

# Using Dyslexia to Explore the Cognitive Characteristics of Illustrations and Text; Using Illustrations and Text to Explore the Cognitive Characteristics of Dyslexia

Peter Coppin  
Faculty of Information  
University of Toronto  
140 St. George St.

Toronto, Ontario, Canada  
petercoppin@gmail.com

## ABSTRACT

Our information presentations reflect how we think and remember. For example, some people create ideas through concept maps or sketches, while some people use writing. *How are ideas presented and/or conceived differently through graphic illustrations relative to text?*

Dyslexia serves as a natural laboratory to explore this question because the characteristics of a “disability” expose the characteristic of *ability*. Dyslexic strengths and weaknesses act as independent variables that enable us to explore the cognitive characteristics of illustrated and text presentations. By extending other studies, we conclude that illustrated presentations are more effective for peripheral vision (relative to text), and are useful for visual comparison. Text presentations may be more effective for foveal (center of) vision (relative to illustrations), which is useful for detecting sequential visual processes.

Illustrated and text presentations can also act as independent variables that enable us to explore the cognitive characteristics of dyslexia. I will speculate about causes for increased creative abilities in dyslexics by connecting “wide-angle” perceptual abilities to mental imagery and concept formation.

Finally, I discuss illustrated and text oriented information presentations within the context of these conjectures.

## Categories and Subject Descriptors

H.5.2 [Information Interfaces and Representation (HCI) (D.2.2, H.1.2, I.3.6)]: User Interfaces - Ergonomics, Screen Design, Theory and Methods.

## General Terms

Measurement, Performance, Design, Experimentation, Human Factors, Standardization, Languages, Theory.

## Keywords

Dyslexia, cognition, mental imagery, visual thinking, graphic illustration, visual reasoning, visual representation

## 1 INTRODUCTION

Our information presentations reflect how we think and remember. For example, I might write a paragraph to represent one kind of phenomena and I might create a map to represent a different kind of phenomena. Also, how *different* people represent the *same* phenomena *differently* externalizes the diversity of cognitive strategies used by individuals. For example, one person might represent directions as a list, while another person might represent directions by drawing a map. This same diversity appears to apply to idea generation; some people create ideas through concept maps or sketches, while

some people use writing. These differences raise the question: *how are ideas presented and/or conceived differently through graphic illustrations relative to text?*

Dyslexia serves as a natural laboratory to explore this question because observing the characteristics of a *disability* exposes the characteristic of *ability*. Reportedly, dyslexics have slower than average reading ability (extreme cases are also referred to as “text blindness”), but also have above-average visual-spatial (Károlyia et al., 2003) and creative abilities (Everatt et al., 1999). Indeed, Schneps (2007) described how dyslexic astronomers were able to spot patterns in images that were invisible to others. Exploring the cognitive characteristics of dyslexics and the characteristics of their interactions with illustrated and text-based presentations could reveal cognitive characteristics of illustrations<sup>1</sup>, text (and dyslexia). A roadmap for this paper follows:

- First, I will describe how dyslexic strengths and weaknesses act as independent variables that enable us to explore the cognitive characteristics of illustrated and text presentations.
  - I will explain how this shows us that illustrated presentations (relative to text) may be more effective for peripheral vision, which is useful for contemporaneous comparative processes (i.e. such as comparing patterns in an image).
  - I will describe how text presentations (relative to illustrations) may be optimized for the foveal (center of) vision, which is useful for temporal sequential visual processes (i.e. reading and visual search).
- Next, the paper will switch gears by describing how illustrated and text presentations can act as independent variables that enable us to explore the cognitive characteristics of dyslexia.
  - I will speculate about causes for increased creative abilities in dyslexics by connecting perception to mental imagery and concept formation.
- Finally, I discuss illustrated and text oriented information presentations within the context of these conjectures.

---

<sup>1</sup> This work is currently distinct from the highly cited *Cognitive Dimensions of Notations* framework (Blackwell, 2006), although connections to those highly useful tools will be pursued in later publications.

## 2 USING DYSLEXIA TO UNDERSTAND THE PROPERTIES OF ILLUSTRATIONS AND TEXT

### 2.1 Dyslexia: Traditional Perspectives

Dyslexia and Learning Disabilities (LD) are interrelated terms that are extremely difficult to define, but both roughly refer to below-average reading speeds, poor attention, difficulty with sequencing tasks, disorganization, and low working memory. There is no correlation between dyslexia/LD and intelligence (Swanson, 2004). However, within at least a certain subset of the population, there appears to be a correlation between dyslexia and visual high visual-spatial ability (Károlyia et al., 2003). There also appears to be a correlation between dyslexia and creativity (Everatt et al., 1999).

More studies have focused on lexical (reading) difficulties in dyslexics than potential strengths in other areas, however, the few recent studies indicate that the “cognitive phenotype” associated with dyslexia and LD could be viewed as a “non-standard” set of strengths and complementary weaknesses that are useful (or not) relevant to a task (Schneps, 2007).

### 2.2 Dyslexia and Newer Discoveries: Discovering Visual-Spatial Strengths

Schneps (2007) proposes that above-average visual-spatial abilities in dyslexics are attributed to an ability to compare patterns within a wider field of view relative to non-dyslexics. Schneps calls this a “parameter-to-center ratio” (PCR). For example, Grosser and Spafford (1989, 1990) reported that non-dyslexics average a PCR of ~10-20 degrees eccentricity along

To use a metaphor, peripheral visual perception is like a wide-angle panoramic lens that enables the visual comparison of features in a scene. Center perception is like a narrow-angle microscopic lens that shows each detail in that scene at extremely high resolution but at the expense of showing few surrounding details. If we are limited to a given number of pixels for each lens, then each feature in the wide-angle lens will be lower resolution, and the microscopic lens would show a feature in high resolution, but with a more limited number of features due to the narrow field of view.

At a risk of over generalizing, we could call these “center perceivers” and “wide-angle” perceivers. Many people may be “medium-angle” perceivers.

### 2.3 Using Dyslexia to Expose the Properties of Text and Illustrations

From our inquiry thus far, we already have our first clues regarding perceptual differences between pictures and prose. Text is optimized for the higher-resolution sequential scanning tasks associated with center vision. Illustrations (relative to text) appear more effective for visual comparison tasks associated with peripheral vision.

Illustrations may be more effective for comparisons between different patterns. Text might be more effective for “burrowing down” into the detailed characteristics of a specific pattern (and in isolation from other patterns). As a professional graphic

the horizontal meridian, and dyslexics average a PCR of ~40-60 degrees.

This increased ability coincided with decreased acuity in the fovea (center of vision). Not surprisingly, decreased foveal visual acuity is presumably the cause for their reading problems because text appears more effective for center sequential scanning tasks (relative to illustrations).

Since the optic nerve has a limited bandwidth, it makes intuitive sense that there would be a trade-off between high foveal perception ability and wide-angle perceptual ability.

#### 2.2.1 A visual thinking perspective to explain the strengths and weaknesses of dyslexia

Stimuli gained through the retina are transferred through the optic nerve to a brain region called “V1,” that is described as a “projection screen for the brain” because retinal stimuli maps to V1. Retinal structures and V1 contain similar geometric properties where the center/foveal regions of both are densely packed with detectors relative to regions adjacent to the center/foveal region that are much less densely packed (lower resolution but over a broader surface area) as shown in Figure 1.

The important thing to remember for this paper is that center/foveal regions are an extremely narrow field of view, but extremely high resolution. Conversely, the peripheral areas adjacent to the foveal/center of vision cover a broader area, but at a much lower resolution.

**Figure 1. Center-view perceivers (left) and wide-angle perceivers (right).**

facilitator<sup>2</sup> recently remarked: “the purpose of this illustration (while pointing to it) is to create a map of what was said during the meeting.” One could imagine ways that an illustration could serve as an overview to show how parts of an idea are interconnected, while text could explain the details of each part of the idea.

A more detailed review of the literature that explains the interplay between center and peripheral vision in human perception could guide how we use illustrations and text together to convey patterns that trigger complex ideas in viewers.

The smart thing to do would be to end the paper here by jumping straight to Section 4. “*Implications for Information Presentations.*” However, by turning our investigation on its head *by using illustrations and text to explore the characteristics of dyslexia*, we have a way to explore possible interconnections between wide-angle perceptual abilities, visual-spatial information, and creativity.

---

<sup>2</sup> Graphic facilitators use sketching and other brainstorming techniques in corporate and non-profit environments to facilitate problem solving in groups. An example of this practice is described in Roam (2008).

### 3 REVERSING OUR OPTICS: USING ILLUSTRATIONS AND TEXT TO EXPLORE DYSLEXIA AND CREATIVITY

Now that we have used dyslexia to explore the properties of illustrations, we will now turn our attention to using illustrations and text to explore the properties of dyslexia and cognition.

*Why do dyslexics demonstrate above average so called "lateral thinking," "divergent thinking," or creative abilities?* Creativity means more than an ability to make connections between patterns in pictures. Creativity is an ability to make connections between concepts, often in order to create new concepts. Many of these concepts are non-visual.

Heilman et al. (2003) defined creativity as "the ability to understand and express novel orderly relationships." Heilman proposed that many factors, such as intelligence, were required for creativity, but that intelligence alone was not enough, saying "creative innovation might require the coactivation and communication between regions of the brain that ordinarily are not strongly connected."

*Could there be a connection between peripheral vision and creative ability?* **What I will propose is the conjecture that wide-angle perceptual abilities may lead to an increased ability to communicate among regions of the brain that ordinarily are not strongly connected in center-view perceivers.** The reason to propose a relationship between wide-angle perception and increased creativity is that (1) cited evidence (Schneps, 2007) in this paper supports the connection between dyslexia, peripheral vision, and visual-spatial ability (at least within a subset of the dyslexic population), and (2) evidence shows that dyslexics have above-average creative abilities (Everatt et al., 1999). Though correlation does not prove causation, the correlation begs for theories that explain a causal link between wide-angle perceptual ability and increased creativity.

#### 3.1 Mental Imagery and Creativity

To support the conjecture that wide-angle perceptual abilities may increase communication between regions of the brain, we will first address what we will call *wide-angle mental imagery*.

Kosslyn and Pomeranz (1977) suggest that *mental imagery* is constructed using the same neurological machinery used to perceive *perceptual/external imagery*. "*These phantom images are constructed in the spatial neural maps that represent the visual field in other areas of the visual cortex, forming an internal sketch that is processed at higher levels, much the same way that external imagery is processed.*" (Ware, 2008, p. 110, quoting Kosslyn, and Pomeranz, 1977).

One can experientially test this theory. Imagining a scene is easier with your eyes closed rather than open. Removing a flow of external visual information reduces distracting visual "noise," enabling a clearer mental picture. When imagining a moving scene, eyes track the imagined objects (you can try this experiment yourself by closing your eyes and imaging an object [i.e. a plane or car moving past]). Laeng and Teodorescu (2002) demonstrated the relationship between mental imagery and eye movements, thus supporting Kosslyn's theory.

Since (as Kosslyn proposes) (1) mental images are constructed in the same spatial neural maps used for perception of external

stimuli, and (2) Schneps demonstrated that wide-angle perceivers have increased visual-spatial ability, we can (3) suggest that mental images for wide-angle perceivers might exhibit wide-angle characteristics. In other words, wide-angle perceivers might have *wide-angle mental imagery*. Conversely, center-view perceivers might have *center-view mental imagery*.

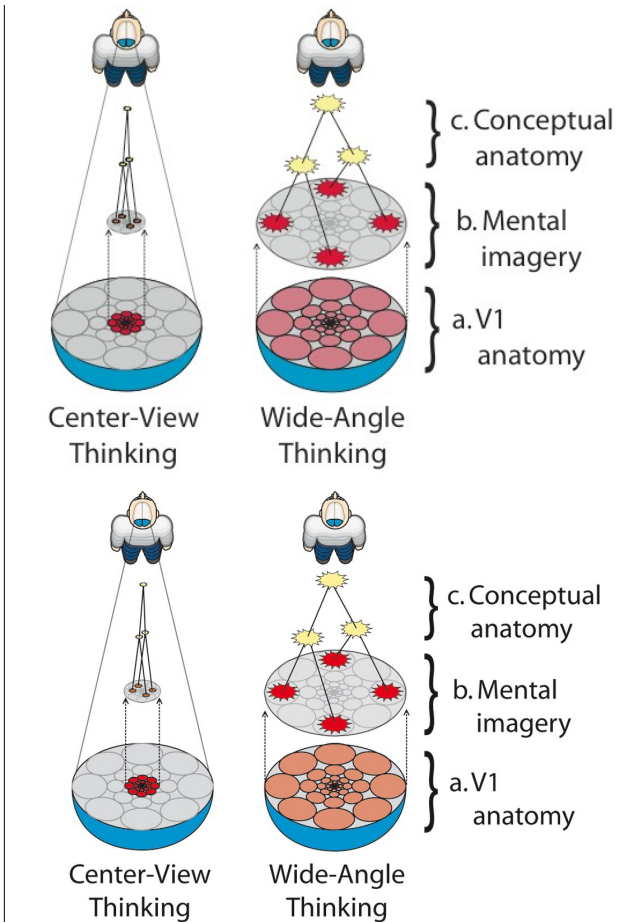
- Wide-angle imaginations might exhibit the same characteristics as wide-angle perceptual abilities (increased ability for image comparison across broad lower resolution areas).
- Center-view imaginations might exhibit the same characteristics as center-view perceptual abilities (decreased ability for image comparisons across broad lower resolution areas but increased, higher resolution, center [foveal] vision ability useful for visual search).

Once again, the smart thing to do would be to end the paper here by jumping straight to Section 4. "*Implications for Information Presentations.*" However, though I have described a possible relationship between increased wide-angle pattern comparison ability that might translate to increased comparison ability in mental imagery (enabling the creation of new patterns [creativity]), other explanations are required to connect such an ability to finding connections between *concepts* (to create new concepts [creativity]), *especially for concepts that are not inherently visual*. We will explore how mental imagery ability might connect to conceptual creativity in the next section.

#### 3.2 Exploring Conceptual Anatomy through a Thought Experiment

Could center-view and wide-angle conceptual structures have different anatomies that enable different conceptual abilities? I propose that these different anatomies may exist because the conceptual structures are constructed from center-view or wide-angle (visual) stimuli. I will attempt to demonstrate this possible relationship through a diagrammatic thought experiment in Figure 2. Figure 2 is based on the following presuppositions:

- The brain and its neurological machinery are material objects with anatomical properties (diagrammatically represented by the center-view and wide-angle representations of V1 shown in Figure 2, level a).
- Mental imagery occurs within the same neurological machinery used for perception (Kosslyn, and Pomeranz, 1977), described in Section 3.1 (Figure 2, level b shows mental image patterns made possible by V1 anatomies).
- Mental imagination ability (center-view or wide-angle) mirrors perceptual ability (our Section 3.2 conjecture) as shown by the center-view or wide-angle patterns in Figure 2 level b.
- Concepts are mental connections between patterns in neurological machinery (as described by Turner & Fauconnier, 1995 [and elaborated in Section 3.3 below]), shown through the hierarchical connections between stimuli in Figure 2 level c (labeled "Conceptual Anatomy").



**Figure 2. Center-view perceivers (left) and wide-angle perceivers (right).**

Guided by our diagrammatic thought experiment, our next step is to find other cognitive science theories that connect Kosslyn's mental imagery theories to concept formation as modeled in Figure 2.

### 3.3 Supporting our Model of Conceptual Creativity with Cognitive Linguistics

Connecting Kosslyn's mental imagery theories to theories of concept formation may be possible through cognitive linguistics (CL). A full overview of CL is not possible here (nor is it my expertise), but the aspect of CL that is relevant to our discussion is that language (and concept) formation is not caused by an innate "language based mental organ<sup>3</sup>." Instead, (according to CL) humans have a powerful pattern detection ability that establishes conceptual structures as patterns of human experience. Patterns of human experience correspond to neural mappings in the brain (Turner & Fauconnier, 1995; Feldman, et al., 2004).

As one example from CL, Tomasello (2003) describes how patterns of human experience enable conceptual development in the form of language development. A child discovers patterns that emerge as objects and nouns. For example, a pattern may emerge because a child's mother may utter the word "juice"

while handing juice to the child. If the child discovers patterns of object-nouns ("drink the juice"), the child has discovered verbs.

For this paper, the point is that *concepts are constructed* by discovering patterns in sensory stimuli. Here, we apply this principle *regardless of sensory modality* so that we can talk about *visual information (rather than verbal language)*. Thus, conceptual structures are patterns of perceived or imagined visual stimuli (level b in Figure 2). This means that because conceptual structures are neural patterns that may emerge from perceptual stimuli (level c in Figure 2), those conceptual structures will be different in center-view versus wide-angle perceivers because the pattern of stimuli is different in center-view and wide-angle perceivers (demonstrated by comparing center-view and wide angle columns in level c of Figure 2).

## 4 IMPLICATIONS FOR INFORMATION PRESENTATIONS

Having discussed possible conceptual anatomies, I will now explore ways to interact with these anatomies through various forms of visual-spatial or text oriented presentations for various tasks, thinking styles (center-view versus wide-angle), for ways to increase the overall effectiveness of presentations, and for tasks that may require both center-view and wide-angle abilities through teamwork.

### 4.1 Presentations Relative to Task

Presentations designed for creative problem solving could be visual-spatial because detecting patterns through peripheral vision and making those patterns accessible to wide-angle neurological machinery may enable increased creativity.

Deep exploration of specific patterns could be achieved through denser, text based descriptions.

The text and illustrated modes could blend in interactive information displays. For example, a visual-spatial model could display patterns that are amenable to making conceptual connections between patterns. Clicking each pattern could expose denser descriptive information about each pattern in the display. A lower tech approach would be to introduce a large document with a visual-spatial model of the contents, and then to assign section headings in the visual-spatial model to various sections in the document.

### 4.2 Presentations and Thinking Styles

Presenters could customize presentations for different kinds of thinkers. Wide-angle thinkers could explore information through visual-spatial presentations that are more easily accessible through peripheral vision (rather than foveal vision). For research and problem solving, wide-angle thinkers could externalize their own memories (cf. Ballard and Hayhoe et al., 1997) through visual-spatial representations that enable them to make creative connections between concepts.

Center-view thinkers could rely less on visual-spatial presentations, because they have difficulty making connections between patterns in imagery. Instead, center-view thinkers could experience information sequentially, through denser text descriptions that are accessible through their (foveal) center-view perceptual abilities that cater to their high memorization ability.

<sup>3</sup> This refers to Noam Chomsky's theories of generative grammar.

### 4.3 Teamwork for Tasks that Require both Wide-Angle and Center-View Abilities

One implication from the conjectures presented in this paper is that center-view and wide-angle cognitive phenotypes are not equally suited for the same tasks. However, each phenotype may bring an increased ability to a task. For tasks that require both a high wide-angle (visual-spatial) acuity and high center-view (foveal) acuity, teamwork may be the solution. For example, many complex information systems require highly interactive visual interfaces. Wide-angle thinkers might excel at producing the visual design for the display, but may excel less at software programming tasks that require above-average memory abilities and high center-view (foveal) acuity for which the text-based API appears oriented. The inverse may apply if ethnographic techniques are required to discover patterns for requirements gathering (cf. Schneps, 2007).

### 4.4 Implications for Education and Workforce Development

Because many educational systems rely so much on rote memorization, a few recommendations follow. Center-view thinkers are better than wide-angle thinkers at using their foveal vision to comb through documents and load the information into memory. Wide-angle thinkers, on the other hand, could externalize memory through visual-spatial presentations that are accessible to their wider-angle visual perception systems. In other words, whereas a wide-angle thinker might “think” by allowing their eyes to saccade over visual-spatial “externalized memories,” center-view thinkers may think by accessing memorized facts that were previously loaded through center-view (foveal) sequential search tasks (i.e. combing through text).

Because many employment scenarios may increasingly require diverse cognitive phenotypes, teaching students to work in teams across phenotypes may become a needed part of workforce development. Furthermore, by tailoring educational presentations (and activities) to serve both center-view and wide-angle thinkers alike, schools may increase the likelihood of academic success for students not served by teaching styles that cater to foveal text-combing coupled with memorization. Academic success may enable more students to enter the workforce, thus enabling them to contribute the abilities associated with their phenotype to help solve the increasingly complex issues of our time.

## 5 CONCLUSION

In this paper, I extended Schneps’ (2007) paper about wide-angle perception (called “high PVR” by Schneps) in dyslexics to explore the cognitive characteristics of illustrations and text. I then used the lens of illustration and text to explore how wide-angle perceptual abilities may explain increased levels of creativity (Everatt et al., 1999) detected in the dyslexic phenotype. I provided an explanatory theory of increased creative ability by first describing how wide-angle mental imagination abilities might mirror wide-angle perceptual abilities by proposing how Kosslyn’s (1977) theories of mental imagery could have wide-angle or center-view characteristics.

I then describe how conceptual creativity could emerge differently in wide-angle perceivers relative to center-view perceivers by drawing on ideas from cognitive linguistics, especially usage based language theories (Tomasello, 2003).

Using the perceptual-cognitive framework presented here, I have proposed that illustrations reflect a wider-angle (but lower resolution) thinking strategy that connects concepts (or elements of a concept) over a broader (but lower “resolution”) conceptual “space.” Conversely, text-based descriptive prose reflects a cognitive strategy optimized for exploring concepts individually or sequentially over a narrower (but higher “resolution”) conceptual “space.” I will add now that I do not think that these different characteristics map to intelligence or are meant to value or devalue particular cognitive strategies (or abilities) utilized by wide-angle or center-view perceivers. On the contrary, my hope is that some ideas presented in this paper can enable us to bring a greater diversity of cognitive strategies to problem solving, thus enabling us to solve daunting tasks that remain unresolved in our time.

From a practical point of view, this theory has implications regarding the strategies we choose (illustrations versus text) to communicate various kinds of ideas. This theory also has implications for how we present ideas to different audiences (wider angle perceivers versus center view perceivers).

Further research will explore how artifacts play roles in teams that use their diverse cognitive phenotypes to solve complex cognitive problems that may extend beyond the abilities of any one cognitive phenotype (team member), drawing on (and possibly extending) theories of distributed cognition as proposed by Hutchins (1996).

## 6 ACKNOWLEDGMENTS

I would like to thank Dr. Stephen Hockema and several anonymous reviewers who contributed to many of the ideas in this paper.

## 7 REFERENCES

- [1] BALLARD, D., HAYHOE, M., POOK, P. & RAO, R. (1997). Deictic codes for the embodiment of cognition. *Behavioral and Brain Science* 20, 723–767.
- [2] BLACKWELL, A.F. 2006. Ten years of cognitive dimensions in visual languages and computing. *Journal of Visual Languages and Computing*, 17(4), 285-287.
- [3] EVERA, J., STEFFERT, B. AND SMYTHE, I. 1999. An Eye for the Unusual: Creative Thinking in Dyslexics. *Dyslexia* 5, 28-46.
- [4] FELDMAN, J. AND NARAYANAN, S. 2004. Embodied meaning in a neural theory of language. *Brain and Language*, 89(2):385–392.
- [5] GROSSER, G.S. AND SPAFFORD, C.S. 1990. Light Sensitivity in Peripheral Retinal Fields of Dyslexic and Proficient Readers. *Perceptual and Motor Skills* 71, 467-477.
- [6] HUTCHINS, E. 1996. *Cognition in the Wild*. MIT Press, Cambridge, MA, USA.
- [7] KAROLYI, C, WINNER, E., GRAY, W., AND SHERMAN, G. 2003. Dyslexia linked to talent: Global visual-spatial ability, *Brain and Language*, Volume 85, Issue 3, Pages 427-431.
- [8] KOSSLYN, S.M. AND POMERANTZ, J.R. 1977. Imagery, propositions, and the form of internal representations. *Cognitive Psychology* .

- [9] LAENG, B. AND TEODORESCU, D. 2002. Eye scanpaths during visual imagery reenact those of perception of the same visual scene. *Cognitive Science: A Multidisciplinary Journal* 26, 207 - 231. .
- [10] ROAM, D. 2008. *The Back of the Napkin*. Penguin Group, Cambridge, MA, USA.
- [11] SCHNEPS, M.H., ROSE, L.T. AND FISCHER, K.W. September 2007. Visual Learning and the Brain: Implications for Dyslexia. *Mind, Brain, and Education* 1, 128-139(12). .
- [12] SWANSON, H.L. 2003. *Handbook of learning disabilities*. Guilford, London.
- [13] TOMASELLO, M. 2003. *Constructing a Language: A Usage-based Theory of Language Acquisition*. Harvard University Press, Cambridge, MA, USA.
- [14] TOPPELBERG, C. AND COLLINS, B. 2004. Book Review of "Constructing a Language: A Usage-Based Theory of Language Acquisition". *Journal of the American Academy of Child & Adolescent Psychiatry* 43, 1305-1306. .
- [15] TURNER, M.; FAUCONNIER, G. 1995. Conceptual integration and formal expression Metaphor & Symbolic Activity, v10 (n3):183-204.
- [16] WARE, C. 2008. *Visual Thinking for Design*. Morgan Kauffman, Burlington, MA, USA.