# Experience in Visual Thinking

## Introduction

Vision links to thinking: creative ~ imaginative/farsighted/dreamer

Define thinking = a constant fact of life which is not easily observed

elusive: hard to be observed like external physical phenomena

pervasive: constant mental activity, hard to completely stop

* physical health related: psychic(mental) functions cannot be readily separated from somatic(bodily) (EG. muscle)
* thinking and feeling cannot be separated. Thinking is colored/directed by emotions and motivations
* Most thinking is not productive

How to productively/creatively think?

Challenge: desire to change

Information: thinking is infor-processing => infor has to be correct and available

**Flexibility**: 3 ways

Easy access to subconscious as well as conscious level of thinking

Freely move from one mental operation to another

Use several vehicles of thought and transfer thoughts from one to another

Flexibility in Levels

thinking consciously + relax to proceed unconsciously

Flexibility in Operations(=form of action that thinking takes)

Analysis: dissect the object into parts

Synthesis: combine ideas into a new entity

Induction: particular observation to a generalized concept

Deduction: general to particular

Flexibility in Vehicles(=means by which this action is represented to consciousness)

much thinking is imageless, below the level of our awareness

Advantages of thinking by sensory imagery

vitalize the sensory and imaginative abilities that are allowed to atrophy by contemporary education

vehicles that are frequently more appropriate to thinker’s needs than language symbols

encourages flexibility in thinking levels

encourages the thinker to utilize thinking operations that are not within the realm of language thinking

## Background

### 1 Thinking by Visual Images

Visual thinking is pervasive from the abstract and theoretical to the down-to-earth and everyday

3 Kinds of Visual Imagery = see + imagine + draw

drawing and imagining: drawing simulates and expresses imagining, imagining provides material for drawing

imagining and seeing: imagination directs and filters seeing, seeing provides raw material for imagining

seeing and drawing: seeing facilitates drawing, drawing invigorates seeing

### 2 Images in Action

Factors Related to Visual Thinking(perception is active and pattern-seeking instead of passive)

Closure

filling in incomplete pattern

finding a desired pattern

Pattern Perception EG. matching, categorizing, pattern completion

Rotating EG. inverse drawing, rotate dice

Orthographic imagination related to visual-spatial operation(strong body orientation)

from another viewpoint

Dynamic structure EG. folded pattern, knots, pulleys

Visual reasoning EG. spatial analogy

deductive reasoning: thinker goes from an abstract to a concrete idea

inductive reasoning: concrete imagery -> abstract (easier to illustrate)

EG. visual induction

Visual synthesis: whole is new identity > its parts

* test scores !=> bad memory; it can be the inaccurate

### 3 Ambidextrous Thinking

Symbolism of the Right and Left hand

Right ~ science(discipline, logic, objectivity, reason, judgment, knowledge, skill, and language)

left brain ~ verbal reasoning + math description

Left ~ openness, receptivity, subjectivity, playfulness, feeling, motivation, and sensory and imagination

right brain ~ sensing + imagining

Bridge within(internal transfer from left to right) EG. internal transfer

Primary and Secondary Creativeness

Secondary creativeness deals with outer world logically, objectively, but lost intimate contact with senses, feeling and inner fantasy life

Primary creativeness comes out of unconsciousness, original.

* conscious primary creativeness is lost by most people as grown up

Complementary Modes of Thoughts

2 stages thinking

primary processes make an array of defined ideas

(rational)secondary processes select among the objects

quality of thinking ~ nature of primary material available for secondary

sensory imagination + symbolic thinking are complementary

visual thinking complements abstract-language thinking

visual and verbal/mathematical thinking are complementary by virtue of differences in structure

### 4 Learning to Think Visually

Can Thinking be Taught?

Lawrence Kubie: thinking processes are automatic => we need to be educated in how not to interfere with inherent capacity of the human mind to think

not laissez faire approach

healthy psychological climate where education doesn’t interfere with thinking

Others: systematic programs for teaching how to think

2 Methods

Discovery method: discover instead of memorizing concepts(think independently)

Strategy method: be taught how to apply thinking strategies

3 R’s and Visual Atrophy

Stop understanding it: art and language are both important to self expression

Misunderstanding: only word indicates the occurrence of thinking

one-side education of 3 R’s => visual atrophy => word-dependent individual

Other reasons:

perceptual loss <= self-consciousness

imaginative loss <= “stop imagining things”

drawing is viewed as “artist”’s thing

3 Obstacles(3 R’s = reading, writing and arithmetic)

Corrected vision “we all see equally well”

seeing is enormously influenced by personal factors(emotion, knowledge, viewpoint)

“I don’t have any imagination”:

it’s inability to contact imagination consciously and direct it productively

Belief that drawing requires rare, artistic talent

How to overcome

Challenge and try

Share with others

Conclusion:

above are external environment conditions, next chapter will be internal preparations

Seeing: vitalize vision + integrate the visual sense with thinking

externalized thinking = in rhw siewxr xonrwzr od awwinf

recentering one’s viewpoint

pattern-seeking and analytical nature of seeing in drawing

Imagining: inward

autonomous dream + hypnogogic -> fantasy -> logical structural imagery

Idea-Sketching: attention directed outward

express visual ideas with graphic language -> idea’s level of abstractness

thinking with pencil(EG. visual brainstorming and development-by-overlay)

* drawing skills != visual-thinking ability
* visual thinking styles vary

## Preparations

### 5 Materials and Environment

Material: drawing and optical

Environment: quiet, organized, material reachable, relax

Group-think:

get all thoughts out

group interaction stimulates individual thinking and also “group-mind”

### 6 Relaxed Attention

Relaxation and Attention: relaxing irrelevant tension + release full energy and attention to the task at hand

vehicle for transmitting human energy is muscular tension

Importance:

Subconscious incubation requires relaxation; Memory works at the same manner

Excessive eye tension => seeing + directed imagination is improved by disciplined form of letting go

Optimal Tonus(Bernard Gunther) = appropriate relevant balance of relaxation and tension(not letting go completely)

Differential relaxation(Jacobsen) = primary(desired activities) and secondary activity(detract from primary activities)

Cause of Excessive Tension

psychological: fear/insecure: every distraction is a potential threat or a chance for relief

physical: energy level and muscular structure are inadequate to the response

Breaking the Cycle by Physical-Relaxation Technologies

Aware of the tension

You are responsible for the excessive tension

Letting go forms = dynamic(involves activities) + passive(lying down and going limp)

Attention types

Forced attention: external demand for attention becomes internalized(force to pay attention)

Immersed attention: natural absorption in developing an idea or enjoying an event

Passive attention: involuntary process of absorption

Preattention: subconscious accumulation of information from the environment

Dispersed attention: attend-withdraw to rest the human organism

Voluntary attention: sufficiently self-aware and consciousness is not taken over entirely by activities.

* Ability to direct attention voluntarily => human freedom/free will

Principles of voluntary attention (with the features of attention

Focus on one related group of things at one time

Undivided: perception seeks one meaningful pattern at a time

Find interest in what you are attending(interest-driven: feelings => perception

Find sth new in the object(attention is dynamic(no staring)

Select an object that pleases you(attention is continual aha

Clear the ground of consciousness

### 7 Externalized Thinking

Def

Seeing is not only to gather sensory information. Thinking and seeing can function together. Thinking by seeing, touching, materials, by externalizing mental process in physical object

Comparison

Externalized visual thinking is to facilitate understanding by using materials

Expression of visual thought is to convey concepts though material

Material Choice

Inflexible => rigidity in thinking

flexible material is better to communicate a visual idea

Advantages of Externalized Thinking

Direct sensory involvement with material => sensory nourishment

Manipulating objects permits unexpected discovery

Engenders a sense of immediacy, actuality, action

Provides visible form(easier to share)

Examples

tower of pulp, tangram, soma cube

### 8 Recentering

Creative Seeing

Seeing is more than sensing. It requires matching an incoming sensation with a visual mem

Knowledge => seeing (knowledgeable people see more subtle details)

create new knowledge by recentering perception (view same thing from a new point)

Imagination and Seeing

what we perceive through senses + imagination from mind => seeing



projection = intrusion of imagination is less. It is strongly influenced by imagination

projection can be creative

stereotyped seeing is inflexible

recentering = flexible ability to change from one imaginative filter to another

here-to-now perception: seeing what is and least influenced by imaginative intrusion

* recentering into here-and-now is important to creative seeing

flexibility to use imagination to recenter viewpoint creatively

Stereotyped Vision

selective mechanism focus on what we need, or need to avoid

EG. looking for a chair, and get a “perceptual concept”

social conditioned: fear-induced visual stereotyping => sees threat that doesn’t exist

EG. dehumanized visual image of the enemy during a war

* be aware of the emotions when we have “unacceptable images”

Healthy Perception is Flexible

inflexible perception: labeled, categorized (EG. cultural cocoon)

creative => mentally imbalanced => healthier

Recentering

lonely and frightening experience <= different view

unlearning experience: not lazy, category-hardened, fear-induced habits of seeing

Here and Now

moving perception away from its usual viewpoint

EG. Feel the actual

Making the Familiar Strange

(making the strange familiar by categorizing and labeling)

Topsy-turvies EG. look the world upside-down; distorted reflections; imaging the room with switched colors; role playing

Relabeling = abandon object labels and relabel the environment according to another method of classification

group things by color instead of function EG. rediture instead of furniture

relabel with flexible ease EG. a rose is a cork

group things by smile => creative and poetic

Unlabeling = abandon words altogether

ceremonial label burning EG. introduce self as lawyer

nonverbal communication EG. clothes, eyes, posture

beyond labels EG. don’t internalize feelings verbally

### 9 Seeing by Drawing

Relaxed attention(eyes, hands)

Free doodling

Disciplined doodling

all drawing is memory drawing(long-term mem is stereotype)

Draw accurately: (1) observe model (2) short mem to drawing (3) refer back and forth between model and drawing

Exploring objects (freedom of gesture)

Expressive lines

Interest book(drawing things that interest you)

### 10 Pattern-seeking

Pattern(perceive an undetailed one) → Analyze(according to your interest)

Gestalt = whole > parts(cohering complex stimuli into simpler groups) EG. fingerpaint

Grouping by proximity, similarity, and line of direction

Tachistoscopic seeing = flash the image quickly

Tendency to seek meaningful patterns

Projection(closure) EG da vinci’s advice

Seeking different patterns and recentering the perception to solve the problem

recentering by repattering EG. incomplete fret

Pattern, then analyze

### 11 Analytical Seeing

Seeing fully takes time

7 million colors to make distinction

2 ways that color is diminished/simplified:

color constancy = see white house all white

color labeling = categorize color by words

to overcome: color matching EG. paint chip hunt

Tactile(defer vision to touching) and kinesthetic(actively moving) eyes

EG. feelies(draw with touching)

EG. contour drawing

Seeing and knowing(be careful with the verbal description)

enhances visual mem by relating visual imagery to existing verbal knowledge

disciplines seeing by joining verbal and visual searching together

educates [ambidextrous thinking](#_2et92p0)

EG. verbal seeing describe to someone who doesn’t see

Analyze, then repattern

2 phases of pattern-seeking & analytical seeing: pattern → analyze → repattern

### 12 Proportion

Superimposition

Pencil-arm method

Grouping scheme upon the whole

Grid

Deliberate distortion to dramatize identity

Functional proportion is reducible to numbers

Aesthetic proportion = harmonious visual relationship of parts to the whole

### 13 Cues to Form and Space

Spatial perception is not perception of space but the relationship between objects

optical reality EG. size, shape

perceptual reality by object constancy → polysensory EG. closer apple and further apple are the same one

Orthographic project = graphic equivalent of perceptual reality

Orthographic projection presents several views of the object (front, top and side views)

Perspective = graphic equivalent of optical reality

convergence(区分optical and perceptual reality) error

reverse convergence: vanishing point is closer

out of convergence: edges don’t converge

askew: vertical lines are not parallel in 2-point perspective

foreshortening = 3d perspective, circle → ellipse

vanishing point: small => far away

translation: dissonance between perceptual and optical reality is unconsciously resolved

Limitation of seeing

cannot see things that are too small; too large/complex; inner structure; time and space limited

limited by our knowledge

## Imagination

### 14 The Mind’s Eye

### 15 Visual Recall

### 16 Autonomous Imagery

### 17 Directed Fantasy

### 18 Structures and Abstractions

### 19 Insight and Foresight

# Experience in Visual Thinking

## 1 Visual Queries

Intro

Experiment

=> subjective impression of perceiving a detailed world but actually partial

“the world is its own memory" focus on important things

How the brain work?

get all infor -> extract task-relevant information -> construct meanings

Def.

Visual thinking consists of a series of acts of attention, driving eye movements and tuning our pattern-finding circuits. These acts of attention are called visual queries

Seeing

brain pixels are concentrated in central region called fovea

non-uniform receiving => non-uniform processing

saccadic eye movement => vision is suppressed

Perception

2 processes

bottom-up process driven by visual information

top-down process driven by demands of attention

2 waves of neural activity

information-driven wave fist passes information to back of the brain

attention-driven wave first originates in attention control center of forebrain

Bottom-Up

retinal image -> detect features -> construct complex patterns -> form object

visual working memory = system that holds about 3 objects in attention at one time

Note:

visual working mem != visual thinking(focus on pattern finding: common solution)

Top-Down

constant priming of action plans

attention => bias of the signal we're looking for

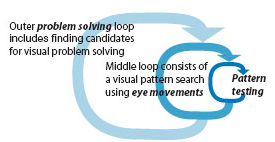
sequencing of eye movements.

Implication

limited visual memory => visual queries should be processed both rapidly and correctly for every important cognitive task the display is intended to support.

EG. map. Interactive graphic display by computer is better than traditional one

Nested Loop



Outer loop deals with generalities

middle loop finds patterns that address visual query (eye movements)

Inner loop deals with details (activated when eye arrives a point of fixation)

Distributed Cognition

No center processing unit; components communicate with other connected ones

Distributed cognition = cognition is the result of a set of interconnected processing modules

Thinking involves constant interplay between new and old pattern

Conclusion

Perceiving = skilled active process (eye movement -> pattern-processing -> critical information transferred to high-resolution fovea)

Understanding visual queries is important to analyze a design in terms of its ability to support the visual queries of others

“designer already has the knowledge expressed in the design, has seen it develop from inception, and therefore cannot see it with fresh eyes”

## 2 What We Can Easily See

Intro

Visual attention directed by the eye movement

Ensuring the important elements are visually obvious

The Machinery of Low-Level Feature Analysis

V1= primary visual cortex, an interlocking region where information is processed

V2 = visual region 2 receives input from V1 and process slightly complex information

* Cortical areas are parallel computers which process every part of the visual image simultaneously

V1 + V2 provide input to 2 processing systems

What system about identification and pattern

Where system about the location and action

* Eye movement planning - biased competition + prior knowledge (EG. search for tomato, red-sensitive cells are active) => V1 tells what is easy to find in visual search

What Stands Out = What We Can Bias For

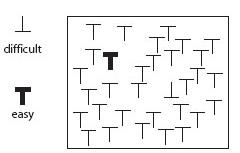
Parallel automatic process

EG. diff thing stands out regardless of the number of distractors <= environment in contrast of the object

Tunable(pre-attentive) effects occurred because of automatic mechanisms operating prior to the action of attention and taking advantage of the parallel computing of features that occurs in V1 and V2

Visual conjunctive search = finding a target based on two features

background varies more => larger difference needs to make a feature distinct



Channel = different ways the visual image is processed in the primary visual cortex

search several things => use different channels(semi-independent processing channels)

Feature channel provides useful way of thinking about what makes something distinct

Motion generates orienting response (emerging things catch attention)

Visual Search Strategies and Skills

previous visual search information => new eye movement

scanning strategy to find the target in the vicinity

detection field are around the center of fovea where target can be detected

bigger target has bigger detection field

blocking strategy to avoid re-visit the known targets

lateral interparietal area on Where pathway

The Visual Search Process

Move and scan loop: move until find the target or find the best viewpoint

Eye movement control loop: biasing mechanism

Pattern-testing loop

Using Multiscale Structure to search => more efficient especially with grouping

Conclusion

pop-up properties to make the object distinct in >= 1 channels

large-scale, moving, previous knowledge can help with visual search

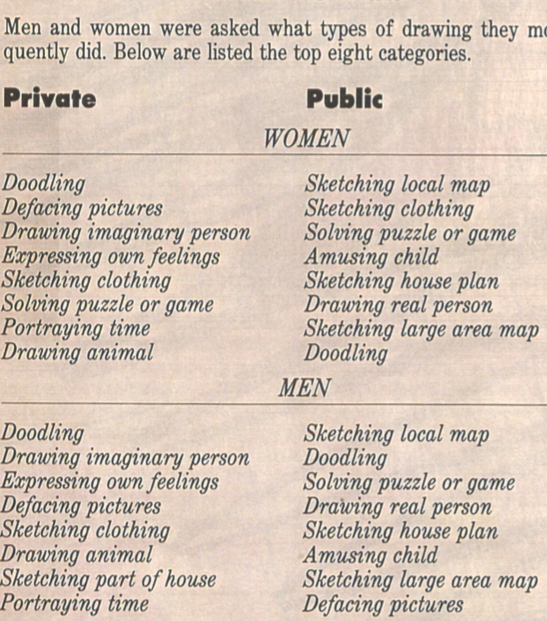
Where and what pathway

# T3-How the Mind Draw

Drawing like talking is a skill with unconsciously generated structure

Articulatory/geometric skill of drawing(EG.drawing suns/flowers) guided by rules

practical logic + cultural variety (EG. China consistency



Assessing ways to clarify what the drawing represents

drawing strategy are governed by semantic interpretation

2 ingredients in drawing = personal style + graphic prosody(communicates how literal our drawings are)

Private drawing (EG. dooling, practical drawing) + public drawing (EG. map)

Difficulties

picturing things in heads

absorbing graphically relevant information with absence of the object

overlooking the fact

dynamic execution: forgot details

# T3-Crossing the Bridge to Illustration

1% inspiration + 99% perspiration becomes 10% execution + 90% illustration

Stages

Concept stage: to come up with ideas ----most difficult

up front(relevant information)

manuscript(read the story and find sth interesting -> brainstorming)

doing HW(researching relevant graphs or concepts)

Sketch stage:

create an illustration sketch and show it to art director

detailed sketch + description OR develop sketches for clients(add new things)

finished art after preliminary sketch is approved

stay in style to distinguish from other artists(style evolves)

# T4-The Road to Creativity

Creativity = known principle ---- uniqueness ----> new combination.

A^n + B^n <------> C! (Reversible yielding process)

Creative Process Stages

Desire: motivated to create original things

Preparation: gather infor, research, experimentation, exposure to get A^n and B^n

Manipulation: putting unrelated concepts

Incubation: let the unconsciousness work

Intimation: close to the solution

Illumination: sudden drawing

Verification: testing process

Creativity Level

Expressive Creativity: most fundamental form. Skills, originality, quality are not important

Productive Creativity: heightened realism, objectivity, completeness

Inventive Creativity: invention and discovery, new use of the old things

Innovative Creativity: requires abstract conceptualizing skills to probe into the hidden/underlying assumptions/principles

Emergentive Creativity: most influential. visualize beyond the scope of understanding

Comparison of creative and non-creative person

| Creative | Non-creative |
| --- | --- |
|  |  |

Plastic Perception = ability to see the same thing in many ways

highly uncreative people tend to sort objects by content

classify objects by their functions

highly creative people tend to sort objects by form and structural symbol

Condition that depress creative thinking

habit, blind reliance or restricted experience, criticism based on presumption, emotional constraint, lack of reward, lack of motivation

Condition that stimulates creative thinking

desire to create, remove the fear of being wrong, reduce physiological stress, no intense emotions

Methods for Stimulating Ideas

Review of properties and alternatives - most common

list modifiable properties(weight, color, length)

list functions (automatic, strong, lightweight)

consider the new possibilities to modify/rearrange/combine the properties/functions

Attribute listing: adapting attributes from known objects

Morphological synthesis: forming new relationship

divide into 12 -> 7 friendly groups -> 7 subgroups each -> matrix

Morphological idea matrix: matrix analysis OR morphological synthesis

describe the problem

select major independent-variable conditions

list ways to satisfy each selected condition

set up a matrix(variable as header of the column

consider feasibility of combinations of methods in the matrix

Brainstorming: building/combining/triggering one another ideas

Synectics: by reversing the order of things

personal analogy: identify sb with an object/process

If I were a flywheel, how would I react if that kind of force were applied

direct analogy: actual comparison between parallel facts in different disciplines

For a desalination, could we learn sth from how a seagull lives on salt water

symbolic analogy: use an image as a way to look at the problem

Image a rope that stillen like a bicycle chain to hold up sth

fantasy analogy: make improbable connection between the world

If we used trained ants for numbers, what kind of self-powered desk calculation could we build

Idea diagram: hard to handle > 1 thoughts @ a time => sketching to add a dimension of flexibility to the mind in seeking alternatives to a problem

Association: associate sth at present to some imagination

Trigger word technique: similar words suggest the alternatives

Functional visualization: serves as an interface between the problem definition and problem solution => avoid the situation “good solution to the wrong problem”

# Lecture

TIPS:

grid to get the relation

Brainstorming with verbal strategies

EG. get continuous water

| energy | source | process |
| --- | --- | --- |
| electrical |  | manufacturing |
| water | underground | transport |
| solar | atmosphere |  |
| fossil |  |  |
| atomic |  |  |

solar + underground + transport: pipe to transport the solar energy underground

solar + atmosphere + manufacturing: using solar energy to combine Hydrogen and Oxygen to generate water

Project:

Broadly speaking, the act of perception is determined by two kinds of processes: bottom-up, driven by the visual information in the pattern of light falling on the retina, and top-down, driven by the demands of attention, which in turn are determined by the needs of the tasks.

EG. First look at the letters and lines. Start with the M and follow the sequence of lines and letters to see what word is spelled. You will find yourself making a series of eye movements focusing your visual attention on the small area of each letter in turn. You will, of course, notice the faces in the background but as you perform the task they will recede from your consciousness.

EG. Next look at the faces and try to interpret their expressions. You will find yourself focusing in turn on each of the faces and its specific features, such as the mouth or eyes, but also as you do this the letters and lines will recede from your consciousness.

Thus, **what you see depends on both the information** in the pattern on the page as it is processed bottom-up through the various neural processing stages, **and on the top-down effects of attention** that determines both where you look and what you pull out from the patterns on the page.

There are actually two waves of neural activity that occur when our eye alights on a point of interest. An **information-driven** wave passes information first to the back of the brain along the optic nerve, then sweeps forward to the forebrain, and an **attention-driven** wave originates in the attention control centers of the forebrain and sweeps back, enhancing the most relevant information and suppressing less relevant information.

The neural machinery of the visual system is modular in the sense that distinct regions of the brain perform specific kinds of computations before passing the processed information on to some other region. The visual system has at least two dozen distinct processing modules, each performing some different computational task, but for the purposes of this overview we will simplify to a three-stage model. The processing modules are organized in a hierarchy, with information being transferred both up and down from low-level brain-pixel processors to pattern and object processors. We shall consider it first from a bottom-up perspective, and then from a top-down perspective.

BOTTOM-UP

In the bottom-up view, information is successively selected and filtered so that **meaningless low-level features in the first stage form into patterns in the second stage, and meaningful objects in the third stage**.

**The main feature processing stage occurs after information arrives in the V1 cortex**, having traveled up the optic nerve. There are more neurons devoted to this stage than any other. Perhaps as many as five billion neurons form a massively parallel processing machine simultaneously operating on information from only one million fibers in the optic nerve. Feature detection is done by several different kinds of brain pixel processors that are arranged in a distorted map of visual space. Some pull out little bits of size and orientation information, so that every part of the visual field is simultaneously processed for the existence of oriented edges or contours. Others compute red-green differences and yellow-blue differences, and still others process the elements of motion and the elements of stereoscopic depth. The brain has sufficient neurons in this stage to process every part of the visual field simultaneously for each kind of feature information. In later chapters, we will discuss how understanding features processing can help us design symbols that stand out distinctly.

At the intermediate level of the visual processing hierarchy, feature information is used to construct increasingly complex patterns. Visual space is divided up into regions of common texture and color. Long chains of features become connected to form continuous contours. Understanding how this occurs is critical for design because this is the level at which space becomes organized and different elements become linked or segregated. Some of the design principles that emerge at this level have been understood for over seventy years through the work of Gestalt psychology (gestalt means form or configuration in German). But there is also much that we have learned in the intervening years through the advent of modern neuroscience that refines and deepens our understanding.

At the top level of the hierarchy, information that has been processed from millions upon millions of simple features has been reduced and distilled through the pattern-processing stage to a small number of visual objects. The system that holds about three objects in attention at one time is called visual working memory. The small capacity of visual working memory is the reason why, in the experiment described at the start of this chapter, people failed to recognize that they were speaking to a different person. The information about the person they were talking to became displaced from their visual (and verbal) working memories by more immediate task-relevant data.

Although something labeled “dog” might be one of the objects we hold in our visual working memory, there is nothing like a picture of a dog in the head; rather we have a few visual details of the dog that have been recently fixated. These visual details are linked to various kinds of information that we already know about dogs through a network of association, and therein lies the power of the system. Concepts that dogs are loyal, pets, furry, and friendly may become activated and ready for use. In addition, various possibilities for action may become activated, leading to a heightened state of readiness. Actions such as petting the dog or avoiding the dog (depending on our concepts) become primed for activation. Of course if it is our own dog, “Millie,” a much richer set of associations become activated and the possibilities for action more varied. This momentary binding together of visual information with nonvisual concepts and action priming is central to what it means to perceive something.

The reason why we can make do with only three or four objects extracted from the blooming buzzing confusion of the world is that these few objects are made up of exactly what we need to help us perform the task of the moment. Each is a temporary nexus of meaning and action. Sometimes nexus objects are held in mind for a second or two; sometimes they only last for a tenth of a second. The greatly limited capacity of visual working memory is a major bottleneck in cognition, and it is the reason why we must often rely on external visual aids in the process of visual thinking.

When we see something, such as a dog, we do not simply form an image of that dog in our heads. Instead, the few features that we have directly fixated are bound together with the knowledge we have about dogs in general and this particular dog. Possible behaviors of the dog and actions we might take in response to it are also activated.

It is tempting to think of visual working memory as the place real visual thinking occurs, but this is a mistake. One reason it is easy to think this way is that this is the way computers work. In a digital computer, all complex operations on data occur in the central processing unit. Everything else is about loading data, getting it lined up so that it is ready to be processed just when it is needed, and sending it back out again. The brain is not like this. There is actually far more processing going on in the lower-level feature processing and pattern-finding systems of the brain than in the visual working memory. It is much more accurate to think of visual thinking as a multicomponent cognitive system. Each part does something that is relatively simple. For example, the intermediate pattern processors detect and pass on information about a particular red patch of color that happens to be imaged on a particular part of the retina. An instant later this red patch may come to be labeled as “poppies.”

In many ways, the real power of visual thinking rests in pattern finding. Often to see a pattern is to find a solution to a problem. Seeing the path to the door tells us how to get out of the room, and that path is essentially a kind of visual pattern. Similarly, seeing the relative sizes of segments in a pie chart tells us which company has the greatest market shares.

Responses to visual patterns can be thought of as another type of pattern. (To make this point we briefly extend the use of the word “pattern” beyond its restricted sense as something done at a middle stage in visual processing.) For most mundane tasks we do not think through our actions from first principles. Instead, a response pattern like walking towards the door is triggered from a desire to leave the room. Indeed it is possible to think of intelligence in general as a collaboration of pattern-finding processors.♦ A way of responding to a pattern is also a pattern, and usually one we have executed many times before. A very common pattern of seeing and responding is the movement of a mouse cursor to the corner of a computer interface window, together with a mouse click to close that window. Response patterns are the essence of the skills that bind perception to action. But they have their negative side, too. They also cause us to ignore the great majority of the information that is available in the world so that we often miss things that are important.

♦This view of intelligence as a kind of hierarchy of pattern finding systems has been elaborated in On Intelligence by Jeff Hawkins and Sandra Blakeslee (Times Books, New York, 2004).

TOP-DOWN

So far we have been focusing on vision as a bottom-up process:

retinal image → features → patterns → objects

but every stage in this sequence contains corresponding top-down processes. In fact, there are more neurons sending signals back down the hierarchy than sending signals up the hierarchy.

We use the word attention to describe top-down processes. Top-down processes are driven by the need to accomplish some goal. This might be an action, such as reaching out and grasping a teacup or exiting a room. It might be a cognitive goal, such as understanding an idea expressed in a diagram. There is a constant linking and re-linking of different visual information with different kinds of nonvisual information. There is also a constant priming of action plans (so that if we have to act, we are ready) and action plans that are being executed. This linking and re-linking is the essence of high-level attention, but it also has implications for other lower-level processes.

At the low level of feature and elementary pattern analysis, top-down attention causes a bias in favor of the signals we are looking for. If we are looking for red spots then the red spot detectors will signal louder. If we are looking for slanted lines then slanted line feature detectors will have their signal enhanced. This biasing in favor of what we are seeking or anticipating occurs at every stage of processing. What we end up actually perceiving is the result of information about the world strongly biased according to what we are attempting to accomplish.

Perhaps the most important attentional process is the sequencing of eye movements. Psychologist Mary Hayhoe and computer scientist Dana Ballard collaborated in using a new technology that tracked individuals’ eye movements while they were able to move freely.♦ This allowed them to study natural eye movements “in the wild” instead of the traditional laboratory setup with their heads rigidly fixed in a special apparatus.

♦Mary Hayhoe and Dana Ballard. 2005. Eye movements in natural behavior. Trends in Cognitive Science. 9(4): 188–194.

The sequence of eye movements made by someone making a peanut butter and jelly sandwich. The yellow circles show the eye fixations. (Image courtesy of Mary M. Hayhoe.)

They had people carry out everyday tasks, such as making a peanut butter and jelly sandwich, and discovered a variety of eye movement patterns. Typically, people exhibited bursts of rapid eye movements when they first encountered the tools and ingredients laid out in front of them. This presumably allowed them to get a feel for the overall layout of the workspace. Each of these initial fixations was brief, usually one-tenth of a second or less. Once people got to work, they would make much longer fixations so that they could, for example, spread the peanut butter on the bread. Generally, there was great economy in that objects were rarely looked at unnecessarily; instead, they were fixated using a “just-in-time strategy.” When people were performing some action, such as placing a lid on a jar, they did not look at what their hands were doing but looked ahead to the jar lid while one hand moved to grasp it. Once the lid was in hand, they looked ahead to fixate the top of the jar enabling the next movement of the lid. There were occasional longer-term look-aheads, where people would glance at something they might need to use sometime in the next minute or two. The overall impression we get from this research is of a remarkably efficient, skilled visual process with perception and action closely linked—the dominant principle being that we only get the information we need, when we need it.

How do we decide where to move our eyes in a visual search task? If our brains have not processed the scene, how do we know where to look? But if we already know what is there, why do we need to look? It’s a classic chicken and egg problem. The system seems to work roughly as follows.♦ Part of our brain constructs a crude map of the characteristics of the information that we need in terms of low-level features. Suppose I enter a supermarket produce section looking for oranges. My brain will tune my low-level feature receptors so that orange things send a stronger signal than patches of other colors. From this, a rough map of potential areas where there may be oranges will be constructed. Another part of my brain will construct a series of eye movements to all the potential areas on this spatial map. The eye movement sequence will be executed with a pattern processor checking off those areas where the target happened to be mangoes, or something else, so that they are not visited again. This process goes on until either oranges are found, or we decide they are probably hidden from view. This process, although efficient, is not always successful. For one thing, we have little color vision at the edges of the visual field, so it is necessary to land an eye movement near to oranges for the orange color-tuning process to work. When we are looking for bananas a shape-tuning process may also come into play so that regions with the distinctive curves of banana bunches can be used to aid the visual search.•