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Human Factors and Ergonomics design principles and guidelines: helping designers to be more creative

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Abstract

The knowledge and application of Human Factors/Ergonomics (HFE) principles and guidelines can help designers to develop better products and services. However, they may also include design constraints that may affect designers' creativity. Although both HFE principles and guidelines and creativity are considered essential in the design of products and services, the link between them is little researched. In this article a discussion is presented on the influence that HFE principles and guidelines can exert on the creativity of designers. It also presents case studies of HFE principles and guidelines and discusses how they can influence designers' creativity. In addition, a set of recommendations is suggested to help designers apply ergonomic design principles and guidelines to stimulate creativity. It is concluded that HFE principles and guidelines can assist designers in creating safer and more efficient products and services and can also broaden their creative process and therefore the originality and appropriateness of products and services.

Keywords: human factors, ergonomics, design principles, design guidelines, design creativity, design constraints

1. Introduction

The knowledge and application of Human Factors/Ergonomics (HFE) principles and guidelines can help designers to develop better products and services. They can also make it easier for designers to apply human factors and ergonomics theories and concepts properly. HFE principles and guidelines serve to optimise human performance and to improve the safety and usability of products and services, and are therefore considered fundamental during the design process. The accurate application of HFE principles and guidelines assists multidisciplinary teams of developers to create effective, useful and enjoyable products and services.

Several researchers have investigated how the principles and guidelines of HFE should be applied to assist in the process of designing or re-designing products and services. Studies of several areas of knowledge, such as medication alerts [1,2];

traffic signs [3,4]; classrooms [5,6]; sustainable buildings [7]; musculoskeletal disorders [8]; furniture [9]; workplaces [10,11]; and healthcare [12] have found that the application of HFE principles and/or guidelines can improve the performance and usability of products and services.

Although HFE principles and guidelines are considered fundamental during the design process, several researchers have found that they are not completely followed by product and service developers [1, 11, 13]. This may be explained, among other reasons, by the fact that some developers either do not know or do not have access to HFE principles and guidelines. Furthermore, it can be argued that HFE principles may include many constraints on project development and therefore may be difficult to follow and/or may increase the costs of project development.

In addition, they may also include product/service design constraints that may affect designers' creativity. Creativity in a product is related to its originality and appropriateness [14, 15, 16], and it plays an essential role in fulfilling the aspects of ergonomic design concerning affectivity, functionality, safety, and usability [17]. Although both HFE principles and guidelines and creativity are considered essential in the design of products and services, the link between them is little researched.

In this article a discussion is presented on the influence that HFE principles and guidelines can exert on the creativity of designers. It also presents case studies of HFE principles and guidelines and discusses how they can influence designers' creativity. In addition, a set of recommendations is suggested to help designers apply ergonomic design principles and guidelines to stimulate creativity.

2. HFE design principles and guidelines and designers' creativity

In order to discuss the influence of HFE design principles and guidelines on the creativity of designers, the main conceptions of principles, guidelines, and creativity are considered. The characteristics of HFE design principles and guidelines and the abilities designers need to enhance creativity are described.

2.1. HFE design principles and guidelines: definitions and characteristics

As pointed out in the introduction, HFE principles and guidelines are fundamental in the design process. Although both serve to provide guidance for the design of optimized systems, they present differences in approach and use. Many researchers have discussed the differences between principles and guidelines. Design principles are considered a "fundamental rule or law", whereas guidelines are a "context-dependent directive" [18]. Principles are applied for the analysis and comparison of design alternatives, whereas guidelines focus on providing advice about 'good practices and cautions against dangers' [19]. Principles are also considered general aims guiding conceptual decisions, whereas guidelines are based on specific principles for a specific design domain [20]. Principles reflect a philosophy or purpose

of the project, whereas guidelines are intended to help designers implement a principle [21].

Creating a design principle or guideline is not an easy task. They must meet many characteristics to be considered valid, useful and easily used by professionals. Human-factor design guidelines include the need to be concise, directive, unambiguous, verifiable, and relevant to human performance [22]. De Souza and Bevan [23] claim that a guideline should contain: the design aims and benefits; the conditions under which the guideline should be applied; the nature of the proposed solution; and the procedures that need to be followed to apply the guideline.

In line with the authors above, Fu, Yang, and Wood [18] point out dimensions of principles that should be considered: "level of supporting evidence or validation, level of granularity or specificity, level of formalization, and position on the spectrum of prescriptive–descriptive". In addition, the other principal aspects that should be considered are: recording the date to indicate the state of the art and the technological, social and economic trends from when the principle was created; defining in which context the principle is usable and useful; defining for whom it would be useful; including prior knowledge and conditions needed for application; including a metric or probability dimension of success in using the principle [18].

Design guidelines may not always be easy for designers to utilize [23; 24]. De Souza and Bevan [23] claim that designers have difficulty integrating "detailed design guidelines" with their experience. Among the criticisms of guidelines, researchers point out that they can be: 'too wordy', 'too general', and 'too hard to understand' [22]: 'too abstract to be easily interpreted and directly applied', conflicting, difficult to retrieve relevant information [24]. It is also claimed that some guidelines are based on the experience of professionals and have never been tested; some are based on one type of medium and may not be applied in another type; guidelines from different authors may be contradictory [25; 26].

Despite these problems, the use of principles and design guidelines relating to human factors during the design process is crucial in achieving high performance and wellness systems. In addition, this paper discusses the role of HFE design principles and guidelines in helping designers to enhance creativity. In order to help with this goal, two case studies are presented as follows.

2.2. Designers' creativity: definition and abilities

Creativity is an essential element of design [27; 28; 29]. Creativity is also a relevant factor in the debate on the quality of a design or a designer [30]. Although there are different definitions and approaches to creativity, there is a definition considered "standard" by many scholars, who consider something creative if it is both novel (also called original) and appropriate (also called useful) [16].

Within design process, creativity is considered "a matter of developing and refining together both the formulation of a problem and ideas for a solution" [31]. It is also considered "the ability to conceive unexpected solutions to apparently insoluble

problems” [32]. Designers’ ability to be creative is related to various factors. Guilford [33] pointed three competences that contribute to the structure of creative thinking: fluency, flexibility, and elaboration. Casakin and Kreitler [28] expanded the framework of Guilford and describe creativity in terms of “fluency, flexibility, elaboration, innovation, usefulness, aesthetic skills in design representation, fulfillment of design requirements, and reference to context”.

Kim, Shin, Shin [34], based on previous researchers [35; 36; 37], identified five cognitive elements of design creativity: fluency, flexibility, originality, elaboration, and problem sensibility. Problem sensibility (i.e. “an ability to find problems”) is a similar concept to ‘discovery orientation’, which is an ability to find and formulate problems where others do not [38].

These five abilities synthesize the skills required to engage successfully in the creative process and, therefore, they were applied to analyse the case studies in this paper. Based on the authors cited, the abilities are defined as:

- fluency - the ability to produce multiple ideas,
- flexibility - the ability to change ideas from different sets,
- originality - the ability to produce rare and new ideas,
- elaboration - the ability to realize ideas with details, and
- problem sensibility - the ability to find problems or needs for change.

3. Case studies

This section presents two case studies regarding human factor design principles and human factor design guidelines, and their relationship to creativity. They explore well-known human factor principles and guidelines and their influence on designers’ creativity. In order to be more easily comparable, both the principles and the guidelines studied came from the field of human-computer interaction.

3.1. Case Study 1: HFE design principles in Human-Computer Interaction

Both HFE and HCI (Human-Computer Interaction) are fields concerned with designing and evaluating systems for human use; however, the former is concerned with all types of human artefacts, while the latter focuses on interactive computing systems.

Several authors have been proposing principles of design in HCI. Among the well-known proposals are the design principles introduced by Norman [39], the Eight Golden Rules of Interface Design [40], and the heuristics of Nielsen [41]. Although they have different approaches, they describe some similar principles, such as feedback and consistency. In addition, although these principles were proposed more than 20 years ago they are up-to-date and still used by designers.

For the sample of this case study, two design principles of HCI were chosen, listed in the book ‘A guide to human factors and ergonomics’ by Helander [42]. These

design principles were chosen because they are considered very important and have been found in different sets of design principles of HCI. Only two principles were chosen, as these were considered enough to illustrate how principles can influence designers' creativity.

They are:

1. "Provide an interface that does not violate the user's expectations or mental model", and
2. "Design a consistent interface. This will improve expectations and reduce user errors".

Principle 1: "Provide an interface that does not violate the user's expectations or mental model".

Mental models are internal representations that users produce to react to new situations. They are represented by "concepts, relations between concepts, propositions, scripts, frames, and mental image" [43].

When reading this first principle, we might think that this can be a considerable obstacle for creativity in design, as the designers incorporate users' expectations or mental model. However, in order not to violate expectations, designers should deeply understand the user's expectation and mental models, and therefore this can help designers to increase their background and to be exposed to various possibilities and opportunities to generate ideas and solutions.

In addition, it also requires the ability of problem sensibility related to creativity. It has been argued that problem sensibility is one of the most needed cognitive skills in order to achieve creativity. Problem sensibility ability can be improved when designers are investigating or trying to find solutions to incorporate users' expectations and mental models. The users' mental model will provide an understanding of the type of knowledge users have and how they organize it [43]. Furthermore, designers will have more instruments to evaluate the suitability of proposed ideas.

Principle 2. "Design a consistent interface".

According to this principle, designing a consistent interface will "improve expectations and reduce user errors". Considered one of the most relevant principles of HCI, consistency within and between systems can improve overall system usability, assist users in learning the system, reduce the number of errors, and thus increase user satisfaction [44]. Mandel [45] indicates five principles to make the interface consistent: "sustain the context of users' tasks", "maintain consistency within and across products", "keep interaction results the same", "provide aesthetic appeal and integrity", and "encourage exploration".

Applying consistent design within a system may make it look repetitive or with a look and feel similar to other systems. However, putting a menu in the same place,

for instance, can allow designers to work with freedom in other elements of the interface. The fact that designers should keep the system consistent with some interface elements may mean that regarding creativity they will need to be more flexible and original with the overall interface.

The system under development needs to be useful and easy to use (and therefore provide a level of consistency), but at the same time it must be attractive and stand out from other systems. This is a challenge for designers, who are supposed to demonstrate fluency, flexibility, and originality in order to achieve a system that has high performance, provides well-being, and attracts users.

3.2. Case Study 2: Health and Human Service (HHS) guidelines

There are various human-factor design guidelines, and each one is related to a specific area and topic. Among so many guidelines it is a hard task to choose one to investigate. The criteria to select the HHS web design and usability guidelines were the fact that these guidelines have been considered “the most complete” [44], “the most comprehensive, well researched and easy to use” set of guidelines for web design [46], and were based on a “meticulous job of scouring the research literature to find support for design guidelines” [47].

The Research-Based Web Design and Usability Guidelines (from now on, called HHS guidelines), were developed by the U.S. Department of Health and Human Services (HHS), in partnership with the U.S. General Services Administration. They were first published in 2003, with 187 guidelines, then revised to 209 guidelines in 2007. The HHS guidelines aim “to assist those involved in the creation of Web sites to base their decisions on the most current and best available evidence”, thus enabling “organizations to make more effective design decisions” [48]. Among the advantages of HHS web design and usability guidelines are the fact that they are written in simple language and illustrated with examples; and each guideline has a rating for “relative importance” to the success of a website and “strength of evidence” supporting the guideline [49]. Ratings are relevant as they allow the user to quickly check which guidelines have the most significant impact on a site's success and also determine the nature and quality of the supporting evidence [48].

The 209 HHS guidelines are divided into 18 main groups, defined by a card-sorting exercise with 20 website designers. They are: Design Process and Evaluation; Optimizing the User Experience; Accessibility; Hardware and Software; The Home Page; Page Layout; Navigation, Scrolling and Paging; Headings, Titles, and Labels; Links; Text Appearance; Lists; Screen-Based Controls (Widgets); Graphics, Images and Multimedia; Writing Web Content; Content Organization; Search; and Usability Testing.

The first aspect considered was the number of guidelines within this set. Two hundred and nine is a significant number of guidelines, which can represent a problem for the creative process of designers. Considering each of these guidelines might interrupt the creative process. However, with the guidelines divided into 18

groups, the designer can consider each group to check during a specific phase of the project development. Also, not all guidelines apply to all audiences and contexts. In addition, designers should consider the ‘relative importance’ and the ‘strength of evidence’ in order to apply the guideline literally, to adapt it, or even consider not applying it.

In order to analyse the influence of HHS guidelines on the creative design process, it has been chosen as ‘The Homepage’ group. Homepages are considered ‘the most valuable real estate in the world’ and also “the most important page on most websites” [50]. The Homepage group consists of 9 guidelines. Table 1 shows the HHS guidelines related to the Homepage topic, their relative importance and strength of evidence.

Table 1. HHS Guidelines: Homepage topic, the guideline’s relative importance, and strength of evidence.

HHS Guideline	Relative Importance	Strength of Evidence
‘Enable users to access the homepage from any other page on the Website.’	5	3
‘Present all major options on the homepage’.	5	2
‘Treat your homepage as the key to conveying the quality of your site’.	5	4
‘Clearly and prominently communicate the purpose and value of the website on the homepage’.	4	3
‘Limit the amount of prose text on the homepage’.	4	3
‘Ensure that the homepage has the necessary characteristics to be easily perceived as a homepage’.	4	4
‘Limit the homepage to one screenful of information, if at all possible’.	3	2
‘Announce major changes to a Web site on the homepage - do not surprise users’.	2	2
‘Ensure that homepage panels are of a width that will cause them to be recognized as panels’.	2	3

In practice, these guidelines suggest that homepages should present the main menu; communicate well but limit the quantity of text; be distinguishable from the others; limit the length of the page; announce major changes to a website; and have panels recognized as such; and that all pages should have a link to the homepage.

These guidelines introduce visual and functional constraints on web designers. They limit homepage size and quantity of information displayed, and they require different information to be included. Therefore, it can be argued that these limitations can also limit designers’ creativity. However, as seen with principles as well as with guidelines some constraints can help designers to amplify creativity. In order to cope with so many limits and requirements,

designers should elaborate detail and complete ideas and evaluate the appropriateness of ideas to the problem, therefore acting in two cognitive elements of creativity.

There are also guidelines that are “abstract” and should be interpreted by designers. For instance, the guideline “Ensure that the homepage has the necessary characteristics to be easily perceived as a homepage” is very dependent on designers’ interpretation. It can stimulate the generation of various ideas as it proposes that the homepage should be different from the other pages.

As we can observe in the table, only three out of nine obtained the top rank of relative importance and none obtained the top rank for strength of evidence (2 ranked 4 out of 5). This means that although some guidelines appear to be relevant, most of them have little research to support their effectiveness and hence little evidence of support. Therefore, designers need to be able to interpret the need for the use of the guideline. This is also a challenge for the designers and an opportunity to foster creativity.

4. The influence of HFE principles and guidelines on designers’ creativity

As illustrated with the case studies above, HFE principles and guidelines can help designers’ creativity, by engaging designers in the production of novel and useful ideas. This conclusion is in line with previous research that has also shown the positive side of using design principles and guidelines to promote creativity. For example, Lidwell, Holden and Butler [51] argue that universal design principles can ‘promote brainstorming and idea generation for design problems’. Souto [26] claims that “design guidelines may assist designers during their creative process by helping them to consider the best practices for designing a project”. Based on the literature and on the case studies described, three main recommendations are presented and discussed to enhance creativity when using HFE principles and guidelines: (1) use the constraints of HFE principles and guidelines as a creative resource; (2) use HFE principles and guidelines focused on users to enrich creativity; and (3) Use the abstraction of HFE principles and guidelines to create novel design.

4.1. Use the constraints of HFE principles and guidelines as a creative resource

Constraints are commonly associated with limitation and requirements [52]. In design, constraints play a powerful role and are considered a relevant part of the design process [53, 54, 55]. Researchers have diverged on the role of constraints in the creative process. For example, Amabile [56] found that extrinsic constraints (e.g. expectation of external evaluation, reward-dependent evaluation, and narrow choice in task engagement) could make people produce work that is lower in creativity. On the other hand, Stokes [57], Biskjaer, Onarheim, Wiltchnig [52], and Biskjaer and Halskov (2014) claim that constraints are essential in the creative process and can help enhance creativity.

Stokes [57] claims that creativity depends on a specialist who selects task constraints and subjects to restructure an existing problem and accomplish a novel goal. Onarheim and Wiltchnig [54] identified four qualities of the creative process concerning constraints and requirements. These qualities are: “creative processes are framed by requirements/constraints”; “creative processes are opened through the introduction and removal of constraints”; “creative processes can be limited through too rigid constraints”; and “in absence of any constraints the creative process becomes borderless and impossible to

evaluate". Therefore, as they point out, constraints should not be too rigid or nonexistent in the design creative process.

HFE principles and guidelines impose some constraints on systems design and, following the authors cited above, we considered that constraints can leverage creativeness by bringing elements to the project that can help the fluency, flexibility, and originality of novel ideas. As was observed in the case study above, HFE principles and guidelines can be used to give freedom to designers and therefore stimulate the generation of ideas. As Rosso [58] points out, freedom can come from "knowing what to do with constraints when they emerge, finding the right constraints in the right balance, and crafting an environment in which they can be perceived as opportunities rather than obstacles".

4.2. Use HFE principles and guidelines focused on users to enrich creativity

There are many principles and guidelines that focus on the relevance of users' experience, users' mental model, and/or users' knowledge. Knowledge about users seems to be a key factor to create successful systems. Although user-centered design methods are important, within a creativity context, they can make it difficult for designers to design systems. Bonnardel [59] argues that designers find it difficult to find new ideas because they suffer from the effect called design fixation (i.e. conformity with examples), as well as in defining relevant constraints for designing future products. In addition, designers should be careful not to confuse users' suggestions with compulsory ideas. Designers cannot expect users to be able to design, and their contribution cannot be considered as an "unquestionable truth" [60].

On the other hand, the generation of new ideas is closely linked with users. Veryzer and Mozota [61] claim that the generation of ideas requires a high level of integration between the customer, the concept, the product and its production, in order to produce promising new ideas. Knowing users better can help designers' fluency in the number of ideas created and designers' flexibility in proposing ideas from different approaches. Users' and designers' mental models may diverge, and these differences may help to create a new solution. Also, the designer's problem sensibility ability can be stimulated with a user-centred approach. As Norman [62] claims:

"The challenge is to use the principles of human-centered design to produce positive results, products that enhance lives and add to our pleasure and enjoyment. The goal is to produce a great product, one that is successful, and that customers love. It can be done" (p. 36).

4.3. Use HFE design principles and guidelines abstraction to create a novel design

As mentioned in the section about HFE design principles and guidelines (2.1.), it is claimed that principles and guidelines can be abstract and not easily interpreted and applied [24]. Principles' abstraction was discussed by Bennett and Hoffman [63]. They claim that on one side is the system developer with the abstract principles; on the other are the specific components that have to be designed. The gap between these two sides, which they call the "creativity gap", means "the extent to which the general principles are translated into specific displays and controls" [63].

On the other hand, Mariage [20] claims that both principles and guidelines require abstract interpretation to be applied and therefore do not limit the designer's creativity. Abstract principles and guidelines may help designers' creativity in different ways. First, it can

be said that in order for designers to interpret the principles and guidelines they will need to approach different contexts and propose different ideas. Thus, this may improve designers' flexibility in changing approaches. Furthermore, it can be considered that abstract principles and guidelines may stimulate designers' originality. This is because designers' interpretation of the principles and guidelines can lead them to generate rare or unique ideas.

5. Final remarks

This study investigated the influence of HFE principles and guidelines on designers' creativity. It is concluded that HFE principles and guidelines can assist designers in creating safer and more efficient products and services and can also broaden their creative process and, thus, the originality and the appropriateness of products and services. The case studies showed that different approaches can be used to stimulate creativity by using HFE design principles and guidelines.

The study points to three recommendations to help designers apply HFE design principles and guidelines to stimulate creativity. They are: (1) use the constraints of HFE principles and guidelines as a creative resource, (2) use HFE principles and guidelines focused on users to enrich creativity, (3) Use the abstraction of HFE design principles and guidelines to create a novel design.

These recommendations were generally discussed based on the literature and the case studies. Further investigation is needed to apply these recommendations to a real project. This would enable them to be expanded, and would illustrate scenarios for their use and the creative solutions proposed by designers to create successful systems.

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