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Designers know the human brain

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Abstract
Huge amounts of information are increasingly being created and shared from various platforms with georeference playing a popular role. New and effective ways to manage and understand information are needed in order to deal with this growing complexity. Graphic and interface design can help. With roots in research on visual perception, the role of visualization is to ease the understanding and managing of complex information. In later work, we presented and applied a set of graphic and interface design fundamentals as hints to the representation of spatiotemporal information. We now support them on perception and cognition through the way the mind works.

Keywords
Graphic design; interface design; mind; perception; cognition; information; interaction

Los diseñadores conocen el cerebro humano

Resumen
Enormes cantidades de información son creados desde diferentes plataformas y los sistemas de coordenadas juega un papel popular. Se necesitan formas nuevas y potentes de comprender la información para hacer frente a esta creciente complejidad. El diseño gráfico puede ayudar. La visualización tiene sus raíces en la investigación de la percepción visual, manteniendo una estrecha relación con la mente humana. En trabajos anteriores aplicamos fundamentos de diseño como sugerencias para la representación de información espacio-temporal. Ahora nuestro objetivo es apoyar esos principios sobre la percepción y la cognición humana, generando conciencia sobre el modo en que funciona la mente.

Palabras clave
Diseño gráfico; diseño de interfaz; mente; percepción; cognición; información; interacción.

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Large amounts of information are increasingly being created and shared from different platforms and devices supporting georeference as a form to further enrich their context in time and space. This highlights the need for new, and powerful ways to access, manage and understand information. Therefore, intuitive and ludic graphic aids are needed in order to help dealing with this complexity.

Visualization started to mean the construction of an image in the mind but is now commonly related to the representation of data and concepts within the graphic design (Tufte, 1990) and graphic user interface (Shneiderman et al., 2009) fields. Considered within the Human-Computer Interaction domain for a long time, the role of the designer is now undisputed. With roots in research on visual perception and cognition, visualization holds a close relation to the mind (Few, 2009) with scientists and algorithms giving place to graphic and interface designers as "applied behavioural scientists" (Meyer & Norman, 2020), generating visual materials that meet the needs and abilities of people (Frascara & Noel, 2012).

It is stated that visualization makes information clear and eases the managing of large amounts of data, allows the discovery of properties, enables the immediate acknowledgement of problems, allows the identification of patterns, and facilitates the formation of hypotheses, thoughts and concerns about the information (Ware, 2012, p.4). The mind is compelled by a graphic representation not only in the process of understanding it but when managing it towards a goal.

In previous work, a set of design fundamentals were addressed as hints to represent spatio-temporal data [n]. The present goal is to shed light on human perception and cognition as the essential features that make those fundamentals effective. Only by acknowledging the way the mind works the designer can effectively design for people. Our approach goes from 1) the human ability to create schemas and mental models as facilitators to understand what we see; 2) memory, which constrains the way people react and manage the information; 3) image as code to information through the metaphors that allow people to best retain meaning from the observed world; 4) gestalt laws as the perceptive essentials of the way we 'read' a composition; 5) aesthetics, through the advantages that beauty brings to the understanding; and 6) the seeking for information through the various ways people use to search for information.

Perception and reasoning through schemas

I am not sure we are ever quite sufficiently surprised at our capacity to read images, that is, to decipher the cryptograms of art (Gombrich, 2000)

The most distinctive property of the brain is its ability to create maps. The human brain maps things, actions and relations among objects outside itself, and in the body that holds them. An analogy for a better understanding of the way the brain creates visual maps is in the electronic billboard, constituted by a pattern that is drawn by the active or inactive highlighted elements, whose state is easily and rapidly changed through the simple redistribution of those elements. The reception of visual information is done by the retina, "an elaborate outpost of the brain" (Damásio, 2010, p. 55) composed of a grid, ready to receive those maps. According to Damásio, the particles of light (photons) reach the retina with a specific distribution, making a pattern that activates the neurons that constitute a temporary neural map. Afterwards, additional maps from the original one are built by the retina in the nervous system (p.58), going from simple to complex perceptive patterns (Arnheim, 1974).

The process of the mind is a flux of images corresponding some of them to the outside world that is being observed, while others are mental (Damásio 2010, p.60). Both external and internal images are equivalent (Gombrich, 2000, p.84; Burnett, 2005) since they all start inside the brain and are constructed either when we are intending to act, or when we are acting already by the "mind's theoretical eye" (Flusser, 1999, p.24). These images are schematic representations that we create and that enable us to make visual concepts in order to recognize patterns of information (Gombrich, 2000).

Schemas represent the shape of an object by its fundamental characteristics (Arnheim 1974, p.40). Humans have the ability to interpret and test the clues gathered through experience from the outside world and recognize these configurations (Gombrich, 2000, p. 276) (Figure 1). We understand and are able to identify integrated patterns only, e.g., we apprehend a human face as a whole pattern composed of components such as the nose or the mouth. If we decide to focus on someone's eye, we are again confronted with another total pattern composed of the circular iris surrounded by ciliated eyelids, and so forth. If we lose the context of each part in the whole, all parts will lose their meaning (Arnheim, 1974, p.78) since we expect to be presented with a specific sign situation, and prepare to cope with it (Gombrich, 2000, p.53). If a result deviates from what we consider possible, we revise our hypotheses and test them against a more accurate observation (p.272).

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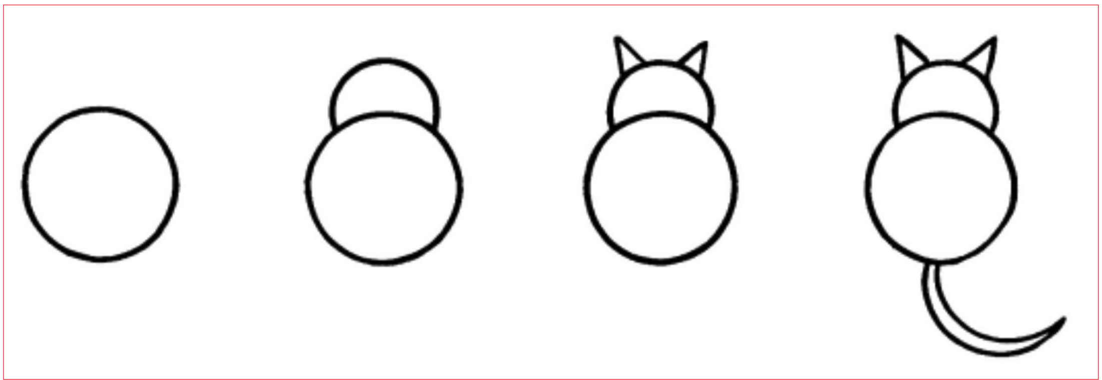

Figure 1. Schema: how to draw a cat (Gombrich, 2000, p. 7)

After capturing the structural shape of the object by sight, perceptive concepts are built in the mind through the maps that constitute memories. This mapping, - functional and useful for the managing of everyday life -, can detect the presence of an object in space as well as locate it, or give its trajectory direction being these situations useful when assessing opportunities and risks (Damásio, 2010, p.55). These perceptive concepts, or mental models, have the power to provide a predictive and explanatory understanding of the interaction between us and the world (Norman, 2013, p. 46).

Susan Carey (1986) states that mental models are "incomplete facts, past experiences, and even intuitive perceptions" that help shape actions and behaviour, influencing what people pay attention to, and how people approach and solve problems (Weinschenk, 2011). Toward design, the representation of something a person has in mind, e.g., a device interface, appears from past experience with the device or assumptions made about it, predicting what it is going to do relating to their expectations (p.73).

After being aware of the mental model of the user, the designer is able to apply it to the conceptual model of the system in a way that its use is more natural and intuitive. A good conceptual model allows people to figure out errors and correct them, being key to understandable and enjoyable products (Norman, 2013, p.32). If there is a mismatch between the person's mental model and the product conceptual model, then the e.g. device or website will be hard to learn (Weinschenk, 2011, p.73). It is therefore important to consider going according to the user's expectations for confusion and disorientation not to be experienced (Apple, 2015).

Mental models are not either accurate or complete and evolve naturally, depending on the past interactions of the user. Memory plays here a crucial role. Our ability to see and hear what is no longer there by memory, by projection (Gombrich, 2000, p.172) is well known. Damásio (2010, p.224) suggests that we were born already with certain connection patterns arranged according to the instructions of our genes. According to the author, after we are born our personal experiences act on those connection patterns. From here, earlier phases overlap in the mind being recalled when needed (Benzon & Hays, 2006; Gombrich, 2000, p.87), "the greater the biological relevance an object has to us, the more will we be attuned to its recognition" (Gombrich, 2000, p.51).

Memory

People understand and remember depending on past experience and choose strategies that help memory, e.g., by "chunking" information together into groups instead of remembering many separate numerals (Baddeley et al., 2019). In order to characterize memory, (Norman, 2013, pp. 92–97) adapts Baddeley's (2002) model and separates it into two major types: i) Short-Term or Working Memory, which retains little amounts information that are automatically retrieved without effort and is very useful when performing everyday tasks; and ii) Long-Term Memory, retained from past experiences it takes time for information to be memorized.

When relating memory with cognition i.e. the retrieve of knowledge, people use (p.98) i) Memory for Arbitrary Things which has no structure and allows people to retain items with no relation to each other and to previous knowledge; and ii) Memory for Meaningful Things, that relates items among each other and among acknowledged things. From here, cognitive and emotional pro-

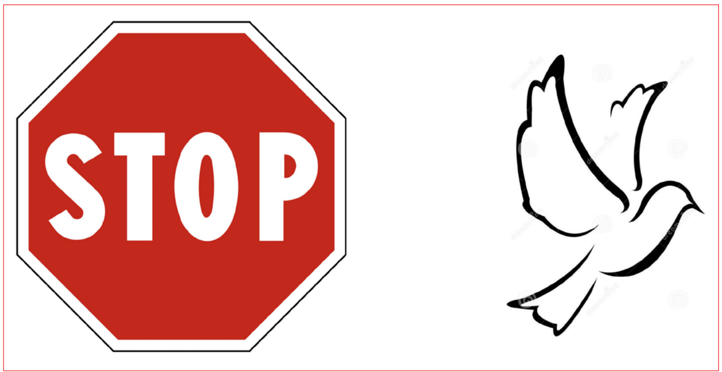

Figure 2. Symbols. Sensory (on the left); arbitrary (on the right)

cesses work together in the brain on three different levels providing an idea about the way people behave (pp.49–54):

- Visceral Level: related to the immediate perception, it is associated with the subconscious being "all about attraction or repulsion";
- Behavioural Level: connected with learned skills and thus subconscious, it is the most important level to assign positive results toward the person's expectations;
- Reflective Level: belonging to the conscious level of cognition, it is where the person makes decisions through reasoning, and the level that drives them to recommend e.g. a device to use, or to avoid.

The three levels of perception work in synchrony, shaping the response of the person in future performances. "Reflective memories are often more important than reality" (p.53), i.e., one might start by having a great experience in the visceral level of perception and end up having problems when performing the task. The first emotional impact might override the latter since "attractive things work better". On the other hand, the difficulties can also influence the final judgement of the user. The first impression is the one that designers hope wins, though.

Interface images function as core elements in the design. They are tools that function as the codes that enable the person to manage information.

Image as code for information

The science of signs originated in the 1920s prompted by the idea of being possible to create visual communication according to scientific principles. The aim was to understand communication between humans and machines. Gombrich (2000) relates the act of reading pictures with the deciphering of a code through the send-receive message process and highlights the role of the beholder in interpreting the message, i.e., in 'supplementing' the partial information given the fact that all representative images are 'incomplete'.

The study of symbols evolved in two perspectives and although there is not a distinctive border separating them, they can be described as following:

- Sensory symbols (Fig. 2, on the left) are designed to stimulate the visual sensory system. They are effective because they match neural processing (e.g., it is common sense to consider a circle as representing a bounded region) (Ware, 2012, p.12);
- Arbitrary symbols (Fig. 2, on the right) obey conventions created by culture and are therefore dependent on the person's awareness of the image context (p.7) (e.g. a flag implies the memorization of that specific code to be understood).

As learned, the latter "will tend to get weaker and weaker if some significant degree of co-occurrence of stimuli is not maintained" (Deacon, 1997, p.68). Ware (p.15) highlights the importance of those though, often created by designers through "perceptually valid forms" e.g., signs for airport procedures concern shapes and colours that function as aids and although being built from conventions, they are based on perceptual skills. Most representations are hybrids (p.12). Whether referring to sensory or arbitrary symbols, they function as metaphors by standing for something other than themselves as "a matter of thought" (George, 1998, p.202). Lakoff and Johnson (1980) conceptualize metaphor as an embodied phenomenon belonging to the physical realm, i.e., grounded in bodily experience. They relate it with Gestalt in the way that it is understood through the perception of the world (e.g., 'more' is 'up').

Gestalt fundamentals

> *"In the essay that gave Gestalt theory its name, Christian von Ehrenfels pointed out that if each of twelve observers listened to one of the twelve tones of a melody, the sum of their experiences would not correspond to the experience of someone listening to the whole melody" (Arnheim, 1974).*

Many assumptions related to the way we perceive objects in composition were retrieved from the Gestalt theory (Arnheim, 1974; Gombrich, 2000),

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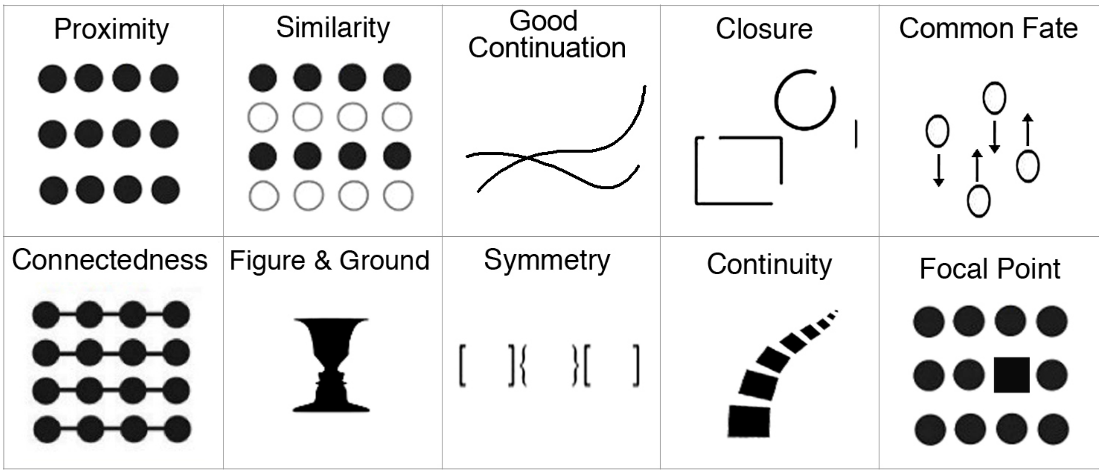

Figure 3. Gestalt laws

a body of scientific principles that derived mainly from experiments in sensory perception (Arnheim, 1974, p.4) that explored relations, interactions, organization and structure among the elements of composition (Sabar, 2013).

According to the theory, the human visual system organizes visual information by grouping the elements in a way that they constitute a whole. Relations and interactions among parts "form and are formed by the organization and structure of the whole, i.e., the Gestalt" (Sabar, 2013). We describe the most relevant Gestalt laws being the first six specifically related to the grouping of elements (Figure 3):

- Proximity: the observer relates to and understands as a group the items that are near each other (Smith-Gratto & Fisher, 1999);
- Similarity: the observer relates and understands as a group the items that are similar to each other (idem);
- Good Continuation: perception tends to group objects with contours that form either a straight or curved line (Galotti, 2013, p.43);
- Closure: an incomplete shape of a well-structured pattern is closed by the eye (Arnheim, 1974);
- Common Fate: elements that are moving together are perceived as being together (Galotti, 2013, p.43):
- Connectedness: considered the most fundamental grouping principle by Smith (2007) refers to the tendency of vision to perceive uniform and connected regions as singular units;
- Figure-ground: foreground and background recognition is a perceptive tendency. Flat two-dimensional pictures do not exist (Arnheim, 1974);
- Symmetry: the mind perceives visual elements as being symmetrical and around a centre point. Perceptually, dividing objects into an even number of symmetrical elements is pleasant for the eye (Soegaard, 2010), and light for memory (Karlsen et al, 2010);
- Continuity: human eye instinctively follows a direction from its visual field (Chang et al., 2002);
- Focal Point: this place in the composition is automatically focused on as being the main "point of emphasis" (Chang et al., 2002).

Effectiveness in the understanding of information is fostered by design that relies on the way the user perceives information, i.e., the Gestalt principles.

The role of aesthetics

"Design choices influence perceptions, elicit different responses and affect a person's ability to complete a task. When we talk about a button or a typeface, the focus should be on the effect of these objects, not the objects themselves. This is the domain of aesthetics" (Anderson, 2011).

It is common sense to define aesthetics as something beautiful and pleasant for the eyes. It is concerned with the theories of sensual perception (Gaviria (2008) and central to the design of artefacts. Imprinted in the information culture in which we live, Lev Manovich (2008) designates it 'info-aesthetics' i) the reflection of the way we live and the objects we use; ii) the way we communicate and interact; iii) in visual conventions (e.g., icons and folders); iv) in the particulars of the media (e.g., shape, material, and texture of a mobile phone); and v) in the fact that these devices are part of people's lives. Thought about and related to information, aesthetics reflect the informationalization (Domingues, 1997; Giannetti, 2005; Manovich, 2008; Sack, 2011; Salem & Rauterberg, 2005; Tufte, 2006), that puts pressure on society "to invent new ways to interact with information, new ways to make sense of it, and new ways to represent it" (Manovich, 2008).

More and more attention is being given to aesthetics considered capable to captivate the person's attention (Gaviria, 2008) and fostering engagement. The way people feel influences the use of a device (Norman, 2005) in the idea that "effective is often affective" (Mackinlay & Winslow, 2009). Aesthetics prompts the intention to start using e.g the device (Kurosu & Kashimura, 1995) and motivates the person to spend more time with it, while being more forgiving when errors occur (Moere & Purchase, 2011).

The simplicity of Apple design is the paradigm that characterizes the aesthetical trend that shapes the design of today. Although important to achieve, the designer must have in mind that complexity is a value (Maeda, 2006) and that the omission of elements in the composition might turn a shape into a more complicated element (Arnheim, 1974, p. 145). The idea is to defend complexity because things that are too simple are viewed as dull and uneventful. John Maeda (2006) explores the idea of improvement through ten simplification principles:

1) Reduce: Shrink, Hide and Embody elements in the composition;
2) Organize: when well organized many elements appear fewer;
3) Time: saving time feels simpler;
4) Learn: knowledge of the system simplifies tasks;
5) Differences: the duality between simplicity and complexity is needed;
6) Context: periphery is not to be neglected;
7) Emotion: the more emotions the user can feel, the best; 8) Trust; simplicity reflects trust;
8) Trust; simplicity reflects trust.
9) Failure: some things are not to be made simple;
10)The one: take out the obvious and add the meaningful.

Simplicity is related to memory for it prevents the short-term memory load. The real challenge is to tame complexity e.g., the cockpit of a plane is not complex for the pilot but it is very complex for other people (Norman, 2005, p. 4). The balance between function and aesthetics must be preserved.

The seeking for information

> *"Imagine a predator, such as a bird of prey, that faces the recurrent problem of deciding what to eat, and we assume that its fitness, in terms of reproductive success, is dependent on energy intake. (…) For the bird of prey, this means that the different habitats or prey will have different access or navigation costs" (Pirolli & Card, 1999).*

Pirolli and Card (1999) consider the seeking, gathering, sharing, and consuming of information by humans as a cultural task, which takes Hantula (2010) to characterize us as species as "informavores". According to the author, people need "increasingly sophisticated information-gathering, sense-making, decision-making, and problem-solving strategies" and therefore, they alter procedures e.g. modifying the strategy or the interface to enhance the finding of information. People choose designs that improve returns of information.

Grounded in the horizontal-vertical mental model from Bono (1990), Marchionini (2006) characterizes the ways of finding information as disclosed next (Figure 4):

- Lookup, related to vertical thinking as a logical, goal-oriented, selective, and utilitarian establishing of the simplest path towards the problem solving;
- Learn Search, enhanced by lateral thinking and happens in a search by neighbour¬hood of interest, by comparison, comprehension and interpretation; and
- Investigate, enhanced by lateral thinking and aiming in the evaluation of the results and accuracy.

Learn and Investigate constitute the Exploratory Search and is considered an enhancer for insights, i.e., *serendipity* discoveries. It is a generative and indirect way of finding information and promotes diverse thinking, the jumping from reference to reference, following ways that look misleading; and the changing the theme while searching (Bono, 1990).

Lookup is a "turn-taking" with the user seeking information through a query which implies a process in which "human and system take turns in retrieving the best result"(Marchionini, 2006). Learn and Investigate search implies more time spent in the search requiring more participation from the user toward exploration.

According to this concept, people alter their search procedures by modifying either the strategy or the structure of the interface in order to

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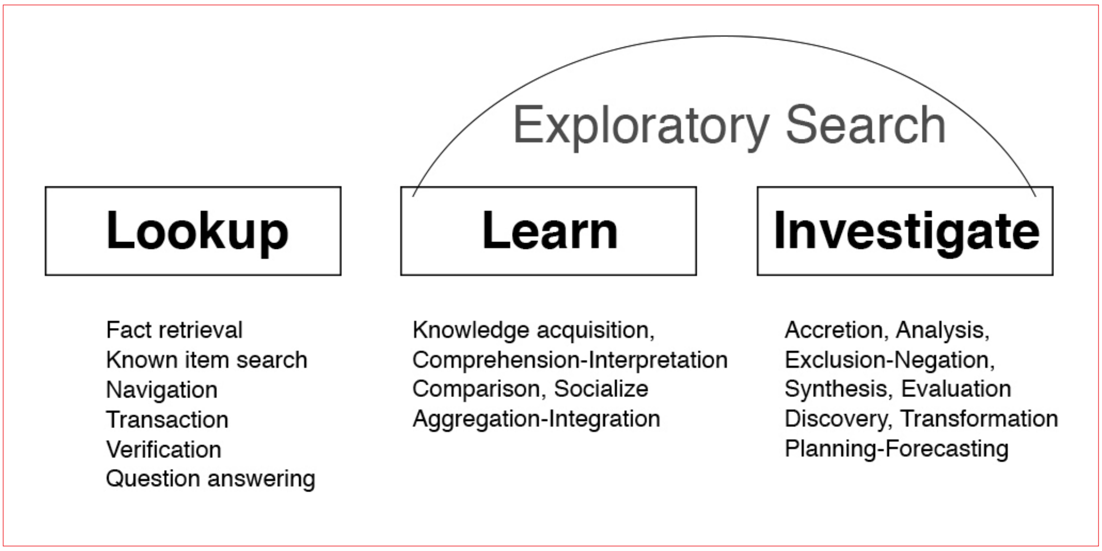

Figure 4. Browsing Activities (Marchionini, 2006)

enhance the finding of information. Due to the amount of information available, the author sees the allocation of attention as a core problem of both information gathering and sense-making. This theory highlights the layout structure as an important player in the role of enhancing the process of retrieving information.

Conclusion

After setting and applying the graphical fundamentals that should guide the design of spatio-temporal information, we disclosed the perceptive features that both support and allow those principles to be effective. We focused on the way schemas and mental models ease the understanding of what is presented to us; memory, that constrains perception and cognition through experience; images as codes through the metaphors that enhance speed recognition; Gestalt laws in the way the elements of the composition are perceived and understood by people; the role of aesthetics in bringing clarity and emotional impact to the process of both engaging and understanding information; the more direct or indirect way of seeking for information depending on both the goal and the person's mind. While aware of the limitations of the present study, we hope to have contributed to effective graphic and interface design through the awareness of the way the human mind works. In the future, we intend to complement the present study with Artificial Intelligence regarding the challenge it presents to the human brain. By accelerating the process, both human perception and cognition are called to change the way they identify, apprehend and perform within the system.

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