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Seeking Chances through Interface Design
The Role of Abduction

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***Abstract*—In this paper we plan to explore the notion of cognitive chance taking advantage of an analysis of the concept of interface. The notion of interface, especially studied in the field of *Human-Computer Interaction* (HCI), can be of help in shedding light on how to design cognitive artifacts able to shape and extend pre-existing cognitive capabilities – and even able to unearth new ones. The cognitive dimension of interfaces will be considered in connection with the notion of cognitive niche. From a theoretical perspective, an interface is a cognitive niche insofar as it selects those aspects of the environment relevant to carry out certain cognitive tasks. In dealing with interface design, we will put forward an alternative conception of affordance based on the notion of abduction. We will argue that an efficient interface can be considered as a set of affordances: it displays as much as possible those signs from which one can correctly infer what to do next.**

***Index Terms*—abduction, affordance, human-computer interaction, interface design, cognitive niche.**

INTRODUCTION

As a matter of fact, humans actively sort out the information they need to control their behavior in the world [1]. They do not store descriptions of pictures, objects or scenes they perceive in a static way: they continuously adjust and refine their perspective through further *cognitively rich explorations* that allow them to get a more detailed understanding. Within this framework, the importance of detecting and then making use of the various cognitive chances offered by the environment is fundamental. By the term cognitive chance we refer to the "information" which is not stored internally in memory or already available in an external reserve, but that has to be "extracted" and then *picked up* upon occasion.[1]

In this paper we plan to explore the notion of cognitive chance taking advantage of an analysis of the concept of interface, which brings our attention to the problem of designing cognitively effective systems for decision-making support. The notion of interface, especially studied in the field of *Human-Computer Interaction* (HCI), can be of that help in clarifying this problem because it sheds light on how to design cognitive artifacts able to shape and extend pre-existing cognitive capabilities – and even able to unearth new ones. Treating the problem of interface design will allow us to explore from an eco-cognitive perspective some of the major theoretical issues underlying the relationship between an agent and its environment.

The cognitive dimension of interface will be considered in the perspective of the notion of cognitive niche. From a theoretical perspective, an interface is a cognitive niche insofar as it selects those aspects of the environment relevant to carry out certain cognitive tasks. In this sense, we will define "designers" as eco-cognitive engineers.

In dealing with the exploitation of cognitive resources embedded in the environment, the notion of *affordance*, originally proposed by Gibson [4] to illustrate the hybrid character of visual perception is extremely relevant. More precisely, we will put forward an alternative conception of affordance based on the notion of abduction: we posit that an effective interface is the one that displays as much as possible those signs from which one can correctly infer what to do next. Within this framework, affordances are states of the world that prompt us to take certain actions rather then others.

Finally, in the last part of the paper we will present some examples from Human-Computer Interaction in order to show how our theoretical approach based on abduction and affordance can provide useful hints for interface design.

I. THE COGNITIVE RELEVANCE OF INTERFACE DESIGN

C.P. Snow pointed out that technology is a queer thing since its ambivalence. It can be a great gift on the one hand, but it can turn out to be irritating on the other. Computer programs, computational tools, cell phones, and all kind of technological stuff, enable us to accomplish a great array of things: calculating, organizing, drawing, writing, playing some instrument, etc.. All that is the great gift Snow talked about. However, carrying out all these activities is not costless. The computer (or our mobile) is not an oracle, that is "just ask, and you'll get back the answer"; we cannot tell a computer, "please, I need to send en email to a friend of mine" and it immediately opens our mail client and it chooses the most suitable layout for the email you are going to write. All these activities involve

[1]Nara and Ohsawa proposed the term "chance discovery" to point the attention to the various activities of extracting chances [2]. For instance, Abe at al. [3] usefully apply abduction to dynamic risk management in nursing, where rare chances (risks or accidents) can be abduced as novel generated hypotheses.

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being able to cope with technologies, and cognitive artifacts in general. Indeed, a tool or a computer program enhances our cognitive abilities, but that implies being able to know how to exploit their functionalities. Hence, the problem is concerned about how to design technologies so that humans can easily exploit their potentialities. How can we design products that can easily help humans accomplish different tasks?

From a general perspective, an interface is defined by the way we interact with an external object, what we do and how it responds [5]. This is a definition which allows us to place attention upon a very simple fact: an interface is not something given or an entirely predefined property, but it is the *interplay* that actually takes place when a product meets the users. More precisely an interface is that interaction that *mediates* the relation between the user and a tool explaining the approach we need to exploit its functions. Hence, an interface can be considered as a *mediating structure*. According to Hutchins [6], a mediating structure is a kind of *representation,* both internal and external, that changes the way a certain task can be carried out.

The question of interface design is not trivial and it is not related only to HCI. We know that external objects can be valuable aids to cognition, as they can easily extend our pre-existing capabilities and uncover valuable chances. Several cognitive scientists have shown how external artifacts shape our cognitive abilities. However, very few words have been spent about how to design those artifacts that can effectively overcome human limitations and extend human cognitive abilities. What are those principles we can fruitfully employ to detect latent cognitive chances?

II. Interfaces as cognitive niches

In order to shed light on the broader cognitive significance of interface design, the notion of cognitive niche turns out to be conceptually profitable. Our main take is that an interface is a cognitive niche. The notion of cognitive niche acknowledges the artificial nature of the environment humans live in, and their active part in shaping it with relation to their needs and purposes. It is within this context that we locate the theoretical issue of interface design.

As already mentioned above, the main theoretical issue involving interface design is that the various external artifacts and objects provide us with various resources. The distributed cognition approach is relevant to this point [6], [7], [8]: it explicitly acknowledges the mutuality between humans and their environment. According to this approach, it is the interaction between the two that provides humans with additional cognitive capabilities. Cognitive activities like, for instance, problem solving or decision-making, cannot only be regarded as internal processes that occur within the isolated brain. Through the process of niche creation humans extend their minds into the material world, exploiting various external resources. For "external resources" we mean everything that is not inside the human brain, and that could be of some help in the process of deciding, thinking about, or using something. Therefore, external resources can be artifacts, tools, objects, and so on. Problem solving activities, for example, are unthinkable without the process of connection between internal and external resources.

In other words, the exploitation of external resources is the process which allows the human cognitive system to be shaped by environmental (or contingency) elements. According to this statement, we may argue that detecting suitable cognitive chances play a pivotal role in almost any cognitive process. Here the notion of cognitive niche is of that theoretical importance: humans have at disposal a range of behavioral options insofar as they are merged into a network of *cognitive niches* [9], [10].

From an evolutionary perspective, the ubiquitous presence of the cognitive niches contribute to introducing a second and non-genetic inheritance system insofar as the modifications brought about on the environment persist, and so are passed on from generation to generation [11]. The main advantage of having a second inheritance system is that it enables humans to access a great variety of information and resources never personally experienced, resulting from the activity of previous generations [11]. That is, the information and knowledge humans can draw on are not simply transmitted, but they can also be accumulated in human niches. Indeed, the knowledge we are talking about embraces a great variety of resources including knowledge about nature, social organization, technology, the human body, and so on.

Now, the point we want to stress is that an interface can be considered as a cognitive niche in the sense that a part of our environment is appropriately manipulated to physically encode and store the changes made upon the environment itself. In turn, these changes become *cues* that can affect a certain reaction.

The mediation of an interface is as selective as that of a cognitive niche. In any cognitive niche the relevant aspects of local the environment are appropriately selected so as to turn the surroundings – inert from a cognitive point of view – into a mediating structure delivering suitable chances for behavior control [11]. The same can be said about the interface: it is selective insofar as it selects those aspects that are relevant to prompt the user a certain reaction, and selects out those which are ambiguous. In this sense, "designers" are eco-cognitive engineers.

More generally, we might claim that an interface mediates the relation between the user and a tool *affording* her or him to use it a certain way.[2] The kind of mediation involved here can be fruitfully investigated from a cognitive and epistemological point of view. More precisely we claim the process of mediating can be better understood when considered to be an inferential one.

III. The inferential nature of Human-Computer Interaction

We have already pointed out that an interface as a cognitive niche is a mediating structure. That is, it provides those cues

[2]We will be dealing with the notion of affordance in section IV.

which assist the agent by simplifying the representation task she faces. It is important to note that this mediating process is *inferential*. By the term "inferential" we do not refer to the sentential dimension typical of logic, rather to the semiotic one [12], [13]. Several researchers [14], [15] have pointed out that designing interface deals with displaying as many cues as possible from which the user can correctly and quickly *infer* what to do next. Shneiderman has suggested that the value of an interface should be measured in terms of its consistency, predictability and its controllability [16]. These are all to some extent epistemological values. But in which sense could an interaction be predictable or consistent?

Even if the inferential nature of such interactions is acknowledged, as of yet no model has been designed which takes it into account. How can understanding the inferential nature of human-computer interaction shed light on some theoretical issues concerning the activity of designing good interfaces?

Here the cognitive task required is twofold: first, investigating what kind of inference is involved in such an interaction. Second, explaining how the analysis of the nature of computer interaction as inferential can provide useful hints about how to design and evaluate inferences. In both cases we will consider the notion of abduction and the one of affordance as keystones of a broad cognitive model.

IV. The notion of affordance and its relevance for interface design

According to Gibson [4] a niche can be seen as a set of *affordances* appropriately designed to certain purposes. This is, indeed, implicit in the selective nature of interface design as a case of that cognitive niche construction we have treated in the previous section. Now, the notion of affordance may help us provide sound answers to the various questions that come up with the problem of interface. The notion of affordance is fundamental for two reasons. First of all, it defines the nature of the relationship between an agent and its environment, and the mutuality between them: affordance cuts across the subjective/objective frontier. Second, this notion may provide a general framework to illustrate humans as chance seekers.

The notion of affordance is highly controversial especially in its application to the Human-Computer Interaction [4], [17], [18]. Generally speaking, affordance is what the environment offers or furnishes in terms of action possibility [4], [19]. For instance, a chair affords sitting, stairs climbing, air breathing, and so on. Analogously, we may argue that an effective interface is the one that affords the user to use a device (a computer, a mobile, etc.) a certain way. Now, some questions immediately come up: is an affordance a property exhibited by the interface? Or a property humans project into it?

Gibson did not only provide clear examples, but also a list of definitions (cf. [20]) that may contribute to generating possible misunderstanding:

1) affordances are chances for action;
2) affordances are the values and meanings of things which can be directly perceived;
3) affordances are ecological facts;
4) affordances imply the mutuality of perceiver and environment.

More generally, we contend that the Gibsonian ecological perspective originally achieves two important results. First of all, human agencies are somehow hybrid, in the sense that they strongly rely on the environment and on what it offers. Secondly, Gibson provides a general framework about how organisms directly perceive objects and their affordances. His hypothesis is highly stimulating: "[...] the perceiving of an affordance is not a process of perceiving a value-free physical object [...] it is a process of perceiving a value-rich ecological object", and then, "physics may be value free, but ecology is not" [4, p. 140]. These two issues are related, although some authors seem to have disregarded their complementary nature. It is important here to clearly show how these two issues can be considered two faces of the same medal.

Having described an interface as a mediating structure can be helpful in dealing with the problem of affordance. Basically, we contend that an interface can be considered as a set of affordances, which are those suitably designed for accomplishing certain tasks rather than others. If an interface is what incorporates signs and cues from which the user infers what to do next, then an affordance can be considered that state of the world in which the cues and signs we can perceive are *highly diagnostic*. That is, the more cues and signs are diagnostic, the more affordances will be visible; the less affordances are visible, the more the interface will be poor (and therefore one's performance in interacting with a device). In order to explain the meaning of "highly diagnostic", the notion of abduction can provide an insightful framework.

V. Abduction, interface design, and affordance detection

Charles Sanders Peirce [21], more than one hundred years ago, pointed out that human performances are inferential and mediated by signs: here signs can be icons, indexes, but also conceptions, images and feelings. We have signs or cues, that can be icons, but also symbols, written words, from which certain conclusions are inferred.

According to Peirce all those performances that involve sign activities are abductions [21]. Abduction is the process of *inferring* certain facts and/or laws and hypotheses that render some sentences plausible, that *explain* or *discover* some (eventually new) phenomenon or observation; it is the process of reasoning in which explanatory hypotheses are formed and evaluated. There are two main epistemological meanings of the word abduction: 1) abduction that only generates "plausible" hypotheses ("selective" or "creative") and 2) abduction considered as inference "to the best explanation", which also evaluates hypotheses [12]. Consider for example the method of inquiring employed by detectives [22]: in this case we do not have direct experience of what we are taking about. Say, we did not see the murderer killing the victim. But we infer that *given* certain signs or cues, a *given* fact must have happened. More generally, we guess a hypothesis that imposes order on data. Analogously, we argue the mediation activity brought about by an interface is the same as that employed by detectives. Designers that want to make their interface more comprehensible must uncover evidence and clues from which the user is prompted to correctly infer the way detective does; this kind of inference, still explanatory, could be called *inference to the best interaction*.

We can conclude that how effective an interface is depends on how easily we can draw the *correct* inference. A detective can easily discover the murderer, if the murderer has left evidence (clues) from which the detective can infer that *person and only that person* could be guilty. According to the definition stated above the interaction is not simply the possible ones, but it is supposed to be *the best*. Thus, how *quickly* the user can infer what to do next is a central point. Sometimes finding the murderer is very difficult. It may require a great effort. More precisely, we may argue that how quick the process is depends on whether it is performed without an excessive amount of processing. If cues are clear and well displayed, the inference is promptly drawn. As Krug put it, it does not have to *make us think* [23].

In order to stress the connection between affordance and abduction, let us make an example. We can say that the fact that a chair affords sitting means we can perceive some cues (robustness, rigidity, flatness) from which a person can easily say "I can sit down". Now, suppose the same person has another object O. In this case, the person can only perceive its flatness. He/she does not know if it is rigid and robust, for instance. Anyway, he/she decides to sit down on it and he/she does that successfully.

Now, our point is that we should distinguish between the two cases: in the first one, the cues we come up with (flatness, robustness, rigidity) are *highly diagnostic* to know whether or not we can sit down on it, whereas in the second case we eventually decide to sit down, but we do not have any precise clue about. How many things are there that are flat, but one cannot sit down on? A nail head is flat, but it is not useful for sitting. This example further clarifies two important elements: firstly, finding/constructing affordances certainly deals with a (semiotic) inferential activity [24]; secondly, it stresses the relationship between an affordance and the information (the cues) that specify it that only arise in the *eco-cognitive interaction* between environment and organisms. In this last case the information is reached through a simple action, in other cases through action and complex manipulations.

VI. A CASE IN POINT: MIMICKING THE PHYSICAL WORLD WITHIN A DIGITAL ONE

Investigating the activity of designing interfaces from the "abductive" perspective described above helps designers mimic the physical world within a digital one to enhance understanding. What follows tries to make an example of the cognitive model we have described so far. Indeed, what we are going to illustrate is meant to be just a brief exemplification of the appeal our approach may have, if further developed. As far as we are concerned here, we limit our treatment to a few hints.

As we have previously seen, the local environment enables us to trigger inferential processes, namely, affordances, which, in turn, are grouped in various cognitive niches: the local environment becomes a cognitive niche if and only if it can embody and encode those signs through which one can infer what to do next. For example, if you are working in your office and you would appreciate a visit from one of your colleagues, you can just keep the door open. Otherwise you can keep it closed. In both cases the local environment encodes the clue (the door kept open or closed) from which your colleagues can infer whether you do or don't want to be disturbed. This can surely count as an activity of cognitive niche construction insofar as the local environment is modified to meet some users' needs. Here the questions we immediately come up with is: how can we encode those signs in a digital world? How can we enrich it so as to render it capable of embodying and encoding cues?

The question of how to enrich the digital world mainly concerns how to mimic some important features of the physical world in the digital one, and it counts as an eco-cognitive activity, in which designers selectively modify the local environment. Often common people refer to an interface as easy-to-use, because it is more intuitive. Therefore, we do not need to learn how the product actually works. We just analogically infer the actions we have to perform from ordinary ones. More generally, metaphors are important in interface design, because they relate digital objects to the objects in the physical world which the user is more familiar with.

In the history of computer interface many attempts have been brought about to replace some physical features in the digital world. For instance, replacing command-driven modes with windows was one of the most important insights in the history of technology and human-computer interaction [25]. It enabled users to think spatially, say, in terms of "*where* is what I am looking for?" and not in terms of "what sequence of letters do I type to call up this document?".

Enriching the digital world deals to some extent with "faking", transforming those features embedded in the physical world into illusions. For example, consider the rule of projection first invented by Filippo Brunelleschi and then developed by great painters like Leon Battista Alberti and Leonardo da Vinci. In Peircean terms, what these great painters did was to scatter those signs to create the illusion of three dimensional representations. It was a trick that exploited the inferential nature of visual construction [26].[3] In his *On Painting*, Leon Battista Alberti [29] devised a method to *simulate* a three-dimensional space.

Hence, the question is: how could we exploit inferential visual dimensions to enhance the interaction in the digital world? In the window metaphor we do not have rooms, edges, folders, just like in the physical world. They are, so to say, illusions, they are all produced by an inferential (abductive) activity of human perception analogously to what happens in smashing three to two dimensions. Here, we aim at showing

[3] About the inferential role of perception, see [27] and [28].

how visual and spatial abductive dimensions can be fruitfully implemented in an interface just as a case in point. Roughly speaking, we argue that *enriching digital world* precisely means scattering clues and signs that in some extension *fake* spatial and visual dimensions – even if that just happens within a flat environment.

A. *Visual abduction*

Visual dimension is certainly one of the most ubiquitous features in web interaction. Users mainly interact with web pages *visually* [15], [30]. Here signs and clues are colors, text size, dotted line, text format (bold, underline, italics): they convey visual representations and can assign weight and importance to some specific part. Consider for example the navigation menu in the figure below:

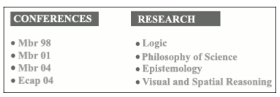

Fig. 1. Visual abduction

Here, colors, capital letters and text size provide visual clues capable of enhancing the processing of information. The attention is immediately drawn by the menu header that represents its content (conference and research); capital letters and the colors serve this function.

Then, the dotted list of the same color of the menu header informs the user about the number of the items. Hence, the fact that items are not visibly marked as menu headers gives a useful overview (Figure 2). Once the user has chosen what to see (conference or research), she can proceed to check each item according to her preference (Figure 3).

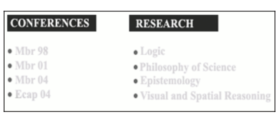

Fig. 2.

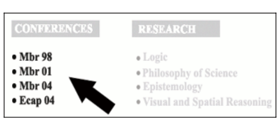

Fig. 3.

In this example the user is guided to draw the correct inference: it enables her to *understand* what she could consult.

In contrast, consider for example the same content represented as in Figure 4.

In this case, even if the content is identical the user does not have any visual clue to understand what she is going to consult. She should read all the items to infer and, hence, understand that she could know something about past and future conferences and about the research topics. If one stopped her reading after the third item (MBR04), she couldn't infer that this page also deals with philosophy of science, with epistemology, and so on. She does not have enough clues to infer that. In contrast, in the first example the user is immediately informed that this website contains information about conferences and research.

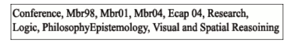

Fig. 4.

B. *Spatial abduction*

As mentioned above, the windows metaphor is certainly one of the most important insights in the history of interface technology. This is due to the fact that, as Johnson maintains, it enables the user to think in terms of "*where* is what I am looking for?" and not in terms of "what sequence of letters do I type to call up this document?", as in a command line system [25]. The computer becomes a space where one can move through just double-clicking on folders or icons, or dragging them. The difference is well described in Figure 5 and Figure 6.

In the first figure (Figure 5), the file named "note.doc" is deleted by *dragging* it to the bin: say, the task of deleting is accomplished by a movement analogous to that used in the physical setting. Whereas, in the second figure (Figure 6) the task is carried out by *typing* a command line composed by the command itself ("rm", that stands for "remove") and the file to be deleted ("note.doc").

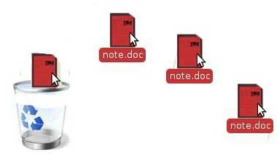

Fig. 5.

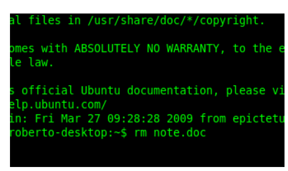

Fig. 6.

In designing web pages, spatial dimension can be mimicked in other ways. One of the most well known examples is represented by the so called *tab*. Tabs are usually employed in the real world to keep trace of something important, to divide whatever they stick out of into a section, or to make it easy to open [23]. In a web site, tabs turn out to be very important navigation clues. Browsing a web site users often find themselves lost. This happens especially when the web pages they are consulting do not provide spatial clues from which the user can easily infer where she is. For instance, several websites change their layout almost in every page: even if provided by a navigation menu, they are not helpful at all. In contrast, tabs enhance spatial inference in one important respect.

Consider the navigation bar represented in Figure 7. In this example, when the user is visiting a certain page, for example, the homepage (Figure 7.A), the correspondent tab in the navigation bar becomes as the same color as the body page. As Krug noted, this creates the illusion that the active tab actually moves to the front [23]. Therefore, the user can immediately infer where she is by exploiting spatial relations in terms of background-foreground.

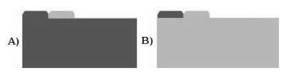

Fig. 7. The tabs.

VII. Conclusion

In this article we have tried to shed light on the notion of interface from a broad cognitive perspective. More precisely, we have been exploring some theoretical issues underlying interface design.

First of all, we have pointed out that an interface can be considered as a cognitive niche. Just like the case of a cognitive niche, an interface involves a selective activity, in which the local environment is modified in order to detect those clues from which the user can correctly infer how to cope with a product.

We have then illustrated how this selective activity aims at affording the user to facilitate the accomplishment of certain tasks exploiting the various chances offered by the local environment. In this sense, an interface can be considered a set of affordances, which have been suitably designed for accomplishing certain tasks rather than others.

The process of affordance detection has been described in abductive terms. Taking advantage of the broader "semiotic" aspects of abduction, we have argued that a good interface is the one that displays the clues from which the user is prompted to correctly infer how to cope with a product. We called this kind of inference, still explanatory, *inference to the best interaction*, which is thought to be at the basis of the process of affordance detection.

In the last part of the paper we have provided a number of examples to show how the approach described can be suitably applied to web interfaces design.

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