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"Honey, Have You Seen Our Hamster?" Consumer Evaluations of Autonomous Domestic Products

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Several autonomous products have been launched in the marketplace in the past few years. These autonomous products do not need any human intervention but operate on their own. An example of such an autonomous product is the self-initiating, independent vacuum cleaner that determines when a floor or room needs to be vacuumed, and does the job by itself, returning to the charging station when it needs to recharge its battery. It is unclear, however, to what extent consumers appreciate this autonomy. Autonomous products take over tasks from the user, which leaves the user the opportunity to take part in other activities. However, consumers may also consider these products complex and the use and purchase of such products risky. In addition, people often show a desire for control and may be reluctant to hand over some control to autonomous products. The advantages of autonomous products may thus be partly compensated by several disadvantages.

The present study aims to explain overall consumer appreciation for autonomous products by integrating the above-mentioned factors in a conceptual model. This conceptual framework was tested in an experiment (N=77). The results reveal that consumers perceive highly autonomous products as more risky and complex than less autonomous products. Perceived risk negatively influenced overall consumer appreciation whereas complexity did not affect consumers' appreciation. Relative advantage, however, compensates the negative effect of perceived risk on overall consumer appreciation. Also, contrary to our expectations, we found that people with a high desire for control perceive less risk. We conclude with managerial implications for developers and marketers of autonomous domestic products.

Introduction

Predictions about "intelligent homes" by authors like Brand [7] and Negroponte [28] increasingly become a reality. Consumer products are made to be smarter by equipping them with information and communication technology. Representative examples of such smart products are small-sized devices like mobile phones and palmtops that show an astonishing increase in the number of new features and functions. Another example is the TIVO device developed together between Sony and Philips. This device is attached to a television set and builds a user profile on the basis of ratings of television shows and the actual viewing behavior of a user. TIVO then uses this profile either to record shows that the user may like or gives advice on shows that the user may want to watch. The Swedish firm Husqvarna provides another example. Their Solar Mower is a robotic lawnmower that measures the length of the grass and decides whether it needs to be cut. When it does, the machine starts mowing without any human interference. However, a product like the

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latter may make consumers fear for the lives of their pets (this explains the article's title). In this article we want to obtain insight into the advantages and disadvantages of these smart products.

Smart products distinguish themselves from traditional products by their ability to process information. Three general consequences of this ability can be discriminated [2,6,29,30,34]. Smart products show at least one of these characteristics. First, products become able to communicate with other products [6,29]. Nicoll [29] states that the age of discrete products may be ending. Instead of being sole entities, products become modular-like devices with built-in assumptions about their relationships with other products. Digital cameras, for instance, show these characteristics. Photographs made with a digital camera can be transferred to a personal computer. The two devices can be connected and thus can communicate with one another. Another example is the wireless communication between palmtops and cellphones. A user can write an email on a palmtop and send it with a cell phone.

Second, the increased ability to process information makes products more flexible [6,29]. Products adapt their actions to different situations. Certain thermostats, for example, take the outside temperature into account in deciding when the heater has to be switched on in order to reach a pleasant temperature at the appropriate time. The lower the outside temperature, the earlier the thermostat switches on the heater. Another example is the front passenger seat developed by Mercedes. It automatically recognizes when a child safety seat is used, thereby reducing air bag power.

BIOGRAPHICAL SKETCHES

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Third, products become autonomous decision-makers due to their ability to process information [2,6,31,34]. Product developers may have provided a smart device with the information needed to make decisions, but some products even are able to collect the information themselves. This information is collected through connections with other products or by using sensors. Examples of such products are the aforementioned autonomous lawnmower and the robotic vacuum cleaner by Electrolux. Both products perform a task that their nonautonomous predecessors could not perform: moving around and fulfilling tasks without the aid of the owner. Both products can accomplish this difficult task by using sensors to collect information about their environment.

Although smart products form an exciting group of new products that appear convenient to potential users, one may question the extent to which consumers will appreciate this smartness. However, little empirical research has been conducted to provide insight into this matter. It is the primary aim of the present research project to gain an understanding of how consumers perceive smart products and how these perceptions may influence the rate of adoption of these products.

The literature on new product diffusion [16,32,35] shows that the rate of adoption of innovations is influenced positively by the innovation characteristics of relative advantage, compatibility, observability, and trialability and is influenced negatively by perceived risk and complexity. The present research provides insights into the way in which smart products are perceived in terms of three of these innovation characteristics that can be considered as most important for technologically intensive consumer durables: relative advantage, perceived complexity, and perceived risk [20,21,32,33].

With respect to product smartness we will focus on the characteristic of autonomy. Autonomous products provide advantages by taking over tasks from the user, which leaves the user the opportunity to take part in other activities. However, consumers also may consider this autonomy complex and the use and purchase of such products risky. In addition, people often show a desire for control and may be reluctant to hand over some of this control to autonomous products. The advantages of these autonomous products thus may be overshadowed partly by several disadvantages. The present study aims to explain overall consumer appreciation for autonomous products by integrating the aforementioned factors in a conceptual framework.

The remainder of this article is divided into four sections. First, the conceptual framework is developed, where an explanation of the constructs in the framework is given and hypotheses on the relationships among those constructs are developed. Second, a description of an experiment that was performed to investigate consumers' appreciation of product autonomy for three product categories is given. Third, the findings of the study are reported. The article concludes with implications, limitations, and suggestions for further research.

Conceptual Framework

Figure 1 presents the conceptual framework that guided our research. Following is an elaboration of the content of the six constructs used in this framework. Support also is provided for the relationships hypothesized in the framework on the basis of the literature.

Product autonomy refers to the principle that a product does not need human intervention but instead takes over on its own. Autonomous products show proactive and self-starting behavior [6], work together with human beings, and take over (some of) the user's normal decision-making functions [34]. A product can be autonomous in several degrees. Baber [2] distinguishes four levels of autonomy, which he illustrates with four versions of a washing machine. The lowest level of autonomy is the *manual level* at which the human continually will operate the product. The conventional washing machine operates at this manual level of autonomy. The user has to put the laundry in the machine, set the program, close the door, and start the machine. The next level is the level of *bounded autonomy*. At this level the user issues commands, performs an initial action, and awaits an outcome. At this level, the machine will start itself after the user has put the laundry in the machine, has set the program, and has closed the door. At the third level, *supervised autonomy*, the user issues commands, but the product is able to give some advice. In addition to the machine at the bounded autonomy level, a washing machine at the level of supervised autonomy would, for example, give suggestions about program settings. The highest level, *symbiosis*, assumes ongoing communication between the user and the product to fulfill some common goal. A washing machine operating at the level of symbiosis may open its door as soon as the user holds laundry in front of it. After all laundry is inserted, the user would close the door, and the machine would set the appropriate program and would run it automatically. This final level implies a full integration of products and sensors in the house [2].

Relative advantage is defined as the degree to which an innovation is perceived as superior to the idea it supercedes [35]. An innovation can be superior in terms of economic profitability, social prestige, convenience, or other benefits. The nature of the innovation determines what kind of relative advantage is important to adopters. Relative advantage should not be seen as an objective attribute of innovations. It only will increase the rate of diffusion when potential adopters perceive it.

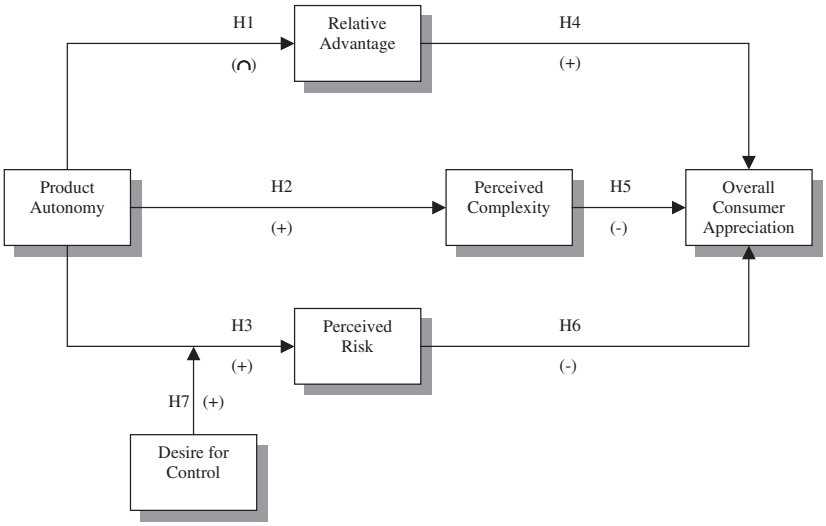

Figure 1. Conceptual Framework

Perceived complexity is a second innovation characteristic introduced by Rogers [35]. The complexity of an innovation concerns the degree to which an innovation is perceived as relatively difficult to understand and to use. Rogers [35] stated that the complexity of an innovation, as perceived by members of a social system, is related negatively to its rate of adoption.

Perceived risk is a multidimensional concept consisting of six components: performance risk, financial risk, social risk, physical risk, psychological risk [22], and the risk of time loss [36]. This study will focus primarily on the most important dimension [22], performance risk. Performance risk can be defined as the risk associated with inadequate and/or unsatisfactory performance of the product [22].

Overall consumer appreciation refers to a consumer's overall judgment of a product. This judgment considers the attitude of consumers to a product: the extent to which they would like to try a product and have it in their house, to receive more information on a product, and to intend to buy the product. Although overall consumer appreciation always does not lead to an actual adoption, significant positive relationships have been found [27]. Overall consumer appreciation is therefore a well-suited indicator of potential adoption.

Desire for control refers to the extent to which people want to exert personal control over their lives [1,8,9,38]. People identified as having a high desire for control are highly motivated to control the events in their lives. They wish to make their own decisions, take on leadership roles in group settings, and react strongly when their perception of personal control is threatened. They are more proactive and eager to gain control in new settings like organizations [1]. People with a high desire for control have a higher perceived control as well [38]. People having a low desire for control are less interested in exercising control over events and are more willing to allow others to make decisions and to take on responsibility for group tasks [8,9].

The Impact of Product Autonomy on Relative Advantage

Product autonomy leads to savings in time and effort of the user [2,12] and therefore is likely to be perceived as offering economic advantage. Autonomous products also can be perceived as leading to a reduction in discomfort, for example, in the case of the robotic vacuum cleaner or the robotic lawnmower. Rogers [35] states that both economic advantage and reduction in discomfort are subdimensions of relative advantage. We therefore suggest that an increase in product autonomy will lead to an increase in relative advantage. The product takes over tasks from the user, which leaves the user the opportunity to take part in other activities.

However, at a certain level of autonomy, the product makes decisions that users may want to make. An example of too much autonomy is the autocorrect function of Microsoft Word. Most users of the program switch off this function, because autocorrect eventually does things to the text that the user does not want. We therefore expect that there is an optimal level of product autonomy. Compared to products with an optimal level of autonomy, lower autonomy products demand more effort from the user and offer less advantage. Products with a degree of autonomy above the optimal level make decisions that users themselves may want to make or do things the user does not want to be done. In short, we expect a curvilinear relation between product autonomy and relative advantage. This line of reasoning can be expressed by means of the following hypothesis:

> *H1: The relationship between product autonomy and relative advantage is described best by an inverted U-shaped curve.*

The Impact of Product Autonomy on Perceived Complexity and Perceived Risk

Products with a higher level of autonomy perform their tasks with less interference from the user. The tasks that are delegated to them are broader. Therefore, more autonomous products are more technically sophisticated, and consumers may find these products more difficult to understand. This was, for instance, the case with home computers when they were introduced. In the early 1980s, home computers were relatively sophisticated products. Consumers perceived home computers as complex, and this had a negative impact on their rate of adoption [35].

Increasing autonomy in products also may impact the perceived risk. It is known that technologically sophisticated products lead consumers to perceive risk [15]. Because more autonomous products are more technologically sophisticated, they will be perceived as more risky. In addition, the tasks of more autonomous products are broader, and a

product therefore is more likely to fail. It is known that a larger chance of failure increases perceived risk [26]. This line of reasoning leads us to hypothesize the following:

H2: The higher product autonomy, the higher the perceived complexity.
H3: The higher product autonomy, the higher the perceived risk.

The Impact of Relative Advantage, Perceived Complexity, and Perceived Risk on Overall Consumer Appreciation

The innovation literature discusses six main innovation attributes influencing a product's rate of adoption: relative advantage, compatibility, complexity, trialability, observability [35], and perceived risk [4]. Following, we will develop hypotheses for the three attributes that are most important for technology intensive consumer durables: relative advantage, complexity, and perceived risk [20,21,32,33].

Ostlund [32] provided early empirical support for the influence of relative advantage, perceived complexity, and perceived risk on the rate of adoption of innovations. He discriminated buyers from nonbuyers for two new consumer products by using consumer characteristics and consumers' perceptions of the innovations as predictors. Among others, these findings lead Gatignon and Robertson [16] to include the three constructs in their enhanced and updated view of diffusion theory. Perceived risk and complexity were proposed to be related negatively and relative advantage to be related positively to the speed of diffusion. The results of several empirical studies supported their theoretical assumptions. For instance, Tornatzky and Klein [37] performed a meta-study on 75 studies on the relationships between perceived characteristics of innovations and their rate of adoption. Relative advantage and complexity were among the characteristics that showed the most consistent significant impact on adoption.

A number of authors [20,21,33] have provided more recent support. Holak [20] reports on a study focusing on the impact of perceived product attributes, environmental variables, and consumer traits on the purchase intention for several technology-intensive innovations. The results show a strong positive relationship between consumers' perceived relative advantage of a product and purchase intention. Complexity and perceived risk have a negative impact on purchase intention. Holak and Lehmann [21] performed a study on the interdependency of six perceived product characteristics and their relations with purchase intention for 19 consumer durable innovations. The results show a strong positive impact of relative advantage and a negative impact of perceived risk on purchase intention. Finally, Plouffe et al. [33] recently reported on a study on multigroup technology adoption in the context of an in-market trial of a new smart card-based electronic payment system. Perceptual data were collected from four groups: consumers and merchants participating in the trial and consumers and merchants not participating in the trial. For all four groups, relative advantage (in this case the financial incentives provided by the electronic payment system) was the most important innovation characteristic leading to adoption intention. Thus, on the basis of the theory and empirical findings discussed above we hypothesize the following:

H4: The higher the relative advantage, the higher overall consumer appreciation will be.
H5: The higher the perceived complexity, the lower overall consumer appreciation will be.
H6: The higher the perceived risk, the lower overall consumer appreciation will be.

The Moderating Effect of Desire for Control

The innovation literature shows that personality characteristics influence how fast a product is adopted by a certain consumer [16,20,32,35]. A personality characteristic that has not been taken into account in the innovation literature may play an important role in the case of autonomous products, namely desire for control. Desire for control refers to the extent to which people want to exert personal control over their lives [1,8,9,38]. We believe that this personality characteristic influences the strength of the relationship between product autonomy and perceived risk. Two lines of reasoning can be followed concerning the direction of this influence.

On the one hand, one could imagine that the relationship between product autonomy and perceived risk will be stronger for people exerting a high desire for control as they do not like to hand over control to the product. On the other hand, one could expect this relationship to be weaker for people exerting a high desire for control because they also have a higher perceived control [38]. People with a

higher perceived control might evaluate autonomous products as less risky than people with a lower perceived control because they believe they will be able to stay in control while using the product. However, we expect the former line of reasoning to be more valid because the product largely determines the control of the user. Hence, we expect that people with a higher desire for control will perceive autonomous products to be more risky. People exerting a low desire for control may care less about being dependent on someone or something else. We hypothesize then:

H7: Desire for control strengthens the positive relationship between level of autonomy and perceived risk.

Research Method

Subjects

Seventy-seven respondents, both men ($N=39$) and women ($N=38$), participated in this study. The age of the subjects ranged from 26 to 50 years. Subjects were selected from a consumer household panel. Participation was voluntary and was rewarded with a small financial compensation.

Stimuli

Stimuli were verbal product descriptions of a vacuum cleaner, a refrigerator, and a television set (see Appendix 1). We selected these product categories because all subjects were familiar with them. We designed three descriptions for each product corresponding with the three most distinct levels of autonomy [2]: one description at the manual level of autonomy (low), one version at the level of supervised autonomy (medium), and one version at the level of symbiosis (high).

Design

The laboratory experiment was a three-within (product category: a vacuum cleaner, a refrigerator, and a television set) by three-between (levels of product autonomy: low, medium, and high) experimental design. This design implies that each subject evaluated one vacuum cleaner, one refrigerator, and one television set. Each subject evaluated one product description at a low level of autonomy, one at a medium level, and one at a high level. Both products and levels of autonomy were presented in balanced orders to avoid systematic carryover effects of one product-level of autonomy combination to another [14].

Procedure

Subjects were invited to the laboratory individually. First, the researchers explained the experimental procedure to the subjects. Next, the subjects filled out a general questionnaire about their age, gender, desire for control, and a number of measures that were included for exploratory purpose. Then subjects received a product description and filled out scales for product autonomy (manipulation check), relative advantage, perceived risk, perceived complexity, and overall consumer appreciation. Subjects could read the product description whenever they wanted while filling out the questionnaire. Upon completion, subjects were interviewed briefly about the product. Subsequently, the two latter steps were repeated for the second and third product description. After the experiment was finished, the subjects were debriefed.

Measures

This research employed six multi-item scales (see Appendix 2). The desire for control measure was developed specifically for this study and consisted of five new items. The measure for overall consumer appreciation was a composite of attitude-measures from the literature [5,24,25] and consisted of eight items. The concepts of perceived risk and perceived complexity were adapted from Bauer [4] and Rogers [35] and were measured with three and five items respectively. The advantage scale was an adaptation of a six-item scale used by Cooper and Kleinschmidt [11]. Because managers usually fill out this scale, it was modified slightly so that consumers could use it. Subjects had to determine the advantage of the presented products in comparison to the vacuum cleaner, refrigerator, or television set they owned. The scale for product autonomy (that was based on the literature and on preliminary interviews with development teams of smart products) was developed specifically for this study and consisted of five new items. All items in this study were scored on anchored seven-point rating scales.

Table 1. Measurement Summary (N=231)

	1	2	3	4	5	Mean	S.D.	α
1. Autonomy (Actual Manipulation Level)						2.00	0.82	—
2. Autonomy (Five-Item Manipulation Check)	**.55**					3.59	1.84	.91
3. Perceived Risk	**.23**	**.23**				3.50	1.10	.75
4. Perceived Complexity	**.23**	.04	−.03			2.96	1.23	.92
5. Relative Advantage	.12	**.17**	−.06	−.01		4.56	1.48	.78
6. Overall Consumer Appreciation	.01	.03	**−.23**	−.08	**.68**	4.68	1.25	.93

Note: Entries are based on seven-point Likert scale. Significant entries are presented in bold ($p<.05$).

Analysis and Results

Properties of the Measures

We purified the measures by assessing their unidimensionality and reliability [10]. To assess empirically the unidimensionality of the scales, principal components analysis with varimax rotation was performed on the items of each scale. In each case, only the first eigenvalue was greater than one, which provided support of the unidimensionality of the scales. Using information from the item-total correlation analysis, we deleted items with low correlations to improve reliability. The scales for measuring desire for control (α=.73), perceived autonomy (α=.91), overall consumer appreciation (α=.93), perceived complexity (α=.92), and perceived risk (α=.75) did not need any purification. Two (out of six) items were dropped from the relative advantage scale because they had a negative effect on the reliability coefficient. This resulted in a four-item scale with a Cronbach's alpha of .78.

To assess the discriminant validity of the scales, we used principal components analysis with varimax rotation. Because of the limited number of respondents, we performed a principal components analysis for each possible pair of scales (15 combinations in total). For each pair the items of the different scales loaded highest on different factors. All together, the results of the tests for unidimensionality, reliability, and discriminant validity provided sufficient evidence for the quality of the scales to be applied in this study. With this evidence, we formed the constructs by averaging the responses to all items in the scale. Finally, we conducted diagnostic tests to establish the multivariate normality of the data. There was no evidence for nonnormality. Table 1 shows the correlation matrix, means, standard deviations, and alpha coefficients for the measured variables.

Manipulation Check

Each subject evaluated the product descriptions on the perceived autonomy scale as a manipulation check for the three levels of autonomy. Analysis of variance showed a significant effect ($\underline{M}_{level1}=2.22$; $\underline{M}_{level2}=3.89$; $\underline{M}_{level3}=4.67$; $F=51.21$; $df=2,228$; $p<.001$) of the manipulation levels on the perceived level of autonomy. A post-hoc Scheffé test indicated that three homogeneous subsets for the perceived level of autonomy could be discriminated for the three manipulation levels.

Testing the Hypotheses

We first assessed whether there is a curvilinear relationship between product autonomy and relative advantage by fitting a quadratic and linear model to the data. H1 was rejected because the linear model appeared to have a better fit ($F=3.20$; $df=229$; $p=.08$) to the data than the quadratic model ($F=1.64$; $df=228$; $p=.20$). However, the fit for the linear model was not significant either. This finding suggests that consumers differ widely in the extent to which they perceive autonomy to offer advantage.[1]

H2–H6 were tested using LISREL 8.30 [23]. To obtain a more favorable ratio of the sample size to the number of parameters to be estimated, a strict path model was formulated in which relationships between observed variables only were estimated. To test H2–H6, the data were fitted to the conceptual model shown in Figure 1 without taking the desire for control variable into account. This model is referred to here as the standard model.

[1] In order to discover individual characteristics that discriminate between consumers appreciating and consumers not appreciating autonomy, a cluster analysis was performed on the five variables in the conceptual framework. No significant relationships were found between the clusters derived and the consumer characteristics of gender, age, education, innovativeness, and desire for control.

Table 2. Estimated Effects within the Causal Model

Constructs	Hypotheses		Path Coefficient (Standardized)	t-value
Autonomy → Relative Advantage	H1	(∩)	.12	1.79
Autonomy → Perceived Complexity	H2	(+)	**.23**	3.64
Autonomy → Perceived Risk	H3	(+)	**.23**	3.59
Relative Advantage → Overall Consumer Appreciation	H4	(+)	**.67**	14.17
Perceived Complexity → Overall Consumer Appreciation	H5	(−)	−.08	−1.65
Perceived Risk → Overall Consumer Appreciation	H6	(−)	**−.20**	−4.18

Note: Significant entries are presented in bold ($p<.05$).

The fit indices for the standard model indicated a good fit with a chi-square of 4.07 (df=4; $p=.40$), GFI=0.99, AGFI=0.97 and CFI=1.00. Another indicator of how well the data fit the model, the ratio of chi-square to degrees of freedom, is 1.02. A value of less than three for the ratio indicates a good fit. Further, the root-mean squared error of approximation (RMSEA) is 0.008. A value below 0.05 for that measure generally is considered as very good. Based on these results, we conclude that the data fit the model well.

Table 2 presents the hypotheses, standardized path coefficients, and t-values that were estimated in the standard model. H2, positing that a product with a higher level of autonomy will be perceived more complex, is supported ($\beta=0.23$, $p<.01$). This finding suggests that products that are more autonomous are perceived as more complex. The analysis also provides support for H3 ($\beta=0.23$, $p<.01$), which states that autonomy has a positive impact on perceived risk. This finding implies that people perceive the likelihood of malfunctioning to be higher for more autonomous products. H4 posits the proposition that relative advantage has a positive impact on overall consumer appreciation. This proposition was supported by the data ($\beta=.67$, $p<.01$). This finding suggests that consumers' appreciation of a product depends on the perception of the relative advantage that a product offers. H5, stating that perceived complexity has a negative impact on overall consumer appreciation, did not find empirical support. The sign is as expected, but the effect is not significant. Perceived risk was found to have a significant negative impact ($\beta=-.20$, $p<.01$) on overall consumer appreciation. This result confirms H6 and suggests that the appreciation of a product by a consumer is influenced negatively by the perceived risk of a product performing badly.

H7 states that desire for control has a moderating effect on the relationship between product autonomy and perceived risk. This relationship was expected to be stronger for people with a high desire for control. This hypothesis was tested using linear regression analysis. We first estimated the unmoderated equation and then estimated the moderated relationship to determine whether the moderating effect of desire for control on the relationship between product autonomy and perceived risk is significant (as proposed by [3,19]). Table 3 shows that the change in R^2 in Step 2 is not significant ($p>0.05$). On the basis of that, we conclude that there is no significant moderating effect of desire for control, and H7 therefore is rejected. However, Table 3 does show a direct negative effect of desire for control on perceived risk. People with a higher desire for control perceive less risk than people with a low desire for control independently of the level of autonomy of the product. This effect is opposite of the kind we expected for desire for control. However, this finding supports the fact that people with a higher desire for control also have a higher perceived control [38].

Table 3. Testing the Moderator Effect of Desire for Control on Perceived Risk

Variables	B	SE B	β
Step 1			
Autonomy	.312	.086	**.232**
Desire for Control	−.181	.075	**−.154**
Step 2			
Autonomy	.312	.086	**.232**
Desire for Control	−.465	.198	**−.395**
Autonomy*Desire for Control	.142	.91	.260

Note: Coefficients significant at the .05-level are presented in bold. Adjusted $R^2=.069$ for Step 1 ($p<.05$); $\Delta R^2=.01$ for Step 2 ($p>.05$).

Discussion and Managerial Implications

This study investigated the impact of product autonomy on overall consumer appreciation through

relative advantage, perceived complexity, and perceived risk. The impact of desire for control on the relationships between autonomy and perceived risk was assessed as well. The data were collected in a laboratory setting with 77 respondents from a consumer panel.

The results demonstrate that there is no clear relationship between product autonomy and relative advantage. This finding means that some consumers appreciate autonomy, while others do not. However, the impact of product autonomy on perceived risk and complexity is clear. Consumers judge products that are more autonomous as more likely to fail and as more complex. Furthermore, as we expected, relative advantage is related positively and perceived risk is related negatively to overall consumer appreciation. The negative relationship between perceived complexity and overall consumer appreciation only approached significance. People with a higher desire for control perceive less risk, independently of the level of autonomy of the product. On the basis of these findings we conclude with a number of issues firms may want to consider in the development and marketing of autonomous products.

Extensive Idea Testing

Although many ideas for autonomous products may seem appealing, their advantages are not directly obvious to all consumers. Volkswagen, for example, developed a rearview mirror that automatically dims when it gets dark, thereby preventing the driver to be bothered by bright headlights of vehicles behind. This idea seems like a very useful improvement of rearview mirrors. However, Volkswagen drivers who like to drive (too) fast complained that they can only see the headlights of vehicles behind and therefore are not able to recognize police cars. This example shows that companies thoroughly should test their ideas about making their products more autonomous before taking them into full development.

Information acceleration (IA) is an example of a technique that may be suited for the testing of product ideas for autonomous products [39]. The basic idea behind IA is to place the consumers in a multimedia virtual environment and to provide them with information on a new product. The information can be provided, for example, by means of virtual prototypes, which can be useful for the testing of ideas for autonomous products. Multiple virtual prototypes of a product can be developed with different levels of autonomy. These prototypes can be evaluated by consumers and thereby can provide companies with information on the appropriateness of the different degrees of autonomy.

Reduction of Perceived Risk and Complexity

This study clearly shows that there is a positive impact of product autonomy on perceived risk and complexity. Products that are more autonomous are expected to break down or to malfunction more, and consumers expect that it may be more difficult to learn how to use these products. Nevertheless, these findings should not discourage product designers to develop autonomous products because several methods exist to reduce the perceived risk and complexity.

Product developers can reduce the perceived risk through the design of the new product. Consumer research can provide insights into the specific doubts and questions people have about a product. Based on the findings from such research, designers can shape the product in such a way that consumers' doubts are reduced. For autonomous products, this reduction may be achieved by equipping them with sufficient indicators that provide feedback to the user on the task that the product is performing at a certain moment. Also, the user always should have the option to interrupt actions of a product at any time.

Companies also can benefit from a number of methods to reduce perceived risk after the product has been developed [17,36]. For example, store image impacts consumers' perceived risk. By mainly selling a product in stores with a good image, consumers' uncertainties can be reduced. In addition, providing money-back guarantees can reduce the risks that buyers perceive. Finally, it is known from diffusion research that the trialability of a product can influence positively the rate of adoption of a new product [35]. Giving consumers the opportunity to experience the use of the product may reduce the perceived uncertainties and thereby increase the likelihood of adoption.

Perceived complexity can be reduced by using analogical learning theory in promotional messages [18]. Analogical learning entails the use of consumers' existing knowledge structures in facilitating consumer understanding on how the new product works and what its benefits are. Increased understanding will lead to a decrease in perceived complexity and therefore to a higher rate of adoption.

Adopters of Autonomous Products

This study demonstrates that consumers differ in the extent to which they appreciate new autonomous products. A common explanation for differences in the likelihood for a person to appreciate new products is consumer innovativeness. Rogers [35] defines innovativeness in terms of the degree to which an individual is relatively earlier in adopting innovations than other members of a social system. However, the results of this study showed no relationship between innovativeness and overall consumer appreciation (see footnote 1).

Dickerson and Gentry [13] refined Rogers' idea about innovativeness by suggesting that the nature of an adopter of an innovation is partially a function of the characteristics of the innovation itself. We expected the personality characteristic of desire for control to influence how a consumer evaluates an autonomous product. However, the expectation that the positive impact of product autonomy on perceived risk would be stronger for people with a high desire for control was not confirmed. On the contrary, our findings showed that, independently of the level of autonomy of the product, people with a high desire for control perceive less risk than people with a low desire for control. An explanation for this finding may be the fact that people with a higher desire for control also have a higher perceived control [38]. They perceive less risk because they believe they can control the product. These findings suggest that the early adopters of autonomous products show special characteristics. This study only provides information on the impact of a single personality characteristic (desire for control). Further research is needed to investigate other characteristics that typify early adopters of this group of products.

Autonomous Products as Icons for the Company

One aspect encountered during our research that has not been addressed so far is the "gee whiz" character of many autonomous products. Making products more autonomous means that these products initiate actions by themselves, and this may be one of the most conspicuous results of the application of information and communication technology in consumer products: a ghost in a machine. Therefore, for branding and corporate public purposes, product autonomy may deliver fine and attention-drawing icons for the company. The British firm Dyson provides an example of such use of product autonomy. The announcement of the development of an autonomous vacuum cleaner resulted in enormous publicity for the company long before the product was launched. This example shows that, besides the advantages of product autonomy that are perceived by certain consumers, creating autonomy also can have public relations and branding benefits.

Limitations and Further Research

The present research project has helped us better understand how consumers perceive autonomy in new products. However, the methods employed have inherent limitations, which lead to opportunities to improve future research.

This research was performed in a laboratory setting by using verbal descriptions of products. Although verbal representations facilitate judgment of new products in comparison to pictorial representations [40], this may not be the case for radically new autonomous products. Consumers have not experienced the use of a radically new product and therefore may not have a clear perception of the real use of these products. Consumers' evaluations of radically new products may be more valid if they are provided with more information about the context of use as is done in, for instance, IA [39].

Furthermore, only three product categories were used in this research. It is a great opportunity for further research to test whether the findings that are reported in this study also hold for other product categories. The contribution of such research would be even stronger if it tests which methods for perceived risk and complexity reduction are best suited to increase the rate of adoption of autonomous products.

An important finding of this study is that the appreciation of product autonomy is consumer dependent. This study has identified the personality characteristic of desire for control to influence consumers' evaluations of autonomous products. It would, however, be interesting to find more aspects that characterize possible adopters of these products, such as their social class, lifestyle, opinions, values, or context of use. The latter aspect especially may be of importance for discriminating adopters from non-adopters for autonomous products, as the perceived advantages of these products may depend on the context of use. For instance, people with pets living in a house full of expensive art and furniture may have

more doubts about the advantages of an autonomous vacuum cleaner than persons living on their own in a simply furnished apartment. Future research on autonomous products therefore should include the context of use of these products to increase the validity of the findings[2].

Another limitation of the study is the fact that it investigated one aspect of smart products in isolation (i.e., autonomy). It would be interesting to study not only the consequences of the communication ability and flexibility of smart products but also how smart product characteristics interact and how consumers evaluate this. Such research would contribute further to our insight into the consequences of the increasing application of information and communication technology in consumer products and, along with that, where the biggest opportunities for companies can be found in developing smart products.

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[2] We thank a reviewer for this observation.

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Appendix 1. Stimulus Material (Product Descriptions and Levels of Autonomy)

Manual Level

Vacuum Cleaner
Capacity: 1500 Watt. This vacuum cleaner is wireless. When using this vacuum cleaner you will not trip over the wire and you don't have to move the plug from socket to socket. The vacuum cleaner has a battery that can be recharged when the product is not used. This vacuum cleaner allows you to move through the house easily.

Supervised Autonomy

Vacuum Cleaner
Capacity: 1500 Watt. This vacuum cleaner is placed in the room you want to clean and the vacuum cleaner will move around the room until the whole surface of the room has been cleaned. The vacuum cleaner signals when it is ready cleaning the room and you will have to take it to another room. When the battery can only supply power for less than 10 minutes the vacuum cleaner will signal this. You will have to put the vacuum cleaner in a recharging-station. All together you don't have to pay a lot of attention to the machine while it's cleaning.

Symbiosis

Vacuum Cleaner
Capacity: 1500 Watt. This vacuum cleaner has to be placed in its recharging-station. With a sensor the vacuum cleaner determines whether there is a need to clean. The vacuum cleaner drives around until all rooms on a certain floor are cleaned. When the battery can only supply power for less than 10 minutes the vacuum cleaner drives back to the recharging-station to recharge the battery. After recharging, the vacuum cleaner continues cleaning. This vacuum cleaner operates completely autonomously.

Manual Level

Refrigerator
This refrigerator can read the barcodes of the products placed in your refrigerator. There is a display on the door of the refrigerator. You can read from the display which products are available in the refrigerator without having to open the door.

Supervised Autonomy

Refrigerator
This refrigerator can read the barcodes of the products placed in your refrigerator. There is a display on the door of the refrigerator. The refrigerator registers which products are taken out of the refrigerator and which are not placed back within one hour. The refrigerator then assumes the article is used and out of stock. The refrigerator adds the article to a shopping list. This shopping list is shown on the display. When you are going to do the groceries you can see which products to buy at a single glance. All together this refrigerator creates a shopping list for you.

Symbiosis

Refrigerator
This refrigerator can read the barcodes of the products placed in your refrigerator. There is a display on the door of the refrigerator. The refrigerator registers which products are taken out of the refrigerator and which are not placed back within one hour. The refrigerator then assumes the article is used and out of stock. The refrigerator adds the article to a shopping list. After you have given permission to do so, the products on the shopping list will be ordered at the supermarket via the internet when the shopping list contains ten products or more. These products will then be delivered at your home. All together this refrigerator creates a shopping list and orders the products at the supermarket automatically.

Manual Level

Television Set
You can tell this television set which TV shows you enjoy. While you are watching television you can ask the television set whether one or more of your favorite shows will be broadcast. With this television set you can easily find the shows you like to see.

Supervised Autonomy

Television Set
You can tell this television set which TV shows you enjoy. When you're watching television the television set notifies you that one of your favorite shows will be broadcast in five minutes. All together this television set draws your attention to the fact that there is a show going to be broadcast you would probably like to see.

Symbiosis	**Television Set** You can tell this television set which TV shows you enjoy. When one of your favorite shows is broadcast the television set stores it in its memory in case your television set is off or in case you are watching another channel. You can watch the show later. All together this television set records a favorite show in case you are not able to watch the show when it is broadcast.

Appendix 2. Measurement Scales

Scales	Items
Desire for Control	Items for which 1="strongly disagree" and 7="strongly agree": 1. Most of the time I don't like giving things out of hand. 2. I like to be in control over the things happening around me. 3. Usually I prefer doing things by myself instead of delegating them. 4. I trust myself more than others. 5. Sometimes I'm afraid to lose control.
Overall Consumer Appreciation (Adapted from [5,24,25])	What is your overall judgment of this product? 6. Very negative – very positive 7. Very bad – very good 8. Very unfavorable – very favorable 9. Very unattractive – very attractive Items for which 1="strongly disagree" and 7="strongly agree": 10. I would like to have this product in my house. 11. I would like to have more information on this product. 12. I would like to try this product. Items for which 1="very unlikely" and 7="very likely": 13. How likely do you think it is that, if you need a new product and money is not an issue, you would buy this product?
Perceived Risk (Based on [4])	Items for which 1="very unlikely" and 7="very likely": 14. How likely do you think it is that this product will operate improperly? 15. How likely do you think it is that this product will have breakdowns? 16. How likely do you think it is that this is a bad product?
Perceived Complexity (Based on [35])	Items for which 1="not much at all" and 7="very much": 17. How much instruction do you think you need in learning how to use this product? 18. How much knowledge is needed to use this product? 19. How much help is needed in taking this product into use? 20. How much effort do you think it costs to learn how to use this product? 21. How many people do you think will find the use of this product complicated?
Relative Advantage (Adapted from [11])	Items for which 1="strongly disagree" and 7="strongly agree": 22. This product offers unique benefits to me – benefits not found in my own product. 23. This product is of higher quality than my own product. 24. In my eyes this product is superior to my own product. 25. This product solves a problem that I have with my own product. 26. I think this product could save money.* 27. I think this product is innovative – the first of its kind on the market.*
Product Autonomy	Items for which 1="strongly disagree" and 7="strongly agree": 28. This product goes its own way. 29. This product does things by itself. 30. This product takes initiative. 31. The user of this product doesn't have to bother about this product a lot. 32. This product works independently.

* These items were dropped to enhance the psychometric properties of the scale.