

How the NeoCortex uses Visual Information to Complete Occupations

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Visual Perceptual Processing

The overall function of the brain is to filter, organize and integrate sensory information to make an adaptive response to the environment

Jean Ayres

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The brain sees **not** the eye

- And for the brain it's all about pattern
 - To survive and thrive we look for patterns that indicate threats and resources
- When we see meaningful pattern
 - We **pay attention** to it
 - Compare it to our **past** experience
 - And use that past experience to create a **current context to direct** our actions
 - **Predict** the sequence of that actions will occur
 - And **formulate a plan** to respond

Hawkins, 2004, 2016; Barrett, 2017

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Prediction and the Brain

- Brain uses **past** experiences to create a **context** for evaluating incoming information
 - Picture yourself sitting in a new Italian restaurant
 - Your brain calls up past experiences with nice Italian restaurants and says: the last time my body was sitting in a restaurant like this
 - What did I see, hear, taste?
- Then uses this **context** to run a **simulation to predict** what you will experience and what will happen next
 - Based on my past experience in an Italian restaurant like this
 - I predict a waiter will come to my table, hand me a menu and the menu will have pizza and Italian dishes on it

Hawkins, 2004; Barrett, 2017

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Context and Environment

- As we go through life, we collect, combine and store our **experiences** in different **environments** to create a library of different **contexts** for our actions
 - **Environment**: “external physical and social conditions that surround the client”
 - **Context**: “environmental and personal factors specific to each client that influence engagement and participation in occupations”
- We link **context and environment** together to construct a plausible hypothesis (e.g. prediction) about
 - What we will see next when we move our eyes and
 - What will happen next when we move our bodies

AOTA Practice Framework 2020

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Vision's Attributes

- Vision is the primary way we acquire patterns
- We are all **primarily** vision learners
 - 90% of all sensory input is visual
 - 1/3-1/2 of the brain is devoted to pure visual processing
- We choose vision because it has certain useful **attributes**

Medina, 2008; Gilbert-A et al., 2011

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Vision is our most **far reaching** sensory system

- **First** to alert us to danger or pleasure
- Enables us to be **anticipatory**
 - Predict what will happen next
- And **plan** for situations



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Vision provides **speed**

- Visual system conveys a **tremendous** amount of information **within seconds**
 - It is our only truly **integrative** sense
 - Telling us everything we need to know
- Can **instantly** identify an object with vision
 - Can also identify objects using your other senses but it will take longer

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Vision's speed and anticipation enables us to adapt to **dynamic** environments

- Operate in two types of environments
 - **Static**
 - Spatial adaptation only
 - **Dynamic**
 - Spatial and temporal adaptation

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Because of its attributes we rely on vision to guide our

- Decision making
 - Size up situations
- Social interactions
 - Facilitate and ensure smooth interactions
- Motor and postural control
 - Avoid situations that challenge postural control

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Vision Rules!

- **Primary** way we acquire information
- **Dominates** recreational activities
- Enables us to participate in **dynamic unpredictable activities**
- **Vision also** builds the **context** we use to predict **respond** to **situations**
 - Being able to **accurately** see the environment is critical to the ability to **make correct decisions** about **how to engage** the environment

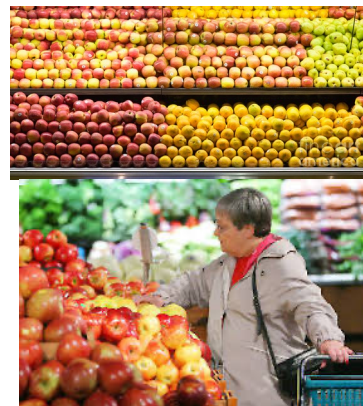


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EXAMPLE

- You are in a grocery store (**environment**) standing in the fruit section of the produce aisle (**context**) and you see something round and red...



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With practice, we get very good at making accurate predictions

- We usually **interpret** context **accurately** and our subsequent **actions are successful**
- If you predict correctly (its an apple)
 - What you are seeing just **confirms** your prediction
 - Visual processing doesn't need to go any further
- When we predict accurately, we **rapidly** and **successfully** respond to situations
 - We purchase the apples and go on our way

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Our Predictions **MUST** be Accurate

- When we can't predict accurately we experience **significant stress**
 - Feels like we're hallucinating-nothing makes sense
 - We become **fearful**
- We express that stress/fear by
 - Becoming frustrated, agitated, angry
 - Shutting down, avoiding, withdrawing



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Vision Impairment

- Causes
 - Disease/conditions
 - Age related eye diseases
 - AMD, glaucoma, diabetic retinopathy
 - Neuro degenerative diseases-
 - Parkinsons, AD, MS
 - Trauma
 - Brain injury-stroke, TBI, tumor, encephalitis, anoxia
 - Eye injuries
 - Age
 - Natural age-related declines in vision
 - Reading acuity, contrast acuity, color acuity
- Combination of causes
 - Especially in the older adult

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Acquired brain injury can alter

- **Quality/amount** of visual input **into** brain
 - Changes in acuity, visual field, oculomotor
- Brain's **ability to process** normal visual input
 - Changes in attention
- Regardless
 - Decreases ability to **visually detect** meaningful **patterns** and **context**
 - And ultimately the **ability to use vision to complete occupations**

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Consequences of Vision Impairment

- Difficulty completing **vision-dependent** activities
- Slow processing **speed**
- **Errors** in decision making
- **Fatigue**
- **Dropping out** of occupations
 - Especially **I-ADLS**

Mennem et al., 2012; Berthold-Lindstedt et al., 2019; Hazelton et al., 2019

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Behavioral Changes

- **Anxiousness** and uncertainty in responding to the environment
- **Slowness** in responding
- **Decreased confidence** in ability to complete activities
- Increased **passiveness** in decision making

Falkenberg et al., 2020; Hazelton et al., 2019; Warren, 2009; de Haan et al., 2015

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In general...

- Experience greatest difficulty with activities completed in **dynamic** environments with **lots of pattern**
 - Community activities
 - Driving, shopping, working, sports
- Person avoids **participating** in activities in these environments
 - Prolongs adjustment to disability
 - Impacts wellness

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Because of vision's importance

- Persons with vision no matter how limited **will always attempt to use vision** to complete occupations
 - Remember 1/3-1/2 of brain is devoted to visual processing
- Therefore OT must focus on enabling the client to **use remaining vision capabilities** to complete needed occupations

Medina, 2008

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Key Lecture Take-Aways

- Vision is the primary **conduit** through which we interact with the world to identify **context, resources** and **threats**
- Vision's attributes enable us to very quickly process information and **predict/plan** for events
- Vision impairment reduces the **accuracy, quality and completeness** of visual input into the brain
 - Person may not see the **critical** features of environment or task that **define the context**
 - Prediction **isn't triggered** or **isn't accurate**
 - **Participation** in occupations **declines**

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Visual Processing Framework for Evaluation and Intervention

The Visual Perceptual Hierarchy

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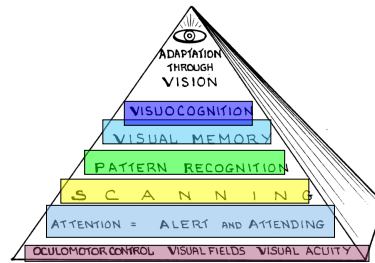
What is Visual Perception?

- Ability to **interpret** what is seen
 - Dependent on ability to use visual input to **identify patterns** and **build concepts/rules**
- Visual perceptual ability develops in childhood
 - As we engage with objects and learn how they behave in space
 - We collect, combine and store **experiences with objects** in different **environments** to create visual **contexts** to drive our actions

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Visual Perceptual Hierarchy

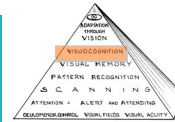
- Visual perceptual processing is comprised of a hierarchy of processes that interact and subserve each other to provide integration of visual information



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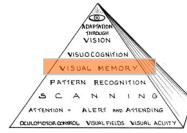
Visual Cognition

- Applying **cognitive concepts** of **space/form** to **interpret** visual input (patterns) to **identify**, **understand** and **use** objects to achieve **goals**
- Works on a **memory prediction** mode
 - We compare the **current** visual **context** to past experiences and **predict** how **objects will behave** in this particular instance
- Context and environment **unlocks** prediction



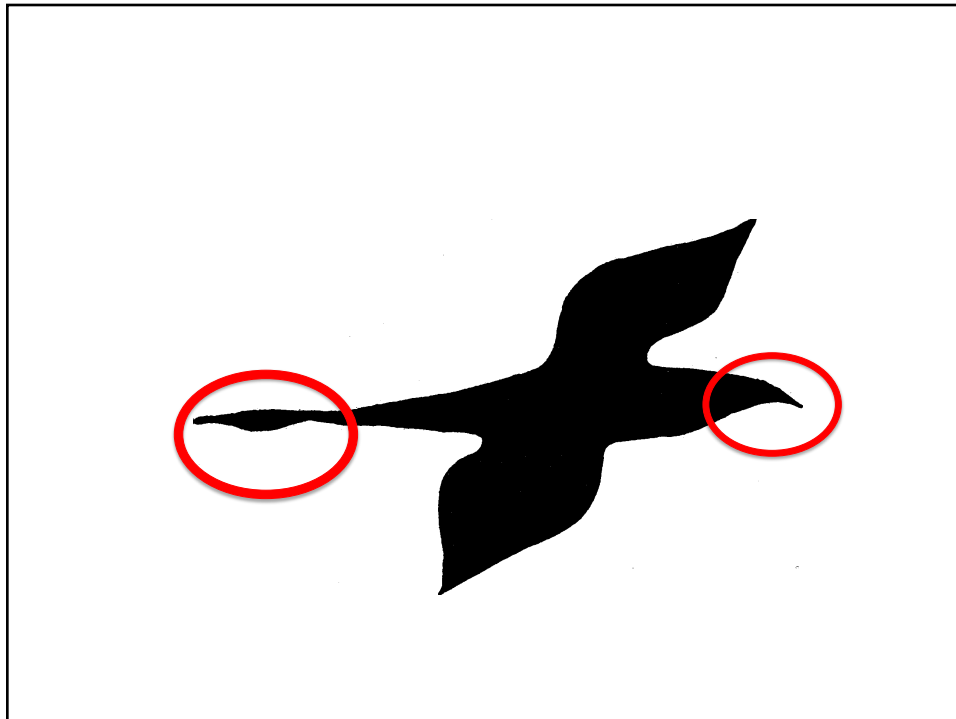
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Visual Memory



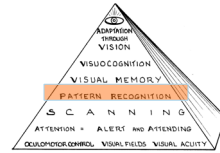
- Supports visual cognition
 - We store thousands of visual images (memories) in the posterior areas of our brain
 - **Seeing** the visual details of an **environment** unlocks a **memory** that creates the **context** for an action
 - **Seeing** a specific object within the **context** of an environment **unlocks** a memory of the object's value and how to use it

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Pattern Recognition



- Basic building blocks of memory
- Determines
 - Whether the image is stored in memory
 - Reject patterns that are nonsensical
- Requires ability to identify **salient** feature
 - *The particular noticeable feature that defines an object and discriminates it from other objects*

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Attractors

- Perceptual template used to create and store memories of objects
- Template enables memory to be activated by **broad range of input**
- Attractors overlap with each other to provide **mental representations of groups**
- Create **generic** memories



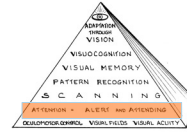
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We collect and store as many attractors/patterns as we can

- The outcome of **experience** is acquisition of sequences of patterns
- Frontal lobes use **stored patterns** when **examining incoming patterns** to make a decision about
 - Whether viewing a **new or familiar** pattern
 - **Whether** to use this pattern (weigh its value)
 - **How** to use this pattern

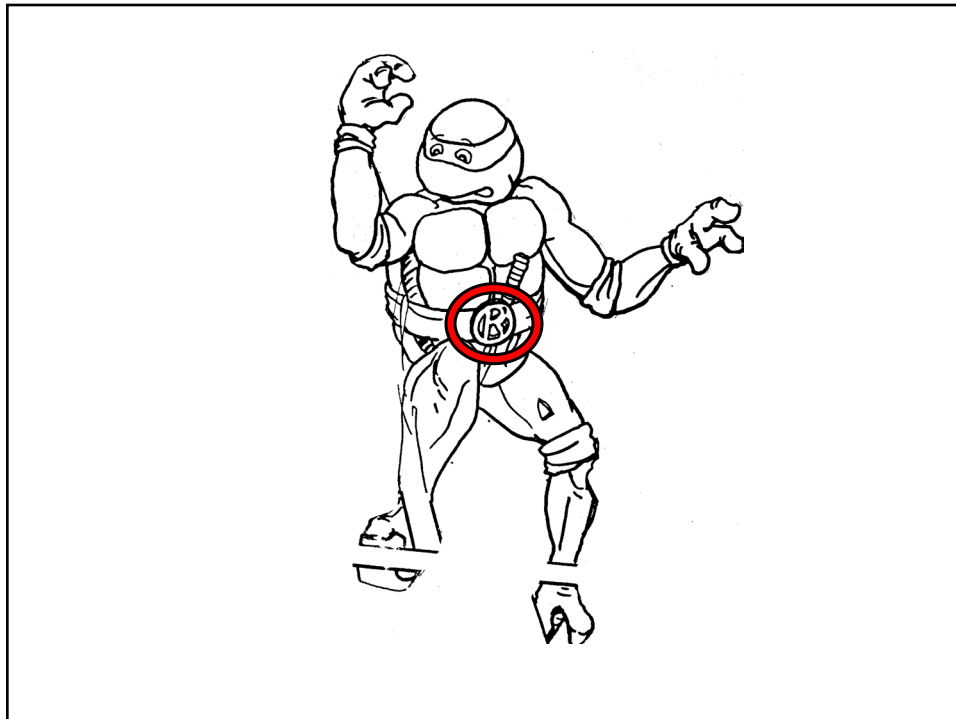
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Visual Search and Scanning



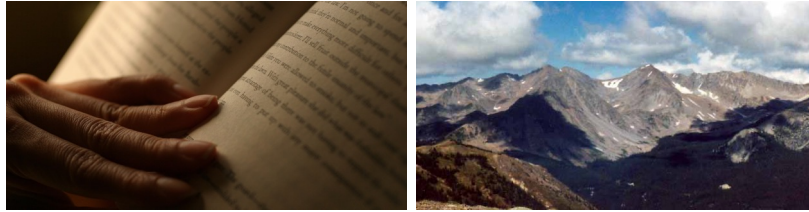
- Sub-serves pattern recognition
 - Must actively search surroundings to locate meaningful patterns
- Uses saccadic eye movements to locate and **foveate** the target
- Occurs on two levels
 - Automatic **reflexive**
 - Directed by brainstem
 - Voluntary **purposeful**
 - Directed by frontal lobes

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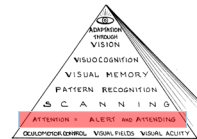
Visual Search and Scanning



- Completed in **an organized, efficient, predictable** pattern dictated by **context** and **goal**
 - Reading-linear
 - Non-structured landscape-often circular

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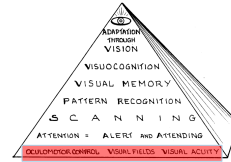
Visual Attention



- Sub-serves **search/scanning**
 - Brain **allocates attentional resources** to initiate search and scanning
- Critical component of visual processing
- **Varies** from global to focal depending visual analysis needed
 - **Global** attention-getting the lay of the land
 - **Selective** attention-applies an **attentional spotlight** to gather specific detail

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Foundation Functions



- **Oculomotor control**
 - Provides perceptual stability
- **Visual acuity**
 - Provides visual clarity-ability to see details
- **Visual field**
 - Provides awareness of objects

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Hierarchy levels must work together

- **Integrated** network
- Loss/ impairment at one level affects functioning of **all other levels**



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Key Lecture Take-Aways

- Each process in the hierarchy is supported by the one that precedes it
- The processes must work together to ensure that information coming into the retina is transformed into images and rules governing visual perception
- Visual functions at the bottom of the hierarchy-acuity, field and oculomotor control-form the foundation for visual processing by ensuring that a high quality image is delivered to the brain
- Attractors-developed through multisensory engagement with objects-help us develop generic memories that enable us to judge incoming patterns; these memories are resilient to dementia, aging and brain injury

Occupational Therapy Approach

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Challenges Addressing Vision Impairment in ABI

- TBI-more visual impairment and often more difficult to identify the impairment
- Stroke-**combination** of **neuro**-related and **age**-related impairment
 - ARED, normal changes in vision due to aging
- Neuro-degenerative diseases
 - Cause **early** and **progressing impairment**
- **Extent** of the injury
 - Mild injuries cause **pathway** damage
 - Moderate-severe injuries cause **structural** damage

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Vision Loss = Hidden Impairment

- Generally observe only the **consequences** of vision impairment
 - Mimics deficits in the performance skills it supports
 - Motor
 - Cognitive
- Often **difficult to identify**
 - May not be **apparent** until other skills improve
 - Must know the key behaviors, assessments
- Some vision impairment **sticks around**
 - Field, acuity, light sensitivity
- Critical to collaborate with other professionals
 - Must have good communication with the eye doctors
 - Ophthalmologists, optometrists
 - All rehab team members must communicate and work together

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Goal of OT Intervention

- Overarching OT Goal
 - “To achieve **health, well-being and participation** in life through engagement in occupation” (p.s5)
- Core beliefs
 - “**Active engagement in occupation** promotes, facilitates, supports, and maintains **health and participation.**” (p.s5)
 - “**Participation occurs naturally** when clients are **actively involved** in carrying out **occupations** or daily life activities **they find purposeful and meaningful.**” (p.s5)
 - “**Participation in occupations** is considered both **the means and the end** in the occupational therapy process.” (p.s7)

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To Achieve Participation

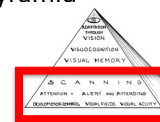
- “Occupational therapy practitioners use their knowledge of the transactional relationship among **the client**, the client’s **engagement in valuable occupations**, and the **context** to design **occupation-based intervention**” (p.s1)
- Intervention is most successful when it clearly **aligns with the client’s occupational goals**
 - Client may say they want “full recovery” of vision BUT what they really want is to be able to complete their valued occupations again
 - Client may say they want independence BUT what they really want is participation

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Changes in Visual Processing Following Acquired Brain Injury

- Primarily result from changes in 5 levels of the hierarchy involved in **delivering** high quality visual input to cortex
 - **3 Basic visual functions** at the foundation of the pyramid
 - **Acuity**
 - **Oculomotor control**
 - **Visual field**
 - Plus 2 processes that help us **acquire visual input**
 - **Visual attention**
 - **Visual scanning**
- Impairment at these lower levels alter the **quality and quantity** of visual input coming into the brain
- Which in turn reduces ability to
 - Identify and categorize objects through **pattern recognition**
 - Create a library of visual **memories** in the posterior cortex
 - And use **vision to achieve goals**



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Our focus when working with ABI client with vision impairment

- Evaluation and intervention focus on identifying/addressing deficiencies in the **foundation visual skills** and **visual attention** and **visual scanning**
- Evaluation
 - Identifying clients strengths and weaknesses in ability to these visual skills to complete daily occupations
- Intervention
 - Enabling client to use vision to participate in desired and required daily occupations

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Evaluation

- “Evaluation process is focused on finding out
 - What the client wants and needs to do;
 - Determining what the client can do and has done;
 - Identifying supports and barriers to health, well-being, and participation”
- Ability to participate in occupation underlies and ties together evaluation and intervention

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Purpose of Evaluation

- To develop an **intervention plan**
 - Evaluation is the **first component** of intervention
 - The **sole** reason evaluate the client is to select the most appropriate intervention
 - OT evaluates **FUNCTIONAL** vision
 - To understand how it hinders and facilitates occupational performance
 - Combines findings with other evaluations
 - To **identify strengths, weaknesses, rehab potential**

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Optimal Client Outcome

- Our goal is for the client to be able to **use vision as efficiently as possible**
- Two options for intervention
- **Option 1: Improve a deficient performance skill**
 - **If we can**
 - We have **zero control** over restoring vision
 - Limited time with the client
 - Client factors that influence recover
 - Most restorative interventions have limited evidence to support their efficacy
 - Many are outside the OT wheelhouse

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OT Intervention Tools

- Option 2: Create a **visible** environment that supports participation **despite** vision impairment
 - We have almost **complete control** over achieving an **optimal** person-environment fit
 - Combine with **meaningful occupations** and purposeful activities
 - Taps into **context** and **learned expertise**
 - Provides an **explicit outcome** to **judge efforts**
- This is **our super power**

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OT Intervention

- Modification aligns with/supports how the neocortex operates
 - Brain initiates and guides actions by **predicting** what is going to happen, **verifying** it through sensory feedback and **modifying** as needed
 - Process begins with **detecting/recognizing** the environmental feature(s) that will **trigger** memory and unlock the sequence
 - A **visible and explicit** environment and a **meaningful context** are crucial for detection and recognition
 - They **prime the brain** for action

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Key Lecture Take Aways

- It is easy to overlook vision impairment because it looks like a deficiency in performance skills it supports
- The purpose of OT evaluation is to develop an effective intervention that enables client to participate in desired occupations despite vision impairment
- Using modification to achieve optimal person-environment fit aligns with how the brain uses vision to direct actions
- Focus intervention on participation rather than restoration
- Collaborate with other vision specialists
- Stay within OT wheelhouse and scope of practice

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