CHAPTER EIGHTEEN

DEVELOPING INTELLIGENT PRODUCTS

Serge A. Rijsdijk and Erik Jan Hultink

18.1 Introduction

The last two decades showed a trend toward equipping physical products with information and communication technology (ICT) in the form of microchips, software, sensors, and other advanced electronics. Due to this application of ICT, an increasing number of products have become able to collect, process, and produce information; essentially, they are able to *think* and can therefore be described as *intelligent products*. While intelligent industrial products (e.g., assembly robots, autopilots, and missiles) have existed for some time, the range of products showing intelligent features is increasing. An example of an intelligent consumer product is the Electrolux Trilobite autonomous vacuum cleaner. This machine uses a sonar system, four motors, and sophisticated electronics to navigate. It has no problem avoiding collisions with anything placed on the floor. When the batteries run low, the Trilobite automatically returns to the charging station and, if necessary, resumes cleaning once they are fully charged. In this chapter the topic of intelligent products is addressed, along with how companies may create ideas for intelligent products and which advantages and drawbacks are attached to the development of intelligent products.

The organization of the chapter is as follows: The chapter first defines product intelligence and describes the capabilities that distinguish intelligent products from nonintelligent products. Next, we discuss how the development of intelligent products can be beneficial for firms. After that, we describe issues that new product developers should take into account when generating ideas for new intelligent products, when designing intelligent products, and when commercializing intelligent products.

18.2 The Capabilities of Intelligent Products

As a result of the use of ICT, intelligent products show six specific capabilities that we will refer to as *product intelligence*. These six capabilities are the ability to *cooperate, adaptability, autonomy, humanlike interaction, personality, and reactivity*. We will also refer to these capabilities as *dimensions* because they are capabilities that intelligent products show to a lesser or greater degree (see also Rijsdijk, Hultink, and Diamantopoulos, 2007). We will describe the six dimensions below in alphabetical order and illustrate them with examples of existing products.

Intelligent products show the six specific capabilities of ability to cooperate, adaptability, autonomy, humanlike interaction, personality, and reactivity.

18.2.1 Ability to Cooperate

The first dimension of product intelligence is the *ability to cooperate* with other devices to achieve a common goal. This directly corresponds to the fact that the age of discrete products that operate in an isolated manner is ending. Instead, products are becoming more and more like modules with built-in assumptions of their relationships with both users and other products and systems such as the Internet. As a result, an increasing number of products are thus able to communicate not only with their users, but also among themselves.

18.2.2 Adaptability

Adaptability is the second dimension and refers to the ability to learn and improve the match between a product's functioning and its environment. By using ICT, products can build up an internal model of their environment and perform complex decision-making tasks. As such, adaptable products are able to respond and adapt to their users or to changes in their surroundings (e.g., the room in which they are placed) over time, which may result in better performance. An excellent example of a physical product that is adaptable is the Chronotherm IV thermostat developed by Honeywell. From the moment of installation, the Chronotherm collects data on the time it takes to raise the temperature in a room. While doing this, the device also takes into account the outdoor temperature. When the user instructs the thermostat to reach a specific room temperature at a certain time, the device will do so on the basis of the data it previously collected and its performance will therefore improve over time.

18.2.3 Autonomy

The third dimension of *autonomy* refers to the extent to which a product is able to operate in an independent and goal-directed way without interference of the user. An example of an autonomous product is the Automower from the Swedish firm Husqvarna. This lawnmower is placed in the garden, after which it moves through the garden and cuts the grass all by itself. By setting the limits of the garden with a metal wire, the owner ensures that the lawnmower will remain within the limits of the garden.

18.2.4 Humanlike Interaction

The fourth dimension, *humanlike interaction*, concerns the degree to which the product communicates and interacts with the user in a natural, human way. Usability is an important determinant of the adoption of new products, and the marketplace is populated by many complex, nonintuitive, cumbersome devices that frustrate their users. One way of increasing product usability is the application of voice production and recognition. For example, car navigation systems produce speech and some of them also understand speech. There is no need for users to push any buttons while driving, and the driver is guided to his or her destination through a dialogue with the navigation system.

18.2.5 Personality

The fifth dimension, *personality*, refers to the ability to show the properties of a credible character. Providing a product with a personality is supposedly beneficial for the user's comprehension of the product. For example, the paperclip—or Einstein assistant in Microsoft Office—suggests that "someone" assists the users. For physical products, the property of personality mainly refers to the way in which users interact with the product. Typical examples of products with a personality are the Furby and Sony's AIBO. These toys express emotions and show certain emotional states.

18.2.6 Reactivity

Reactivity is the last dimension of intelligence and refers to the ability of a product to react to its environment in a stimulus/response manner. A good example of a reactive product is the Philips Hydraprotect hairdryer. This hairdryer lowers the temperature of the air when the humidity of the hair decreases, thereby preventing damage to the hair caused by hot air. Reactive products distinguish themselves from adaptable products in that

their reactions to the environment are merely direct responses. In contrast to adaptable products, they have no internal models of their environment and are not able to learn and adapt the nature of their reactions over time.

18.3 The Opportunities of Product Intelligence for Firms

Making products more intelligent offers several opportunities for firms that are involved in new product development. First, intelligent products may gain an advantage over competing products. A more intelligent product may perform its central function better than a nonintelligent competing product. A product may also contain intelligent features that make it superior in terms of the benefits that it offers. An example of an intelligent version of a long-existing product category is the Siemens WIQ 1430 washing machine. Due to the use of ICT, the WIQ 1430 is able to do several things that conventional washing machines are not able to do. The machine weighs the laundry in its drum and advises the user about the amount of detergent to use. Also, the machine has a certain amount of autonomy in that it detects how dirty the drained water is. Depending on the amount of dirt, the machine decides to reuse this water to wash the laundry or not. As such, the intelligence of the washing machine results in the reduction of water and detergent use. This is environmentally friendly and also cost reducing for the owner of the washing machine.

Second, the development of intelligent products may open up new markets. The application of ICT can lead to products that do things that could not be done before. A typical example of such a product is the Sony AIBO, which was mentioned in Section 18.2.5. Also, personal digital assistants (PDAs) and smartphones form a product category that would not exist without ICT. One of the first PDAs was the Newton from Apple Computer. At the time it was a unique product; it contained advanced features such as handwriting recognition, and it also fulfilled multiple functions such as those of a diary and a calculator. Although the Newton was not successful in the marketplace, it caused the emergence of a new category of products and eventually set the stage for the development of smartphones such as the iPhone.

Third, intelligent products can serve as showpieces for the company. Because of their technological sophistication, intelligent products often contain cutting-edge technology. As such, intelligent products can provide the company with the image of being technologically advanced. Honda, for example, is developing the humanoid robot ASIMO. ASIMO is the result of a project that was started in 1986 with the idea of developing a new form of mobility

and creating a new kind of robot that can function in society by walking on two legs. Honda currently uses the most advanced version of the ASIMO for publicity purposes by letting it travel around the world and meet prominent people such as European politicians and Olympic medalists. With its advanced robot, Honda further strengthens its image as a technological leader.

Several leading institutes and companies have set up specialized laboratories to conduct research on the integration of ICT into new consumer products and people's living environments. For example, the Massachusetts Institute of Technology (MIT) has set up House_*n*, a home of the future consortium (see www.architecture.mit.edu). This consortium has the ultimate goal of developing a house that adapts to people's needs and reacts to environmental influences. The "n" represents adjectives such as *next generation* and *neural*. The researchers envision a house with an electronic "nervous system" that learns the habits of those who live in it and assists in their living patterns. In business, Microsoft and Philips have set up comparable projects. Microsoft set up the EasyLiving project that aims to develop architecture and technologies for intelligent environments. Philips founded the "Homelab" and envisions a future of ambient intelligence in which they bring advanced intelligent technologies into people's homes. As such, intelligent technologies will form a key element in both today's and tomorrow's new products. Those companies that take the lead in this area may benefit by being able to create superior products and gain an advantage over their competitors. However, several barriers may have to be overcome before customers will adopt these products.

18.4 Potential Barriers for Intelligent Product Acceptance

Besides the advantages that were described above, the development of intelligent products also has some disadvantages. First, intelligent products may contain hidden functionality. Second, intelligent products may be perceived as complex. Third, the unique capabilities of intelligent products may encounter resistance from customers in the form of perceived risk. We will further elaborate on these disadvantages of intelligent products below.

18.4.1 Hidden Functionality

Due to the fact that the functionality of intelligent products is largely based on microelectronics and software, the relation between a product's form and how it can be used is less obvious than in most traditional products.

In some intelligent products this relation is even absent. Customers may therefore have difficulty understanding an intelligent product's functionality and how it should be operated, because product form often fulfills an important role in the communication of such information to the customer (Veryzer, 1995). Product form provides cues about product attributes and helps customers to understand and categorize a product. As a result, a product that effectively communicates its function and method of operation can facilitate successful interaction between the customer and the product and positively influence customers' preferences and choices (Veryzer, 1995).

With intelligent products, however, this communication function is frequently absent because microelectronic and software components influence product form only to a limited extent. This provides developers with considerable freedom to determine the product's form. However, the functionality of most intelligent products is so complex and diverse that it is often impossible to fully express it by a product's form. An example of a product that suffers from the problem of hidden functionality is the smartphone. A challenge in marketing smartphones is to help consumers recognize and appreciate their functionality, particularly those functions that are not apparent from the product's surface attributes. In conclusion, customers may have difficulty observing the functionality and benefits of intelligent products. This disadvantage may hamper the success of intelligent products.

18.4.2 Complexity

Product complexity negatively influences new product success; this is also the case for intelligent products. Norman (1998) recognized that "as technology has advanced, we have understood less and less about the inner workings of the systems under our control," and he illustrates the problem by comparing a pair of scissors to a digital watch (pp.12–13):

> Consider a pair of scissors: even if you have never seen or used them before, you can see that the number of possible actions is limited. The holes are clearly there to put something into, and the only logical things that will fit are fingers… . You can figure out the scissors because their operating parts are visible and the implications clear… . As a counterexample, consider the digital watch, one with two to four push buttons on the front or side. What are those push buttons for? How would you set the time? There is no way to tell—no evident relationship between

> the operating controls and the functions… . With the scissors, moving a handle makes the blades move. The watch … provides no visible relationship between the buttons and the possible actions, no discernible relationship between the actions and the end result.

The problem with the digital watch is also applicable to intelligent products. Intelligent products can be considered as some of today's most technologically advanced products, and many customers may find it difficult to understand and use them. Intelligent products have the reputation of being hard to understand, harder to use, and sometimes even inappropriate to complete the tasks they are designed for. Some intelligent products are equipped with a large number of features, but they lack appropriate user interfaces that make their functionality clear and understandable. Another factor that may complicate the use of intelligent products is the lack of feedback in the form of movements or noise. Processors and memory chips do their work invisibly and silently (Den Buurman, 1997). Several examples illustrate the complexity of intelligent products. For example, only a minority of the owners of DVD recorders can program these devices for delayed recording. Many users of cell phones do not know that certain functions exist. In other cases, customers stop using certain functions because their operation is too difficult to learn and use. Such complexity problems can be barriers to the adoption of intelligent products.

18.4.3 Perceived Risk

A third barrier to the adoption of intelligent products is the risk that customers perceive in these products. Although the capabilities of intelligent products may result in the benefits that were described in Section 18.2, they also have their downsides. Customers may, for example, lack confidence in the product. The idea of an autonomous vacuum cleaner may at first seem attractive. However, customers need to have sufficient confidence in the vacuum cleaner before they have it clean the floors of their house. If the vacuum cleaner cannot avoid collisions with other objects, it might cause damage. Also, customers may feel that they lose control when intelligent products start to make decisions for them. A washing machine that itself determines how much detergent should be used and at what temperature the laundry should be washed may be perceived as incapable of properly performing its task, even when it makes better decisions objectively than its owner. As such, the sometimes far-reaching functionality of intelligent products may be a reason for customers not to adopt them.

18.5 Recommendations for the Development of Intelligent Products

The development of intelligent products requires specific attention in different phases of the new product development process. This section describes several research-based implications. First, we provide suggestions for how managers should generate new ideas for intelligent products. Second, we provide suggestions for how new concepts for intelligent products can be tested. Third, we describe recommendations on how to design intelligent products in a way that reduces the negative effects resulting from their increased complexity and perceived risk. Finally, we provide suggestions on how intelligent products should be commercialized.

18.5.1 How to Generate Ideas for Intelligent Products: Analogical Thinking

Despite the negative consequences that these intelligence dimensions may have for customer perceptions, new product developers can use these dimensions to think about their products and come up with new product ideas using analogical thinking (Dahl and Moreau, 2002). *Analogical thinking* means that existing information from one domain is transferred to another. As such, development team members or other practitioners involved in the generation of new product ideas can apply the six dimensional conceptualizations of product intelligence to their own products. For example, for a new cell phone, one could generate ideas by striving for a more autonomous, a more adaptable, or a more reactive cell phone. Generating new product ideas in such a way may result in original and successful intelligent product ideas.

Research has shown that certain product intelligence characteristics are more problematic than others (Rijsdijk and Hultink, 2009). New product ideas that are generated using one intelligence dimension as an analogy may therefore be more likely to succeed than ideas using another dimension. Idea generation in which one draws an analogy with product autonomy will result in new product ideas that are most likely to succeed. Although autonomous products may be perceived as more likely to fail than nonautonomous products, customers also generally associate higher levels of autonomy with higher levels of product advantage. Also, in some cases, higher levels of autonomy may lead to a decrease in perceived complexity when a product takes over complex cognitive tasks. A product with increased autonomy that demands less effort from users is perceived to offer more advantage and be less complex than competing products. Research, for example, showed this effect for a washing machine that decides which washing program should be

used. As such, this product took over a relatively complex task from the user, and potential customers perceived this as an advantage. We expect that other new product ideas with similar functions can be relatively successful.

Intelligent products showing properties that correspond to the dimensions of adaptability and reactivity are perceived as being more advantageous and more compatible with customer behavior. Such characteristics, however, may also lead to higher levels of perceived complexity and risk. Therefore, the generation of ideas for adaptive or reactive products can be fruitful, but it should be accompanied by measures against the increasing perceived complexity and risk. Section 18.5.3 provides several suggestions on how possible perceptions of complexity and risk can be reduced by the design of the product. Section 18.5.4.1 provides suggestions on how this can be achieved by adaptation of the commercialization phase.

Generating ideas for new products that can cooperate with other products is relatively problematic in that this process does not always deliver advantages in the eyes of the customer and the compatibility with existing customer behavior that one would wish for. When a product is able to communicate and collaborate with a larger number of products, customers may feel that the products are no longer compatible with their needs and their current way of living. Products with which a specific product can cooperate should not be too far from the core function of the specific product. Customers do not perceive advantages in functionality that is too remote from the central functionality. Developers of products that cooperate with other products should therefore extensively test their new product ideas. We will further discuss the issue of idea testing in the next section.

18.5.2 Testing Concepts of Intelligent Products

Once a series of new intelligent product ideas has been generated, it is necessary to evaluate their potential. As with all new product ideas, criteria such as the product's fit with a company's mission and strategy, degree of technical difficulty, and competitors' ability to follow can be used. The new product ideas that appear least viable on the basis of these criteria can be killed. Following this initial selection, however, it will be necessary to collect information from customers on their perceptions of the remaining new product ideas. Although customer concept tests for intelligent products may be generally similar to those for other types of products, our research suggests that there are several points one should pay special attention to in the concept testing of intelligent products. We will discuss these in the following section.

18.5.2.1 Specific Issues to Pay Attention to During the Testing of Intelligent Product Concepts. Our research showed that during intelligent product concept tests, specific issues should be addressed. Independent of the question of whether the concept tests have a qualitative or quantitative form or whether the tests are conducted using verbal product descriptions or working prototypes, specific attention should be paid to the complexity and risk that customer perceive in intelligent products. Our research showed that all product intelligence dimensions are associated with increased complexity and perceived risk. During concept tests, new product developers should inquire whether this is also the case for their product and how this product may be improved to decrease its perceived complexity and risk. Section 18.5.3 provides some suggestions on how to do this through the design of the product.

For autonomous products, new product developers should also carefully assess whether the autonomy decreases the level of input required by the user of the product. Our research showed that autonomy that requires less input from customers is evaluated more positively than autonomy that requires more input. Because the answer to this question only becomes really clear during product use, it would be most fruitful to collect information on autonomous product concepts using working prototypes.

For multifunctional products and products that are able to cooperate with other products, one should assess whether the added functionality or the products with which the new product cooperates are close enough to the new product's core functionality. Our research showed that customers may have problems dealing with products that have extended functions that are atypical for the product category. Also, the multifunctionality and the ability to cooperate with other products should not be too high, and customers should be able to deal with these dimensions. Different concept versions with various levels of these dimensions could be presented to customers in order to gain information on the intelligence level that is most appreciated.

18.5.3 Reducing Complexity and Risk Perceptions Through Product Design

The complexity and risk that customers perceive in intelligent products can be reduced. Perceived complexity may be reduced by equipping intelligent products with indicators that provide feedback to the user on the task that the product is performing at a certain moment. This may be especially effective for autonomous, adaptable, and reactive products. Such products may operate without direct input from the user. From the user's perspective, some actions of these products may be unexpected or illogical; it is therefore important to inform the user why the product performs

these actions. Also, perceived risk may be reduced when the user always has the option to interrupt the action of the product at any time.

For products that cooperate with other products, customers must be able to cope with the additional functionality that follows from this cooperation. Keeping certain possibilities hidden from the user may be helpful. Only when a user specifically requests a certain connection with another system or product does it becomes available and visible to the user. Functionality that is relatively unimportant or too specific may remain invisible and will not confuse the user. It may also be fruitful to introduce additional connectivity to the market step by step. New generations of a specific product may be equipped with extra connections that did not exist in previous generations. Thus, customers are given the opportunity to learn and get accustomed to higher levels of connectivity.

18.5.4 Implications for Intelligent Product Commercialization

Research suggests several implications for the targeting strategy and promotional activities surrounding the commercialization of intelligent products. We will first provide suggestions on how we think that target groups for intelligent products should be determined. Next, we will provide implications for promotional activities.

Research into whether customer characteristics play a role in the formation of perceptions of intelligent products did not show a general pattern that could distinguish adopters of intelligent products from nonadopters. Therefore, intelligent products do not demand specific target groups. Developers of, for example, an intelligent version of a washing machine are therefore advised to maintain a targeting strategy that is based on existing knowledge about the market segments for this product category in general.

18.5.4.1 Reducing Perceived Complexity and Risk in the Commercialization Phase. Customers generally perceive intelligent products as more complex and risky than nonintelligent products. In addition, customers are not always convinced of the benefits that intelligent products may offer. Several measures can be taken in the commercialization phase to deal with these problems. Naturally, promotional messages should be aimed at emphasizing the benefits of the intelligent product and reducing the complexity and risk that customers perceive. Perceived complexity can, for example, be reduced by using analogical learning theory (Gregan-Paxton and John, 1997). Analogical learning entails using customers' existing knowledge to increase their understanding of how the new product works and what its

benefits are. A good example of how analogical learning is used is the Ford Mondeo advertisement, which explains the principle of the Intelligent Protection System by illustrating the car with a guardian angel on top of it. Another way of reducing the perceived risk and complexity of an intelligent product may involve increasing the trialability of the product. Diffusion research has shown that products with a higher level of trialability are more likely to be adopted. Therefore, choosing distribution channels that are willing to demonstrate the new intelligent product or give customers the opportunity to use it is likely to increase the adoption of the product and thereby its success.

18.6 Summary

As physical products are increasingly being equipped with ICT, they are becoming more intelligent. We stated that intelligent products have six capabilities that cannot be found in nonintelligent products, namely, the ability to cooperate, adaptability, autonomy, humanlike interaction, personality, and reactivity. Developing new products that include such capabilities provides firms with a competitive advantage over competing firms because of improved product functionality. Intelligent product development may also create new markets or deliver flagship products that contribute to firms' image as technological leaders. The adoption of intelligent products may, however, also be hampered because the functionality provided by intelligent products is often hidden within the product and is not communicated through its form. Also, customers may perceive intelligent products as complex and risky.

As physical products are increasingly being equipped with ICT, they are becoming more intelligent.

Firms that want to develop new intelligent products may generate ideas through analogical thinking. The capabilities that are most likely to deliver interesting products ideas are product autonomy and the ability to adapt or react to the environment. Such functionality is likely to easily increase the advantages provided by the product without delivering high complexity and perceived high risk as well. Complexity might also be reduced by specific adaptations of the product design or during product commercialization. By taking into account the recommendations provided in this chapter, firms are likely to develop potentially successful new products.

References

Dahl, W.D. and Moreau, P. (2002). The influence and value of analogical thinking during new product ideation. *Journal of Marketing Research* 34(1): 47–60.

Den Buurman, R. (1997). User-centered design of smart products. *Ergonomics* 40(10): 1159–1169.

Gregan-Paxton, J. and John, D.R. (1997). Consumer learning by analogy: A model of internal knowledge transfer. *Journal of Consumer Research* 24(3): 266–284.

Norman, D.A. (1998). *The Design of Everyday Things*. London: MIT Press.

Rijsdijk, S.A. and Hultink, E.J. (2009). How today's consumers perceive tomorrow's smart products. *Journal of Product Innovation Management* 26(1): 24–42.

Rijsdijk, S.A., Hultink, E.J., and Diamantopoulos, A. (2007). Product intelligence: Its conceptualization, measurement and impact on consumer satisfaction. *Journal of the Academy of Marketing Science* 34(3): 340–356.

Veryzer, R.W. (1995). The place of product design and aesthetics in consumer research. *Advances in Consumer Research* 22: 641–645.

Serge A. Rijsdijk is Assistant Professor of Innovation Management at the Rotterdam School of Management (RSM), Erasmus University, in The Netherlands. He received his MSc in Industrial and Organizational Psychology from the Free University of Amsterdam and his PhD from Delft University of Technology. His research interests concern the adoption of intelligent products, product advantage, and managerial control of new product development projects. He has published his work in such journals as the *Journal of Product Innovation Management, Journal of the Academy of Marketing Science, Entrepreneurship Theory and Practice, Marketing Letters,* and the *Service Industries Journal.*

Erik Jan Hultink is Professor of New Product Marketing at the Faculty of Industrial Design Engineering, Delft University of Technology, in The Netherlands. He received his MSc in Economics from the University of Amsterdam and his PhD from Delft University of Technology. His research focuses on the means for measuring and improving the process of new product development and launch. He has published articles on these topics in such journals as the *International Journal of Research in Marketing, Journal of the Academy of Marketing Science, Journal of High Technology Management Research, Industrial Marketing Management, R&D Management, IEEE Transactions on Engineering Management,* and the *Journal of Product Innovation Management.*