

DESIGNING INNOVATIVE USER ACTION ORIENTED PRODUCTS USING AXIOMATIC DESIGN: A CASE STUDY OF A TANGIBLE MP3 PLAYER

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ABSTRACT

New technologies offer to the designers a great opportunity to extend their creative abilities from the design of forms to the design of experience. Unlike technical mechanical devices which impose through their internal logic a shape and an interaction mode, today's products, often reduced to beautiful boxes with screen and buttons, contain electronic components that offer a great freedom of shaping and possible interactions. The question designers are facing with is how to exploit this freedom of shaping for designing acceptable products and reducing the apparent complexity without reducing functionalities. What are the guidelines underlying the design for experience and how to design rich experience products? This article examines the relationship between the product's design parameters and the user actions as being a potential factor of success for digital products. The axioms of the Axiomatic design theory have been used and transposed in order to design innovative User-Action Oriented interfaces. Through an Axiomatic Design analysis done on 4 music players, we propose a positioning on a two dimensional space, easy of use and attractiveness, of the products, and propose some indications for specifying attractive products.

Keywords: Technological product design, tangible design, axiomatic design, innovation

1 INTRODUCTION

It is the responsibility of the designers to do a good use of the meanings carried by the product in order to make it attractive, to highlight usage values, to improve the usability, and to propose new experiences through the product's usage. A design approach [1], focused on user's experience, assumes that the way the user interacts with the product is as important as the results of the interactions. Depending on the way the product is designed, the actions of the user on the physical elements of the products may suggest to the user new sensations and enjoyable experiences.

For many well-designed products, what is making possible through the usage of the product often emanates from the product-user interaction. In the same way, the efficiency of a given task achievement is often the result of an expressive interaction with the system.

Many design theories study the link between the functionalities of a product and the design parameters (functional analysis, value analysis, axiomatic design [2], [9]). Axiomatic Design aims at building a functional model of the relations between the functional requirements (FRs) of the users and the means dedicated to satisfy it (the design parameters DPs). This method is useful for product design or re-design, taking into account the functionalities needed by the user and the design parameters, i.e. the physical arrangement of the products components. The axiomatic design rules are built on the two following axioms [3]:

- Satisfy functional requirements by maximizing the independence of the functional elements (avoid undesirable couplings). Independence allows a huge freedom of design by reducing couplings. (the DPs and the FRs are related in such a way that a specific DP can be adjusted to satisfy its corresponding FR without affecting other FRs)
- Minimize the contents of information (= maximizes success) (The best design is a functionally uncoupled design that has the minimum information content) Among all concepts that satisfy the

Independence Axiom, the one with minimum information content is the best one (in relative terms)

The best design selection stage is to favour the candidates who answer axiom 1, then among these selected ones, to favour the one who answers axiom 2.

In this paper we propose to analyse user-product interaction according to the axiomatic design theory. We analysed four MP3 players, and we studied the relationship between the design parameters and the user's actions. We finally propose a trade-off between user complexity and user attractiveness, presenting the relations between the diversity of User actions and physical Design Parameters as key factors.

We present in section 2 the methodology used for the study of the design of MP3 players. Section 3 is dedicated to the case study and describes the analysis of MP3 players according to the axiomatic design theory. Four music players (two existing products and two prototypes) have been analysed and characterized through their Functional Requirements (FRs) and Design Parameters (DPs).

In section 4, a transposition of the axiomatic design axioms is made. The links between the design parameters and the user actions are analysed through the axiomatic design theory. Section 5 proposes a synthesis of the study by the design brief of a new MP3 player, taken into account the results of the surveys. Conclusions and perspectives are drawn in section 6.

2 METHODOLOGY

Within a design project done at the *Odic Lab* in the UTC, we developed two music players on the basis of tangible design. Both prototypes intend to be intuitive and pleasant, and aim to fit collective use. The first step of the design process concerned the concept findings, then the transformation of the ideas into product functionalities, and then the phase of embodiment. At this stage, which can be done in many ways, we were facing with the question of how to guarantee the better design for the final user? What structure, what organisation of the materiality would fit better the users' experience? Through the analysis of two existing products, a simple model and the largely sold *Apple iPod*, we found some factors that could contribute to a great experience and so to the success of a technological product. We then analysed the two music players prototypes and deepened the findings that it could exist a relation between the diversity of user actions and the degree of pleasantness of a product.

3 CASE STUDY: ANALYSIS OF MP3 PLAYERS USING AXIOMATIC DESIGN

Since the apparition of the standard MP3 (MPEG-1/2 Audio Layer 3) algorithm of compression that generates a drastic compression of musical files without losing perceptible acoustic quality for the human ear perception spectrum, many MP3 devices have been designed and launched on the international market. After its announcement in 2001, and for the six last years, the *Apple iPod* and its declination (mini, shuffle, photo, nano) have radically changed the world of music listening and the way people interact with music.

How *Apple* has been able to convince the consumers that they should buy an *Apple iPod*, if any, is an interesting question for the designers and researchers. Success companies do not conquer the customers in selling them qualities of a product, but by creating "higher experiences" [4]. Given the appeal of new products such as the *Apple iPod*, the potential benefits of tangible interaction to digital music databases can be one answer. Indeed, while many existing MP3 players - very similar in physical appearance - offer a wide range of button-loaded controls interfaces, the *iPod's* capacitive sensor's interface recognises position, touch of a user's finger as a normal touchpad and enables various user interactions taking into account location, trajectory and speed.

3.1 Products

In this way, we analysed the following four digital music players: the most basic design (A), the *Apple iPod* (B) and two new designs taking into account the user experience (C and D). The devices are presented in figure 1.

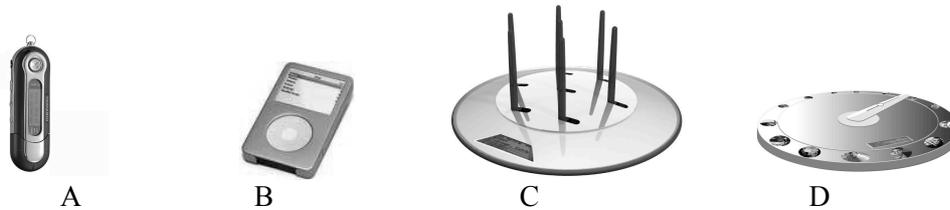


Figure 1. Picture of the four MP3 players, A, B, C and D.

The prototypes C and D are functional prototypes, as presented in the section 3.2, the images C and D above are CAD models. In order to design C and D as tangible and attractive devices, we investigated how the perceptual-motor skills of the users can be involved in order to design pleasant interactions. Among the references in the interaction design field, we tried to integrate the 4 advices from Norman [5], presenting a good design interface as being (1) visible, (2) easy to form a conceptual model, (3) having a good mapping between interface and functions, (4) presenting feedback.

We noticed as well the advices from Dourish [6], i.e. the intuition behind tangible computing is that, because we have slightly developed skills for physical interactions with objects in the world, we can make interaction easier by building interfaces that exploit these skills. Pat Jordan [7] proposes some keys in order to design products and services that people love: Physio, Socio, Psycho and Ideo-pleasures. Jordan puts the pleasure at the top level, in front of functionality and usability, among the sales influencing factors.

Overbeeke et al. [8], leading research on interaction design as well, have proposed the Interaction Frogger, a design framework to couple action and function through feedback and feedforward. With this framework, it is possible to illustrate the couplings that are representative for different interaction styles. These methods and guidelines have been used to design two innovative Music players, C and D, analysed in the next section.

3.2 Analysis of the products with the axiomatic design theory

Based on the principles of axiomatic design [2], the 4 products have been analysed in order to produce a relevant comparison and to propose specifications of the “best” product, regarding the axiomatic design. For this study, we focus only on the FRs concerning the use of the product, not on other FRs (stockage, transport, ergonomics, ...) The design equation of the products, involving the DPs (Design Parameters) and FRs (Functional Requirements) have been defined after an analysis of the products by an engineer-designer. For the device A, all the Design Parameters were considered. For the remaining products (B, C, D), for simplicity, only the DPs corresponding to a physical support of the system (e.g. buttons) were considered (the DPs corresponding to the physical quantity (e.g. force, or velocity)), or the state of the system, were not included in the design equation.

The former type MP3 (A)

- We consider the DPs (Design Parameters) and the FRs (Functional Requirements) of the A type MP3

FR1 [On] turn the system on (long press play/pause button)

FR2 [Off] turn the system off

FR3 [Play]

FR4 [Pause]

FR5 [Next play]

FR6 [Previous play]

FR7 [Change volume]

DP1 [sensor a]

DP2 [sensor b]

DP3 [sensor c]

DP4 [sensor d]

DP11 [short press on sensor a]

DP12 [long press sensor a]

DP13 [memory about the state of the system (On/Off)]

DP14 [memory about the play/pause mode]

- Design equation

$$\left\{ \begin{array}{l} \text{FR1} \\ \text{FR2} \\ \text{FR3} \\ \text{FR4} \\ \text{FR5} \\ \text{FR6} \\ \text{FR7} \end{array} \right\} = \left(\begin{array}{cccccccc} \text{x} & \text{o} & \text{o} & \text{o} & \text{x} & \text{o} & \text{x} & \text{o} \\ \text{x} & \text{o} & \text{o} & \text{o} & \text{x} & \text{o} & \text{x} & \text{o} \\ \text{x} & \text{o} & \text{o} & \text{o} & \text{o} & \text{x} & \text{o} & \text{x} \\ \text{x} & \text{o} & \text{o} & \text{o} & \text{o} & \text{x} & \text{o} & \text{x} \\ \text{o} & \text{x} & \text{o} & \text{o} & \text{o} & \text{o} & \text{o} & \text{o} \\ \text{o} & \text{o} & \text{x} & \text{o} & \text{o} & \text{o} & \text{o} & \text{o} \\ \text{o} & \text{o} & \text{o} & \text{x} & \text{o} & \text{o} & \text{o} & \text{o} \end{array} \right) \left\{ \begin{array}{l} \text{DP1} \\ \text{DP2} \\ \text{DP3} \\ \text{DP4} \\ \text{DP11} \\ \text{DP12} \\ \text{DP13} \\ \text{DP14} \end{array} \right.$$



Figure 2. Former type MP3 (A)

We can observe that the former type MP3 respects the first axiom only for functions FR5 FR6 FR7. Parameter DP1 has a coupling between the 4 functionalities FR1 FR2 FR3 FR4: on/off/play/pause.

The iPod type MP3 (B)

We consider the physical DPs (Design Parameters) and the FRs (Functional Requirements) of the iPod type MP3

- Common FRs with the Former type MP3:

- FR1 [On] short push on play/pause button or short push on the central button
- FR2 [Off] long push play/pause button
- FR3 [Play] push play button or caress tactile jog then push central button 3 times
- FR4 [Pause]
- FR5 [Next play]
- FR6 [Previous play]
- FR7 [Change volume] caress tactile jog but only if Play mode selected, otherwise not

- New specific FRs of the iPod regarding music, and physical DPs:

- FR8 [Menu access] menu button
- FR9 [Select a Function: i.e. a playlist, an artist, an album, a compil, a gender, a composer, etc] tactile knob + central button
- FR10 [Play a selected title] caress tactile knob then push play or push central button
- FR11 [Random play] push menu then tactile knob + central button then tactile jog + x times central button
- FR12 [Repeat] push menu then tactile knob then central button then tactile jog then x times central button
- DP1 [Force sensor a] = play/pause
- DP2 [Force sensor b] = next
- DP3 [Force sensor c] = previous
- DP4 [Capacitive knob] and only when play mode is selected
- DP5 [Force sensor d] = menu button
- DP6 [Force sensor e] = central button

- Design equation

$$\left\{ \begin{array}{l} \text{FR1} \\ \text{FR2} \\ \text{FR3} \\ \text{FR4} \\ \text{FR5} \\ \text{FR6} \\ \text{FR7} \\ \text{FR8} \\ \text{FR9} \\ \text{FR10} \\ \text{FR11} \\ \text{FR12} \end{array} \right\} = \left(\begin{array}{cccccccc} \text{x} & \text{o} \\ \text{x} & \text{o} \\ \text{x} & \text{o} \\ \text{x} & \text{o} \\ \text{o} & \text{x} & \text{o} & \text{o} & \text{o} & \text{o} & \text{o} & \text{o} \\ \text{o} & \text{o} & \text{x} & \text{o} & \text{o} & \text{o} & \text{o} & \text{o} \\ \text{o} & \text{o} & \text{o} & \text{x} & \text{o} & \text{o} & \text{o} & \text{o} \\ \text{o} & \text{o} & \text{o} & \text{o} & \text{x} & \text{o} & \text{o} & \text{o} \\ \text{o} & \text{o} & \text{o} & \text{x} & \text{o} & \text{x} & \text{o} & \text{o} \\ \text{o} & \text{o} & \text{o} & \text{x} & \text{x} & \text{x} & \text{o} & \text{o} \\ \text{o} & \text{o} & \text{o} & \text{x} & \text{x} & \text{x} & \text{o} & \text{o} \end{array} \right) \left\{ \begin{array}{l} \text{DP1} \\ \text{DP2} \\ \text{DP3} \\ \text{DP4} \\ \text{DP5} \\ \text{DP6} \end{array} \right.$$



Figure 3. iPod MP3 (B)

Regarding the first axiom, we can observe that the independence of the functional elements is realized for FR5 to FR8. FR1 to FR4 (functions on, off, play and pause) are linked, to DP1. Regarding the 5 functional requirements FR8 to FR12, which are accessible through the button “menu”, they all present a dependence to the design parameter DP4 and DP6, and DP5 (which is the parameter linked to the menu function).

Discussion for products A and B

Regarding both equations, since the number of physical DPs is lower than the number of FRs, we can say that the design is coupled (different functions involve the same buttons). We are facing with a paradox, how a coupled design, not satisfying completely the axiom 1, can even be a great product, a best seller in the world of music devices. The sales number of *iPod* is increasing drastically each year since 2001. We suggest the hypothesis there could be another factor and perhaps a rule to be taken into account for designing the best product, and we will explore the actions of the user involved in the interaction to grasp the relationship between the potential success of a product and its design.

Regarding the *iPod* MP3 player, the menu presents a quite huge representation mapping, implying the user in a reading task, mobilising his/her attention on the screen in order to get visual information and to navigate. Each function existing in the menu has got visual and acoustic feedback, and is accessible through 2 dimensions gesture. Indeed, compared to the former type MP3 (A), the *iPod* (B) presents not only new functionalities but also new ways of browsing it. The user, involved so far with one dimension gesture (push button) is in this case involved in a 2 dimensions gesture in which position, duration of pressure and trajectory of the finger are meaningful and taken into account by the device. This last observation leads us to consider the hypothesis that the experience elements could be seen also as key factors for the success of the product. In this context, and in the aim presented in § 2 (i.e. the more the body is involved, the more the device can be pleasant and doing so the more the product will be interesting –if not successful), we developed two playing music prototypes.

The antenna type MP3 (C)

Both prototypes do no focus on nomadic use, but the study results could be applied to that type of music players. Following the previous result regarding the *iPod*, which is the increasing involvement of the perceptual motor skills of the user during the use of the product, we developed 2 prototypes based on the coupling of action and function [8]. In this way, this device does not include button on/off, the action of manipulating an antenna triggers off the music playing. Furthermore, each antenna represents a play list and contains a certain amount of titles, which are accessible according to the way the user acts with. The working principle of this product is common with other MP3 players, it gives the user access to music from recorded playlists. Each title is recorded very easily on one of the stems as shown below. The downloading of the musics can be done from USB keys. Thus, one can consecrate each stem to a musical style, or to a family member. This product offers several modes for accessing the titles: in a direct way: drawing one of the stems, one launches the corresponding title play. It is possible to choose the song that one wants to listen by lifting up more or less the stem. In a random way, while tilting on one of the stems, one launches the random playing of the corresponding playlist. In a BPM (beat per minute) way, one selects a music type (slow, fast, ...) according to the "stroke" done on the antenna. For that, it suffices simply "to caress" the stems more or less quickly.

The Functions Requirements and the physical DPs are presented below:

FR1 [Play a play-list] pull antenna 1	DP1 [Slider sensor] play-list 1
FR2 [Play a selected title] pull antenna 1 until the selected play	DP2 [Slider sensor] play-list 2
FR3 [Random play within a play-list] push the selected antenna	DP3 [Slider sensor] play-list 3
FR4 [BPM play] (<i>Beats Per Minute</i>) push selected antennas	DP4 [Slider sensor] play-list 4
with a certain speed	DP5 [Slider sensor] play-list 5
FR5 [Next play] push down the playing antenna	DP6 [Slider sensor] play-list 6
FR6 [Previous play] pull up the playing antenna	DP7 [Slider sensor] play-list 7
FR7 [Change volume] glide the cursor	DP8 [Slider sensor] volume
FR8 [Stop] push down all antennas	DP9 [Force sensor] random on play-list 1
	DP10 [Force sensor] random on pl 2
	DP11 [Force sensor] random on pl 3
	DP12 [Force sensor] random on pl 4
	DP13 [Force sensor] random on pl 5
	DP14 [Force sensor] random on pl 6
	DP15 [Force sensor] random on pl 7

- Design equation

In this case, the physical DPs are of 3 types: 7 sliders controlling the 7 play-lists; one sliders controlling the volume; 7 force sensors controlling the random mode and the BPM (Beats Per Minute) mode, according to the users interaction gesture.

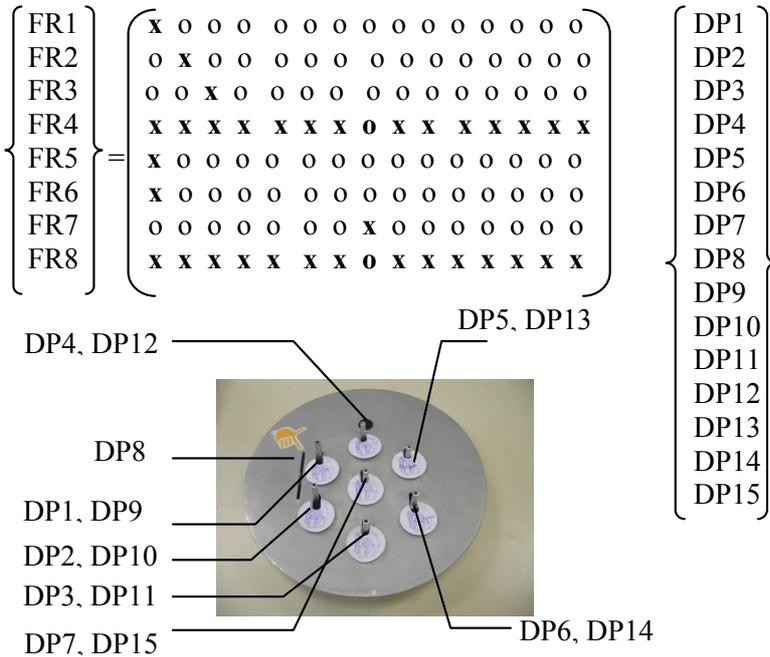


Figure 4. The Antenna type MP3

The physical elements are directly coupled to musical data, The action to grasp some elements has a direct relation with the music played. Furthermore, the way the user tilts one antenna or caresses some of the antennas is taken into account as well, and is related respectively to the random and the BPM modes. In the design equation, from the FR1 to FR3, where the functional elements are not coupled, we can say that the axiom 1 is well respected. On the other hand, from FR4 to FR8, we can observe a dependency of the elements, due to the use of the same elements within different interactions modes. In order to better understand what is given possible for the user through the use of the device, we did a survey whose results are presented in section 3.3.

The arm type MP3 (D)

Presentation of the arm type MP3: The working principle of this product is common with other MP3 players, it gives to the user access to music from recorded playlists. Each title is recorded very easily on one of the angular segment as shown on the picture. The downloading of the musics can be done from USB keys. Thus, one can consecrate each angular segment to a musical style, or to a family member. This product offers several modes for accessing the titles: In a direct way, rotating the arm launches the corresponding title play. It is possible to choose the song that one wants to listen on the playlist while sliding more or less the slider on the arm. In a random way, pushing the slider with a certain force launches the random play of the corresponding title. In a BPM way, pushing the arm with a certain speed between two music areas corresponds to a certain music play, according to BPM.

The FRs and physical DPs are as follow:

- | | |
|---|-----------------------|
| FR1 [Play a playlist] turn arm until the selected area | DP1 [Rotation sensor] |
| FR2 [Play a selected title] pull slider until a selected play | DP2 [Slider sensor] |
| FR3 [Change volume] glide the cursor | DP3 [Slider sensor] |
| FR4 [Random play within a play-list] push the slider with a certain force | DP4 [Slider sensor] |
| FR5 [BPM play] push arm with a certain speed between two music areas | DP5 [Slider sensor] |
| FR6 [Next play] pull slider | DP6 [Slider sensor] |
| FR7 [Previous play] push slider | DP7 [Slider sensor] |
| FR8 [Stop] turn slightly the arm between two music areas | DP8 [Slider sensor] |

- Design equation

$$\begin{Bmatrix} \text{FR1} \\ \text{FR2} \\ \text{FR3} \\ \text{FR4} \\ \text{FR5} \\ \text{FR6} \\ \text{FR7} \\ \text{FR8} \end{Bmatrix} = \begin{pmatrix} \text{x} & \text{o} & \text{o} \\ \text{o} & \text{x} & \text{o} \\ \text{o} & \text{o} & \text{x} \\ \text{x} & \text{o} & \text{o} \\ \text{o} & \text{x} & \text{o} \\ \text{o} & \text{x} & \text{o} \\ \text{o} & \text{o} & \text{x} \\ \text{x} & \text{o} & \text{o} \end{pmatrix} \begin{Bmatrix} \text{DP1} \\ \text{DP2} \\ \text{DP3} \end{Bmatrix}$$

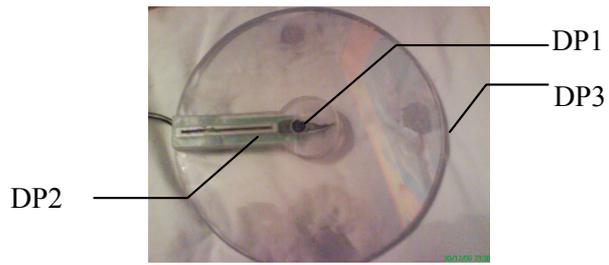


Figure 5: First prototype of the Arm mode MP3 (D)

In this case, the physical DPs are of 2 types, one rotating sensor controlling the play-list mode and the BPM mode, according to the user's interaction gesture. One slider is controlling the titles selection within a list and the random play, while the second slider is controlling the volume. Each physical element and its correlated gestures of interaction are directly coupled to musical data, for example depending on the way the user will turn the arm, he/she will switch from a play-list mode to a BPM mode or to the random mode. The speed and trajectory of the arm have got a direct relation with some music selection. In the design equation, from the FR1 to FR3, where the functional elements are not coupled, we can say that the axiom 1 is well respected. On the other hand, from FR4 to FR8, we also can observe a dependency of the elements due to the use of the same elements within different interactions modes.

Discussion for products C and D

For both prototypes, since the number of DPs is lower than the number of FRs, we can say that the design is coupled. The prototype C presents many DPs dedicated to the same function for the 7 play-lists. The design can be improved with respect to the Axiomatic Design for model C as well as for model D. Nevertheless, the survey gave results that are a good indication of what could be a rich experience for the user. The model C has been manipulated by many people, music amateurs as well as music experts, who gave us their qualitative evaluation. The model C has been considered as a new way of browsing music and a new way of selecting titles, easy to use, even not very explicit as a on shelf laying product. Once antennas have been grasped, it becomes easy to control and to enjoy in a collective use. The results of the survey gave interesting information on people enjoyment, many testers would have like to experiment it longer in the real life, and would be ready to pay a reasonable price for getting it. The model D is still under testing and so far we can observe that it induces another experience for the user, different from model C.

3.3 Results of the survey done during the "FDS" event

The FDS (Fête De la Science) is a national event, as existing sciences festivals in many countries, promoted by the French Ministry for Research and higher education, and aims at making closer science and society, informing people on future technology applications and getting information feedback in return.



Figures 6 & 7: Users testing the Antenna mode MP3 (C)

At this occasion, a hedonic questionnaire has been launched in order to get quantitative and qualitative information on the attraction power of the device. The result, the sharing out of the answers to the survey, is presented in table 1. To the question, *among the 6 pre-definite answers, could you mark the position which fits the best to your feeling regarding the device*, we can observe a very high amount of positive answers (63%) “I would buy it at a reasonable price” and an equivalent amount of answers (14%) in the choice 1 “I really want it” and “I would accept it if someone gives it to me”. Very few people rejected it (respectively 3% “really do not want it, 4% “do not see any interest in it” and 1% “found it really stupid”).

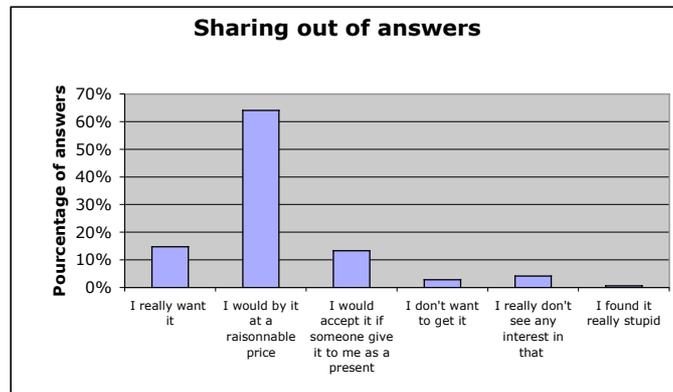


Table 1: Sharing of answers of the survey done at the FDS 2006 (%)

As many testers said while trying the device, the system allows one’s to navigate among the music titles intuitively, giving feedback on the actions through music playing and control screen display. Mainly, tester’s actions started with pulling one antenna and were associated with careful listening on what was going on. Then, pushing, tilting and caressing were tested and understood as far as team members started to encourage testers to discover the system.

As a result, we get different propositions from professionals (dancers and Djs) for deepening the testing phase of the device in a real context of use, such as a dance salon and parties.

We plan to lead further experiments in order to validate the elements we found that make it possible the pleasurable experience.

We assume that, in addition to the axiom 1 (maximize independency between elements), and axiom 2 (minimize the content of information), that is not used at this stage in this study, the best design – i.e. the design that satisfies better the users needs – is, among the solution which satisfy axioms 1 (and 2), the solution that satisfies better the diversity of the user’s actions involved during the use. This aspect will be developed in the section 4.

The prototypes C and D were built based on the tangible design principles, they present physical components accessible to the user, that can be pulled, pushed, turned, tilted or caressed, as the location of the elements, the type of action, the speed of action, the duration of the gesture (smooth caress or quick one), is taken into account. All of the products and prototypes are analysed through the angle of the user actions in the next section.

4 ANALYSIS OF THE USER ACTIONS

Compared to the former type MP3, which satisfies greatly the axiom 1, the product *iPod*, as well as both prototypes C and D, offers a partial satisfaction to the axiom 1, as presented in the previous sections for FR1 to FR3 and for FR8 to FR12. In the case of *iPod*, part of the Functional Requirements are linked to coupled elements, some FRs are linked to the same physical DPs, but depending on the mode (listen or not listen), the same gesture implies different functions, for example “sliding a finger on the tactile knob” will be “controlling volume” during music play and “browsing the menu” in the other cases.

Aware of the success of *iPod*, we assume that, in addition to the satisfaction of axiom 1 and 2, the best design should be the one which satisfies better the user constraints. We could interrogate the novelty of the system *iPod* (one product + one online music service) as being one key of its success. Nevertheless, since the product interface present novelty as well, we assume that the interface, and

especially the actions done by the user, can be potentially a key of satisfaction for the users, and a factor of success of the product. For the two prototypes C and D, the effort has been done to develop a richer interaction with the user, involving more freedom of action, taking into account the evolution in the interaction from gesture in one dimension (1D) (A, former type MP3) to 2D (B, *iPod* MP3) as being a potential factor of satisfaction for the user. To illustrate this point, we propose to analyse each device in the light of user action (UA), focusing on the relation between the Functional Requirements and the User's Actions involved.

- FRs and UAs relations for the former type MP3 (A)

$$\left\{ \begin{matrix} \text{FR1} \\ \text{FR2} \\ \text{FR3} \\ \text{FR4} \\ \text{FR5} \\ \text{FR6} \\ \text{FR7} \end{matrix} \right\} = \left(\begin{matrix} \text{x} \\ \text{x} \\ \text{x} \\ \text{x} \\ \text{x} \\ \text{x} \\ \text{x} \end{matrix} \right) \left\{ \text{UA1} \right\} \text{press}$$



Figure 8. Former type MP3 User Actions

In this case, as in many digital devices, all user actions (UAs) are on the same type, one finger 1D press button action. Comparing the Diversity (d) and the Number (n) of User Actions to the Number of physical Design Parameters (presented in section 3.2), we can observe the following relation between UAs and DPs: $dUAs = 1$ and $nUAs = nDPs = 4$

- FRs and UAs relations for the *iPod* MP3 (B)

$$\left\{ \begin{matrix} \text{FR1} \\ \text{FR2} \\ \text{FR3} \\ \text{FR4} \\ \text{FR5} \\ \text{FR6} \\ \text{FR7} \\ \text{FR8} \\ \text{FR9} \\ \text{FR10} \\ \text{FR11} \\ \text{FR12} \end{matrix} \right\} = \left(\begin{matrix} \text{x} & \text{o} & \text{o} \\ \text{o} & \text{x} & \text{o} \\ \text{x} & \text{o} & \text{x} \\ \text{x} & \text{o} & \text{o} \\ \text{x} & \text{o} & \text{x} \\ \text{x} & \text{o} & \text{x} \end{matrix} \right) \left\{ \begin{matrix} \text{UA1} \\ \text{UA2} \\ \text{UA3} \end{matrix} \right\} \begin{matrix} \text{press shortly} \\ \text{press long} \\ \text{slide} \end{matrix}$$

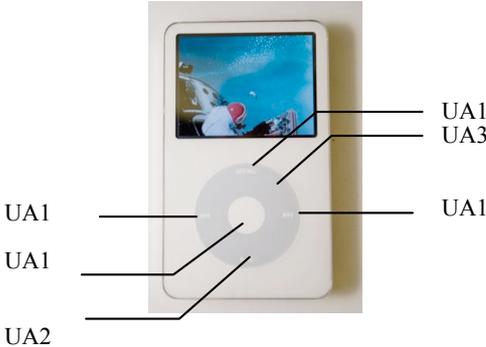


Figure 9. iPod MP3 User Actions

In the case of *iPod*, the User Actions are of 3 types, short, long press and slide. Comparing the Diversity (d) and the Number (n) of User Actions to the Number of physical Design Parameters, we can observe the following relation between UAs and DPs:

$$dUAs = 3, \text{ and } nUAs = 6 \text{ } nDPs = 6$$

- FRs and UAs relations for the antenna MP3 (C)

In the case of the Antenna type MP3, the User Actions are of 5 types, pull, push, tilt, caress and slide. Comparing the Diversity (d) and the Number (n) of User Actions to the Number of the physical Design Parameters (presented in section 3.2), we can observe the following relation between UAs and DPs:

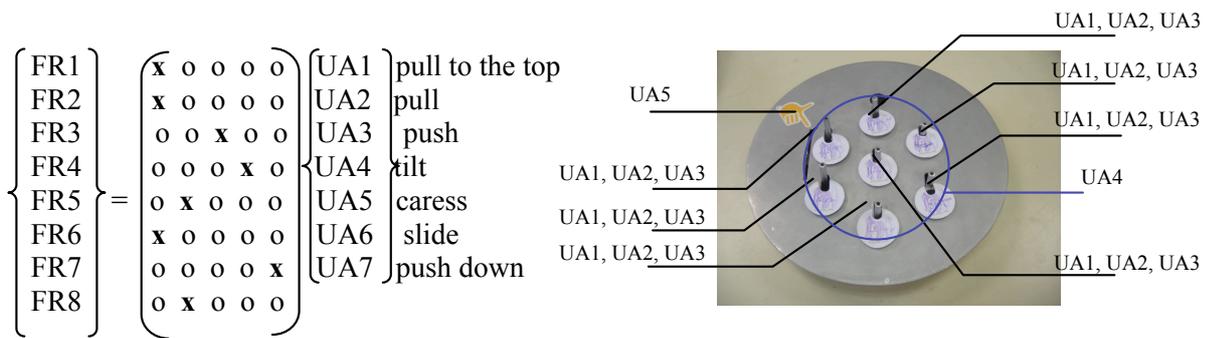


Figure 10: The Antenna type MP3 User Actions

$dUAs=7$, and $nUAs=23$, $nDPs=15$, $nUAs > nDPs$

- FRs and UAs relations for the arm MP3 (D)

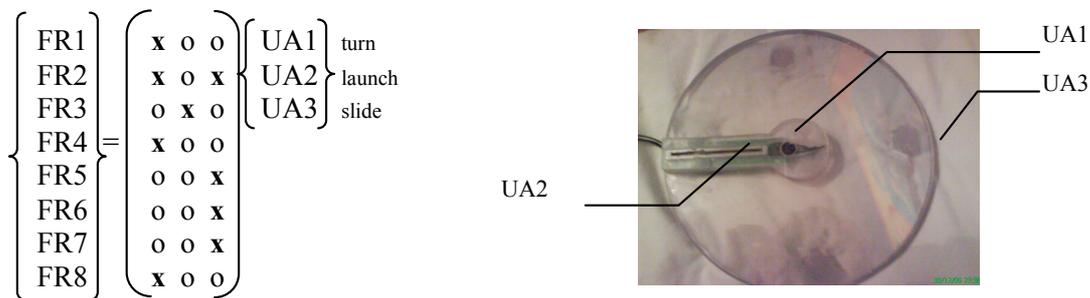


Figure 11: The Arm type MP3 User Actions

In the case of the Arm MP3, we can observe that the D model presents the following relation between UAs and DPs: $dUAs = 3$, and $nUAs = nDPs=3$

Discussion

For product A, the number of the user actions and the number of physical devices he/she will be given to interact with is quite equivalent. In this case, one action corresponds to one physical design parameter. On the contrary, the model B presents a quite important diversity of user actions, comparing to the model A, and a number of physical design parameters not so important, relatively to the model C or D, and is perceived as attractive and relatively easy to use. The model C presents a quite important diversity of user actions and a high number of physical design parameters, it is perceived as attractive but a little bit complex to apprehend. The model D presents a quite important diversity of user actions and a relatively not so high amount of physical design parameters, equivalent to model B, its experimentation and appreciation analysis are still under processing.

From this analysis, we propose a representation in a 2D space, showing the tradeoff between user complexity and user attractiveness, as in the figure 12 below.

We notice the importance of the diversity of the user actions as key factors for the attractiveness of the devices: we observe that an easy of use product presents a weak numbers of physical DPs, and a relative decoupling DPs/FRs, on the contrary a not easy of use product will present a great number of DPs and coupling. Regarding the second dimension, we observe that an attractive product presents a great number of user actions and a great diversity of user actions.

The design of a technological and mass consumption device could be improved by examining the position regarding these two aspects. These aspects are usually expressed on the design brief, and once positioned within these subjective and qualitative descriptors, the design specifications can be defined through the respect of the rules, ie “if” the product has to be attractive “then” the $dUAs$ has to be important as well as the $nUAs$, and “if” the product has to be easy to use, “then”, the $nDPs$ has to be as low as possible.

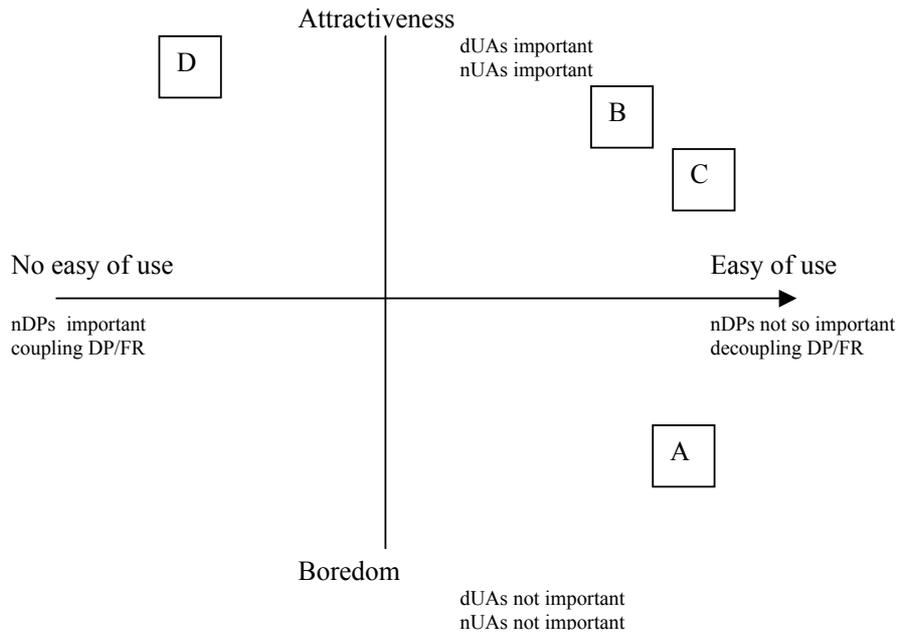


Figure 12: representation of the positioning of the design, on the two axes attractive or boredom and easy to use or not easy to use, depending on dUAs, nDPs and nUAs in the case of close or equivalent FRs number. For example, we can observe that a mean to reduce the apparent complexity of the model D could be to reduce the number of physical Design Parameters.

5 BRIEF FOR A « BEST » DESIGN REGARDING AXIOMATIC DESIGN AND COMPLEMENTARY RULE

Based on the analysis of design equations, we developed the brief for the arm system (prototype D) with a better satisfaction of axiom 1, trying to maximize the independence of the elements, and with a better satisfaction of the attractiveness factors, found as a tradeoff between user actions and design parameters, trying to improve the diversity of user actions (from 3 to 4), without improving so much the number of physical Design Parameters (from 3 to 4).



Figures 13, 14 and 15: Illustrations of actions for selecting and playing a list, selecting a play within a play-list, selecting music plays according to the BPM mode

$$dUAs = 4, nUAs = 4, nDPs=8 \qquad nUAs < nDPs$$

The second prototype is now built in respect to axiomatic design, (at this stage only on the first axiom), and presents a higher diversity of user actions without improving so much the number of physical Design Parameters. Its physical interface includes 8 design parameters, and present 4 different user actions to control it. It involves the user through 4 types of gestures - turn, launch, slide and push - which are linked to the 8 functional requirements with the 3 types of design parameters.

6 CONCLUSION

In this paper, we studied both theoretically and experimentally some digital music devices. After characterizing each device through axiomatic design, we collected some elements of the user experience and did relations between the User Action - factors of experience, and the products Design Parameters.

We found that satisfying only the axiom 1 is not sufficient to do enjoyable products, but Axiomatic Design can be used and transposed in order to allow one's to integrate the factors of experience in the early stage of the design process. We proposed a relation between the User Actions and the Design Parameters, as being a key factor of satisfaction and enjoyment. We tested the first prototype with different populations, and we get quantitative and qualitative interesting information on the attractive characteristics of the device. We found out that the maximization of the number and diversity of user actions could participate to the success of the product.

We analysed the 4 devices regarding the types of actions the user are involved with, and we found out that enjoyable music devices have a higher number and diversity of actions compared to basic ones. From these evaluation of UAs and DPs, we proposed a positioning of the product on two dimensions (no easy to use –easy to use; boring-attractive) in relation with the design parameters and the user actions.

This method answers to the problem of time shortening of the design process, especially in the early steps which request paradoxically from the designers better proposals and more relevant user oriented concepts. These results could be integrated in the design of user interface for leading to higher enjoyment.

This method establishes a correlation between subjective aspects of the user regarding the product and objective specifications of the product. The added value of this approach is to be able to take into account the user's experience as a design factor, and to provide some guidelines to the design team to achieve the best design, fitting the user needs and expectations. In perspective, we will conduct experiments in order to validate in a more general way, the relationship between the number and the diversity of user actions and the degree of his/her satisfaction and enjoyment. We will work on the finding of criteria that can be taken into account in a design for experience.

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