PERCEIVED QUALITIES OF SMART WEARABLES
Determinants of User Acceptance

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ABSTRACT
Wearable computers are one of the new technologies that are expected to be a part of users' lives extensively in near future. While some of the users have positive attitudes towards these new products, some users may reject to use them due to different reasons. User experience is subjective, and effected by various parameters. Among these the first impression, namely the perceived qualities has an important impact on product acceptance. This paper aims to explore the perceived qualities of wearables and define the relations between them. An empirical study is conducted, to find out the hierarchy and meaningful relationships between the perceived qualities of smart wearables. The study is based on personal construct theory and data is presented by Cross-Impact Analysis. The patterns behind affection and affected qualities are explored to understand the design requirements for the best integration of wearables into daily lives.

Categories and Subject Descriptors
A.0 [GENERAL]: Conference Proceedings
H.5.2: User interfaces, User-centered design, Input devices and strategies.

General Terms
Experience design, human values

Keywords
Smart wearables, perceived qualities, user preferences

1. INTRODUCTION
Technology is getting into people's lives with faster developments than people can follow [1, 2]. It is a common understanding that the more the technology develops, the more it will be a part of everyday life. People are first surrounded with infrastructures, and then by the context aware and intelligent systems which enable them to connect to the systems whenever they want and wherever they are. Hereby, developments in technology gave mobile applications and products the ability to be utilized everywhere. In relation, ubiquitous computing is the technology that exists everywhere and reached whenever needed, allowing the users to get connected to the world wherever the user is [3-5].

The state of art of smart wearables illustrated in shows the main technological developments and their effects on product attributes and usage areas.
One of the most important contributions of technology is the capability of context awareness. By this capability, smart wearables became aware of the locations and activities that their user is in and were capable of exchanging data between the user and its environment. With the assistance of ubiquitous systems, wearables are improved in terms of multi-tasking and flexibility in action, supporting the continuity of the interaction with the systems. In addition, the miniaturization of the electronic parts and the products made it possible to carry lighter replicas of already existing electronic products, such as computers and music players.

As soon as the capabilities and potentials of wearables were understood, computer and electronics engineers began to work on interaction and research was focused on innovative attempts that would last with new demands. In other words, design of wearables began to serve for a dual need which requires a broadened perspective: fulfilling existing needs and creating novel experiences.

At first hand, the attempts were on creating software applications such as: environmental interactions, i.e., detecting finger movements for image capturing by wearing an image capturing system [31], bodily interactions, i.e., creating body-based interfaces [32]; capturing changes in the body i.e., monitoring the human body's physiological functions through wearing ambient sensors [33], and sharing human emotions and experiences, i.e., identifying social interactions [34]. Apart from engineers, in 2000's, the wearables also attracted the attentionof fashion

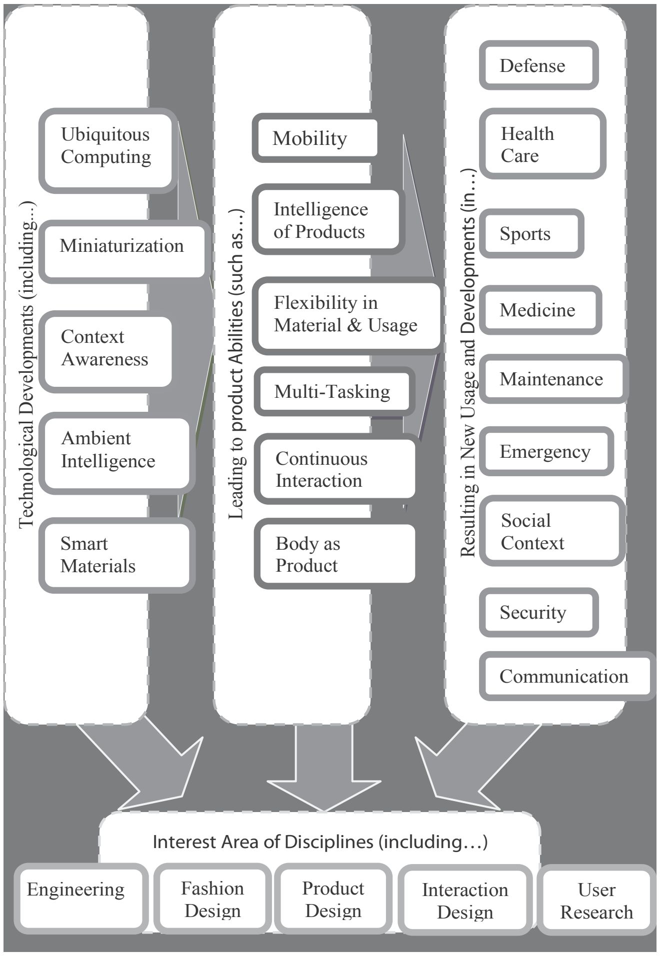

Figure 1. State of art of Smart Wearables

designers [35], as well as jewelry [36], interaction [32] and product designers [14].

Currently, the wearables are still in the main research interest of engineers who are the pioneers of the field. The examples of technological developments that led commercialization of wearables are listed at Table 1.

In addition to these technological developments, the most untouched part, "the usage" begun to be criticized by various authors in 2000's.

Some of the wearable's were criticized to be huge and complex for a user to put on and use [13]. The complexity of the products created negative use experiences and resulted with rejection by the users [37]. As a result of these assessments, at the end of the 2000's, product design-related issues came into prominence [4, 8, 34, 37, 38]. A potential area which supports design in this phase was user research focusing on the empirical analysis of people and their preferences.

It is evident that, the abilities of smart wearables will lead to various use experiences in different usage areas. The experience and interaction will change in the sense that it will be more personal than any other product that users currently interact. In this sense, wearable's generated numerous issues worthy of investigation, including dimensions of user experience, adaptation, emotions, expectations, intimacy etc.

Table 1. Technological Developments and their Contributions to Smart Wearables

Technological Development	*Development Outcomes*	*Improvement of Wearable Quality*
Ubiquitous Computing	*Availability of information and communication in anywhere-anytime [5] *Uninterrupted user mobility [6]	Empower networking system of wearables [7] Supports mobility [8] Enable localized information [9]
Context Awareness	*Sensing the users' location, emotional state and environment [10, 11] *Acting and adopting to the sensed context [12]	Sense where, in which condition the user is [13] Act according to the sensed situations [13] Enable more effective usage [14] Empower the mobility of the user [15]
Ambient Intelligence	*Creating environments for specific needs at homes, schools or other public places [16] *Changing interactions- gesture, natural language and voice recognition [17, 18]	Store data to be transferred from/to intelligent environments [19] Change in interaction dimensions [19] Become smarter [20]
Miniaturization	* Smaller-sized and higher-speed versions of devices and system boards with all needed functions [21]	Small and light-weight products [22-24] Portability and wearability of the personal products [25]
Smart Materials and Textiles	*Flexible LED displays [26] and batteries [27] *Production of conductive fabrics [28] *Integrated sensors and microprocessors into the fabrics [29]	Flexibility in form of the wearable [14] Intimate interaction with user, in user's personal space [30] Support the wearability of the device [30]

2. USER ACCEPTANCE

It is important to acknowledge that information communication technologies are infusing into people' lives and they become prevalent in our lives. Parallel to this progress, users may need different adaptation patterns. The devices developed until today were worn as earpieces, watches, belts, glasses and clothes [4]. Meanwhile, they offered different interactions with users, namely a digital interaction with the world [39, 40]. There is a gap between the initiation of these products and their life cycles. The number of research findings that will help designers to enhance the acceptability of wearables is very limited or very case specific; there is a lack of systematic knowledge.

In the smart wearables field, it is stated that the off-body technologies have been well-developed, but the same cannot be said for on-body systems, as they are immature for users to be found attractive and accepted [14, 24]. To achieve acceptance, several qualities are listed by several researchers. For example, Bodine and Gemperle [41] claim that perceptions of functionality and comfort of a wearable are the main dimensions for acceptance.

Besides, Starner [7] states that user's taste is an important factor for acceptance, and perception of design affect the acceptance of a wearable. Similar to what Starner stated, Ariyatum, Holland, Harrison, & Kazi [42] assure that the first thing that plays an important role in acceptance of a wearable is its physical appearance; it should fit the user' lifestyle and personality. Its usability and price, its functionality and eco-friendliness also affect the acceptance of users [42]. Combining the previous studies, Dvorak [14] defines some qualities for smart wearables to be accepted by the users, which are *(i)* wearability (easy to wear the wearable), *(ii)* ease of use (achieving what the user wants easily), *(iii)* compelling design (aesthetics and attractiveness), *(iv)* functionality (appropriate functions for performing), and *(v)* price of the product (affordable price). The problem is that all of these product qualities are mainly derived from technology acceptance theories and/or findings. Hence, none of them provide empirical evidence on the level of importance of the product qualities and meaningful attributes for the acceptability of wearables.

The research done by Duval and Hashizume [43] is an important attempt to understand how users adopt a wearable. The study highlights the perceptions of two cultures, namely French and Japanese. The authors suggest five requirements for a wearable to be adopted by these cultures: *(i)* expression of gender differences, *(ii)* comfort, *(iii)* safety, *(iv)* communication with other devices all time especially in severe conditions like disabilities in specific conditions, and *(v)* control of the product by the user as well as an artificial intelligence. The authors finally suggest that cultural differences have implications on product properties and it would be an important criterion in order to achieve acceptability.

A recent investigation done on adoption of smart wearables [37] acknowledged that the first thing users care about the wearables is the style of the wearable. Subsequently, price, technical functionality and widespread use of a wearable come into prominence for users to adopt a wearable.

Bryson [38] defines three main considerations that users apply while deciding either to use or not to use a wearable. These are the *(i)* anatomical considerations (whether the wearable fits the user's body size or not), *(ii)* physiological considerations (whether the wearable creates physiological changes on the body, such as excessive sweating) and *(iii)* psychological considerations (whether the user feels emotionally comfortable and safe with the wearable or not). All three considerations are related to how the wearable is worn, and directly to its comfort.

The factors that affect the comfort and ergonomics of a wearable are connected to acceptance of wearables, and are explored for understanding possible problems and usages of wearables. Lin and Kreifeldt [44] state that the main reason for rejection of wearables is their either bulky or uncomfortable form which is not suitable for wearing. Their main criticism is that, although ergonomics of a wearable is an important factor for users, it is already ignored by engineers. They also state that ergonomics requires specialization, thus design of a wearable should be done in a team of engineers, designers and ergonomists so as to produce aesthetically pleasing, functional and comfortable products.

Comfort of a wearable can be affected by physical properties of the wearable such as its size and weight, its affect on movement and pain, or by psychological responses of the user such as the pride of the user when wearing the product [45]. The research done by Knight and Baber aims to develop a scale for measuring the comfort level of a wearable.

Another research done by Bodine and Gemperle (2003) examines the relationship between perceived functionality and comfort. They hypothesize that there is a positive relationship between users' perceptions of functionality of the wearable and its comfort, and find out that users expect from a wearable to have maximum usefulness with minimum bulk and weight. All three researches listed above [41, 44, 45] define similar issues: The user expects functionality together with form efficiency and comfort.

3. PERCEIVED QUALITIES OF WEARABLES

As discussed above, user acceptance is effected by various parameters and studying underlying reasons would solve one of the problems of wearable's as it may minimize commercialization failures [37, 46]. There are several approaches that may be employed to study this phenomenon. In this study, it is considered that exploring perceived qualities and therefore understanding users' values and the product qualities they appreciate would be valuable information for designers.

3.1 Data Collection

The goal of this study is to understand the perceived qualities of smart wearables. The patterns behind values and the affected qualities are explored to understand the design requirements for the best integration of wearables into daily lives.

The proposed study required direct information to understand how users perceive products with their own explanations. To generate and analyze affluent data, a validated procedure, Personal Construction Theory [47] was employed as the basic data collection and analysis methodology.

Designing Pleasurable Products and Interfaces, June 22–25, 2011, Milan, Italy.

A total of 30 participants (12 female, 18 male) with ages ranging from 20 to 30, and with a mean value of 24.1 participated the study. The reason behind selecting young participants for the current study was that, younger individuals are more open to technology than are older individuals [48]. The study was conducted in usability laboratory (UTEST) of Middle East Technical University, Department of Industrial Design. Two dome cameras were used to record the actions and comments of the participants.

Participants of the study were shown five different conceptual wearable phones that have different product qualities. A4 sized colored boards were created for each product, showing detailed information on the usage and qualities of the products.

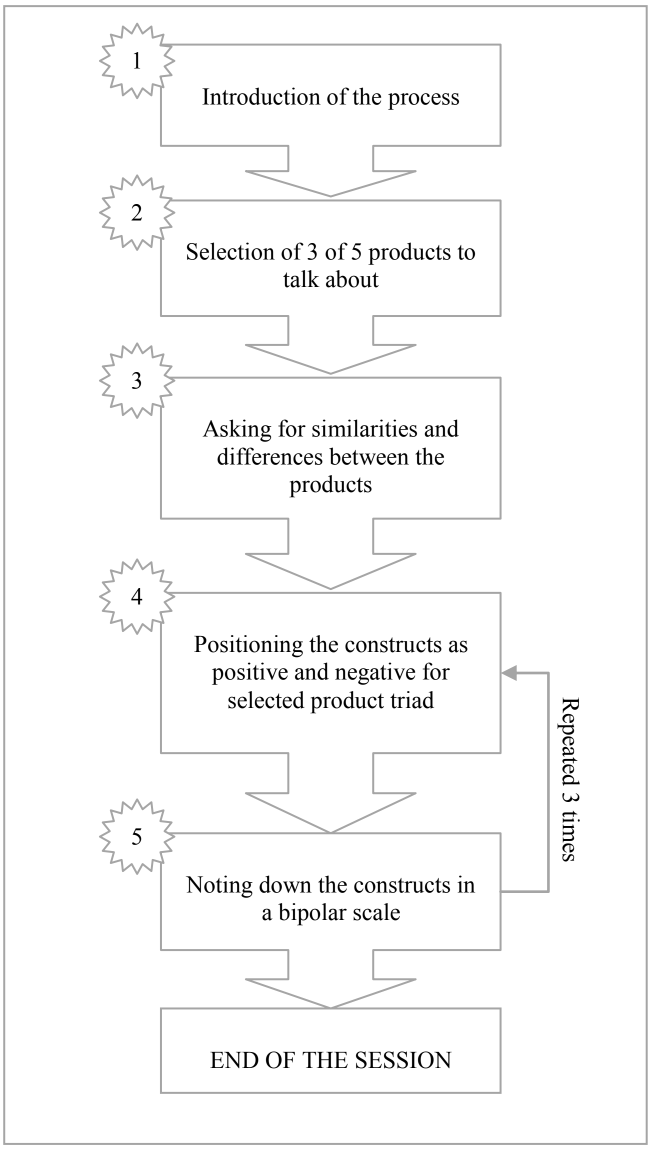

Figure 2. A typical Data Collection Procedure

The data collection procedure, illustrated in Figure 2, started with the introduction of the products. Then three of the five products which were randomly selected were given (Table2). Participants were asked to think of a way or dimension in which two of the products seem similar and different. They were then asked to label these qualities in a bi-polar scale, as positive and negative. Each construct the participant mentioned was first noted on a paper by the interviewee while the participant continued talking.

After a few constructs, the interviewee requested the participant to talk about the noted dimensions and requested to label these constructs as positive and negative; if stated positive participant was asked to label the negative or vice versa (Figure 3).

Figure 3. Data Collection Environment

To achieve an in depth understanding, laddering down and up procedure was applied. After collecting data for the first triad, a second random triad was presented. The process continued with three triad sets for each participant. The session ended when participant stated that s/he could not find any more differences or similarities between the products. In total, number of constructs collected from the users change between 17 and 30.

3.2 Data Analyses

The participants of the study gave valuable data on perceived qualities of smart wearables and their assessment criteria. The visual qualities of the products as well as their personal attributes were mainly the major findings of the interviews. The participants, while talking about the positive and negative constructs, mentioned about other relevant construct that affect their perception. To understand these underlying dimensions, during data analysis, the main construct was named as “affected quality” and the underlying reasons were named as “causal quality”. The constructs were classified under sub-topics, like “being practical, easy to handle and easy to interact” and were then grouped under main qualities, like “novelty” and “ease of use”. The same terminology was used to name the affected and causal qualities. Table 2 shows three examples of keywords and qualities.

Table 2. Examples of Keywords and Qualities

POSITIVE	NEGATIVE	CAUSAL QUALITY*	AFFECTED QUALITY**
Attractive	Repulsive	Product expression	Aesthetically pleasing
Compact	Easy to use (components)	Usefulness	Compactness

* affect the perceptions of affected quality and are defined by the discussions of the participants
** the main quality that explains positive-negative constructs

The methodology utilized in the study allows different quantitative analysis. Besides statistical analysis to understand clusters and relations, another method of analysis was utilized in the study. The construct patterns derived from participant were presented due to their level of importance in design and interrelations which is believed to be a more understandable presentation technique for designers than cluster diagrams. The technique is named as cross impact analysis (CIA) and presented in Figure 4.

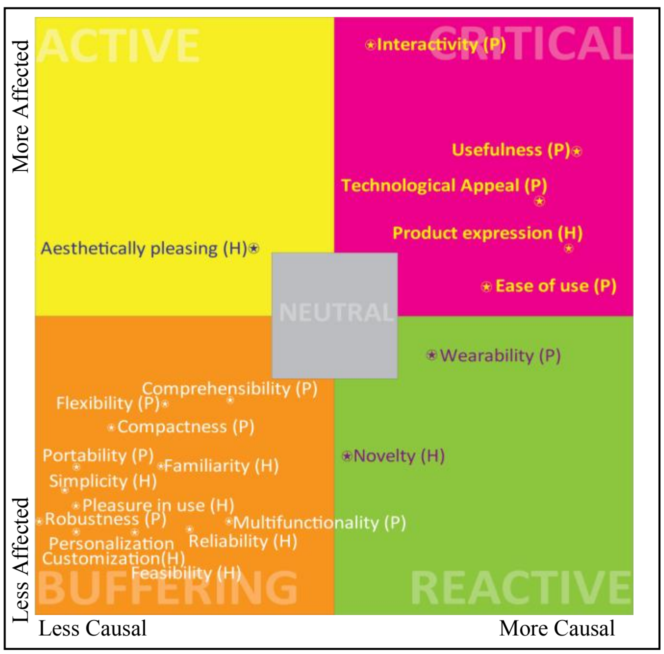

Figure 4. Cross Impact Analyses Chart

CIA uses a cross-impact matrix for systematic description of all potential modes of interaction between a given set of variables and for the assessment of the strength of these interactions [49]. Participants stressed twenty major qualities of wearables with varied importance. In the matrix, the qualities in horizontal column indicated the level of affecting other qualities and vertical column indicated the level of being affected by other qualities. The matrix finally was turned into cross-impact analysis graph shown in Figure 3.

CIA graph is composed of 5 areas; each area represents the causal-affected position of the qualities. The qualities that are less affected and less causal are buffering; less affected but more causal are reactive; more affected less causal are active; more affected and more causal are critical and the ones that are moderately affected and causal are neutral. With these in mind, the results show that, ***ease of use, interactivity, product expression, technological appeal and usefulness*** are critical qualities; ***novelty and wearability*** are reactive qualities**;** ***aesthetically pleasing*** is active quality; ***robustness, pleasure in use, personalization / customization, comprehensibility, reliability, multifunctionality, portability, familiarity /traditionality, compactness, feasibility, simplicity, flexibility and product language*** are buffering qualities. There is no quality in neutral area.

3.3 Discussions

The categorization of the qualities listed by users is based on Hassenzahl [50]. According to Hassenzahl, pragmatic qualities are about the functionality of the product and all other remaining attributes are defined as hedonic qualities, such as; providing new opportunities, representing the important past events, relationships and thoughts that users appreciate or giving the users to express them. In the light of these definitions, the qualities in each area of the above graph can be categorized as either "hedonic" or "pragmatic" quality. Table 3 shows the qualities and their categorization.

Table 3. Product Qualities and Their Categorization

Hedonic Qualities	• Aesthetically pleasing • Familiarity/Traditionality • Feasibility • Novelty • Personalization/Customization • Pleasure in Use • Product Expression • Reliability
Pragmatic Qualities	• Compactness • Comprehensibility • Ease of Use • Flexibility • Interactivity • Multifunctionality • Portability • Robustness • Simplicity • Technological Appeal • Usefulness • Wearability

For a smart wearable, hedonic qualities are as important as pragmatic qualities. In active, critical and reactive quadrants, while the hedonic qualities have been mentioned with a mean value of M=83, the value for pragmatics was M=108. Users need to appreciate product's hedonic qualities like its novelty, aesthetics and product expressions to perceive that smart wearable is worth using, as well as its pragmatic qualities like interactivity, usefulness, wearability, technological appeal and ease of use of a wearable to understand that the product functions well. Therefore, incorporating hedonic and pragmatic qualities simultaneously into the design of the wearables are extremely important for creating positive first impressions.

Meaningful attributes would create positive use experience, or at least have a positive effect on product appraisal. If the meaning in the appearance of a product can be identified and the priority order in the meaning attached to the products can be decomposed, this information would be very beneficial for designers. Achieving such knowledge, designers will be able to incorporate intended qualities to products.

In the graph, the buffering area is the most intensive one in terms of the listed qualities. The users do not stress these qualities as much as others; they are mostly supportive for the perceptions of other qualities. For example, "personalization/customization" is a buffering quality but it is important for empowering the product expression. Therefore, buffering qualities are exclusively important since they affect how active, critical and reactive a smart wearable can be.

In the critical area, the only hedonic quality stated is "product expression", which refers to the product qualities that fit users' taste and individual characteristics. It is in line with the understanding that, wearables will become means of self expression.

All the other critical qualities have pragmatic characters, and are mainly connected into one-another. If the user thinks that the product is hard to interact (interactivity) because its technological qualities do not support usage (technological appeal), then the user will probably find it hard to use (ease of use) and useless (usefulness). That's why, all critical pragmatic qualities of a smart wearable is interrelated.

Being aesthetically pleasing was the only active quality and it has a hedonic character. It was implied that perception of "aesthetically pleasing" is affected by other properties of a smart wearable. When the physical form or interaction type seems to support the usage, then the product itself can lead to aesthetic applause. For example, when a smart wearable is perceived to be easy to interact because the visual qualities support its usage, then it can easily be perceived to be aesthetically pleasing. Therefore, perception of aesthetically pleasing is associated with pragmatic qualities of smart wearables.

Reactive product qualities mostly support the perceptions of other qualities. "Novelty" and "wearability" are listed as passive qualities. "Novelty", for example, influences the users' assessments of "technological and new", therefore special attention is required for a wearable to be useful and usable. "Wearability", on the other hand, poles apart from novelty. It is related to the functionality of a smart wearable and it is an inherent quality. The perceptions of "ease of use" either for wearing or carrying a smart wearable affect the insight related to both pragmatic and hedonic qualities.

To conclude, the results of the current study support the idea that although there is a priority order, all product qualities of smart wearables are associated with each other. Failure in one of these qualities would lead to negative use experiences that might be followed by product failure.

4. FURTHER STUDY

In the current paper, the product qualities that are important for users to have a positive first impression were discussed. The qualities that are in active, reactive and critical quadrants of the CIA chart were discussed. It should be noted that, there are also relations between these qualities. For example, there are strong relations between the perceptions of product expression and being aesthetically pleasing. Also the effect of "technological appeal" on "interactivity" and "product expression" on "aesthetically pleasing" are the strongest links. These relations are illustrated Figure 5.

It is observed that within the minor qualities "robustness" does not does not have an effect on any of the 8 major qualities. In addition, "compactness" only strengthens the technological appearance of a smart wearable. On the other hand, "multifunctionality" and "comprehensibility" are the two minor qualities that strongly support the interactivity of a smart wearable. It is also observed that, the other role of "comprehensibility" is to reinforce ease of use. Apart from these, "flexibility" assists the usefulness perception and "(non)familiarity-traditionality" endorses novelty. The other minor qualities do not explicitly stand for the eight major qualities.

The discussion of these relations in detail is a topic of another paper. As a further study, the relations of the qualities and the product characteristics that influence the perceived qualities will be realized.

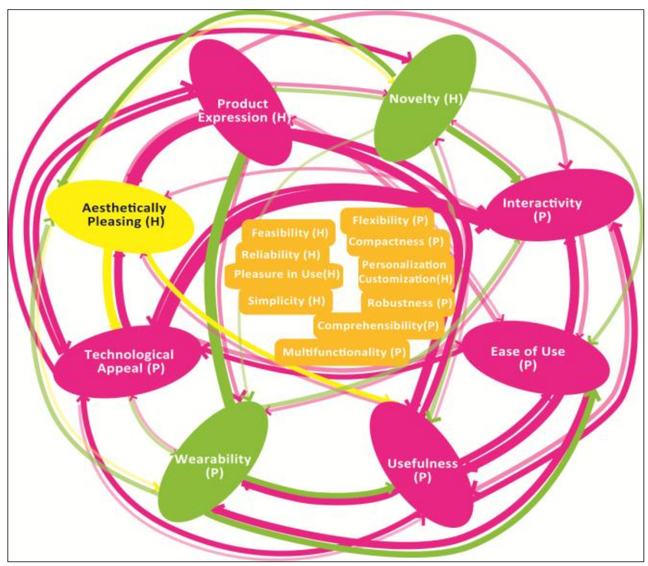

Figure 5. Relations between the Product Qualities [1] [2]

[1] Color indications: Yellow: Active, Green: Reactive, Orange: Buffering, Magenta: Critical Qualities

[2] The strength of the effects are indicated by the thickness of the lines

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