How Today's Consumers Perceive Tomorrow's Smart Products

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Abstract	This manuscript investigates consumer responses to new smart products. Due to the application of information technology, smart products are able to collect, process and produce information, and can be described to 'think' for themselves. In this study, consumers respond to smart products that are characterized by two different combinations of smartness dimensions. One group of products shows the smartness dimensions of autonomy, adaptability and reactivity. Another group of smart products are multifunctional and can cooperate with other products. We measure consumer responses to these smart products in terms of the innovation attributes of relative advantage, compatibility, observability, complexity and perceived risk. A study among 184 consumers shows that products with higher levels of smartness are perceived to have both advantages and disadvantages. Higher levels of product smartness are mainly associated with higher levels of observability and perceived risk. The effects of product smartness on relative advantage, compatibility and complexity vary across product smartness dimensions and across product categories. For example, higher levels of product autonomy are perceived as increasingly advantageous while a high level of multifunctionality is perceived disadvantageous. The paper discusses the advantages and pitfalls for each of the five product smartness dimensions and their implications for new product development (NPD). The manuscript concludes with a discussion of the limitations of the study and it provides suggestions for further research.
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How Today’s Consumers Perceive Tomorrow’s Smart Products

Abstract

This manuscript investigates consumer responses to new smart products. Due to the application of information technology, smart products are able to collect, process and produce information, and can be described to ‘think’ for themselves. In this study, consumers respond to smart products that are characterized by two different combinations of smartness dimensions. One group of products shows the smartness dimensions of autonomy, adaptability and reactivity. Another group of smart products are multifunctional and can cooperate with other products. We measure consumer responses to these smart products in terms of the innovation attributes of relative advantage, compatibility, observability, complexity and perceived risk. A study among 184 consumers shows that products with higher levels of smartness are perceived to have both advantages and disadvantages. Higher levels of product smartness are mainly associated with higher levels of observability and perceived risk. The effects of product smartness on relative advantage, compatibility and complexity vary across product smartness dimensions and across product categories. For example, higher levels of product autonomy are perceived as increasingly advantageous while a high level of multifunctionality is perceived disadvantageous. The paper discusses the advantages and pitfalls for each of the five product smartness dimensions and their implications for new product development (NPD). The manuscript concludes with a discussion of the limitations of the study and it provides suggestions for further research.

Introduction

The application of microchips and software is drastically changing the nature of today’s consumer products. Modern lawnmowers, for example, operate without manual control. They drive through the garden when cutting the grass and when the battery runs low the machine autonomously finds its way back to the charging station. In modern houses, light switches have become obsolete because rooms in these houses are equipped with sensors that decide whether the light should be turned on or off. These sensors base their decisions on information whether there is someone present in the room or not, as well as the amount of available daylight. Numerous other examples of ‘smart’ products containing information technology can be found in the marketplace: autonomous vacuum cleaners, the Sony AIBO robotic dog, personal digital assistants (PDA’s), car navigation systems, mobile phones and digital video cameras. Smart products share the ability to collect, process and produce information, and can be described to ‘think’ for themselves. As a result, smart products can, for example, operate autonomously (e.g., the Electrolux autonomous vacuum cleaner), respond to their environment (e.g., the Sony AIBO), or communicate with other products (e.g., PDA’s).

Research on smart products can mainly be found within the fields of ergonomics and industrial design. The ergonomics literature addressing product smartness (see e.g., Feldman, 1995; Freudenthal and Mook, 2003; Han, Yun, Kwahk, and Hong, 2001) emphasizes the importance of appropriate interface designs. Within the area of industrial design, the focus of the literature is mainly on the new opportunities that product smartness offers to designers, and how they should deal with these opportunities (see e.g., Den Buurman, 1997; Holmquist et al., 2004; Robertson, 1992).

The focus on smart products has so far been limited in the new product development (NPD) literature. Rijsdijk and Hultink (2002) referred to the capabilities of smart products as product smartness and defined this construct as consisting of seven dimensions: autonomy, adaptability, reactivity, multifunctionality, ability to cooperate, humanlike interaction, and personality. In another study, these authors showed that specific problems are attached to the development of smart products. They conducted a study on consumer perceptions of *autonomous products* and found that consumers perceive products with higher levels of autonomy as more difficult to understand and use than products with lower levels of autonomy (Rijsdijk and

Hultink, 2003). In addition, consumers perceived products with higher levels of autonomy as more likely to malfunction.

The present paper aims to further investigate product smartness as follows. In addition to the investigation of consumer responses to product autonomy, the manuscript investigates consumer responses to four additional product smartness dimensions: adaptability, reactivity, multifunctionality, and the ability to cooperate. A large number of smart products that are currently in the marketplace show characteristics that correspond to these smartness dimensions. Insight into how consumers evaluate these dimensions, however, is limited. The second contribution of this paper lies in the investigation of the effects of the product smartness dimensions on consumer perceptions at the product category level. Previous research (Rijsdijk and Hultink, 2003) only studied the effects of product smartness on consumer responses at the aggregate level. The results of the present study show that the effects of product smartness dimensions on consumer responses sometimes differ by product category. These findings deepen our insight into the consequences of product smartness and have significant implications for professionals that develop and market smart products.

We will continue this manuscript with a more in depth discussion of the construct of product smartness. Next, we will explain the conceptual framework that guided our research and we will develop the hypotheses for this framework. Next, we provide a description of the conjoint study that was conducted and we will discuss the results. Next, we will provide implications for NPD and address the limitations of the study. We conclude the paper with suggestions for further research.

Product Smartness

Smart products are products that contain IT in the form of, for example, microchips, software and sensors, and that are therefore able to collect, process and produce information. As a result, smart products show a range of capabilities that can only be found in non-smart products to a limited extent. Rijsdijk and Hultink (2002) collectively refer to these abilities as “product smartness”. Product smartness consists of the dimensions of autonomy, adaptability, reactivity, multifunctionality, ability to cooperate, humanlike interaction, and personality. Smart products possess one or more of these dimensions to a lesser or higher degree. Therefore, the overall smartness of a product can be conceptualized as the extent to which it possesses these dimensions[1].

The first 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 by the Swedish firm Electrolux. 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. Another example of an autonomous product is the Samsung Robot Vacuum cleaner.

Adaptability is the second dimension of product smartness and refers to a product's ability to improve the match between its functioning and its environment (Nicoll, 1999). This ability has traditionally been considered to be an aspect of the intelligence of artifacts (Turing, 1950). For adaptable products, this dimension concerns the ability to respond and adapt to their environment (e.g., the user or the room in which they are placed) over time, which may result in better performance. One example of a product that is adaptable is the Chronotherm IV thermostat developed by Honeywell. From the moment of installation, the Chronotherm IV collects data on the time it takes to raise the temperature in a room. While doing this, the device also takes the outdoor temperature into account. When the user instructs the thermostat to reach a certain room temperature at a certain time, the device will do so on the basis of data it has previously collected.

Reactivity is the third dimension of product smartness and refers to the ability of a product to react to changes in its environment (Bradshaw, 1997). An 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 (reflexes). In contrast to adaptable products, they have no internal models of their environment and are not able to adapt the nature of their reactions over time.

The fourth dimension, *multifunctionality,* refers to the phenomenon that a single product fulfills multiple functions (Poole and Simon, 1997). The application of

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[1] Non-smart products may show these dimensions to a limited extent (e.g., washing machines can be described as autonomous). However, when such functionality is not based on IT, we do not describe these products as ‘smart’. We thank one of the anonymous reviewers for raising this issue.

information technology in physical products enables a larger set of attributes to be designed into one product (Dhebar, 1996). Modern cell phones, for example, can also be used to play games or send photos and text messages. Similarly, PDA's provide the user with multiple functions such as a calendar, email, games and a calculator.

The fifth dimension of product smartness is the *ability to cooperate* with other devices to achieve a common goal. According to Nicoll (1999), the age of discrete products may be ending. Instead, products are becoming more and more like modules with in-built assumptions of their relationships with both users and other products and systems. An increasing number of products are thus able to communicate not only with their users, but also among themselves (Nicoll, 1999). For example, desktop computers cooperate with other products; they can be attached to scanners, printers, musical instruments, video cameras and so on. Other examples of products that can cooperate are mobile phones and PDA's. The user of these products can write emails on the PDA and send these via the mobile phone.

The sixth dimension, *humanlike interaction,* concerns the degree to which the product communicates and interacts with the user in a natural, human way. Bauer and Mead (1995) suggest that 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 during driving and the driver is guided to his/her destination through a dialogue with the navigation system.

The final dimension, *personality*, refers to a smart product’s ability to show the properties of a credible character. Bradshaw (1997) discusses the property of a software agent to have a ‘believable personality and emotional state’. Providing an agent with a personality is supposedly beneficial for the user’s comprehension of the agent. For example, the paperclip or Einstein assistants in Microsoft Office suggest 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.

Conceptual Framework and Hypotheses

Figure 1 presents the conceptual framework that guided our research. In the present study, we will focus on five product smartness dimensions. An examination of over 30 smart products that are currently in the marketplace showed that these smartness dimensions occur most frequently. Autonomy, adaptability, and reactivity can, for example, be found in the Electrolux Automower and in the Samsung Robot Vacuum cleaner. Multifunctionality and ability to cooperate can, for example, be found in smart products such as car radios, digital photo and video camera's, Tablet PC's, mobile phones, copiers, and PDA's. Most versions of these products nowadays can perform multiple functions and communicate with other products. The smartness dimensions of humanlike interaction and personality are less common in products that are currently in the marketplace and are therefore not included in the current study.

As we expect that the five smartness dimensions under investigation influence each of the separate innovation attributes in a similar way we will develop our hypotheses at the overall product smartness level. We will do so by innovation attribute.

<<Insert Figure 1 about here>>

Relative Advantage

Relative advantage is defined as the degree to which an innovation is perceived as superior to the idea it supersedes. An innovation can be superior in terms of utility, social prestige (see e.g., Hirschman and Holbrook, 1982), convenience or other benefits (Rogers, 1995). Several studies (Holak, 1988; Plouffe, Vandenbosch, and Hulland, 2001) showed that relative advantage positively influences the rate of adoption.

We expect that smarter products will be perceived as offering more relative advantage. With respect to the dimension of autonomy, we expect that higher levels of autonomy increase the levels of advantage that consumers perceive. This expectation is based on Baber (1996) who described that higher levels of autonomy deliver savings in time and effort. An empirical study by Rijsdijk and Hultink (2003) supported this relationship. We also expect that products that are able to learn will be perceived as more advantageous. TV's could, for example, gain a higher relative advantage by being able to provide a viewer with personal recommendations. Such recommendations could be based on information about which viewer uses the TV (Hara, Tomomune, and Shigemori, 2004) or on the basis of personal profiles (Murasaki, 2001). Comparably, products with a higher reactivity are likely to be perceived as offering more advantage. For example, a door that opens when someone approaches it has the advantage over other non-reactive doors in that people do not have to use muscle force to open it.

We also expect that higher levels of multifunctionality will be perceived as offering more advantage. Each additional function of a product can offer an extra benefit. Also, products that are able to cooperate with a larger number of products are expected to deliver more relative advantage. Previous research (see e.g., Katz and Shapiro, 1985) showed that for network products, the utility of a network product strongly depends on the number of other users that are in the same network. The utility that a consumer derives from purchasing a telephone, for example, depends on the number of other households or businesses that are in the same telephone network. Analogous to that, we expect that higher levels of ability to cooperate are associated with a larger utility because they enable the product to cooperate with a larger number of products. For example, a PDA that is able to communicate with both mobile telephones and personal computers has a higher relative advantage than a PDA that can only communicate with a mobile phone. As a result, the former mobile phone offers more advantages. As such, we hypothesize:

H_1: Product smartness increases perceived relative advantage.

Compatibility

The second innovation attribute of *compatibility* is the degree to which an innovation is perceived as consistent with existing values, past experiences, and needs of potential adopters (Rogers, 1995). A product that is more compatible is more familiar to the potential adopter and fits more closely with the individual's way of living. Innovations with a higher compatibility have a relatively higher rate of adoption (Holak, 1988; Plouffe, Vandenbosch, and Hulland, 2001).

We expect that smarter products will be perceived as more compatible. First, products with higher levels of autonomy are likely to be perceived as more compatible. Baber (1996) described how highly autonomous products may achieve a level of symbiosis in which there is a perfect match between the actions of the product's owner and what the product does. At this level of symbiosis the presence of certain products may even become unnoticed. For example, a vacuum cleaner at this level of symbiosis would start its work when there is nobody in the house and stop its work when someone comes in. Also, products that are able to learn will likely be perceived as more compatible. In fact, it is the basic idea behind the construction of, for example, user profiles to have a product better match the user’s need. The better a product is able to learn, the more accurate a user profile becomes (Waern, 2004) and, as such, will be considered as more compatible. More reactive products will also be considered as more compatible in that they respond to their users. For example, the previously described reactive Hydraprotect hairdryer reacts to the humidity of the hair by lowering the temperature of the air. Similarly, properly functioning reactive toilets flush when needed, doors open when someone approaches, and lights switch on when a person enters the room. As such, we expect that products with higher levels of reactivity will be perceived as more compatible. Finally, we expect that when a product is able to cooperate with multiple products it can be embedded within a network of other products that a consumer already owns. The PDA that is able to cooperate with, for example, both a mobile telephone and a personal computer is more likely to be perceived as compatible than a PDA that can only communicate with a mobile phone. This leads us to hypothesize:

H_2: Product smartness increases perceived compatibility.

Observability

Observability refers to the degree to which the consequences of the use of an innovation are visible to others (Rogers, 1995). The results of some innovations are easily observed, because these products are frequently used in public (e.g., mobile phones). The results of other innovations may be less visible to others, because they are mainly used indoors (e.g., vacuum cleaners). Observability positively influences the rate of adoption.

Our hypothesis with respect to the impact of product smartness on observability is based on the observation that many smart products contain hidden functionality. A large extent of functionality is a result of their IT elements in the form of, for example, software. Rogers (1995) stated that products with an important software element therefore usually have a slower rate of adoption. In smart products, the relation between product form and how it can be used is less obvious than in non-smart products. For example, a PDA can contain functionality such as a diary, calculator, and address book. However, this functionality is not communicated by the product’s form. As a result, consumers may have difficulty in observing a product's functionality and its operation procedure (see e.g., Veryzer, 1995). We therefore expect that:

H_3: Product smartness decreases perceived observability.

Complexity

Complexity is a fourth innovation characteristic introduced by Rogers (1995). The complexity of an innovation refers to the degree to which an innovation is perceived as relatively difficult to understand and use. Rogers (1995) stated that the complexity of an innovation, as perceived by members of a social system, is negatively related to its rate of adoption.

We expect that smarter products will be perceived as more complex. This complexity will play a role when consumers start using a product and also when they have used the product over a longer period of time. Rijsdijk and Hultink (2003) found that consumers perceived higher levels of complexity in product concepts with higher levels of autonomy. With respect to the smartness dimension of adaptability, Alpert et al. (2003) found that users of a user-adaptive interface had difficulty to understand how it worked.

Besides the complexity that will be perceived at first, we expect that consumers will also perceive complexity in smart products in later phases of use. Due to the use of IT elements, most functionality of smart products is hidden inside a black box (Bauer and Mead, 1995). Norman (1998) stated "as technology has advanced, we have understood less and less about the inner workings of the systems under our control." A pair of scissors is easy to use because all operating parts are visible and the implications are clear. The holes in the scissors have a size so that only fingers will fit and the number of possible actions with the scissors is limited (Norman, 1998). For smart products this is not the case. These products can be considered as some of today's most technologically advanced products and many consumers have difficulties understanding and using these products (Bauer and Mead, 1995). This is also due to the fact that users do not receive feedback in the form of movements or noise when using these products. 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. Some users do not know that certain functions exist. In other cases, consumers give up on using certain functions because their operation is too difficult to learn and use (Han, Yun, Kwahk, and Hong, 2001). Concluding, we hypothesize:

H_4: Product smartness increases perceived complexity.

Perceived Risk

Perceived risk as a construct was introduced by Bauer (1960) and later developed by Roselius (1971) and Jacoby and Kaplan (1972) to a multidimensional concept consisting of six components: performance risk, financial risk, social risk, physical risk, psychological risk, and the risk of time loss. The most important dimension of perceived risk is performance risk and it is associated with inadequate and/or unsatisfactory performance of the product (Jacoby and Kaplan, 1972). The rate of adoption of an innovation is negatively influenced by the risk that adopters perceive.

We expect product smartness to increase the performance risk that people perceive. First, technologically sophisticated products generally lead consumers to perceive more risk (Folkes, 1988). In line with that, Rijsdijk and Hultink (2003) showed that perceived risk is positively associated with product autonomy. Also, Morel (2000) found that consumers doubt the quality of multifunctional hybrids (combinations of two or more separate products), such as TV-video recorder combinations. In addition, smart products frequently perform tasks that were previously performed by their users. It is likely that consumers will not trust these tasks to the product, because they expect them to fail. The tasks of smart products are also frequently broader and more complex. It is known that a larger chance of failure increases the risks that are perceived (Mitchell and Greatorex, 1993). These findings lead us to hypothesize:

H_5: Product smartness increases perceived risk.

Method

Design

We conducted a conjoint study with product attributes representing the product smartness dimensions. We chose to investigate two combinations of smartness dimensions on the basis of a study on recent smart product announcements and smart products that are currently in the market. In the remainder of the manuscript we will describe these combinations as *Combination A* and *Combination B.*

The product profiles for Combination A were constructed using attributes representing the product smartness dimensions of *autonomy*, *adaptability* and *reactivity*, where each attribute had two levels (low/high). For this combination we constructed product profiles for three different product categories. The full factorial conjoint design with three product attributes of two levels each resulted in eight product profiles for each product category. This design enabled us to investigate both main effects and interaction effects of the product smartness dimensions.

Combination B concerned the dimensions of *multifunctionality* and *ability to cooperate* that were each represented by a product attribute with three different levels (low/medium/high). With a full factorial conjoint design this resulted in nine product descriptions for each of the three product categories. The section below provides further information on the product profiles.

Stimuli

Stimuli were verbal product profiles. Previous research showed that, in comparison to pictorial product descriptions, verbal product descriptions facilitate judgment (Vriens, Loosschilder, Rosbergen, and Wittink, 1998). For Combination A, we constructed product profiles for a vacuum cleaner, lawnmower, and washing machine. For Combination B, we constructed product profiles for a refrigerator, digital camera, and washing machine. We chose these product categories because they are relatively common. As such, we avoided respondents' evaluations to be biased because of product unfamiliarity or novelty.

The product profiles were composed of attributes that represented the different levels of the product smartness dimensions. The content of the product attributes was based on smart versions of the specific product categories that can currently be found in the marketplace. However, the nature of the attributes representing the higher levels of the smartness dimensions is sometimes more sophisticated than contemporary functionality but it may be found in the marketplace in the future. Appendix A provides short descriptions of the product attributes as they were used in the study for each product category. Appendix B shows the full descriptions of a product profile for the vacuum cleaner representing Combination A and the refrigerator representing Combination B.

All product attributes were tested in a series of pretests. We pre-tested the attributes to ensure that they showed significantly different levels of the corresponding smartness dimensions. In these pretests, all together 164 students in industrial design engineering were presented with the descriptions of the various levels. The students evaluated the descriptions on 7-point multi-item scales that measured the relevant product smartness dimensions. The measurement scales were adopted from Rijsdijk and Hultink (2002). Appendix C provides an overview of the measurement scales, Cronbach's alphas and the mean scores for the different levels of the dimensions that resulted from the pre-tests. Post-hoc Scheffé tests indicated that, within each dimension, the ratings for the separate product attributes (as described in Appendix A) differed significantly at the $p<.05$ level.

Sample

We drew a sample from a panel that contains 1700 households who participate in consumer research in return for small financial incentives. The sample consisted of 355 respondents that varied in age, educational level and gender. The questionnaire was sent to the respondents by mail. To ensure that respondents were familiar with the relevant product category, each respondent received a questionnaire on a product from a category that was present in their household (i.e., we keep track of product ownership for all households in our database).

Procedure

Each respondent received eight (for Combination A) or nine (for Combination B) product profiles on cards for one of the six products. After going through a detailed instruction, respondents were provided with descriptions of the innovation attributes and were subsequently asked to rank order the product descriptions on each of the five innovation attributes. They were first asked to rank order the product descriptions from 'least complex' to 'most complex'. Next, the respondents were asked to use the results of the first ranking task to form a new sequence that indicated the degree of complexity of each profile on a 7-point scale. Respondents performed the same task for the innovation attributes of relative advantage, compatibility, observability, and perceived risk.

Results and Analysis

Overall, we received 184 usable responses implying an effective response rate of 52%. For the products in *Combination A*, we received 84 responses in total (28 for the washing machine, 24 for the lawnmower, and 32 responses for the vacuum cleaner). For the products in *Combination B*, we received 100 responses in total (34 for the washing machine, 34 for the refrigerator, and 32 for the digital camera). We will further discuss our results for each combination below.

Combination A: Autonomy, Adaptability, and Reactivity

For *Combination A*, we analyzed the data in a 2 x 2 x 2 x 3 repeated measures ANOVA with autonomy (low level vs. high level), adaptability (low level vs. high level), and reactivity (low level vs. high level) as within-subjects factors and product category (washing machine vs. lawnmower vs. vacuum cleaner) as a between-subjects factor. The multivariate tests for all main and interaction effects[2] were significant ($p<.05$). Table 1 shows the results for all within-subjects contrasts for Combination A and the estimated mean differences between the low and high levels of autonomy, adaptability and reactivity on the five innovation attributes (in the "Difference" column) plus the standard errors (in the "S.E." column) of the mean differences. We will first discuss the main effects that are not associated with any significant interaction effects. Subsequently, we will discuss the effects of the smartness dimensions that should be interpreted in the light of their interactions with product category.

<<Insert Table 1 about here>>

Main Effects: Effects That Hold for All Product Categories for Combination A

Table 1 shows that, except for the effect of autonomy on the innovation attributes of compatibility and complexity, all main effects of autonomy, adaptability, and reactivity are significant at the $p<.05$ level. A higher level of autonomy is perceived as offering a significantly higher relative advantage ($\underline{M}_{\text{estimated difference}} = 1.40$; $F(1, 81) = 39.228$; $p<.05$) and observability ($\underline{M}_{\text{estimated difference}} = 1.52$; $F(1, 81) = 47.550$; $p<.05$). The effects of autonomy on compatibility ($\underline{M}_{\text{estimated difference}} = .37$; $F(1, 81) = 1.746$; $p>.05$) and complexity ($\underline{M}_{\text{estimated difference}} = -.05$; $F(1, 81) = .035$; $p>.05$) were not significant. The impact of autonomy on perceived risk will be addressed in the

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[2] The current analyses do not include the interactions between the smartness dimensions because preliminary analyses showed that these effects were not significant.

section below on the interactions between the smartness dimensions and product category.

With respect to the dimension of adaptability, a higher level of this smartness dimension results in an increase in compatibility ($\underline{M}_{\text{estimated difference}}$ = .50; F(1, 81) = 7.565; $p<.05$) and observability ($\underline{M}_{\text{estimated difference}}$ = .71; F(1, 81) = 27.162; $p<.05$). Also, a higher level of adaptability is perceived as more complex ($\underline{M}_{\text{estimated difference}}$ = .39; F(1, 81) = 4.880; $p<.05$). The significant effects of adaptability on relative advantage and perceived risk will be discussed below in the section on the interaction effects.

An increase in the level of reactivity of a product is positively associated with observability ($\underline{M}_{\text{estimated difference}}$ = .88; F(1, 81) = 31.911; $p<.05$) and perceived risk ($\underline{M}_{\text{estimated difference}}$ = .69; F(1, 81) = 43.755; $p<.05$). The significant effects of reactivity on relative advantage, compatibility and perceived risk will be discussed in the section below.

Interaction Effects: Differences Across The Product Categories for Combination A

The interaction between autonomy and product category on perceived risk was significant (F(2, 81) = 5.434; $p<.05$). We looked further into this effect separately for the washing machine ($\underline{M}_{\text{estimated difference}}$ = 1.19; S.E. = .33; $p<.05$), lawnmower ($\underline{M}_{\text{estimated difference}}$ = 2.35; S.E. = .35; $p<.05$), and vacuum cleaner ($\underline{M}_{\text{estimated difference}}$ = 2.60; S.E. = .31; $p<.05$) and found that the effect was positive and significant for all categories. The interaction effect, however, indicates that the size of the impact of autonomy on perceived risk varies across product categories.

Adaptability significantly interacted with product category in its impact on relative advantage (F(2, 81) = 20.018; $p<.05$) and indicated that the impact of adaptability on relative advantage was significant for the washing machine ($\underline{M}_{\text{estimated difference}}$ = 2.27; S.E. = .22; $p<.05$) and the vacuum cleaner ($\underline{M}_{\text{estimated difference}}$ = .72; S.E. = .21; $p<.05$) but not for the lawnmower ($\underline{M}_{\text{estimated difference}}$ = .34; S.E. = .24; $p>.05$). Possibly, the respondents saw no benefit in a lawnmower that learns to mow the lawn more efficiently over time. In contrast to an autonomous vacuum cleaner, an autonomous lawnmower in operation is less likely to interfere with activities of its owner because it operates outside the house. The significant interaction effect between adaptability and product category on perceived risk (F(2, 81) = 3.470; $p<.05$) showed that the nature of the effect is positive for the washing machine ($\underline{M}_{\text{estimated difference}}$ = 1.81; S.E.

= .29; $p<.05$), lawnmower ($\underline{M}_{\text{estimated difference}}$ = .73; S.E. = .31; $p<.05$), and vacuum cleaner ($\underline{M}_{\text{estimated difference}}$ = 1.09; S.E. = .27; $p<.05$) but that it varies in size across product categories.

Reactivity interacted significantly with product category in its effect on relative advantage (F(2, 81) = 8.666; $p<.05$), compatibility (F(2, 81) = 7.941; $p<.05$), and complexity (F(2, 81) = 3.122; $p<.05$). The results across product categories showed that for the washing machine ($\underline{M}_{\text{estimated difference}}$ = .95; S.E. = .23; $p<.05$) and vacuum cleaner ($\underline{M}_{\text{estimated difference}}$ = 1.45; S.E. = .21; $p<.05$) the effect of reactivity on relative advantage was significant. For the lawnmower it was not significant ($\underline{M}_{\text{estimated difference}}$ = .11; S.E. = .24; $p>.05$). Apparently, the respondents did not find the anti-theft alarm beneficial. In line with that, respondents perceived the higher level of reactivity of the washing machine ($\underline{M}_{\text{estimated difference}}$ = 1.07; S.E. = .26; $p<.05$) and vacuum cleaner ($\underline{M}_{\text{estimated difference}}$ = .99; S.E. = .24; $p<.05$) as more compatible than the low level. This was not the case for the lawnmower ($\underline{M}_{\text{estimated difference}}$ = -.29; S.E. = .28; $p>.05$). The effect of reactivity on complexity was significant for the lawnmower ($\underline{M}_{\text{estimated difference}}$ = .91; S.E. = .28; $p<.05$) but not for the washing machine ($\underline{M}_{\text{estimated difference}}$ = -.04; S.E. = .26; $p<.05$) and vacuum cleaner ($\underline{M}_{\text{estimated difference}}$ = .27; S.E. = .25; $p>.05$). The differences across the three product categories in terms their reactivity suggests that consumers prefer a discreet form of reactivity. This form of reactivity does not demand attention from the user and becomes operational only when a certain event occurs. We will elaborate on this in the discussion section.

Combination B: Multifunctionality and Ability to cooperate

For Combination B, we analyzed the data in a 3 x 3 x 3 repeated measures ANOVA with multifunctionality (low level vs. medium level vs. high level) and ability to cooperate (low level vs. medium level vs. high level) as within-subjects factors and product category (washing machine vs. refrigerator vs. digital camera) as a between-subjects factor. All multivariate tests for the main effects and interaction effects were significant at the $p<.05$ level. Also, the Mauchly sphericity tests were significant at this level for both multifunctionality and ability to cooperate for all innovation attributes. We therefore investigated whether the significance levels that resulted from the Huyn-Feldt correction formula differed from those that assume sphericity (Crowder and Hand, 1990). The differences, however, were negligible and Table 2 therefore reports the significance levels of all within-subject contrasts. We will first discuss the main effects that do not need to be interpreted in the light of interactions with product category. Subsequently, we will discuss the effects that differed by product category.

<<Place Table 2 about here>>

Main Effects: Effects That Hold for All Product Categories for Combination B

Multifunctionality significantly influences relative advantage (F(1, 97) = 4.249; $p<.05$). More specifically, the medium level is perceived as providing a significantly higher relative advantage than the low level ($M_{\text{estimated difference}} = .78$, $p<.05$). The differences across the high vs. low and medium levels were not significant. As such, the relationship between multifunctionality approaches that of an inverted U-shape. In line with this, the quadratic within-subject contrast was also significant (F(1, 97) = 13.164; $p<.05$). Also, for the effect of multifunctionality on compatibility both the linear contrast (F(1,97) = 37.199; $p<.05$) and quadratic contrast (F(1, 97) = 32.558; $p<.05$) were significant. We found that the high level of multifunctionality was perceived as significantly less compatible than the low ($M_{\text{estimated difference}} = -1.53$, $p<.05$) and medium level of multifunctionality ($M_{\text{estimated difference}} = -1.56$, $p<.05$). As such, the relationship between multifunctionality and compatibility will also be referred to as an inverted U-shape. Higher levels of multifunctionality were also perceived as having increasingly higher levels of observability (F(1, 97) = 44.699; $p<.05$). Table 2 also shows that all three levels of multifunctionality were perceived as significantly different in terms of complexity (F(1, 97) = 364.697; $p<.05$) and perceived risk (F(1, 97) = 325.877; $p<.05$). Higher levels of multifunctionality were perceived as increasingly more complex and risky.

All three levels of ability to cooperate were perceived as significantly different from each other in terms of observability (F(1, 97) = 25.886; $p<.05$) and complexity (F(1, 97) = 355.390; $p<.05$). Higher levels of ability to cooperate were perceived as offering increasingly more observable advantages but also as increasingly complex. As such, the effects of ability to cooperate have two sides. The effects of ability to cooperate on relative advantage, compatibility, and perceived risk will be explained in terms of their interactions with product category in the section below.

Interaction Effects: Differences Across The Product Categories for Combination B

We found no significant interaction effects between multifunctionality and product category on any of the innovation attributes. Ability to cooperate was found to interact with product category in its effect on relative advantage (F(2, 97) = 8.154; $p<.05$). Our results showed that this effect was not significant for the washing machine and refrigerator. However, for the digital camera, increases in ability to cooperate were perceived as delivering significantly higher levels of relative advantage ($\underline{M}_{\text{low level}}$ = 2.86; $\underline{M}_{\text{medium level}}$ = 4.27; $\underline{M}_{\text{high level}}$ = 4.48).

Ability to cooperate was also found to interact with product category in its effect on compatibility (F(2, 97) = 51.280; $p<.05$). The three levels of ability to cooperate were perceived as significantly different from each other for the washing machine ($\underline{M}_{\text{low level}}$ = 4.55; $\underline{M}_{\text{medium level}}$ = 3.46; $\underline{M}_{\text{high level}}$ = 2.66) and the refrigerator ($\underline{M}_{\text{low level}}$ = 4.87; $\underline{M}_{\text{medium level}}$ = 3.94; $\underline{M}_{\text{high level}}$ = 2.06). As such, the effect of ability to cooperate on compatibility was negative for these product categories. For the digital camera, however, the effect was opposite as we found that the low level of ability to cooperate was perceived as significantly less compatible than the medium ($M_{\text{estimated difference}}$ = 1.41, $p<.05$) and high ($M_{\text{estimated difference}}$ = 1.84, $p<.05$) levels. The difference between the medium level and high level in terms of compatibility was not significant. For the washing machine and refrigerator, higher levels of ability to cooperate are perceived as less compatible. However, consumers perceived the medium and high level of ability to cooperate in the digital camera as significantly more compatible than the low level.

Finally, the results showed that ability to cooperate significantly interacts with product category in its effect on perceived risk (F(2, 97) = 8.311; $p<.05$). At the product category level, this effect is significant and positive for the washing machine ($\underline{M}_{\text{low level}}$ = 3.10; $\underline{M}_{\text{medium level}}$ = 4.37; $\underline{M}_{\text{high level}}$ = 5.73), refrigerator ($\underline{M}_{\text{low level}}$ = 2.71; $\underline{M}_{\text{medium level}}$ = 4.07; $\underline{M}_{\text{high level}}$ = 5.78), as well as for the digital camera ($\underline{M}_{\text{low level}}$ = 3.25; $\underline{M}_{\text{medium level}}$ = 3.69; $\underline{M}_{\text{high level}}$ = 4.59). Apart from the low and medium level of the digital camera ($M_{\text{estimated difference}}$ = .44, $p>.05$), all levels of ability to cooperate are perceived as significantly different from each other in terms of perceived risk. Thus, we can state that higher levels of ability to cooperate are generally associated with higher levels of perceived risk. We will further discuss the results of our study in the following section and provide implications for NPD.

Discussion and Managerial Implications

This manuscript extends the product smartness literature by investigating consumer responses to product profiles that combine multiple product smartness dimensions. Two combinations of smartness dimensions are investigated. The first combination includes the dimensions of autonomy, adaptability, and reactivity. We apply this combination to three product categories: vacuum cleaners, lawnmowers and washing machines. The second combination concerns the dimensions of multi-functionality and ability to cooperate and is applied to the categories of digital cameras, refrigerators and washing machines. We measure the consumer responses in terms of the innovation attributes of relative advantage, compatibility, observability, complexity, and perceived risk. We hypothesize that all product smartness dimensions positively influence relative advantage, compatibility, complexity, and perceived risk. We hypothesize a negative impact of the smartness dimensions on observability.

The results of a conjoint study that was performed among 184 consumers partly confirm our hypotheses. Table 3 provides an overview of the results. Higher levels of product smartness dimensions always result in higher levels of perceived risk. Also, higher levels of product smartness generally increase perceived relative advantage, compatibility, and complexity. However, these results often vary by smartness dimension and by product category. Also, we find that, opposite to our expectations, higher levels of product smartness result in higher levels of observability.

Overall, the study increases insight into how consumers perceive contemporary and future smart products. We will provide a number of managerial implications that follow from our research below. These implications are ordered by product smartness dimension because each dimension has its own unique pitfalls and advantages. We will conclude this paper with a discussion of the limitations of the study and we will provide suggestions for further research.

<<Place Table 3 about here>>

Product Autonomy: A Potential Complexity Reducer

As expected, product autonomy increases the advantages that consumers perceive in a smart product. Also, we find that consumers consider these advantages as more observable. As such, creating products with higher levels of autonomy is likely to result in products that deliver benefits that cannot be found in competing products.

We find no significant main effect of autonomy on complexity. Because this finding is different from previous research, we also looked into this effect for the washing machine ($\underline{M}_{\text{estimated difference}}$ = -1.03; S.E.=.50; $p<.05$), lawnmower ($\underline{M}_{\text{estimated difference}}$ = .36; S.E.=.54; $p>.05$), and vacuum cleaner ($\underline{M}_{\text{estimated difference}}$ = .50; S.E.=.47; $p>.05$) separately. For the lawnmower and vacuum cleaner, the effect of autonomy on complexity is not significant. However, for the washing machine this effect is significant and *negative*. This finding is opposite to a study by Rijsdijk and Hultink (2003) where autonomy was found to positively influence complexity.

Possibly, the non-significant effect of autonomy on complexity at the aggregate level can be explained by the fact that for the lawnmower and vacuum cleaner the lowest level of autonomy already shows some autonomy. In the study by Rijsdijk and Hultink (2003) the levels of autonomy varied from no autonomy at all to high autonomy. Consumers may perceive a significant difference in complexity between products with no autonomy and products with at least some autonomy. They may perceive no significant difference in the complexity between products with medium levels and products with high levels of autonomy.

The negative impact of autonomy on complexity for the washing machine may be explained by the fact that the high autonomy machine sets the user free from a complex decision making task. The high autonomy washing machine chooses the appropriate washing program for the user and starts it while the low autonomy machine only gives an advice on the appropriate washing program. Consumers appear to appreciate this sort of autonomy. As such, our results suggest that autonomous products that take over a complex cognitive task from the user will be perceived as less complex. The study by Rijsdijk and Hultink (2003) that showed a significant positive impact of autonomy on complexity investigated autonomy that takes over physical tasks from the user. As such, our results suggest that autonomy that takes over cognitive tasks is perceived as decreasing complexity and, through that, increases the likelihood of product adoption. For autonomous products that take over physical tasks this is not the case.

As with all product smartness dimensions, product autonomy increases the risk that consumers perceive. This finding is in line with the results from previous research (Rijsdijk and Hultink, 2003) and indicates that new product developers should aim to reduce this negative effect. This can, for example, be done by an adaptation of the design of the new product. Providing an autonomous product with indicators that inform the user about what the product is doing may reduce risk perceptions. Also, selling a product in stores where consumers can try a product before they have to purchase it may decrease the risk that consumer perceive in products.

Product Adaptability: Extensive Idea Testing

Our findings indicate that adaptability has its advantages in that it increases the perceived levels of compatibility and observability. A product that is adaptable is likely to better fit with consumers' needs. On the other hand, adaptability increases complexity and perceived risk and thus asks for a proficient design and marketing of the product. The most conspicuous result concerning this dimension, however, is that its impact on relative advantage varies by product category. Adaptability has a significantly positive impact on relative advantage for the washing machine. This effect was also significant for the vacuum cleaner but not for the lawnmower, although the operationalization of adaptability was similar for both products. This operationalization implies that the products learn the shortest route through the garden or through the house. Apparently, consumers perceive it useful when a vacuum cleaner moves through the house as quickly as possible and disturbs the household members as little as possible. For the lawnmower, this ability is not perceived as beneficial because the mower operates in the garden and is less likely to disturb anyone.

This finding suggests that extensive idea testing for adaptable functionality is important. Although many ideas for adaptable products may seem appealing, their advantages are not directly obvious to all consumers. New product developers may, for example, use Information Acceleration (IA) techniques for the testing of new smart product ideas (Urban, Weinberg, and Hauser, 1996). The idea behind IA is to place consumers in a multi-media virtual environment and provide them with information on a new product. Multiple virtual prototypes of a product can be developed with different levels of adaptability. Consumers can evaluate these different levels and thereby provide companies with information on the appropriateness of adaptable functionality.

Reactivity: Preferably Dormant

Our findings with respect to reactivity largely differ by product category. We find that reactivity positively influences relative advantage, compatibility, observability and perceived risk for the washing machine and vacuum cleaner. There is no significant impact of reactivity on complexity for these products. For the lawnmower, the reactive functionality also positively influences observability and perceived risk. However, reactivity does not affect relative advantage and compatibility for this product but it does have a significant positive impact on complexity. As such, new product developers need to carefully design and market reactive products because they may be perceived as likely to malfunction.

In addition, the nature of the reactivity appears to affect consumer perceptions. The washing machine and vacuum cleaner in our study are both equipped with a relatively discreet form of reactivity. The washing machine signals if it is overloaded with laundry and the vacuum cleaner selects extraordinary large objects into a separate compartment. The lawnmower, however, reacts with an anti-theft alarm if someone removes it from the area where it is normally located. Switching off the alarm would require the use of a special code and imply user involvement. This form of reactivity is not perceived as advantageous and compatible but increases the complexity that consumers perceive. The art of creating reactive products therefore appears to be developing dormant functionality that remains unnoticed as long as needed. Once it becomes necessary, reactive functionality should require little user involvement. As a result, this functionality will be perceived as advantageous and compatible and not as complex.

Multifunctionality: Step by Step

Multifunctionality increases the complexity and risk that consumers perceive. Multifunctionality has a positive impact on observability but only a limited positive impact on relative advantage. The highest level of multifunctionality is not perceived as delivering a higher relative advantage than the two lower levels. In contrast to our expectations, the highest level of multifunctionality is perceived as significantly less compatible than the low and medium levels. These results suggest that the benefits of adding functions to a product are limited. There appears to be a maximum level of multifunctionality that consumers appreciate and this finding supports the idea to only introduce products into the marketplace with a moderate increase in multifunctionality. This suggestion is in line with developments that we see in practice. Philips Electronics, for example, recognized that many consumers have trouble dealing with products that fulfill many functions. Therefore, in 2004, Philips

Electronics launched its new marketing campaign that proclaims "Sense and simplicity" (www.philips.com). Consumer research may provide insight into what level of multifunctionality is still acceptable for consumers and which level demands too much adaptation. In line with findings of such research, developers may have to implement their ideas for multifunctional products in a stepwise manner and provide consumers with the opportunity to get used to certain levels of product smartness. Once the market is ready for higher levels, new generations with such levels can be introduced into the marketplace. As with the stepwise introduction of new product features (Thoelke, Hultink, and Robben, 2001), a stepwise introduction of extra functions may also be interesting from a strategic perspective because it may provide competitive advantages over a longer period of time.

Ability to Cooperate: Take Into Account Consumers' Product Conceptions

As with all other smartness dimensions, ability to cooperate positively influences observability, complexity, and perceived risk. Furthermore, we find that ability to cooperate generally has a negative impact on compatibility and only affects relative advantage in a limited way. More specifically, we find that the ability to cooperate is more problematic for the washing machine and refrigerator than for the digital camera. This result may be explained by the fact that the core function of a digital camera demands this product to be multifunctional and able to cooperate with other products. This is not the case for the washing machine and refrigerator. In addition, consumers have certain ideas of what a product category should and should not do. For some product categories, these ideas might be more versatile than for other product categories. In our case, ideas about what a washing machine and refrigerator should do may be less versatile than for a digital camera. As such, new product developers need to take this into account and investigate the extent to which consumers are susceptible for modifications of specific product categories. For some product categories, it may be difficult for consumers to accept that their functionality is extended with the ability to cooperate with other products. When consumers have relatively negative attitudes towards products that cooperate with other products, new product developers may want to emphasize the benefits that this cooperation delivers. Preferably, consumers need to be convinced of these benefits through product tryouts and demonstrations.

Conclusions

Overall, we can conclude that product smartness has its advantages in that it may result in new and fruitful product benefits. Important disadvantages that are attached to product smartness are increased levels of complexity and perceived risk. The extent to which advantages and disadvantages play a role varies by product smartness dimension and sometimes by product. While the smartness dimension of autonomy has relatively few disadvantages, the dimensions of multifunctionality and ability to cooperate are more problematic. All dimensions, however, deliver certain benefits and for most of their disadvantages solutions exist. We provided several suggestions on how to deal with these disadvantages and, as such, the current paper delivers useful input for the developers of new smart products. As with all research, however, our study suffers from several limitations. Also, it has raised new questions. We will discuss the limitations and suggestions for further research below.

Limitations

A limitation of the present study is that it only investigates consumer perceptions of smart products in an experimental setting using verbal product descriptions. Although this setting enables a controlled investigation of the effects of product smartness and that previous research showed that consumers are better able to judge product concepts when they are only described verbally (Vriens et al. 1998), generalization of our findings to actual consumer behavior remains uninvestigated. Actual smart product adoption behavior is likely to be influenced by factors such as brand, price, and product form.

Suggestions for Further Research

The current manuscript has further increased our insight into how consumers respond to product smartness. Some of our findings, however, were not in accordance with previous research. Rijsdijk and Hultink (2003) found that an increase in product autonomy causes an increase in perceived complexity. In the current study, we find that product autonomy can also decrease the complexity that consumers perceive. We explain this difference by hypothesizing that autonomy reduces complexity when it implies that the product takes over a complex cognitive task. Further research should investigate whether this explanation holds.

Also, future research into smart products should investigate how other product characteristics such as product form, brand, or price influence the perception of smart products. It may, for example, be possible that strong brands reduce the risk that consumers generally perceive in smart products.

Finally, future research could also explore whether or not adopters of smart products have special characteristics. In our analyses we did not take respondents' characteristics such as social class, lifestyle, or values into account. However, the adoption literature (see e.g., Andrews and Currim, 2003) suggests that the nature of the adopter of an innovation is partially a function of the characteristics of the innovation itself. It could very well be the case that consumers with certain specific characteristics are more likely to adopt smart products than other consumers. Further research into this issue is important for segmentation and targeting purposes. As a result of such research, new smart products may become more successful.

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References

Alpert, Sherman R., Karat, John, Karat, C.M., Brodie, C., and Vergo, J.G. (2003). User Attitudes Regarding a User-Adaptive Ecommerce Web Site. *User Modeling and User-Adapted Interaction* 13 (4): 373-396 (November).

Andrews, Rick L. and Currim, Imran S. (2003). Recovering and Profiling the True Segmentation Structure in Markets: An Empirical Investigation. *International Journal of Research in Marketing* 20 (2): 177-192 (June).

Baber, Chris (1996). “Humans, Servants and Agents: Human Factors of Intelligent Products.” Paper presented at the *Conference on Artificial intelligence in Consumer and Domestic Products*, London.

Bauer, Raymond A. (1960). “Consumer Behavior as Risk Taking.” Paper presented at the *Proceedings of the Educators' Conference*.

Bauer, Sherie and Mead, Pamela (1995). After You Open the Box: Making Smart Products More Usable, Useful, and Desirable through Interactive Technology. *Design Management Journal* 6 (4): 21-27 (Fall).

Bradshaw, Jeffrey M. (1997). *Software Agents*. Menlo Park, CA: American Association for Artificial Intelligence.

Crowder, Martin J. and Hand, David J. (1990). *Analysis of Repeated Measures* (1st ed.). London: Chapman and Hall.

Den Buurman, Rudy (1997). User-Centered Design of Smart Products. *Ergonomics* 40 (10): 1159-1169 (October).

Dhebar, Anirudh (1996). Information Technology and Product Policy: 'Smart' Products. *European Management Journal* 14 (5): 477-485 (October).

Feldman, Laurence P. (1995). Increasing the Usability of High-Tech Products through Design Research. *Design Management Journal* 5: 27-33 (Fall).

Folkes, Valerie S. (1988). The Availability Heuristic and Perceived Risk. *Journal of Consumer Research* 15 (1): 13-23 (June).

Freudenthal, Adinda and Mook, Riejanne (2003). The Evaluation of an Innovative Intelligent Thermostat Interface: Universal Usability and Age Differences. *Cognition, Technology & Work* 5 (1): 55-66 (April).

Han, Sung H., Yun, Myung Hwan, Kwahk, Jiyoung, and Hong, Sang W. (2001). Usability of Consumer Electronic Products. *International Journal of Industrial Ergonomics* 28 (3-4): 143-151 (Sept-Oct).

Hara, Yumiko, Tomomune, Yumiko, and Shigemori, Maki (2004). Categorization of Japanese Tv Viewers Based on Program Genres They Watch. *User Modeling and User-Adapted Interaction* 14 (1): 87-117 (February).

Hirschman, Elizabeth C. and Holbrook, Morris B. (1982). Hedonic Consumption: Emerging Concepts, Methods and Propositions. *Journal of Marketing* 46 (3): 92-101 (Summer).

Holak, Susan L. (1988). Determinants of Innovative Durables Adoption: An Empirical Study with Implications for Early Product Screening. *Journal of Product Innovation Management* 5 (1): 50-69 (March).

Holmquist, Lars Erik, Gellersen, Hans-Werner, Kortuem, Gerd, Schmidt, Albrecht, Strohbach, Martin, Antifakos, Stavros, Michahelles, Florian, Schiele, Bernt, Beigl, Michael, and Mazé, Ramia (2004). Building Intelligent Environments with Smart-Its. *IEEE Computer Graphics and Applications* 24 (1): 56-64 (Jan-Feb).

Jacoby, Jacob and Kaplan, Leon B. (1972). “The Components of Perceived Risk.” Paper presented at the *Proceedings of the Third Annual Conference of the Association for Consumer Research*.

Katz, Michael L. and Shapiro, Carl (1985). Network Externalities, Competition, and Compatibility. *American Economic Review* 75 (3): 424-440 (June).

Mitchell, V-W. and Greatorex, M. (1993). Risk Perception and Reduction in the Purchase of Consumer Services. *The Service Industries Journal* 13 (4): 179-200 (October).

Morel, Kaj P.N. (2000). *Consumers' Reactions to Ambiguous Product Information*, Doctoral Thesis, Delft University of Technology.

Murasaki, Yasuhiro (2001). Tv Program Selection Based on a User Model Agent, in AI2001-50: NHK Science & Technical Research Laboratories.

Nicoll, Derek (1999). Taxonomy of Information Intensive Products. Edinburgh: The University of Edinburgh Management School (working paper).

Norman, Donald A. (1998). *The Design of Everyday Things* (1st ed.). London, England: The MIT Press.

Plouffe, Christopher R., Vandenbosch, Mark, and Hulland, John (2001). Intermediating Technologies and Multi-Group Adoption: A Comparison of Consumer and Merchant Adoption Intentions toward a New Electronic Payment System. *Journal of Product Innovation Management* 18 (2): 65-81 (March).

Poole, Stephen and Simon, Matthew (1997). Technological Trends, Product Design and the Environment. *Design Studies* 18 (3): 237-248 (July).

Rijsdijk, S.A. and Hultink, E.J. (2002). “The Impact of Product Smartness on Consumer Satisfaction through Product Advantage, Compatibility, and Complexity.” Paper presented at the *Proceedings of the 13th PDMA Research Conference*, Orlando, USA.

Rijsdijk, S.A. and Hultink, E.J. (2003). "Honey, Have You Seen Our Hamster?" Consumer Evaluations of Autonomous Domestic Products. *Journal of Product Innovation Management* 20 (3): 204-216 (May).

Robertson, Alec (1992). “Technolust Versus Creative Design: Some Implications of 'Intelligent' Products for Design.” Paper presented at the *IEE Colloquium on Intelligent Consumer Products*.

Rogers, Everett M. (1995). *Diffusion of Innovations* (4th ed.). New York: The Free Press.

Roselius, Ted (1971). Consumer Ranking of Risk Reduction Methods. *Journal of Marketing* 35 (1): 56-61 (January).

Thoelke, Jurg M., Hultink, Erik Jan, and Robben, Henry S. (2001). Launching New Product Features: A Multiple Case Examination. *Journal of Product Innovation Management* 18 (1): 3-14 (January).

Turing, A.M. (1950). Computing Machinery and Intelligence. *Mind* 59: 433-460.

Urban, G.L., Weinberg, B.D., and Hauser, J.R. (1996). Premarket Forecasting of Really-New Products. *Journal of Marketing* 60 (1): 47-60 (January).

Veryzer, Robert W. (1995). The Place of Product Design and Aesthetics in Consumer Research. *Advances in Consumer Research* 22: 641-645.

Vriens, Marco, Loosschilder, Gerard H., Rosbergen, Edward, and Wittink, Dick R. (1998). Verbal Versus Realistic Pictorial Representations in Conjoint Analysis with Design Attributes. *Journal of Product Innovation Management* 15 (5): 455-467 (September).

Waern, Annika (2004). User Involvement in Automatic Filtering: An Experimental Study. *User Modeling and User-Adapted Interaction* 14 (2-3): 201-237 (June).

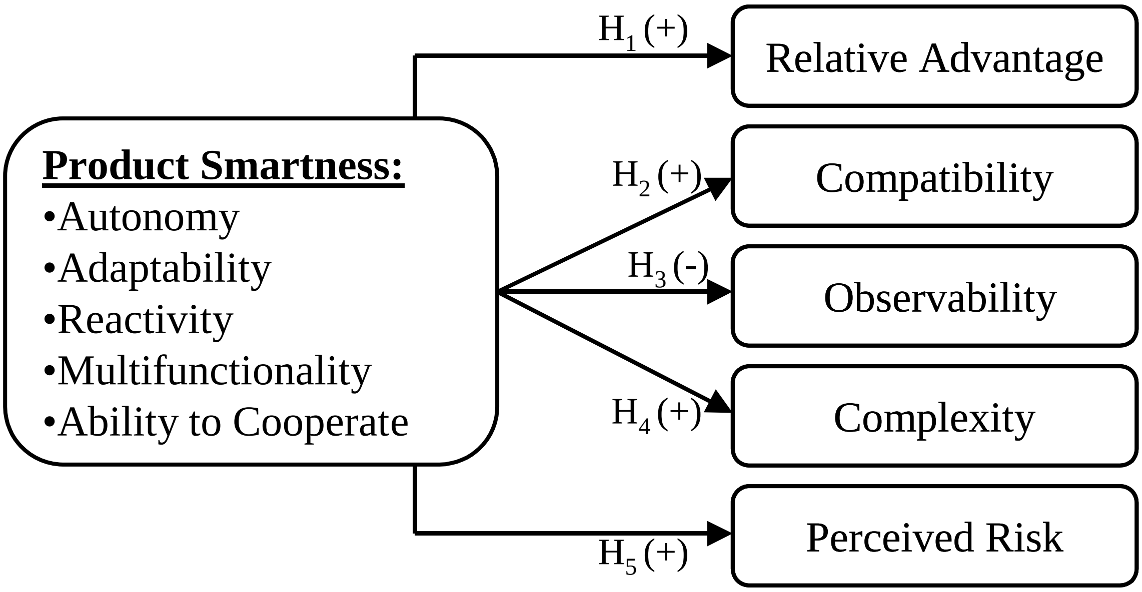

Figure 1. Conceptual framework

Table 1. Linear within-subjects contrasts for Combination A

Independent Variables	Dependent Variables	df	F	Sig.	Difference	S.E.
Autonomy (AU)	Relative Advantage	1	39.228	**.000**	**1.40**	.22
	Compatibility	1	1.746	.190	.37	.28
	Observability	1	47.550	**.000**	**1.52**	.22
	Complexity	1	.035	.853	-.05	.29
	Perceived Risk	1	115.186	**.000**	**2.05**	.19
AU*Product category (PC)	Relative Advantage	2	1.930	.152		
	Compatibility	2	.537	.587		
	Observability	2	2.422	.095		
	Complexity	2	2.893	.061		
	Perceived Risk	2	5.434	**.006**		
Error (AU)		81				
Adaptability (AD)	Relative Advantage	1	72.348	**.000**	**1.11**	.13
	Compatibility	1	7.565	**.007**	**.50**	.18
	Observability	1	27.162	**.000**	**.71**	.14
	Complexity	1	4.880	**.030**	**.39**	.18
	Perceived Risk	1	51.946	**.000**	**1.21**	.17
AD*PC	Relative Advantage	2	20.018	**.000**		
	Compatibility	2	2.857	.063		
	Observability	2	3.071	.052		
	Complexity	2	.240	.787		
	Perceived Risk	2	3.470	**.036**		
Error (AD)		81				
Reactivity (REAC)	Relative Advantage	1	40.905	**.000**	**.84**	.13
	Compatibility	1	15.302	**.000**	**.59**	.15
	Observability	1	31.911	**.000**	**.88**	.16
	Complexity	1	6.079	**.016**	**.38**	.15
	Perceived Risk	1	43.755	**.000**	**.69**	.10
REAC*PC	Relative Advantage	2	8.666	**.000**		
	Compatibility	2	7.941	**.001**		
	Observability	2	2.287	.108		
	Complexity	2	3.122	**.049**		
	Perceived Risk	2	.050	.951		
Error (REAC)		81				

Significant differences at the *p*<.05 level are in **bold**.

Table 2. Linear Huyhn-Feldt within-subject contrasts for Combination B

Independent Variables	Dependent Variables	df	F	Sig.	Difference Low vs. Medium	S.E.	Difference Low vs. High	S.E.	Difference Medium vs. High	S.E.
Multifunctionality (MF)	Relative Advantage	1	**4.249**	**.042**	**.78**	.18	.62	.30	-.16	.21
	Compatibility	1	**37.199**	**.000**	.03	.18	**-1.53**	.25	**-1.56**	.19
	Observability	1	**44.699**	**.000**	**.96**	.16	**1.61**	.24	**.65**	.17
	Complexity	1	**364.697**	**.000**	**1.04**	.10	**2.72**	.14	**1.68**	.10
	Perceived Risk	1	**325.877**	**.000**	**.92**	.10	**2.82**	.16	**1.89**	.12
MF*Product category (PC)	Relative Advantage	2	2.897	.060						
	Compatibility	2	.670	.514						
	Observability	2	1.953	.147						
	Complexity	2	.040	.960						
	Perceived Risk	2	3.034	.053						
Error (MF)		97								
Ability to Cooperate (AtC)	Relative Advantage	1	**7.937**	**.006**	.24	.16	**.68**	.24	**.44**	.17
	Compatibility	1	**22.895**	**.000**	-.20	.15	**-.95**	.20	**-.74**	.17
	Observability	1	**25.886**	**.000**	**.49**	.15	**1.40**	.28	**.91**	.17
	Complexity	1	**355.390**	**.000**	**1.31**	.10	**2.96**	.16	**1.64**	.12
	Perceived Risk	1	**172.976**	**.000**	**1.02**	.11	**2.35**	.18	**1.32**	.12
AtC*PC	Relative Advantage	2	**8.154**	**.001**						
	Compatibility	2	**51.280**	**.000**						
	Observability	2	1.033	.360						
	Complexity	2	.542	.584						
	Perceived Risk	2	**8.311**	**.000**						
Error (AtC)		97								

Significant differences at the *p*<.05 level are in **bold**.

Table 3. Overview of the results

	Relative Advantage (H_1)	Compatibility (H_2)	Observability (H_3)	Complexity (H_4)	Perceived Risk (H_5)
Autonomy	+	*n.s.*	+	*n.s.*	+
Adaptability	Product dependent	+	+	+	+
Reactivity	Product dependent	Product dependent	+	Product dependent	+
Multifunctionality	Inverted U-shape	Inverted U-shape	+	+	+
Ability to cooperate	Product dependent	Product dependent	+	+	+
Hypothesis	*Partly confirmed*	*Partly confirmed*	*Not confirmed*	*Partly confirmed*	*Fully confirmed*

"+" = linear positive effect, "n.s." = not significant, "Product dependent" = the nature of the effect depends on the product category, "Inverted U-shape" = non-linear relationship.

Appendix A. Short descriptions of the product attributes.

Combination A

Product category	Dimension	Level	Attributes
Vacuum cleaner	Autonomy	Low	Autonomous vacuum cleaner that has to be started and recharged by its owner.
		High	Autonomous vacuum cleaner that starts itself and also recharges itself.
	Adaptability	Low	This vacuum cleaner chooses a random route.
		High	This vacuum cleaner learns the optimal route through the house over time.
	Reactivity	Low	Vacuums normally.
		High	Vacuums normally and sorts out relatively big or heavy objects such as earrings or coins.
Lawnmower	Autonomy	Low	Autonomous lawnmower that has to be started and recharged by its owner.
		High	Autonomous lawnmower that starts itself and also recharges itself.
	Adaptability	Low	This lawnmower chooses a random route
		High	This lawnmower learns the optimal route through the garden over time.
	Reactivity	Low	No anti-theft alarm.
		High	Equipped with anti-theft alarm that needs to be switched off with a secret code when using the lawnmower outside the area where it normally operates.
Washing machine	Autonomy	Low	Washing machine chooses itself what kind of detergent to use (for colored or white laundry). User chooses washing program.
		High	Washing machine chooses itself what kind of detergent to use (for colored or white laundry) and chooses washing program.
	Adaptability	Low	Always uses same amount of detergent.
		High	Learns over time how much detergent is needed for certain amounts of laundry.
	Reactivity	Low	No alarm in case of too much laundry in machine.
		High	Alarm in case of too much laundry in machine.

Appendix A. Short descriptions of the product attributes (continued).

Combination B

Product category	Dimension	Level	Description
Refri-gerator	Multi-functionality	low	Cools.
		medium	Cools and has a display that provides access to a digital cookbook.
		high	Cools and has a display that provides access to a digital cookbook, health-tips concerning food, TV, radio stations, and the Internet.
	Ability to cooperate	low	Contains a scanner and shows all products in the refrigerator on a display on the outside of the refrigerator.
		medium	Has a display that shows all products in the refrigerator. The information on the content of the refrigerator can also be retrieved by cell phone.
		high	Has a display that shows all products in the refrigerator. The information on the content of the refrigerator can also be retrieved by cell phone, personal computer or the television set. The device is also connected to security cameras around the house and can show their images.
Digital camera	Multi-functionality	low	Photo camera.
		medium	Photo and video camera in one.
		high	Photo and video camera in one and can also be used to edit the pictures and films, make sound recordings and play mini-CD's.
	Ability to cooperate	low	Has floppy disk with large capacity.
		medium	Has floppy disk with large capacity and can be connected to personal computer.
		high	Has floppy disk with large capacity and can be connected to personal computer, TV, video recorder, and printer.
Washing Machine	Multi-functionality	low	Washes.
		medium	Washes, can give advice on washing based on the color, type of fabric, and dirtiness of the laundry.
		high	Washes, can give advice on washing based on the color, type of fabric, and dirtiness of the laundry. The machine also has Internet functionality that, for example, enables additional advice concerning washing.
	Ability to cooperate	low	Has a digital display.
		medium	Has a digital display and can be started using a cell phone.
		high	Has a digital display and can be started using a cell phone, personal computer or via the Internet. When finished, the machine can send a signal to a cell phone or television set.

Appendix B. Examples of two full product profiles.

Combination A: Example of a card with a vacuum cleaner description.

Vacuum cleaner X

Semi-autonomous

This vacuum cleaner is a wireless vacuum cleaner that automatically drives through the house after the user has started it. Due to the use of sensors the vacuum cleaner never collides into other objects. The vacuum cleaner stops when the battery is empty. The user then has to reload the vacuum cleaner by placing it in the charging station and restart it when the battery is recharged.

Random route

This vacuum cleaner lets its route through the house depend on the objects it runs into. Therefore the route of the vacuum cleaner can be different for every time it vacuums.

Filter system

This vacuum cleaner vacuums everything a normal vacuum cleaner vacuums, but reacts to relatively big or heavy objects, such as an earring, by separating them from the dust. These objects end up in a separate compartment.

Combination B: Example of a card with a refrigerator description.

Refrigerator X

Cooling function + cookbook

This refrigerator cools your products just like any other refrigerator. By means of a build-in display you also have access to a digital cookbook.

Display

This refrigerator is equipped with a scanner that is able to recognize every product on the basis of their form, color or barcode. On a display on the outside of the refrigerator one can read which products the refrigerator contains.

Appendix C. Pilot measures and results.

Measurement scales* and Cronbach alpha's.

Autonomy (α = 0.81)

1. This product goes its own way
2. This product takes the initiative
3. This product works independently
4. This product does things by itself

Adaptability (α = 0.95)

1. This product can learn
2. This product improves itself
3. This product acts on the basis of previously collected information
4. This product delivers a better performance over time

Reactivity (α = 0.89)

1. This product keeps an eye on its environment
2. This product directly adapts its behavior to the environment
3. This product observes it's environment

Multifunctionality (α = 0.82)

1. This product has multiple functions
2. This product can do a lot
3. This product performs multiple tasks
4. This product fulfils multiple functional needs

Ability to cooperate (α = 0.79)

1. This product communicates with other devices
2. This product achieves a common goal in cooperation with other products
3. This product can be attached to other products
4. This product works better in cooperation with other products

* All items were scored on 7-point scales (1 = "Totally disagree", 7 = "Totally agree")

Mean scores* of the different levels for the products of Combination A.

	Autonomy		Adaptability		Reactivity	
	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
Vacuum Cleaner	3.70	6.05	2.41	6.04	1.76	4.51
Lawnmower	3.96	5.90	2.45	6.34	2.25	4.44
Washing Machine	3.66	5.70	1.59	6.16	1.94	3.73

* Post-hoc Scheffé tests indicated that within each dimension the scores for the different levels differed significantly at the $p < .05$ level.

Mean scores* of the different levels for the products of Combination B.

	Multifunctionality			Ability to cooperate		
	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
Refrigerator	2.48	4.63	5.67	2.76	4.75	5.49
Digital Camera	2.89	5.15	6.01	2.97	4.97	5.92
Washing Machine	3.05	4.06	4.82	1.67	4.64	5.51

* Post-hoc Scheffé tests indicated that within each dimension the scores for the different levels differed significantly at the $p < .05$ level.

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