympic gold medal for the marathon in Munich in 1972, a running boom was launched in the US. With the running boom came a huge demand from the masses for comfortable shoes suitable for road running. Bowerman's designs were well-suited to exploit that demand.

In this invention–innovation scenario, Phil Knight played the role of Matthew Boulton from the previous case and managed to successfully steer BRS through a contract dispute involving distribution and trademark issues with Onitsuka that could have destroyed the fledgling company. It is interesting to see once again the expression of the dual aptitudes required in a successful venture. The pattern of initial limited implementation followed by extensibility is seen again as Bowerman's interests were initially focused on the needs of high-performance athletes. The opportunity for mass marketing and expansion into adjacent businesses was successfully exploited by Nike although they did not create the running boom.

The US Navy: Scott and Sims (*cf.* Morrison 1966)

Prior to 1898, gunnery accuracy at sea was dismal. In the space of six years, accuracy was increased by 3000% based on the ingenuity and doggedness of two men, Sir Percy Scott of the British Navy and William Sims, an American naval officer. Scott provided the basis

for a process of continuous aim firing by adjusting guns on ships so that gunners could rapidly alter the positioning of guns to compensate for the roll of the ship. He also made changes to the telescopic sight so that gunners could continually sight their targets. Scott made these improvements in 1898 and began recording remarkable gunnery records. In 1900 Scott met Sims and showed him his new technique. Before long, Sims began to demonstrate similar improvements in gunnery accuracy to Scott. Then he set out to educate the US Navy who would surely welcome this new advance with open arms. On the contrary, they set out to prove that it was physically impossible to produce the results that Sims produced. He was dismissed and regarded as a falsifier of evidence. In a highly unusual move for a naval officer, Sims wrote to President Roosevelt to express his conviction about the value of continuous aim firing and in 1902 he was made Inspector of Target Practice. Scott's method was finally adopted by the US Navy over a period of about six years.

Continuous aim firing was a process made up of components brought together by Percy Scott, none of which he invented individually – guns, gears, telescopic sights – but he put them together in a highly successful way. William Sims, possessed of a desire to revolt against the rigidity of the status quo, provided the commitment and passion to bring Scott's process into use. This case illustrates again the dual aptitudes mentioned already but also demonstrates the role of chance in bringing innovative components together. We also see the resistance to change in any society where the people in it have limited identifications. In the Navy at that time, gunners were not influential due to the ineffectiveness of their craft and others in that society, who focused on battle strategy, were not readily stepping forward to relinquish their power when gunners started to hit their targets. In a hopeful attempt to address the issue of limited identifications, Morison suggested:

"Any group might begin by defining for itself its grand object and see to it that everyone understands what it is." (Morrison 1966).

If one wants to create an innovative organization of a few people or of thousands, it is worthwhile to consider the aptitudes in staffing that would be required. Innovation is a messy, disruptive business often accompanied by personalities to match these qualities. In many companies, great ideas and concepts may be languishing for the attention of a Boulton, Knight, or Sims. Some inventions may not be seen as grand enough to warrant interest. This attitude misses the point that small-scale but profitable implementation may be all that is needed at first before the landslide of another industrial revolution, changes in warfare, or an exercise boom occurs. Like a forest fire, large scale innovations may have very small beginnings.

Benefits

Inherent in the earlier definitions of invention and innovation is that an innovation provides a benefit to its user, one not obvious in current practice. An important consideration is that this benefit is consumer-perceived.

By the early 1970s Philip Morris had acquired the Miller Brewing Company. By the middle of that decade two products were introduced that had a major impact on their industries. One was Miller Lite and the other was a cigarette called Merit. These brands were based on remarkably similar benefits for consumers or, perhaps more accurately, perceived benefits. In the case of Miller Lite a technical advance in brewing technology, the invention, allowed the management teams at Philip Morris and the Miller Brewing Company, the innovators, to introduce a product with extremely low carbohydrate content without sacrificing taste. Similarly, a novel advance in tobacco flavor technology provided the opportunity to introduce Merit and to promote a cigarette with flavor equal to full flavor rivals at half the tar. At the time, tar reduction implied a health benefit from the consumers' perspective. These two products contributed to new categories that became as important to their companies' revenues as the original categories.

The introduction of the Merit cigarette brand was not the first time that perceived health benefits drove fortunes in the tobacco industry. After Louis Pasteur connected disease to microbes in the 1860s, there was a lag until the general public became aware of the germ theory of disease in the 1880s. The spread of tuberculosis from sputum became a common concern and with it the health implications of chewing tobacco, the dominant form of tobacco use in the US in the 19th century. Smoking forms, such as pipes and cigars, began to increase as chewing tobacco declined, and in 1910 the future of the tobacco industry looked firmly hooked on smoking, or pipe, tobacco. Then in 1913 the whole industry abruptly changed when R.J. Reynolds blended Bright and Burley tobacco to make a suitable inhalation form to create modern cigarettes. Lung absorption of nicotine and delivery to the bloodstream is far more efficient than buccal absorption as occurs with chewing tobacco. Ironically, a consumer health issue ignited consumers to turn to cigarettes and away from chewing tobacco, which they perceived to be an unhealthy alternative. This is the benefit that resonated with consumers and led to the creation of a multi-billion dollar industry.

The Merit/Miller Lite scenario seemed ripe for a repeat after Philip Morris acquired General Foods in the 1980s. Technology for removing caffeine from coffee using a CO_2 extraction process seemed appropriate to take nicotine out of cigarettes to simulate what had been done with decaffeinated coffee. A product with little or no nicotine was test marketed in the late 80s under the brand name "Next". This product was a failure and a valuable

lesson because it underscored the importance of understanding what a company's products provide to consumers. Decaffeinated coffee is still a warm, good tasting beverage with consumer benefits. However, in removing nicotine from cigarettes, the main psychoactive substance that contributes to cigarette consumption was removed and there also may have been important sensory effects due to nicotine that disappeared on extraction.

Consumer-perceived benefits, whether justified or not, can drive major changes in the fortunes of companies and even create new businesses. Next, we will examine whether these ideas also apply in science and whether the simple dual roles discussed earlier still apply.

The Invention-Innovation Paradigm in Science

Contrary to popular opinion, and what is often reported in the media, science is not concerned with discovering the truth or facts about the world. Science is concerned with representations and testing them to choose the most useful model. Scientific models are inventions and, when they are broadly adopted for the benefits they provide, we can call them innovations. As an example, consumers of behavioral research in sensory and consumer science have certain basic needs and they judge the benefits provided by the methods and models proposed according to their ability to satisfy those needs. Broadly, there are two general interests. One interest is to scale features that differentiate among products and the other is to represent why people like or choose certain products or brands.

According to legend, Gustav Fechner, a physicist, lay late in bed on the morning of October 22, 1850 contemplating a log-law relationship between physical and mental quantities to explain known data. His conception that morning gave birth to the field of psychophysics in which theories concerning the relationship between the physical world and its mental representation are nurtured. October 22 has been traditionally celebrated as "Fechner Day" around the world by Fechnerian psychophysicists and the festivities include a special conference by the International Society of Psychophysicists. It is doubtful that their excitement will ever create a civil disturbance or compete with the Carnival in Rio de Janeiro. Nevertheless, for this small group of followers, Fechner made a scientific advance in psychological scaling that affected the thinking of all students of mental processes. Commercial applications of functions linking physical quantities, such as the time it takes for a gallon of water to exit a drain, to their mental representations, such as the perceived elapsed time (think of the immediacy of water leaving a clear drain compared to the seeming hours it takes for a partially clogged drain to clear), abound in consumer product categories. Although the ultimate judge of product quality is the consumer, physicochemical measures validated by psychophysical techniques reduce the cost and time of product development and improve the quality of consumer products. Fechner's conceptual invention from 1850 is today a successful innovation in the form of procedures for understanding the relationship between physical and chemical measures and subjective experience.

There are items for which a clear physicochemical correlate is not obvious, such as the beauty of art or handwriting specimens, and yet we still would like to produce relative scale values. In the consumer products area, an example might be the quality of a fine fragrance. In 1927, Louis L. Thurstone invented a basis for a "purely" psychological theory for scaling that met this need. His papers from this period led to a wealth of new models collectively referred to as "Thurstonian models" (Ennis 2016.) These models specify two basic ideas – the information and cognitive processes leading to decisions are probabilistic and there is a definable decision rule that depends on task instructions. In the cases of invention and innovation discussed earlier, the separate roles of inventor and innovator were connected to individuals. Inevitably, this simplification may not describe the role of many other players in some innovations. In the case of Thurstonian scaling, it could be thought that Thurstone's invention was popularized and, in some cases, commercialized not by one innovator but by a community of scientists and programmers who contributed to the dissemination of useful tools. These tools were then used to bring Thurstonian scaling to those who would benefit from them.

Let us turn now from scaling intensities to models of hedonicity, including liking and preference. It is quite natural when thinking of a hedonic response to consider it to be based on a hedonic or utility continuum as we would a sensory variable such as sweetness. This idea is a direct extension of the previous section. Thinking of liking or preference responses as arising from judgments based on a hedonic or utility scale makes it possible to consider using Thurstonian models. Then to find explanatory variables for this hedonic or utility scale, one could use a linear combination of explanatory variables. An alternative to Thurstonian ideas for preferential choice is to consider using the logit, which can be expressed in closed form. Although the logit has well recognized process limitations compared to its Thurstonian alternative, the logit's closed form propelled it to the status of a major innovation in a number of fields including economics, marketing and public health. Contributors to choice models, such as the logit and its applications, include Daniel McFadden who was awarded the Nobel Prize in Economics in 2000 and R. Duncan Luce who was awarded the 2003 National Medal of Science for work he completed in 1959.

A more imaginative alternative to the idea of the hedonic or utility continuum, discussed in the previous section, is to consider that scaling emotional responses involves the possibility of individual internally generated points which are used to make liking or preference

decisions. Sometimes these points are referred to as ideal points or motivation points. This conceptual invention is credited to Clyde Coombs (1950) and implementation of it leads to what is today called "unfolding." The result of an unfolding analysis is the generation of a spatial representation of the hedonic data in a low dimensional space of liking or utility drivers. For half a century, unfolding did not become an innovation because it suffered from a deficiency that often led to degenerate solutions with limited or no interpretation. This problem was solved by combining a Thurstonian probabilistic similarity model (Ennis 2016, Chapter 7) with Coombs' insight and introduced in a method called Landscape Segmentation Analysis® (LSA) in 2001. This method has many applications in the behavioral sciences which are discussed in Ennis and Rousseau (2020). A successful alternative based on a deterministic model was also introduced in 2005 (Busing et al. 2005.)

The Time Scale of Innovations

The impact and even the source of innovations can take decades or even centuries to be identified. Watt conceived of the separate condensing vessel in about three hours but took fifteen years to implement the idea in an innovation. Coomb's ideal point concept required a half century and new analytic tools to reach successful implementation. Duncan Luce, who was seventy-nine when he received the National Medal of Science prize from President Bush, remarked: "This is a great honor for which I am most grateful … I'm also grateful for my genes, which have enabled me to live a long life and enjoy this honor."

Final Remarks

For inventions to blossom into innovations, they usually benefit from the confluence of certain characteristics:

They have an initial, possibly quite small, profitable application.

They need to have consumer perceived benefits.

They may coincide with a movement or trend, such as the running boom or a demographic shift.

They may develop from seemingly unrelated fields.

They require the skills of individual or community entrepreneurs who are often not the inventors.

They should be easily implemented.

They require significant amounts of vision, patience, and time.

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