Considering Aesthetics and Usability Temporalities in a Model Based Development Process

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ABSTRACT

Model driven engineering provides solutions to create user interfaces (UI), especially in the case of complex UI such as adaptable UI. However, they suffer from the poor quality of the generated UIs. This paper addresses this drawback by integrating aesthetics and usability study steps in a model driven development process. This proposal is based on an experiment, which shows that aesthetics improves the user's evaluation only at the mere exposure stage. Further, usability improves the users' evaluation only after some use experience.

Author Keywords

Usability; aesthetics; design; process; model

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous. H5.2. User Interface: Graphical User Interfaces

INTRODUCTION

Model Driven Engineering (MDE) provides powerful solutions to tackle the design and the implementation of User Interfaces (UIs), opening possibilities such as more evolving and reusable systems [13], greater quality, early detection of defects and inclusion of knowledge in executable models [30], and, carried to the extreme, dynamic adaptation to the context of use [2].

However, three main critiques are made to MDE. [34] identifies a high threshold of use – the complexity to master models and transformations–, the lack of wide walls – the limited possibilities of exploring various solutions – and a low ceiling, which stands the poor quality of generated UIs. We focus here on this last issue. Model-based UIs are indeed known for offering low aesthetics and not considering enough usability questions.

If UI development processes integrate usability studies, they do not offer many elements dealing with aesthetics issues. However, the importance of aesthetics is recognized on the users' perceived ease of use [20,42], on the overall impression [42,35] and on the appraisal of a system [25].

In this paper, we propose to consider altogether usability and aesthetics in a model-driven development process. We hypothesize that usability and aesthetics have a reciprocal [42,8,37,43,14] and timely influence [1,15]. So to identify when studying each aspect, we conduct a large-scale experiment on the impact of each one on the user's experience. In this experiment, aesthetics and usability are treated as independent variables so as to make it possible to establish the chronology of their influence on the user independently of their reciprocal influence. Our main finding suggests starting UI designs by aesthetics before introducing usability aspects: it sheds a new light on the way to consider UI design processes. Thus, we draw first implications upon this finding to improve user experience at different steps of a UI design process.

The second section of the paper presents the state of the art about human-computer interaction design processes and aesthetics impact. The third and main section presents the development process, which will be extended with aesthetics and usability steps. Next we present and detail an experimental study to understand the impact of usability and aesthetics over time. Then we propose an extension of our process. Finally, the last section concludes and opens on perspectives.

STATE OF THE ART

User interface development processes are usually focused on usability aspect. They are based on iterative cycles, which allow designers to refine mock-ups or final UIs so as to obtain usable UIs [32,27]. These processes use techniques such as participatory design [31] or scenarios [16] to consider the user's point of view. For instance, with the worth based design approach, [6] introduces design principles that are more general than usability. However, the authors recommend starting the development process by identifying the value that the system has to offer and ending it with value measurement. Their approach

remains principle-based without direct recommendation for UI design.

UI development processes don't offer many elements dealing with aesthetics issues, even if some of them offer large parts about usability. For instance, the RUP [19] only mentions that the software architect is "concerned with" aesthetic issue, whilst it insists several times on usability issues. The Diane+ method [41] makes it explicit that usability relies on ergonomics elements but also doesn't mention aesthetics. Model-based approaches, such as MACAO [7], Teallach [11] or UsiXML [44] offer detailed processes for creating the needed models and developing or generating the UIs, but do not focus on usability and aesthetics issues even if MACAO refers to generic software quality criteria from [17], which includes for instance the ease of use.

In the field of industrial design (which relates to the design of objects and not of UIs), [46] focuses on improving aesthetics during design and states that it has a "relatively strong influence on the success of the product on the market". This paper presents an iterative approach for dealing with aesthetics issues. It recommends defining aesthetics criteria, assessing products against them and identifying new concepts from this evaluation. Authors exemplify their method with criteria such as "Harmony between subsystems", "Compactness", "Desired style", "Minimisation of the number of different forms". Even if this works relates to another domain and does not deal with usability issues, the recommendations show the relevance of aesthetics in a development process.

In guidance made of recommendations, several guides or approaches mentioned aesthetics. User-Centred Design [24,12] offers guidelines for designing UIs while including users in the process. They insist on increasing usability thanks to iterative, incremental development and user's evaluation, but they give no recommendation about aesthetics. Moreover, these works offer principles and techniques that are not included in a development process or more precisely, as [36] says, are "decoupled from the software development lifecycle". In a more practical way, some guides such as [39,10] mention visual aesthetics because of its impact on usability. But their recommendations are not included in a process. Some UI design guides, such as [21], exclude the question of aesthetics, considering this is not very important.

From the related works, we can note that 1) even if users are consulted during processes, the focus is on usability and aesthetics is only lightly discussed (at best); 2) some recommendations exist about aesthetics but none of them is integrated into a UI development process.

So our contribution is to propose steps to consider altogether aesthetics and usability during a model-based process. The next section describes the process that we will extend.

THE DEVELOPMENT PROCESS TO EXTEND
In [3], M2Flex is a metamodel for creating flexible process models, i.e. processes that can be adapted to the project's situation (goals, constraints, team competencies and knowledge…). This metamodel is used in [4], to define a "flexibilized" version of the UsiXML methodology [44], which is dedicated to the
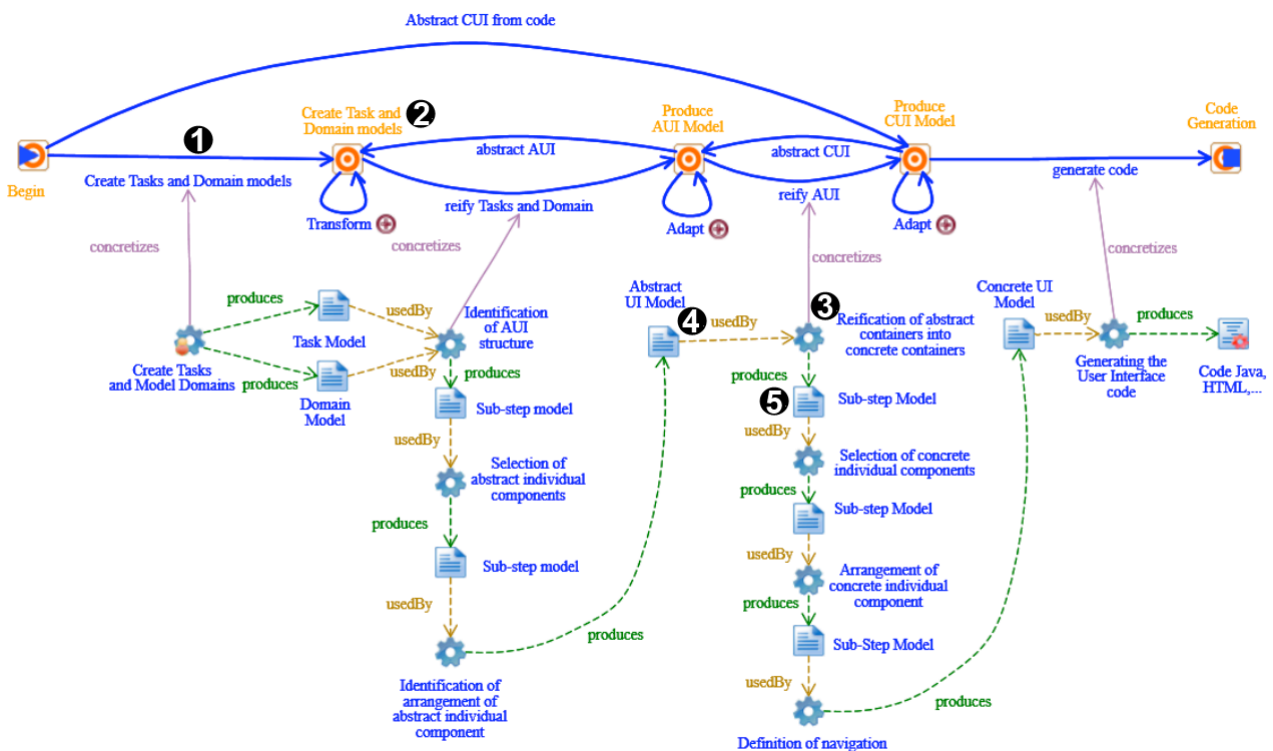

Figure 1 - UsiXML flexibilized process model

design and development of adaptable UIs. As recommended in the Cameleon reference framework [2], the process (Fig. 1) is based on four kinds of models: Tasks, Domain, Abstract User Interface (AUI), Concrete User Interface" (CUI). Different strategies are proposed allowing designers not to create all models.

Figure 1 shows this flexibilized process model, with various strategies (1) connecting goals (2) and reified into more or less detailed activities (3), with the used (4) and produced (5) artefacts. Despite its huge ability to adapt to its users and their project, this process model remains perfectible, as it offers only guidance for creating models and transforming them into other models. There is no mention about ergonomics, even if it is awaited to be taken into account in an UI development. We thus want to complete this process by including recommendations for increasing the quality of the generated UIs, particularly on aesthetics and usability.

The way users estimate aesthetics and usability differently – that will in turn influence the stages considering these questions in the development process - has already been stated by [9], which shows that if people appreciate beauty, they don't want it to increase the cost of the product nor reduce its usability. Aesthetics must then be a bonus on the top of a usable UI. From the designers' point of view, it is also a key factor of success [42,38,5]. But for dealing with aesthetics and usability that might be opposite to each other without increasing drastically the cost, engineers need to be guided. To be able to guide them, we first need to understand when aesthetics and usability impact users' experience to know when each of them has to be studied during the process. So we start by realizing an experience, which hypotheses that the two aspects are not taken into account at the same time by users. The experiment we drove for verifying this hypothesis is presented in the following section.

EXPERIMENTAL STUDY

Goals and hypotheses

The experiment examines how the users' experience (pleasantness, playfulness, and perceived value) differs depending on usability and aesthetics and how it evolves. Several studies about the use of interactive products show that these three dependant variables (pleasantness, playfulness, and perceived value) are the most relevant. These works show that the use of technological products induces affective responses (e.g., [28, 47]). The fun aspect of using user interfaces and its influence on UI's worth have been highlighted by several studies in different fields of research. For instance, about technological acceptance models, [45] shows that **playfulness** positively influences satisfaction while interacting. The positive aspect of such variable appears in several works such as modeling user experience on Internet (e.g., [33]) or using mobile phones [23]. Similarly, works done in the information system research field (e.g. [40]), underline the importance of **pleasantness** while interacting with a

system. Finally, **perceived value** is also a key aspect of user experience while using user interfaces: a broad range of works from HCI, information system and markerting research fields states it (e.g., [26]).

In collaboration with marketing researchers, we conducted a large-scale experiment [18]. We examine the users' evaluation of their experience **over time** at two consecutive stages:

- **Exposure** (first stage): interface experience based on three tasks based on visual inspection of the web sites, *without* user interaction;

- **Use** (second stage): interface experience based on three tasks *implying* user interaction with the web sites.

We suggest that the role of interface aesthetics and usability should vary depending on the users' experience stage.

So the hypotheses are:

- **H1: After the exposure stage**, high (vs. low) interface aesthetics imply a higher (vs. lower) (a) pleasantness, (b) playfulness, and (c) perceived value of the interactive device.

- **H2: After the exposure stage**, the interface usability has no impact on (a) pleasantness, (b) playfulness, and (c) perceived value of the interactive device.

- **H3: After the use stage**, high (vs. low) interface aesthetics has no impact on the different scores of (a) pleasantness, (b) playfulness, and (c) perceived value of the experience.

- **H4: After the use stage**, high (vs. low) interface usability implies a higher (vs. lower) (a) pleasantness, (b) playfulness, and (c) perceived value of the interactive device.

Experimental Method

The two-stages study asked participants to evaluate a travel website thanks to a questionnaire. The first stage (**exposure**) consisted in asking participants to evaluate it based on a visual inspection of the web sites, without user interaction. During the second stage (**use**), participants had to evaluate the same travel website after having manipulated it through user interaction. Versions of a same travel website were designed and developed according to two factors: high (vs. low) usability, and high (vs. low) aesthetics. So by combining these 2 values (low vs. high) for our two variables (aesthetics and usability), four versions of the website are created (Fig. 2).

Procedure and Tasks

In the first stage (exposure), in order to evaluate one assigned version of the four websites, the participants had to achieve three tasks (it just requires to browse the website) related to three questions they had to answer to:

1. Which country does the travel agency promote?

2. What is the name of the first hotel that you can see on the travel agency's website?

3. What activity does the online travel agency offer?

We provided multiple choices answers for each question, with only one correct option.

In the second stage (use), the participants had to interact with one website user interface and then to answer questions. They were given three tasks to achieve. For instance, one of the tasks consists in searching for a 5-stars hotel that offers a visit in the desert. While using the web-based user interface, they were asked to achieve four tasks related to the following questions to be answered:

1. How many 5-stars hotels offer a visit in the desert?

2. What is the name of the hotel that you found?

3. What city is this hotel located in?

4. What is the minimum price per person for this stay?

Participants
Using a panel from Qualtrics (an internet-based research company) and the online Qualtrics survey tool, **we collected responses from 203 participants**. The participants were randomly assigned to one specific version of the web site user interface (among the four versions). The participants (40.9% male, mean age 44.16, σ=13.95) were quite familiar with travel websites (mean=4.31, s.d.=1.65: in answer to the statement "I am familiar with travel websites"; from 1 "do not agree at all" to 7 "totally agree").

UI designs and apparatus
The study used mock travel agency's websites. The participants were asked to navigate one website to plan a hypothetical visit to Morocco, and they were then asked to evaluate the website. The participants were offered different options, such as various types of stay, hotels categories, cities, hotels comparison, activities, and types of package.

The four designs of the travel website were created by a website designer/developer (figure 2). To create these designs, basic functionalities and minimal user interaction were first specified through the generation of a task model and user interface mock-ups. As recommended by Tuch et al. [43], we manipulated—as independently as possible—the aesthetics and the usability of the website user interface. In order to verify the manipulations of aesthetics factors (high vs low) and usability factors (high vs low), a pretest has been driven with 58 students. Participants were exposed to the four UIs and evaluated their aesthetics and usability. Two scores for differences in average have been computed: one for low and one for high levels for aesthetics (M_{diff_aesth}) and for usability (M_{diff_usab}). Results show a statistically significant difference in the averages of high and low aesthetics ($t(57)=15.40$, $p<.0001$, $M_{diff\_aesth}=2.30$, s.d.=1.13) as well as regarding usability ($t(57)=10.15$, $p<.0001$, $M_{diff\_usab}=1.35$,
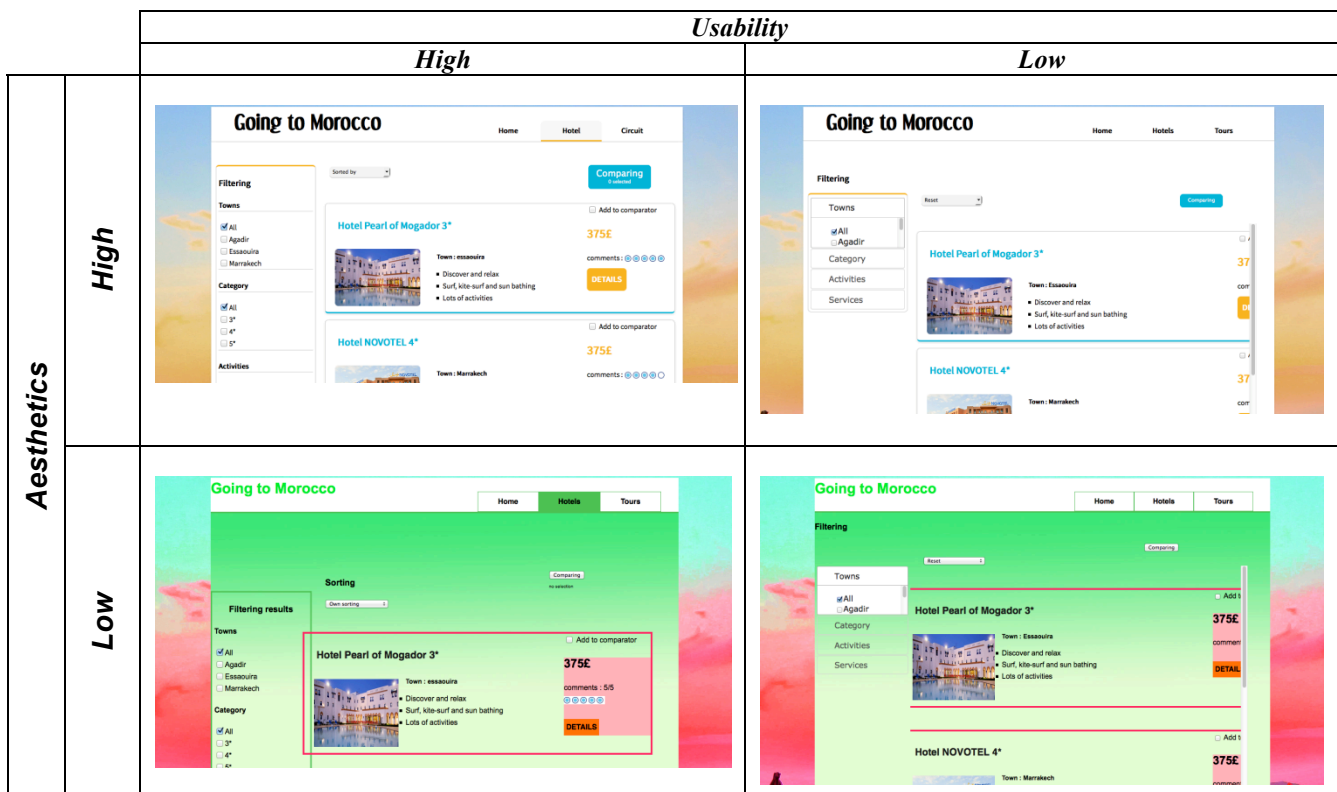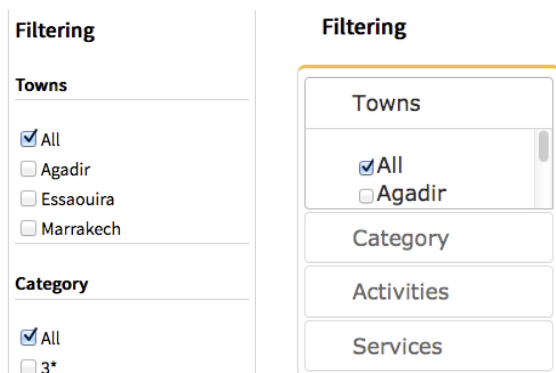

Figure 2: Four versions of a web site user interface: usability x aesthetics

Figure 3: Filtering criterion: expanded list (left: high usability) vs. cumbersome dynamic menu (right: low usability).

Figure 4: high (top) vs. low (bottom) interface-aesthetic.

s.d.=1.01). This validates the manipulation of aesthetics and usability factors in the four sites.

Thus, usability was first considered at the task level (i.e. interaction distance and workload) as well as in terms of concrete user interface. For the low usable version, the concrete user interface level was redesigned for increasing the workload, i.e. by using the navigational factors related to the ease of information access (interaction distance, additional unnecessary articulatory subtasks). For instance, as shown in figure 3, the list of hotels can be filtered using filtering criteria (left side of the user interface): the low usable version presents one criterion (vs. all criteria) at a time through a dynamic menu. Another example, some navigation elements were removed such as redundant hyperlinks.

To create a high vs. low interface-aesthetic, only the graphic factors were manipulated. As shown in figure 4, this included the background colour (bright vs. light), the framework shape (square vs. round), and the formatting (non-aligned vs. aligned) as studied in [29].

The four designs were included in the online survey thanks to Qualtrics' online application. It allows completing the survey while navigating the travel web site within a single web page.

Study design: survey and measures
The experiment used a three-factor mixed design. The between-subject independent variables were the interface usability with two levels (low and high), and the interface aesthetics with two levels (low and high). The within-subject independent variable was the user experience that includes two stages (exposure and use).

During the first stage (**exposure**), participants answered questions related to the tasks to achieve as well their exposure experience (pleasantness, playfulness, and perceived value).

During the second stage (**use**), after completing the three tasks, the participants answered questions similar
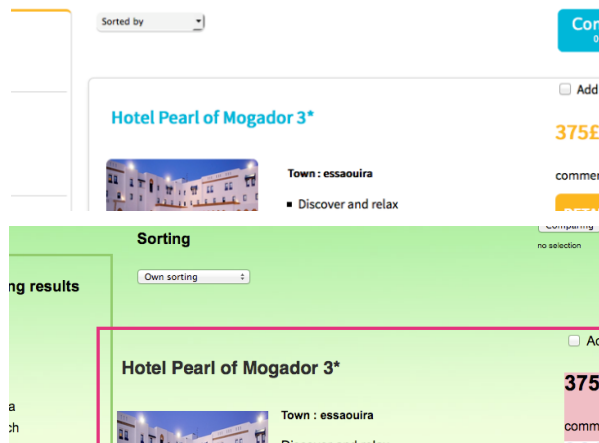
to stage one about their use experience (pleasantness, playfulness, and perceived value). The participants answered additional questions relating to the manipulation (usability and aesthetics), and answered some profile questions (age, gender, and familiarity with travel websites).

Thus, the four different versions are designed to operationalise the independent variables.

For measuring the participants' experience, the survey included several seven-point scale-based questions (e.g. 1="strongly disagree" and 7="strongly agree"):

- *Pleasantness*: two items adapted from Venkatesh (2000): "this website is pleasant to use"; and "this website is nice to use".

- *Playfulness:* three items adapted from Venkatesh (2000): "this website is fun"; "this website is playful"; and "this website encourages a good mood".

- *Perceived value*: six items adapted from [38]: "overall, I think it is worth visiting this website"; "this website is useful"; "this website meets my expectations"; "visiting this website should be a good experience"; "this website is one that I can trust"; and "I believed the information provided by this website".

To ascertain the reliability of these measures, correlation calculations (Pearson and Cronbach's alpha) were achieved after each stage for each measure: it shows a very high correlation (over 0.927 at least with p <0.001) between items. As the scale properties were satisfactory, we created an average index for the three dependent variables (pleasantness, playfulness, and perceived value) at both the exposure and use stages to test our hypotheses.

Therefore, to test the exposure effect, we focused on the means of the indices relating to the website evaluations. To test the use effect, we compared the individual

participants' website evaluations after the use stage with their evaluations at the exposure stage. We calculated a difference score for the use stage evaluations and for the exposure stage evaluations for the three dependent variables. This difference score estimates the improvement or the deterioration of the website evaluations (pleasantness, playfulness, and perceived value) due to the users' experience with the web site user interface.

To ascertain whether the high- (vs. low-) aesthetics/usability website led to higher (vs. lower) perceived aesthetics/usability, the participants assessed the perceived aesthetics and usability of the website. Therefore, to measure perceived usability and perceived aesthetics, we used respectively a four-item seven-point scale and a three-item seven-point scale, both adapted from [22]:

- *Perceived usability*: "this website allows information to be quickly found"; "this website does not need specific effort to find information"; "this website offers easy n*avigation"; and "th*is website offers a clear and understandable experience".

- *Perceived aesthetics*: "this website is visually attractive"; "this website is beautiful"; and "this website has an attractive design".

To ascertain the reliability of the measures, correlation calculations (Cronbach's alpha) were achieved after use stage for both measures: it shows a very high correlation (respectively 0.970 and 0.967 with $p < 0.001$) between items.

As the reliability results were satisfactory, we computed two indices (average index) to test whether the perception of aesthetics and of usability respectively differ on the two factors: aesthetics (high vs. low) and usability (high vs. low).

Results

Perceived usability and aesthetics in line with the UI designs

The results confirm that UI usability impacts significantly and positively the perceived usability: ANOVA showed ($F_{1,201}=7.22$ $p=0.0078$) that a website showing a high usability is perceived as easier to use than a website showing a low usability. Similarly, aesthetics impacts significantly and positively on the perceived aesthetics: ANOVA showed ($F_{1,201}=7.22$ $p=0.0078$) that a website showing a high aesthetics is perceived as more appealing than a website showing a low aesthetics.

Table 1: Results of two sample t-tests after exposure stage

		Mean	Std. dev.	t_{201} (t-test)	p value
Pleasantness	**Low aesthetics**	**4.18**	**1.41**	**2.00**	**0.046**
	High aesthetics	**4.55**	**1.17**		
	Low usability	4.46	1.23	0.944	0.346
	High usability	4.49	1.37		
Playfulness	**Low aesthetics**	**4.52**	**1.33**	**3.482**	**< 0.001**
	High aesthetics	**5.09**	**0.97**		
	Low usability	4.95	0.98	1.695	0.091
	High usability	4.67	1.35		
Perceived value	**Low aesthetics**	**4.52**	**1.23**	**2.700**	**0.007**
	High aesthetics	**4.93**	**0.93**		
	Low usability	4.77	0.95	0.567	0.567
	High usability	4.68	1.23		

Table 2: **Results of two sample t-tests after use stage**

		Mean	Std. dev.	t_{201} (t-test)	p value
Pleasantness	Low aesthetics	-1.00%	97.1%	-0.784	0.433
	High aesthetics	10.35%	109.0%		
	Low usability	**-14.81%**	**107.5%**	**2.667**	**0.008**
	High usability	**23.39%**	**95.8%**		
Playfulness	Low aesthetics	1,49%	98.4%	-0.963	0.336
	High aesthetics	-13.59%	123.5%		
	Low usability	**-33.84%**	**125.2%**	**3.506**	**< 0.001**
	High usability	**20.19%**	**90.6%**		
Perceived value	Low aesthetics	-3.55%	88,5%	-1.221	0.223
	High aesthetics	-19.57%	97.0%		
	Low usability	**-25.41%**	**103.6%**	**2.046**	**0.041**
	High usability	**1.28%**	**80.0%**		

In the following, tables 1 and 2 show the results in tabular form and Figure 5 shows the results in graph form.

Exposure stage: aesthetic comes first
The results emphasize that, after an exposure to the website display, a high aesthetic user interface provides a higher website evaluation than a low aesthetic user interface; however, user interface usability does not increase website evaluation at this stage.

Indeed, to test our hypotheses (H1 and H2), we computed two-sample t-tests (see Table 1, degrees of freedom=201) to test the impact of usability and aesthetics on the three dependent variables (pleasantness, playfulness, and perceived value).

As shown in Figure 5 (see Graph 1a), the *pleasantness* results show that **aesthetics has a statistically significant positive impact** on the perceived pleasantness of the website (p=0.046). However, usability has no significant impact (p=0.346).

As shown in Figure 5 (see Graph 1b), the *playfulness* results similarly show that **aesthetics has a statistically**

significant positive impact on the perceived playfulness of the website (p<0.001). However, usability has no significant impact (p=0.091).

As shown in Figure 5 (see Graph 1c), the *perceived value* results show that only **aesthetics has a statistically significant positive impact** on the perceived value of the website (p=0.007). However, usability has no significant impact (p=0.567).

Use stage: usability effect
The results emphasize that, comparing the exposure stage to the use stage, a high user interface usability improves website evaluation, whereas a low interface usability reduces website evaluation. The results show that the user interface aesthetic does not modify the website evaluation relating to use.

Indeed, to test our hypothesis (H3 and H4), we computed two-sample t-tests (see Table 2, degrees of freedom=201) to test the impact of usability and aesthetics on the three different scores (pleasantness, playfulness, and perceived value).
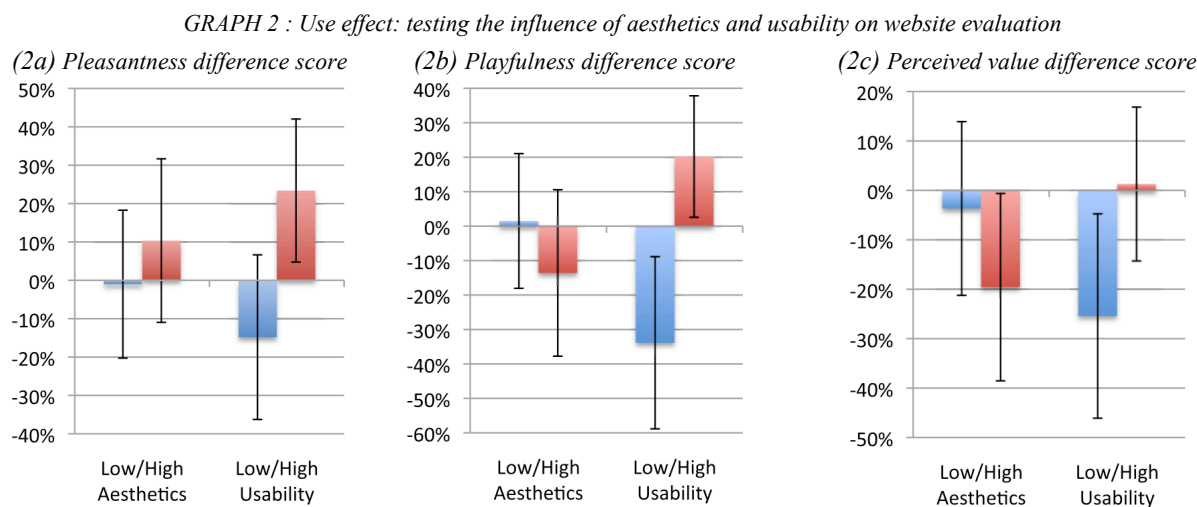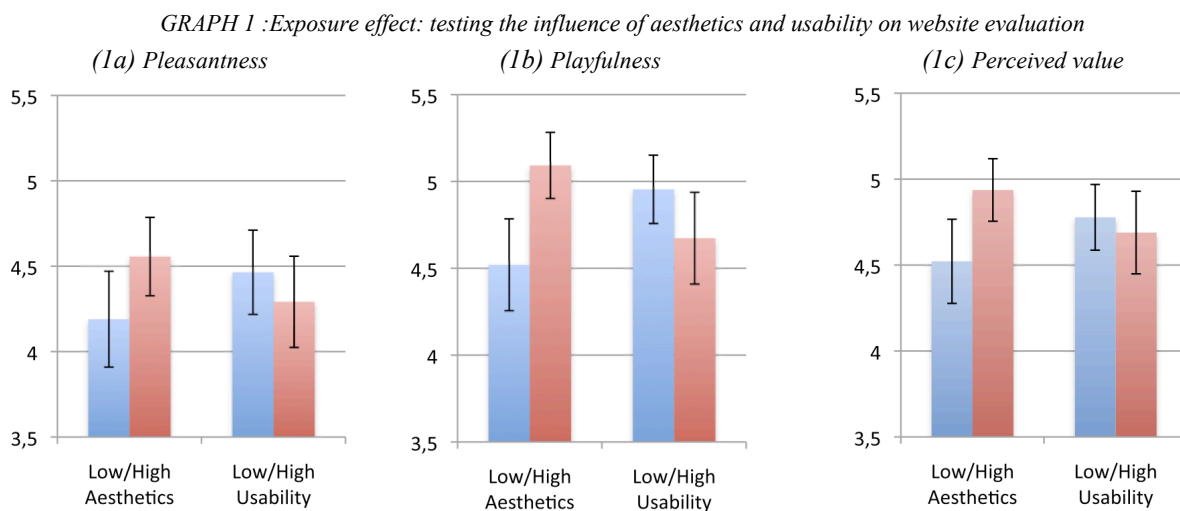
GRAPH 1 :Exposure effect: testing the influence of aesthetics and usability on website evaluation

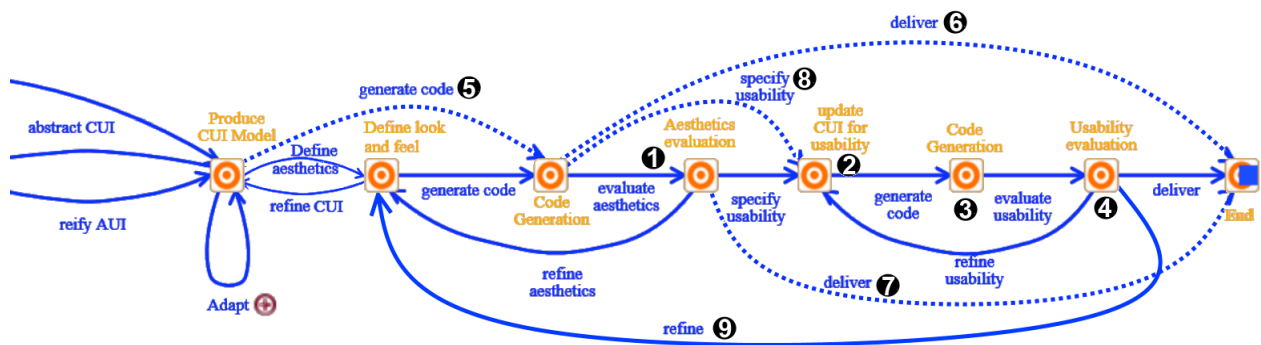Figure 5: Exposure effect results (GRAPH1: 1a, 1b, 1c) and use effect results (GRAPH2: 2a, 2b, 2c)

Figure 6 - UsiXML flexibilized process model including aesthetics and usability considerations

As shown in figure 5 (see Graph 2a), the *pleasantness* difference score (percentage) results show that aesthetics has no statistically significant impact on the website pleasantness difference score (p=0.433). However, **usability has a statistically significant and positive impact** on the website pleasantness difference score (p=0.008).

As shown in figure 5 (see Graph 2b), the *playfulness* difference score (percentage) results similarly show that aesthetics has no statistically significant impact on the website playfulness difference score (p=0.336). However, **usability has a statistically significant and positive impact** on the website playfulness difference score (p<0.001).

As shown in figure 5 (see Graph 2c), the *perceived value* difference score (percentage) result again shows that aesthetics has no statistically significant impact on the website perceived value difference score (p=0.223). Only **usability has a statistically significant and positive impact** on the website perceived value difference score (p=0.041).

Potential bias of the experiment
At the exposure stage, we may observe that, for each measured values (pleasantness, playfulness, perceived value) the average is between 4 and 5 for seven-points scales. However, the range of values varies from 1 to 7 and the t-tests show significant differences for aesthetics. Looking at percentage difference score, significance is strengthening between exposure stage and use stage. For instance, for the low usable version, playfulness' average score decreases by 1.65 (-33.84%) from 4.87 to 3.22.

Although these results are encouraging, they must be mitigated as we designed this experiment considering very obvious differences between perceived aesthetics and perceived usability. For instance, we carefully designed the low aesthetics version in order to avoid impacting readability (guidance criteria) with inappropriate colours for labels. Furthermore, we underline that: (1) the visual inspection as well as the use of the web sites were achieved only once by the participants; (2) the tasks are non-critical and are without time and security constraints; (3) the experiment is limited to a single hand-crafted web-site.

It advocates for additional experiments to strengthen these results. Currently, the experiment is extended with additional web sites.

IMPACT OF THE EXPERIMENT ON THE DEVELOPMENT PROCESS
Regarding UIs aesthetics, the results show that it only impacts the participants' evaluation at the exposure stage – when the users have to look for information through visual inspection of the web sites. In contrast, aesthetics do not influence the participants' evaluation at the use stage – when the users have to look for information based on their interaction with the website. Regarding user interface usability, the results show that usability does not influence the participants' evaluation when the users visually inspect the website (exposure stage). However, user interface usability improves the participants' evaluation when the users actually experience the website (use stage) through user interaction. In other words, user interface aesthetics only improves a user's evaluation of an interface after a mere exposure, whereas user interface usability only increases a user's evaluation after a use experience.

Thus, this experiment confirms that usability and aesthetics have a timely influence. Users are more impacted by aesthetics during the exposure stage, e.g. when they discover the application. This temporality can be taken into account by designers and developers. We therefore state a first recommendation that during a user interface design process, at early stage, designers should first study and propose the UIs aesthetics, and in a second phase focus on usability. Figure 6 shows the (end of the) resulting flexible process model after including the goals, strategies and activities corresponding to our experiment's results. Goals for exploring (1) aesthetics and evaluating it (2), as well as exploring usability (3) and evaluating it (4), have been added. The corresponding strategies have been included. As we need the process model to remain as flexible as possible, strategies (5, 6) have also been redefined for making it possible to deliver the software without having to consider aesthetics and usability. For similar reasons, we also added a strategy for considering aesthetics but not usability (7) or usability only (8). As UI development is an iterative process, strategy (9) makes it possible to refine the aesthetics

and usability elaboration by returning to the Concrete UI production, earlier stages being accessible from there. Dotted lines (5,6,7) signify that, although these strategies exist and make it possible to avoid aesthetics and usability considerations, we do not recommend enacting them.

As a complement to the impact on process models, we also draw a recommendation that is, while conducting usability evaluations and testing phases, aesthetics has to be tackled first as it might have a bias effect on the results.

CONCLUSION AND PERSPECTIVES
This paper presents a step towards integrating aesthetics and usability in a model based UI development process. An experiment shows the temporal influence aesthetics and usability: it advocates for considering aesthetics before usability in a UI development process. So we extend a model based process to include aesthetics and usability study steps. We will complete this work to refine the aesthetics step. Moreover, other aspects of user experience can be studied, such as trust or perception of innovations. Their impact on the quality perceived by users must also be considered while designing a UI. Finally, we also will drive an experiment for evaluating if the proposed UI design process increases users' and designers' satisfaction.

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