Vision and Movement: What Happens When Sight Changes?

CCL Ignite July 2025

ABOUT US

Gaurav Seth
PhD Candidate, Rehabilitation Science
NYU Steinhardt

Mahya Beheshti
Physician Scientist
NYU Langone Health
PhD Candidate, Mechanical and Aerospace Engineering
NYU Tandon

Supervisors

Dr. John-Ross Rizzo

Dr. Smita Rao

Dr. Amy Hurst

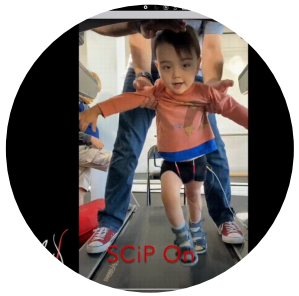
How I Got Here

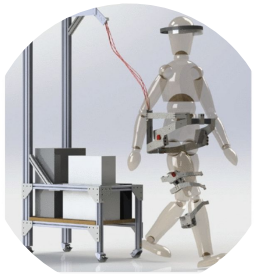
Evolutionary Biomechanics

2019

2020-21

Neuromechanics [1]

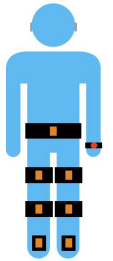




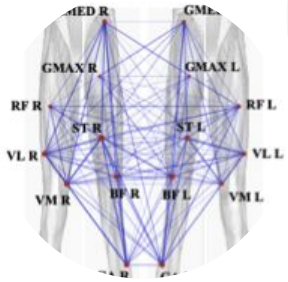
Rehabilitation Robotics [2]

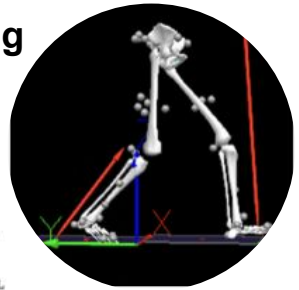
2021-22

2022 ++



Biomechanics & Biosignal Processing

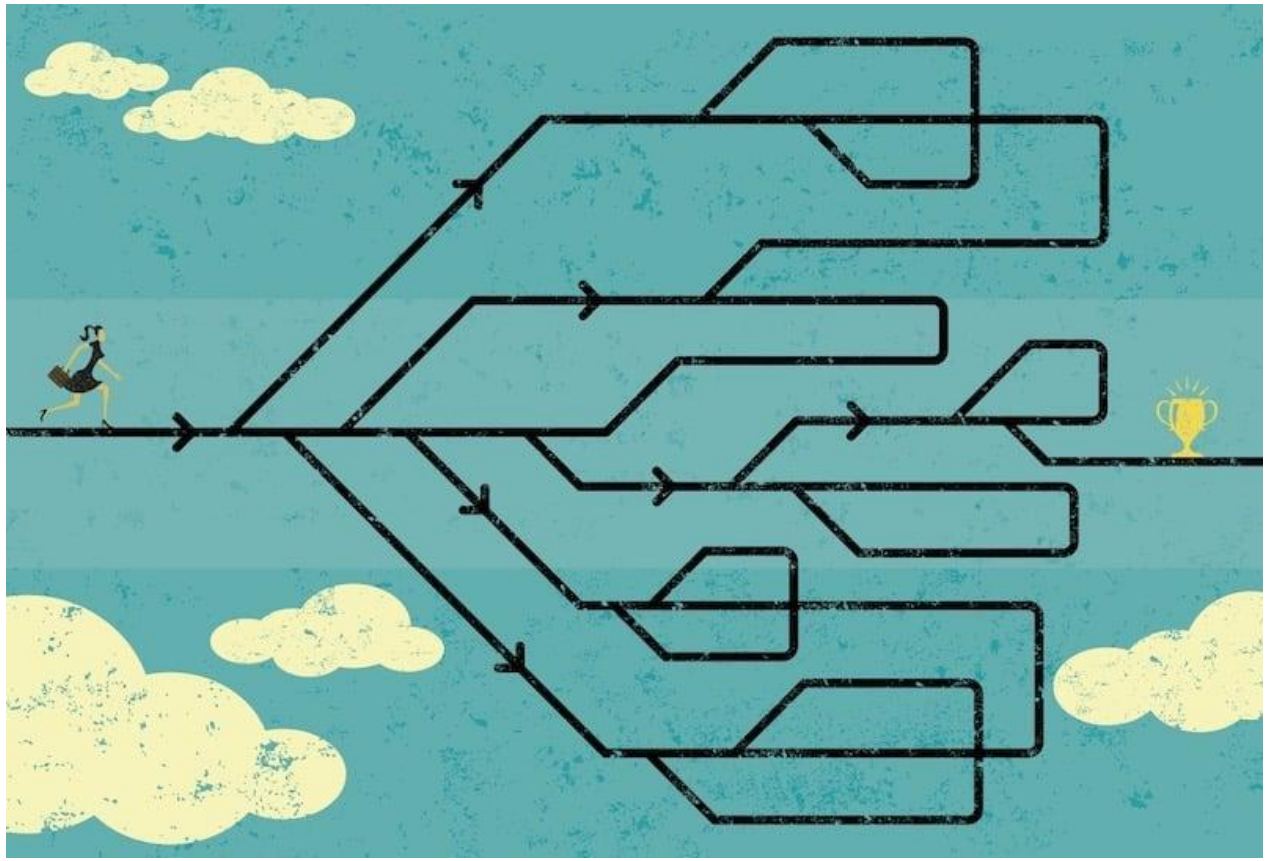




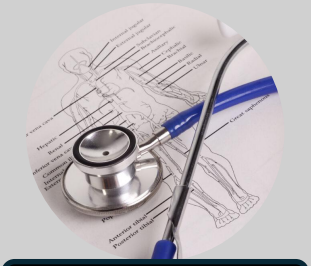
How I Got Here (Spoiler: It Wasn't a Straight Line!)

How I expected my training and career to look

What my training and career actually look like



Plan:



Medical School

Internship

Cardiology Residency

Cardiologist

Medical School

Internship

Neurology/Radiology Residency

Neuroradiologist

Medical School

Internship


Medical School
Internship
Physician-Scientist


Medical School
Internship
Physician-Scientist
MAE PhD

How Do You Move Through the World?

Think about when you walk down a busy sidewalk or hallway:

- How you strategize to pass the obstacles?
- What changes happens to different part of your body?
- How would that change if your vision were blurred, dimmed, or absent?

LET'S EXPERIMENT IT

Walking + Obstacle Negotiation in 3 conditions

- Normal sight

- Simulation Glasses

- Blindfold

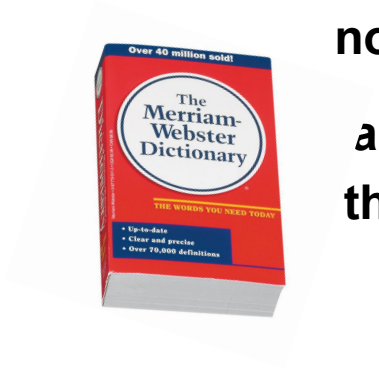
OBSERVATION

Which parts of your body were engaged?

<list here online in class>

1. *Hesitation*
2. *Slow walking*
3. *Feet haptic exploration*
4. *More head movement*
5. *Not a lot of head movement in blindfold*

LOW VISION (loh vizh-uhn]



noun

***a* result of having an eye condition that prevents someone from doing the things that they want to do.**

- A person with low vision is one who has impairment of visual functioning even after treatment, and/or standard refractive correction, and has a visual acuity of less than 6/18 to light perception or a visual field of less than 10 degrees from the point of fixation, but who uses, or is potentially able to use, vision for the planning and/or execution of a task.

The U.S. Centers for Disease Control and Prevention (CDC) defines visual impairment as the condition when "a person's eyesight cannot be corrected to a 'normal' level."

Resources for the visually impaired include modified eye exams performed by a low vision specialist.

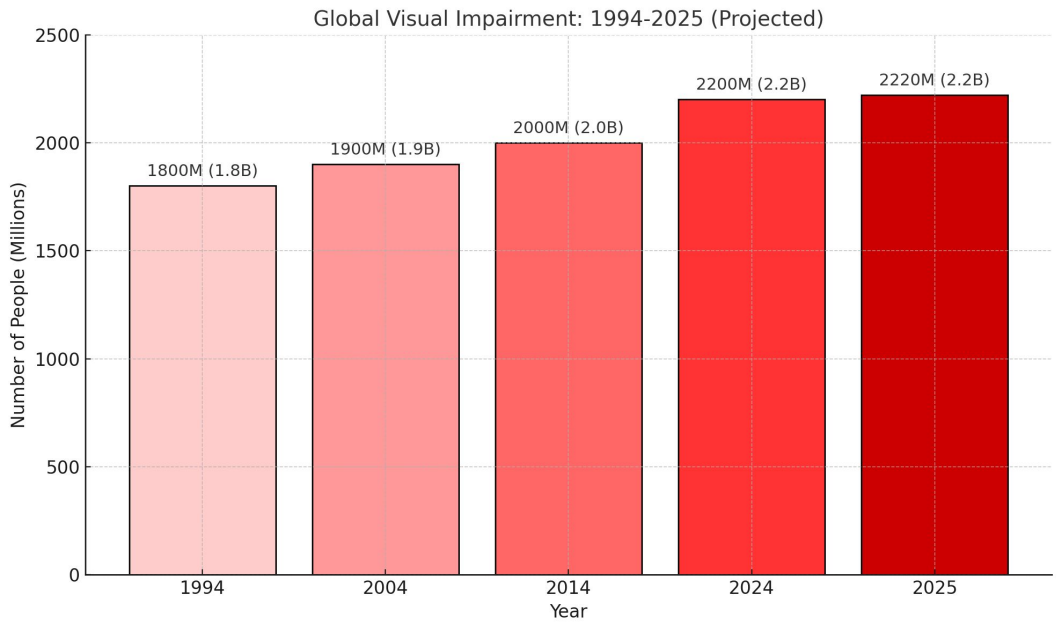
According to CDC, vision impairment may be due to a loss of visual acuity, where the eye does not see objects as clearly as usual, or a loss of visual field, where the eye has a diminished field of view (reduced peripheral vision).

When caused by reduced visual acuity (VA), CDC defines visual impairment as "having VA of 20/40 or less."

VISUAL IMPAIRMENT

World Health Organization (WHO, 2023)

- **2.2 billion people globally** affected by visual impairment or blindness.



CDC & National Eye Institute (NEI, 2024)

- **12 million people aged 40+** have visual impairment (includes blindness).

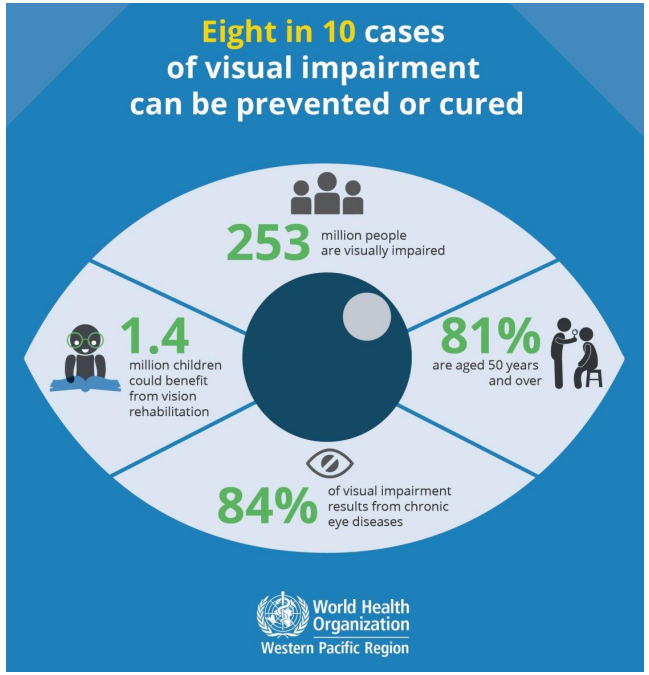
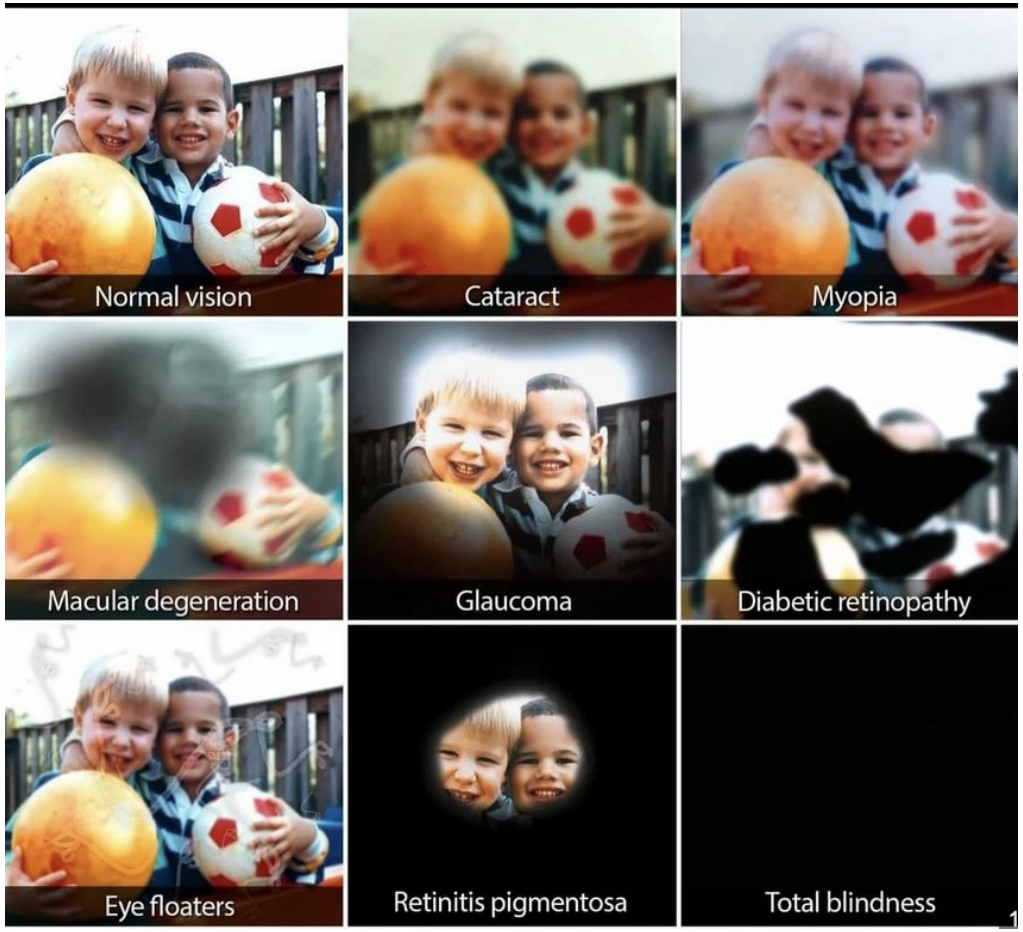


Image source: WHO World Report on Vision (2019); WHO Updates (2023); Global Burden of Disease Study; Bourne et al., *The Lancet Global Health* (2021).

LEADING CAUSE OF VISUAL IMPAIRMENT



Credits to National Institutes of Health/Hashem Al-Ghaili

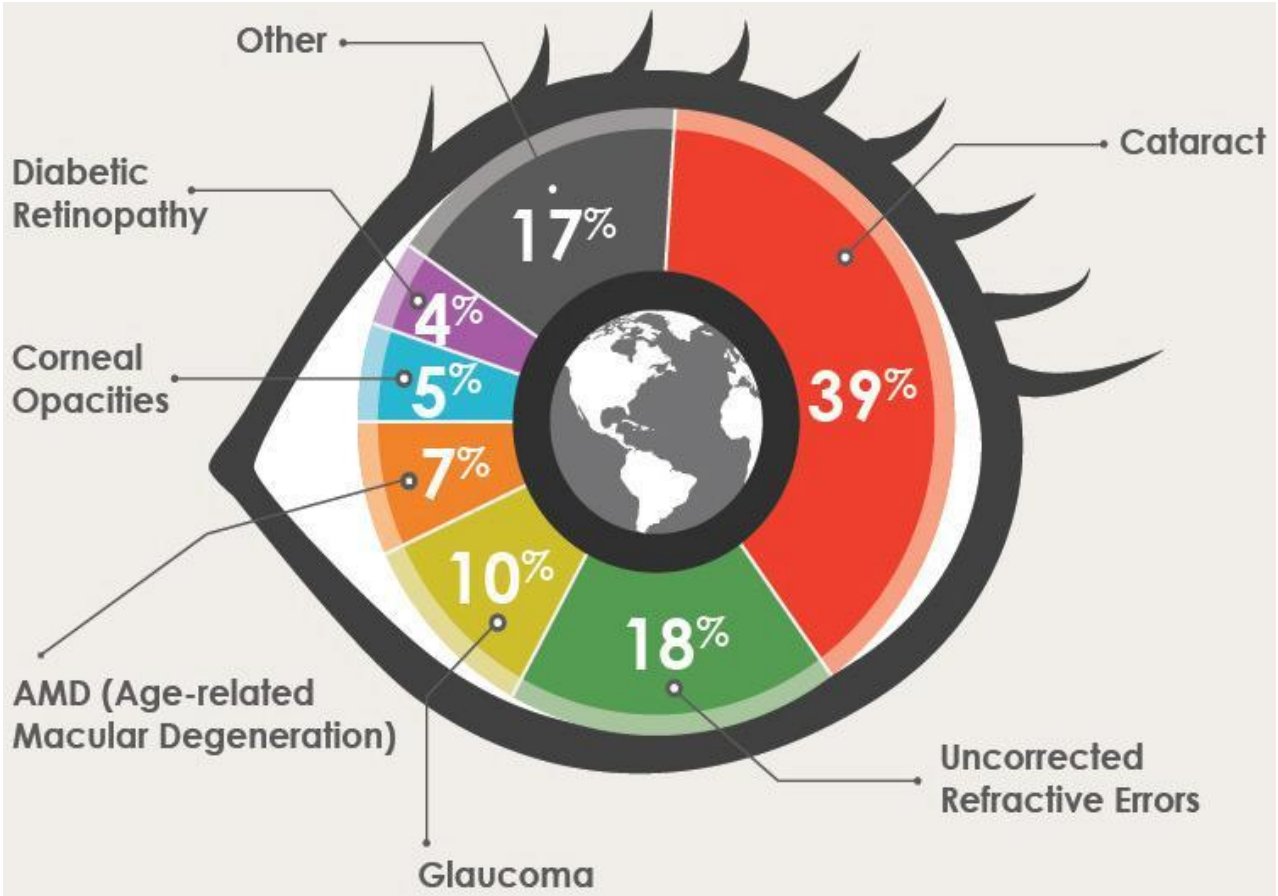


Figure is adopted from https://nursesrevisionuganda.com/visual-impairment/

MYTHS AND FACTS

- ***Myth: Blind people see only darkness, nothing else.***
  Fact: Only ~18% are totally blind — most can perceive light and shapes.
- ***Myth: Blind people have special gifts: a "sixth sense."***
  Fact: They don't have super senses — they just learn to rely more on other senses.
- **Myth People with Low Vision Are "Faking It"**
  Fact: Low vision varies; some see well in daylight but struggle in low light — it's real, even if not always visible.
- **Myth: *People who are blind can't live independently.***
  Fact: With training, blind individuals can live fully — work, travel, raise families, and more.
- **Myth: *People who are blind can't use most technology.***
  Fact: Blind individuals use computers, phones, and apps daily — tech enhances their independence.

MYTHS AND FACTS

Only ~18% are totally blind; most can perceive light and shapes.

MYTHS AND FACTS

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MYTHS AND FACTS

With training, blind individuals can live fully — work, travel, raise families, and more.

MYTHS AND FACTS

Blind individuals use computers, phones, and apps daily — tech enhances their independence.

MYTHS AND FACTS (1)

Myth: Blind people see only darkness, nothing else.

Fact: Only approximately 18 percent of people who are legally blind are classified as being totally blind and the majority of blind people can still differentiate between light and dark.

Myth: Blind people have special gifts: a "sixth sense."

Fact: People who are blind are not endowed with a sharper sense of touch, hearing, taste, or smell. Blind people just learn to pay more attention to information from their other senses.

Myth People with Low Vision Are “Faking It”

Fact: Low vision is an invisible disability, and its variability can lead to misunderstanding. Some individuals with low vision may appear to navigate without difficulty in bright environments but struggle significantly in dim light or at night. This can lead others to doubt their condition, causing frustration. It’s essential to trust individuals when they share their experiences of vision loss.

MYTHS AND FACTS (2)

Myth: ***People who are blind can't live independently.***

Fact: People who are blind can do almost anything. They just do it differently. Not only can people who are blind live independently, they can raise a family, have a meaningful career, play sports, travel and more. Vision-loss rehabilitation and other training teaches skills and strategies so a person who has lost vision can live the life they want to. Eye2Eye exists to provide the emotional support that rehabilitative services often do not include.

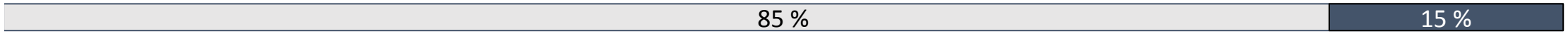
Myth: ***People who are blind can't use most technology.***

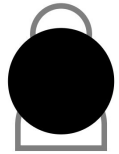
Fact: Technology is a way of life for people who are blind. People who are blind use computers, mobile phones, apps and other tech to enhance their independence and make the world more accessible. Many people who are blind say technology has revolutionized their lives.

BACKGROUND RESEARCH - STATISTICS AND DEFINITIONS

- Blindness and Low Vision (BLV) affects over 4 million people in the U.S., with numbers expected to double by 2050 [3,4]

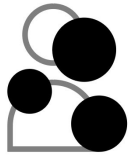
Visual Impairments occur at a spectrum and only about 15% of the BLV population is completely blind according to the American Foundation for the Blind [5]



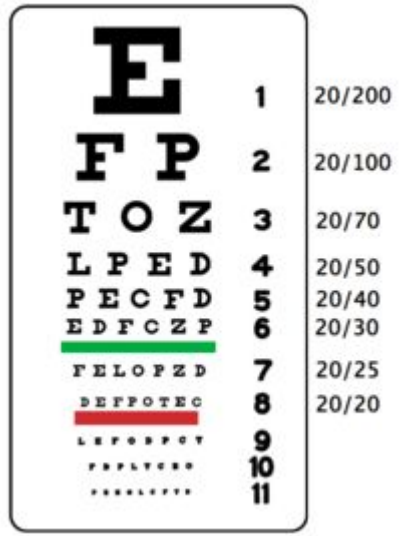


Central Vision Loss

Peripheral Vision Loss



Diabetes Retinopathy Vision



- A person is considered legally blind [5] if:
  - Visual acuity is 20/200 or worse in the better eye with the best possible correction, OR
  - Visual field is 20 degrees or less in the better eye (even with correction).

CONSEQUENCES OF VISUAL IMPAIRMENT

- Persons with Blindness and Low Vision (pBLV) face significant mobility challenges, including difficulties with balance, navigation, and a heightened risk of falls [5-8]
- High risk of musculoskeletal conditions [9]
- Decreased physical mobility [7]

Consequences of Limited Mobility

Mental and Social Wellness

- More likely to experience depressive symptoms [10,11]
- BLV students often engage in solitary after-school activities and experience loneliness and low self-esteem [12-14]

Employment

- Transportation and mobility challenges are major barriers to employment [15-16]
- Employment barriers for BLV individuals result in a $410B global productivity loss (~0.3% of GDP) [17]

Quality of Life

- Lower quality of life and increased dependence [18-20]
- Worsening vision increases accident risk and limits daily activities [19,20]

BACKGROUND RESEARCH – WALKING

How does visual impairments impact walking behaviour?

Studies show that individuals with visual impairments adopt more **cautious walking strategies** [21-27]

BACKGROUND RESEARCH - CAUTIOUS WALKING

- Decreased Walking Speed
- Decreased Cadence (Steps per minute)
- Decreased Stride Length
- Increased Stride Width

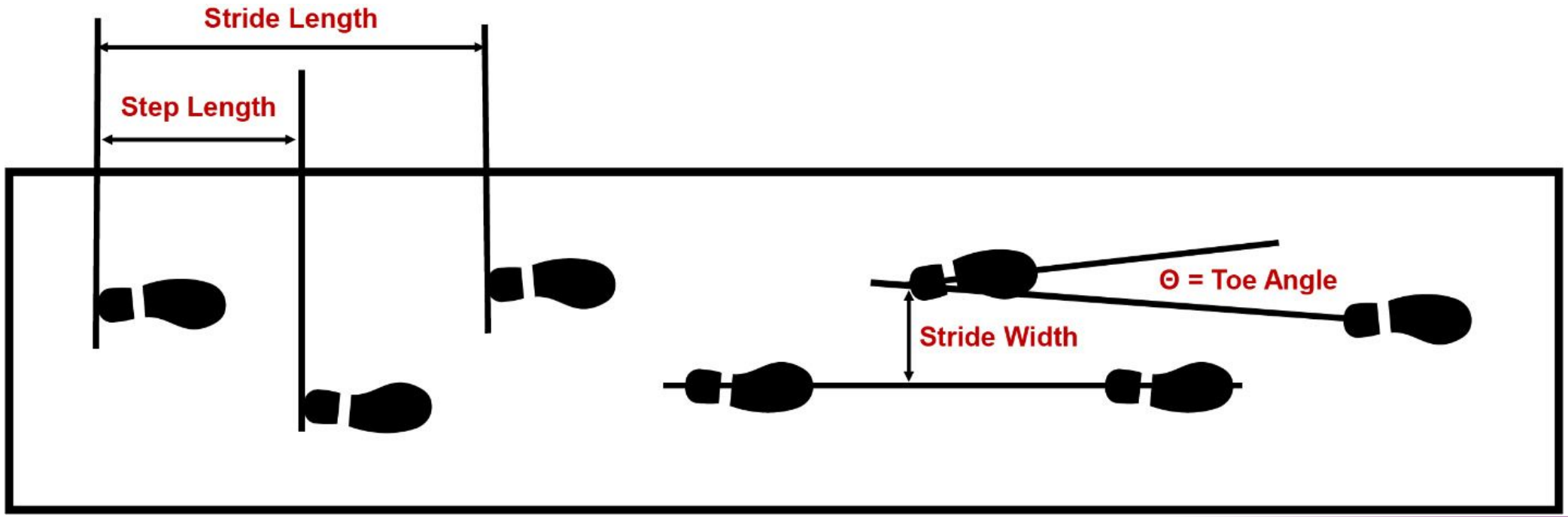
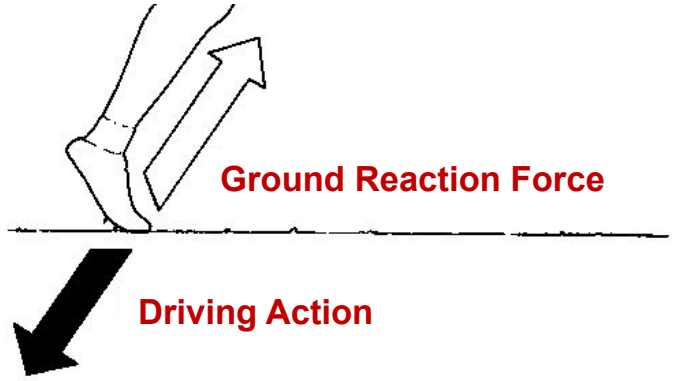


image source:
https://ijspt.scholasticahq.com/article/94606-reliability-of-an-instrumented-pressure-walkway-for-measuring-walking-and-running-characteristics-in-young-athletic-individuals

BACKGROUND RESEARCH – CAUTIOUS WALKING

- Decreased Ground Reaction Forces



Newton's third law of motion:
For every action, there is an equal and opposite reaction

- Increased Double Support Duration

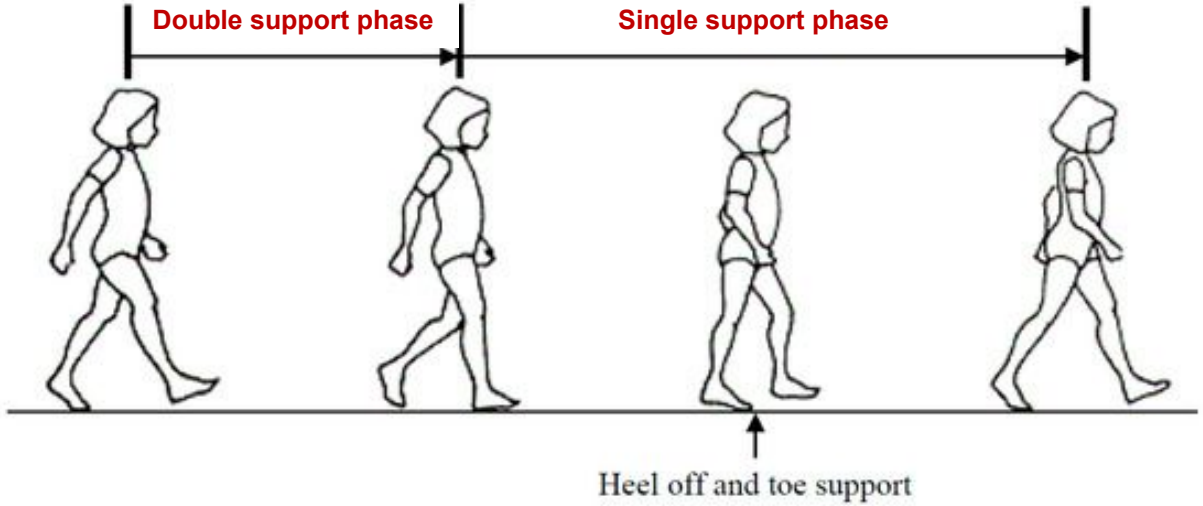
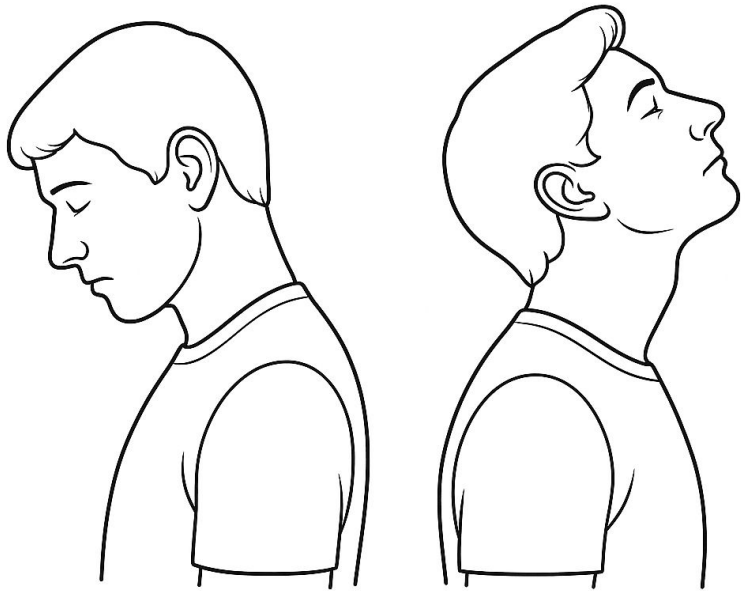


image source: https://jay-jee.blogspot.com/2009/11/ground-reaction-force-definition.html
https://www.mdpi.com/2076-3417/7/5/499

BACKGROUND RESEARCH – CAUTIOUS WALKING

- Increased Head flexion



Head Flexion Head Extension

- Decreased Ankle max angle

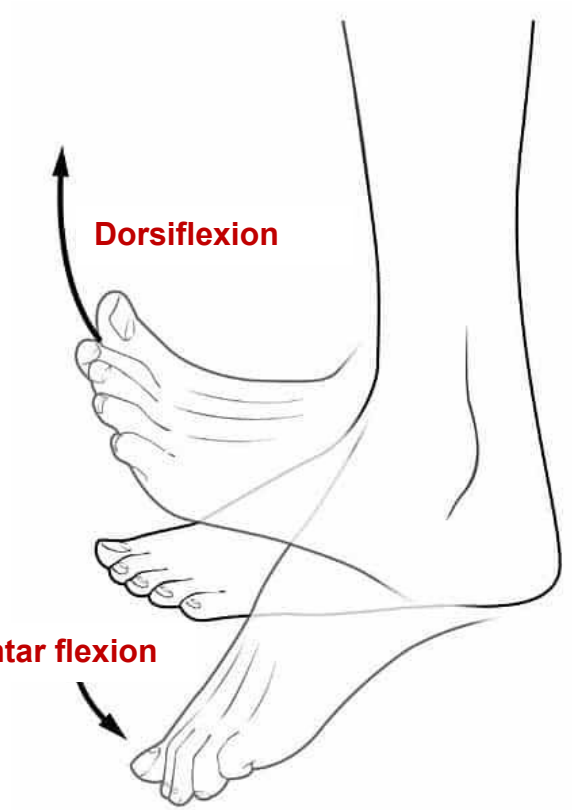


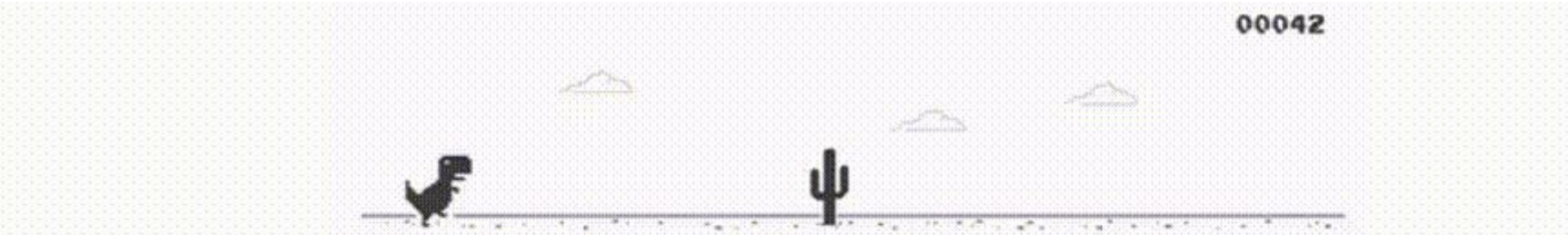
image source: chatGPT generated
https://teachmeanatomy.info/the-basics/anatomical-terminology/terms-of-movement/

BACKGROUND RESEARCH – OBSTACLE NEGOTIATION

How does visual impairments impact obstacle negotiation behaviour?

Studies looking into **Adaptive Locomotion**

Definition: Locomotion while modifying the basic movement patterns to propel in response to environmental constraints



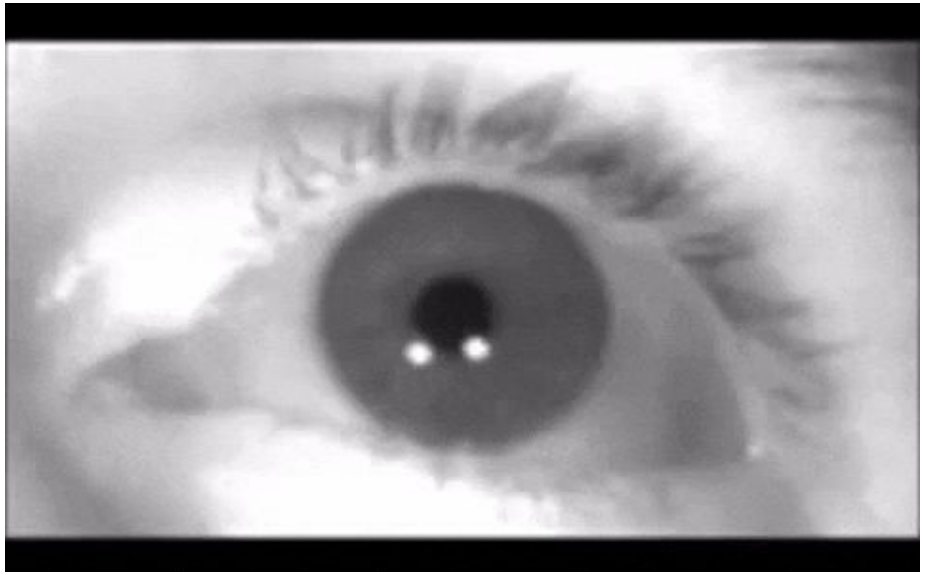
NAVIGATING URBAN ENVIRONMENT: A CHALLENGE OF DAILY LIFE

- Urban navigation is complex due to moving objects, architectural structures, and variable lighting.
- Successful navigation depends on eye and head movements to control the line of sight.
- Eye-head coupling synchronizes these movements to stabilize gaze and aid in:
  - Perceiving
  - Localizing
  - Recognizing objects during navigation.
- The central nervous system orchestrates this coordination for efficient, stable visual navigation.

EYE MOVEMENT

- Eye movements
  - **saccades**, smooth pursuit movements, vergence movements, and vestibulo-ocular movements

- We are constantly making fast eye movements
  - 3/second □ 180/minute □ 11k/hr. □ 260k/day



EYE-HEAD COORDINATION

- Eye-head coupling: Synchronizes eye and head movements for efficient gaze shifts.
- Process:
  - Saccadic eye movement initiates gaze shift.
  - Head movement follows to optimize target acquisition.
- Benefits:
  - Stabilizes vision
  - Minimizes excessive eye movements
  - Balances speed and accuracy
- Normal Vision: Smooth, efficient coupling supports mobility and orientation.

LOW VISION AND NAVIGATION STRATEGIES

- **Adapting to Visual Impairment**

- **Low vision** affects navigation differently based on:
  - Central vs. peripheral vision loss
  - Reduced visual acuity

LOW VISION AND NAVIGATION STRATEGIES

- Adaptive strategies:
  - Increased head movements
  - Use of environmental cues (road markings, building edges)
  - Peripheral loss: Greater head reliance
  - Central loss: Erratic eye movement patterns

- *Naturalistic studies needed to capture:*
  - How individuals truly adapt visuomotor strategies
  - How oculomotor, sensory, and motor systems interact

REVISITING OBSERVATIONS

1. *Hesitation*
2. *Slow walking*
3. *Feet haptic exploration*
4. *More head movement*
5. *Not a lot of head movement in blindfold*
6. *Reduced cadence*

RESEARCH QUESTIONS

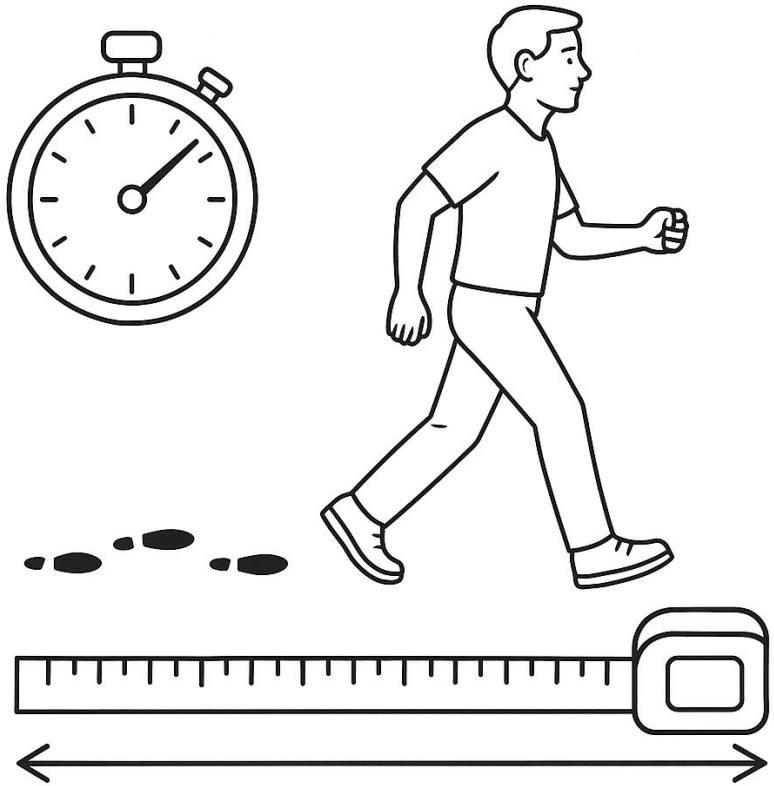
<develop research question based on observations in lecture>

Research Question 1: The effect of visual impairment on walking

Research Question 2: The correlations between VL extent and walking adaptations

METHODS – INSTRUMENTATION

Studies have used basic instruments such as stopwatches, measuring tapes, and manual step counts to assess parameters like task completion time, walking speed, and cadence



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METHODS – INSTRUMENTATION

Force Plates - specially instrumented tiles with piezoelectric sensors that measure the forces exerted by the body on the ground

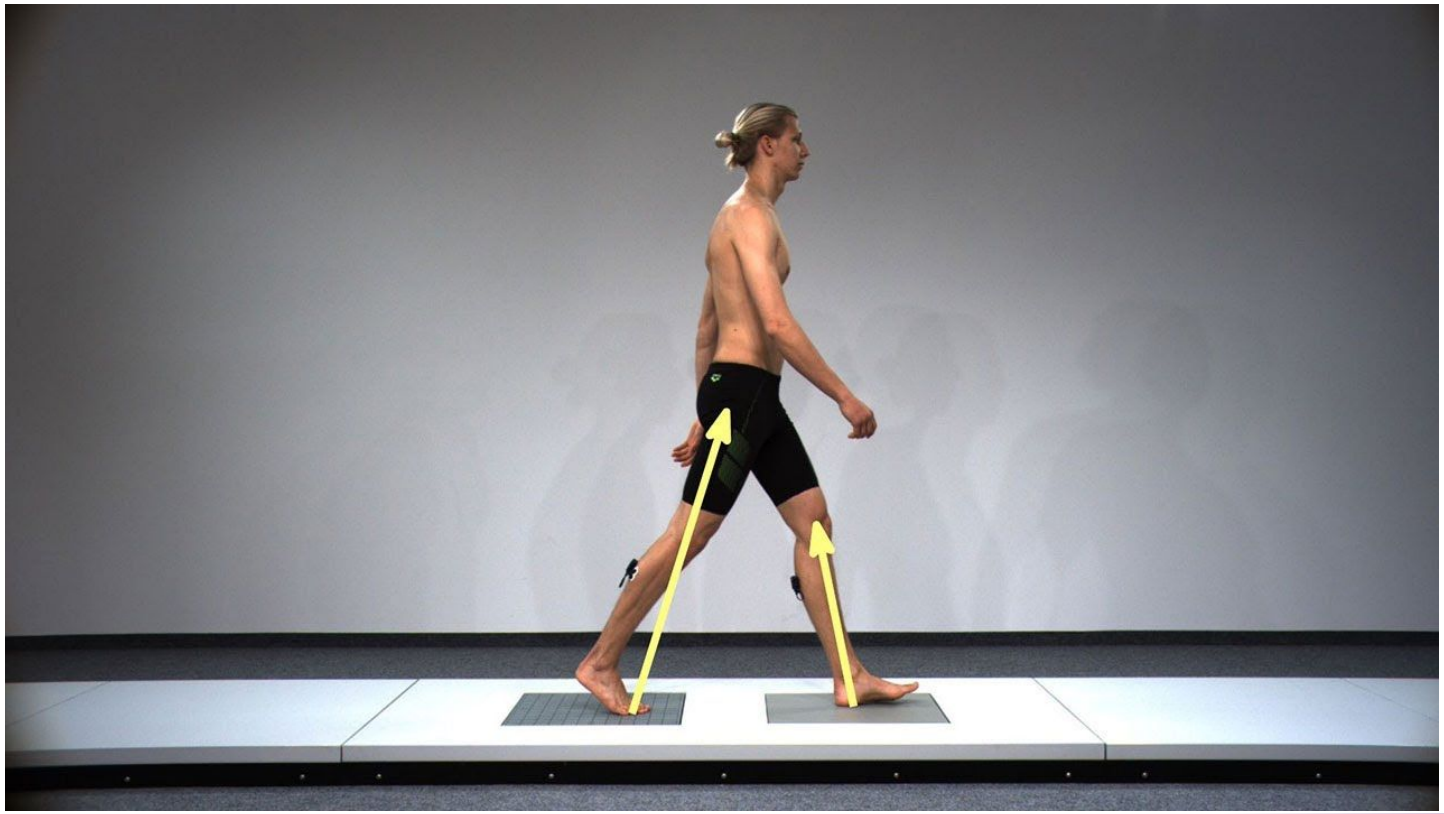
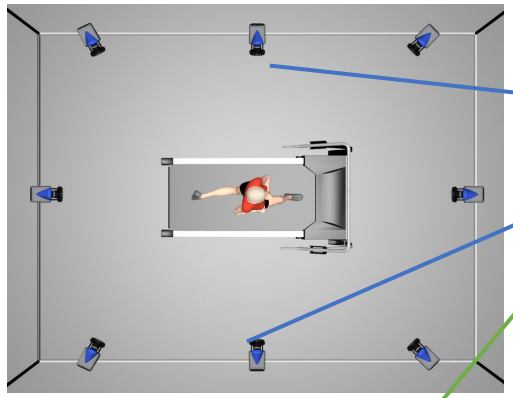


image source: https://contemplas.com/en/hardware-force-measurement/

METHODS – INSTRUMENTATION

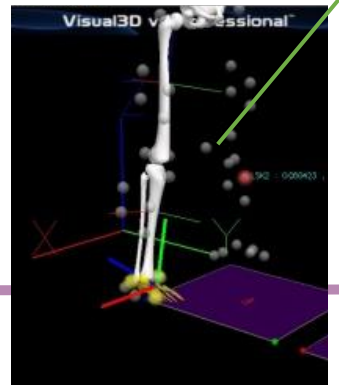
Motion Capture - technologies that track and record body movements using reflective markers and cameras or inertial sensors to analyze joint and limb motion

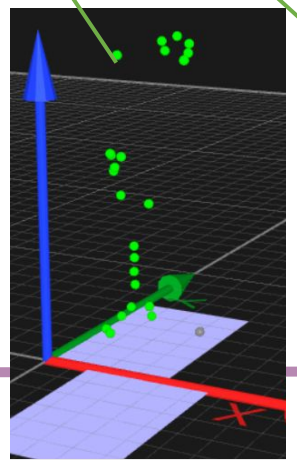
Optical Motion Capture Systems (marker-based)

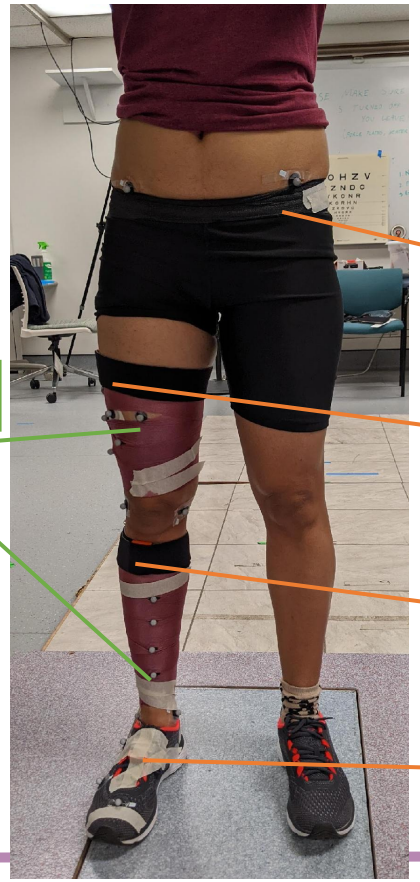


6-16 Cameras

Reflective markers

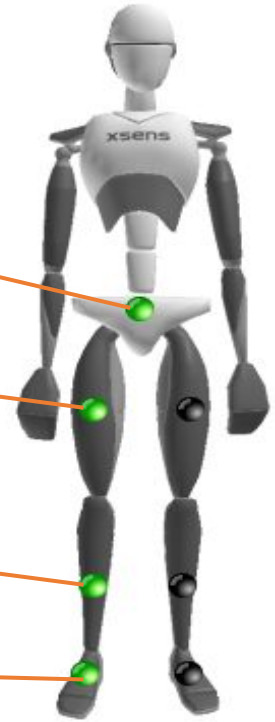




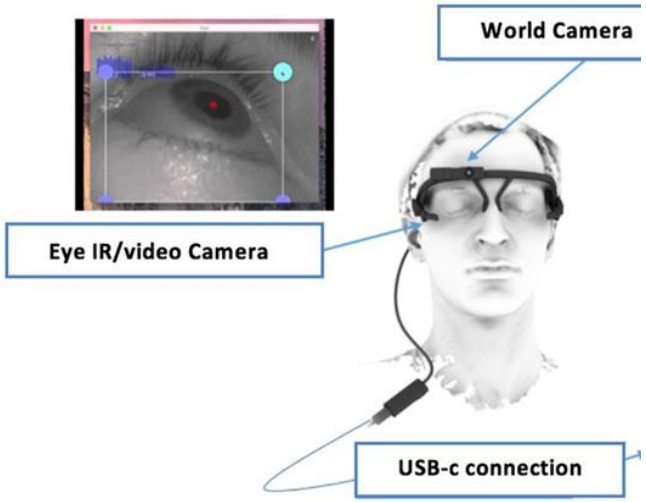


Inertial Motion Capture Systems (IMU-based)

IMU Units



METHODS – INSTRUMENTATION



- **Mobile Eye-tracking Device**
- Eye Cameras: Small cameras mounted on the glasses capture high-resol to measure pupil size and gaze direction.
- Scene Camera: A forward-facing camera records the visual environment from the user's perspective.
- What It Measures:
  - Gaze Direction: Where the user is looking.
  - Pupil Diameter: Changes in pupil size over time.
  - Eye Movements: Saccades, fixations, blinks.
  - Gaze-Scene Mapping: Integrates gaze data with video from the scene camera.
- The pupil labs eye tracker provides data regarding eye movements, head movements (using the embedded Inertial Measurement Unit (IMU)

METHODS – EVERYDAY TECH AROUND US

We don’t need a lab to start asking scientific questions.
Our phone, earbuds, smartwatch, and other tech. around us are full of sensors.

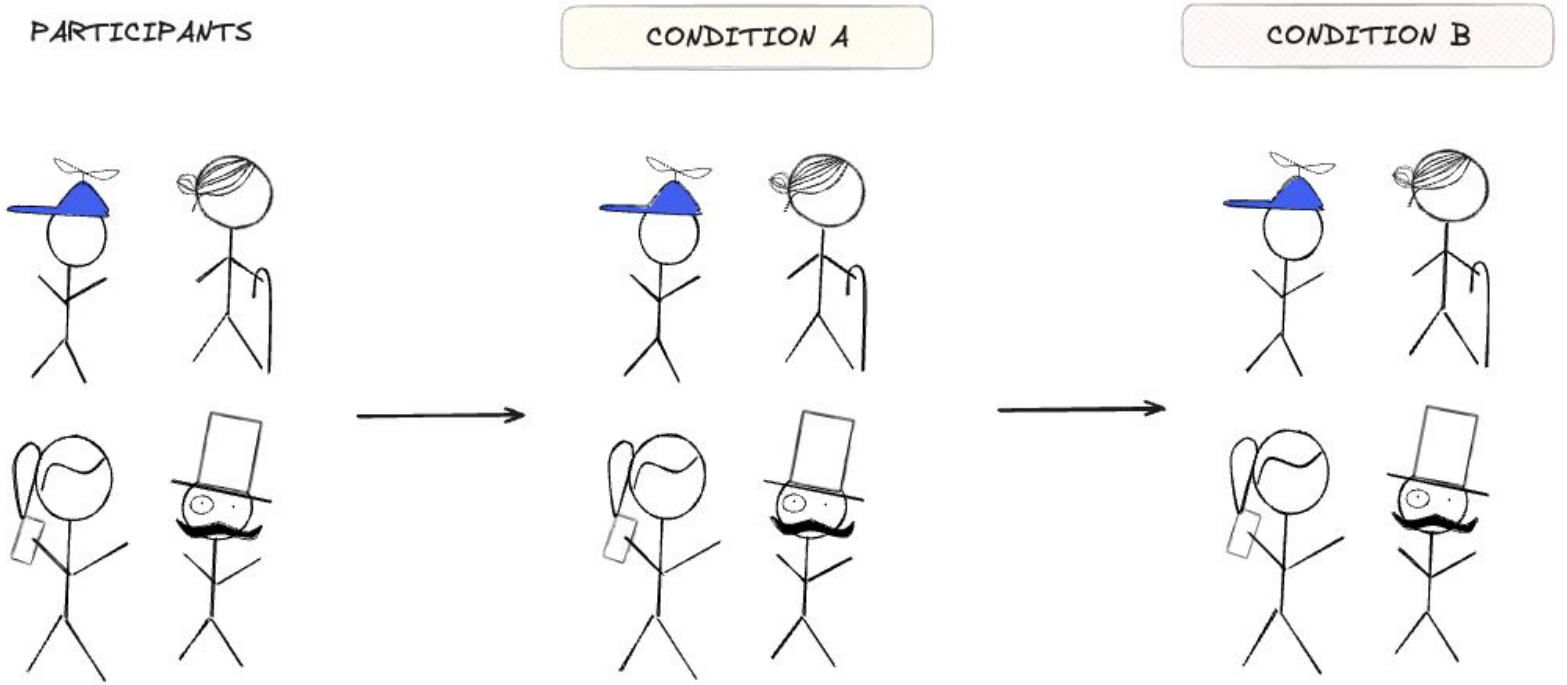
- Smartphones: Equipped with *accelerometer, gyroscope, GPS, magnetometer, barometer, ambient light sensor, proximity sensor, microphone, and camera* — useful for tracking motion, orientation, location, and environment.
- Smartwatches: Include sensors like *heart rate monitor, accelerometer, gyroscope, and sometimes skin temperature and blood oxygen* — great for measuring activity, physiology, and movement in real time.
- Wireless Earbuds (e.g., AirPods): Contain *accelerometers and gyroscopes* to track head movement and orientation — useful for studying balance, posture, or attention direction.

While not as precise as scientific-grade tools like motion capture, these sensors are **accessible**, **affordable**, and perfect for **starting your own research project**.

STUDY DESIGN

Repeated Measures Study:

- The same participants are measured under multiple conditions or time points
- Each person acts as their own control, reducing variability
- Ideal for studying effects of different conditions on the same group



STUDY DESIGN

<fill in the table below during lecture >

	Condition 1	Condition 2	Condition 3
Task 1			
Task 2			

<fill in the list below during lecture >

List of Variables we will compare today:

1.

< we can measure the following in lecture >

- step length
- velocity
- cadence
- double support %
- head orientation

DATA COLLECTION

Walking

< fill the table in lecture >

	Normal	Simulated VI	blindfolded
Head movement			
cadence			
Walking speed			
Variable 4			
Variable 5			

DATA COLLECTION

Obstacle Negotiation

< fill the table in lecture >

	Normal	Simulated VI	blindfolded
Head movement	On plots		
cadence	98	79	62
Walking speed	4.07	3.9	1.51
Variable 4			
Variable 5			

WHICH PARTS OF YOUR BODY WERE ENGAGED?

Eyes

- **Role:**
  - Gather visual information about the environment.
  - Anticipate obstacles, adjust step placement.
  - Initiate gaze shifts to guide the head and body.

- **In Walking:**
  - Saccades and fixations direct attention.
  - Smooth pursuit adjusts to moving objects.

WHICH PARTS OF YOUR BODY WERE ENGAGED?

Head & Neck

- **Role:**
  - Align gaze with environmental features.
  - Stabilize vision during motion (vestibulo-ocular reflex helps keep gaze stable).
- **In Walking:**
  - Subtle head movements refine gaze direction.
  - Larger turns help with orientation and spatial planning

WHICH PARTS OF YOUR BODY WERE ENGAGED?

Trunk

- **Role:**
  - Stabilizes upper body.
  - Transfers rotational energy during turns.
  - Maintains balance and posture.

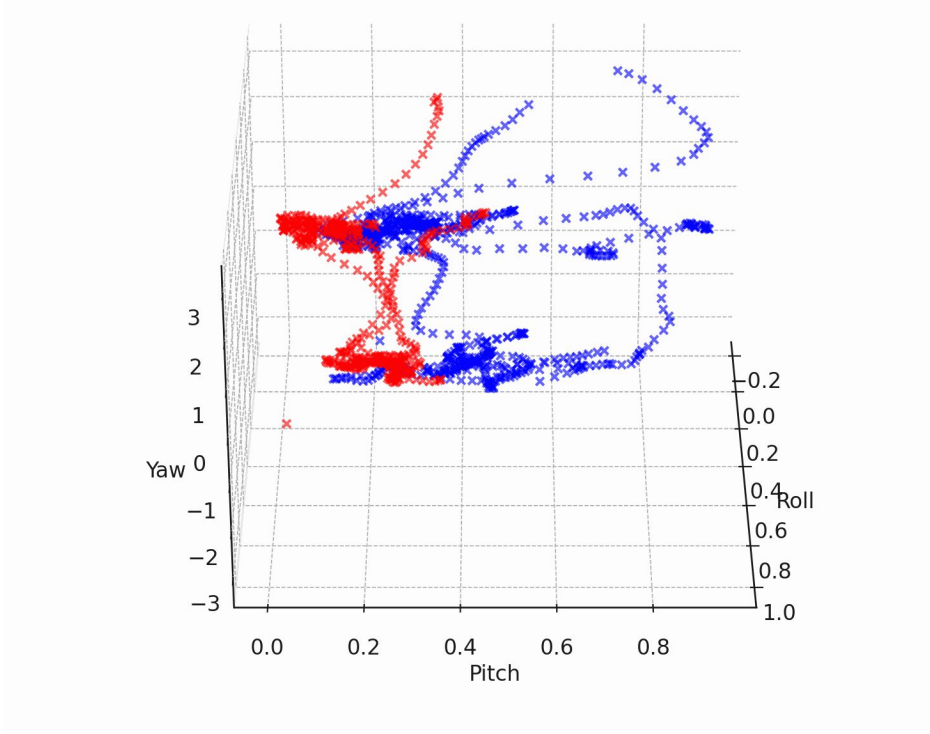
Lower Body (Legs & Feet) - Primary Engine of Locomotion

- **Hips:** Initiate leg swing and control stride length.
- **Knees:** Absorb impact, control elevation and stability.
- **Ankles/Feet:** Provide propulsion, adjust to surface irregularities.

DATA ANALYSIS – VISUALISATION

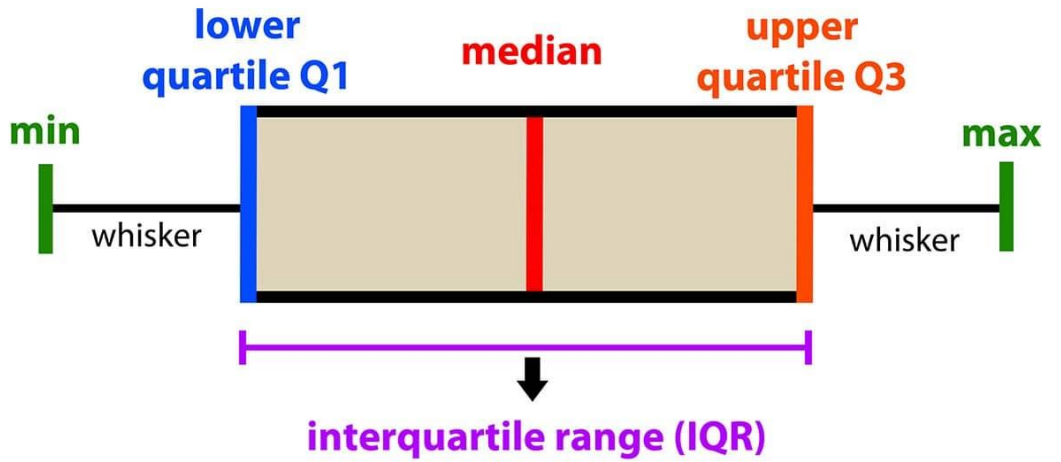
Scatter Plot

- Show relationships between three variables simultaneously



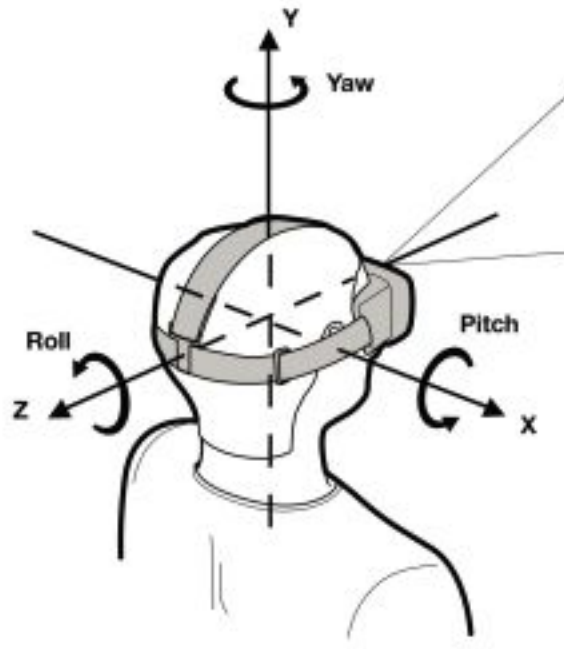
Box and Whiskers Plot

- Summarize the distribution of a single variable (e.g., pitch or yaw)
- Display median, quartiles, and outliers clearly



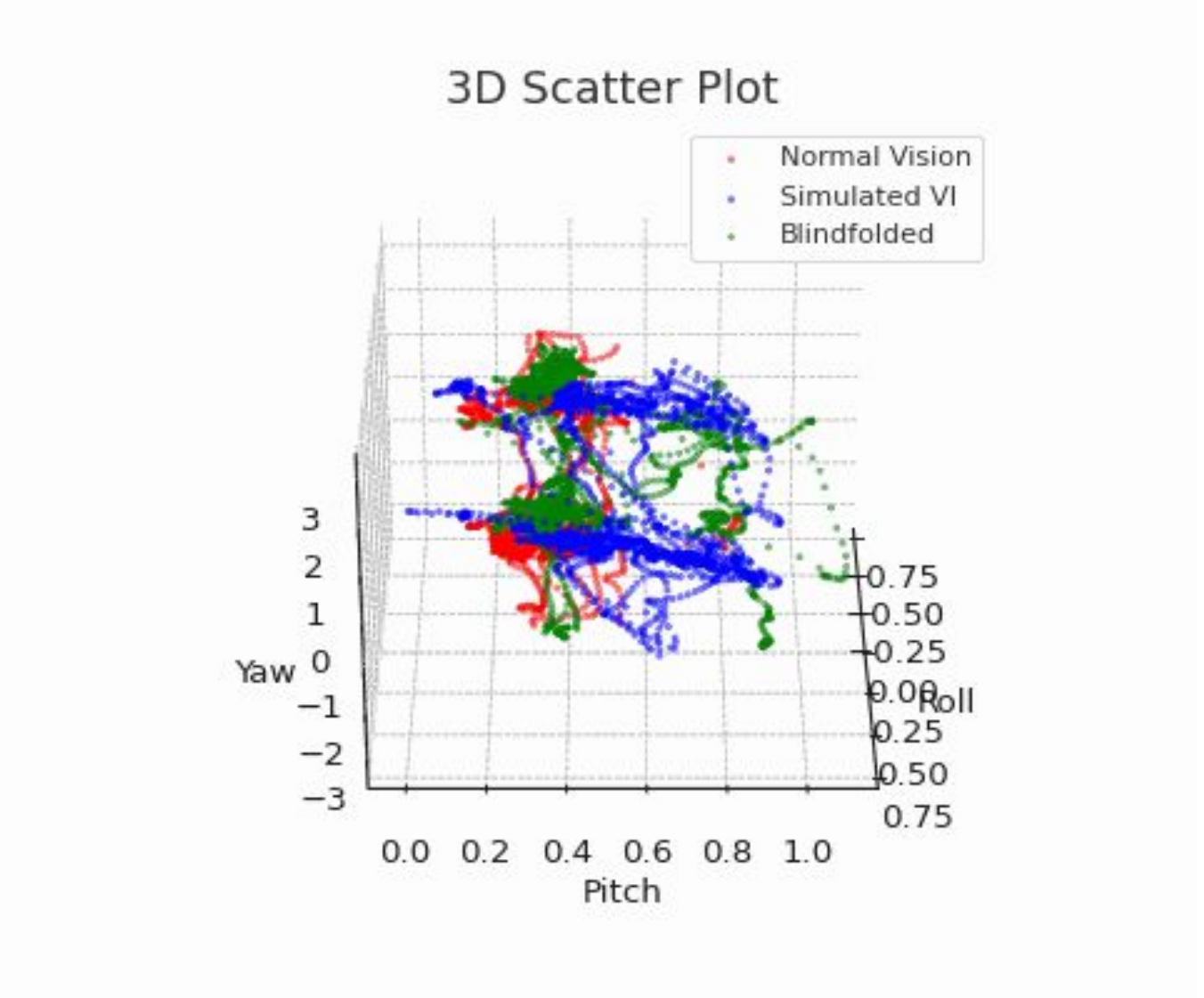
RESULTS

<Input plots live in lecture>



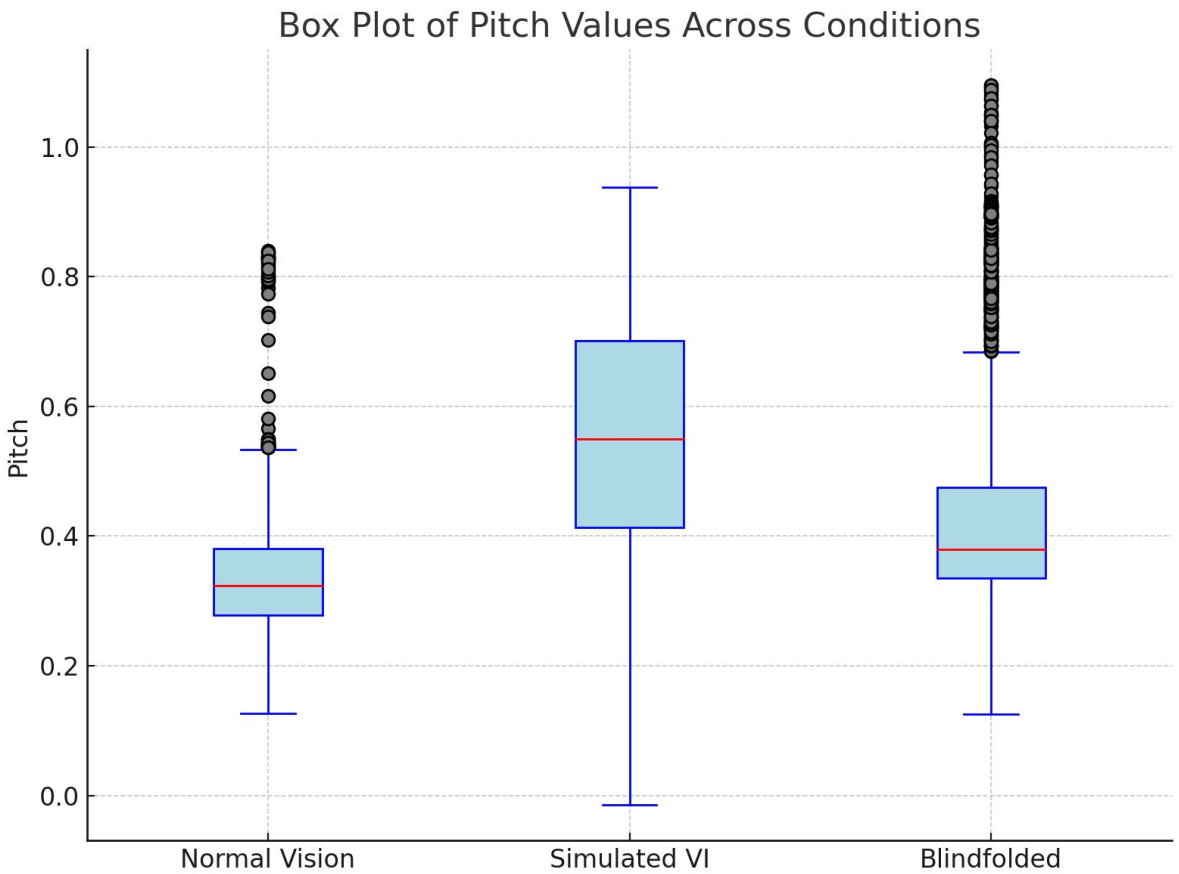
RESULTS

<Input plots live in lecture>



RESULTS

<Input plots live in lecture>



DISCUSSION

< Based on the results we saw, did we answer the questions? >

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Thank You
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