On Exploring the Use of Mobility Parameters in the Analysis of Early Childhood Developmental Disorders

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Bio

- Name: Rama Krishna Thelagathoti
- Pursuing PhD In Information Technology at University of Nebraska Omaha.
- Research Interests
  - Mobility analysis for Healthcare
  - Correlation Networks
  - Artificial Intelligence for Health
- 10 + years of industry experience
- Ex-Qualcomm & Ex-NXP semiconductor

Projects

- A Population Analysis Approach using Mobility Data and Correlation networks for Depression Episodes Detection
- A novel population analysis approach for identifying decease levels using correlation networks and mobility analysis

Research question

How **mobility and its associated mobility parameters have** been used in the **early childhood developmental disorders**

Method

- Literature study and analysis from the articles that includes

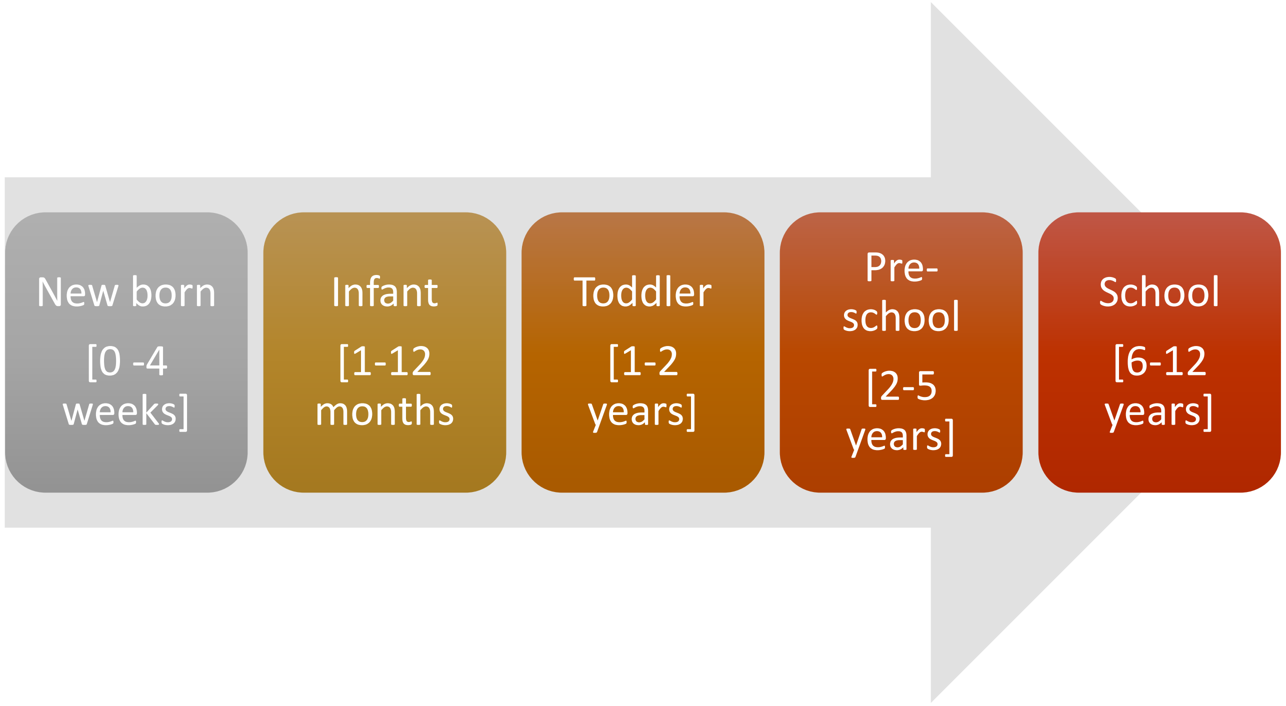
1. Data collection using wearable sensors

2. Early childhood developmental disorders

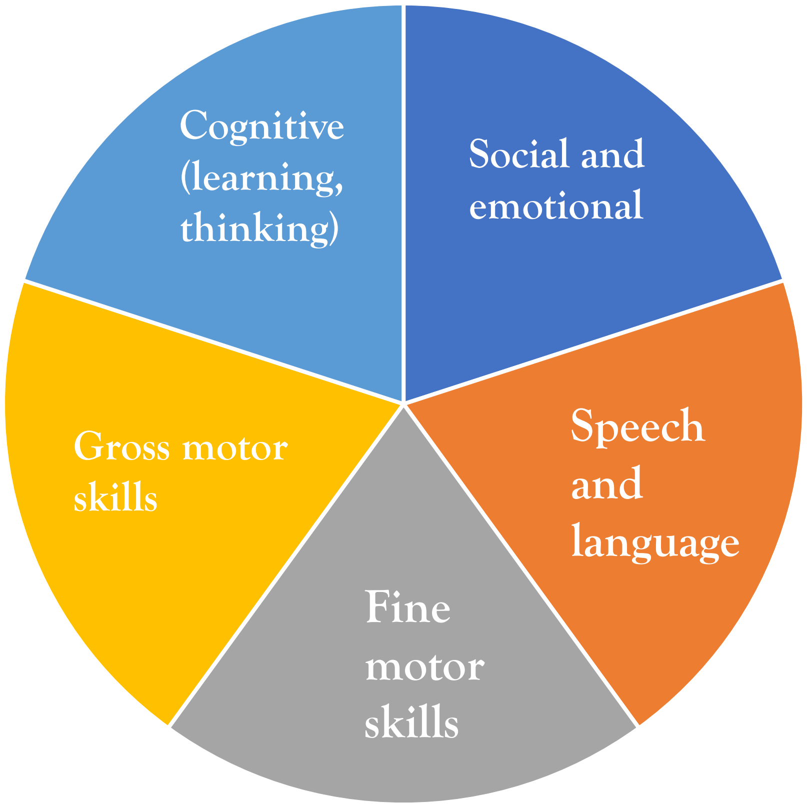
3. Mobility assessment as a method of diagnosis

Introduction

What is a developmental disorder?



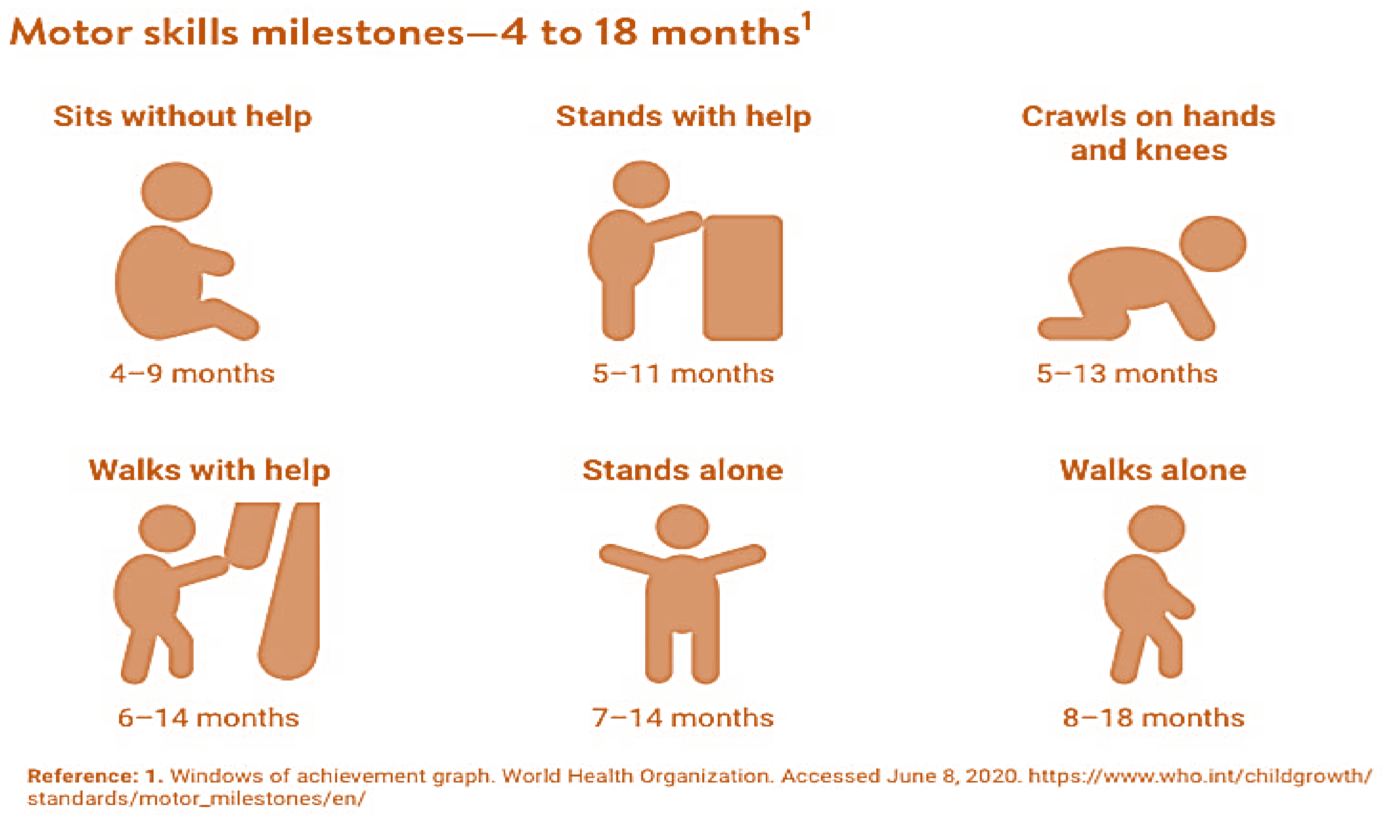
5 stages in childhood



5 types of skills developed during childhood

What is a developmental disorder?

What most babies do by this age?



What is a developmental disorder?

- **Lag (delay)** in core functions
  - movements, speech, etc
- **Abnormal development of the nervous system[1,3].**
- Manifestation during **birth** or **school age**
- **Delay** may lead to **lagging** in one or more **skills** of the child[2].

1. Abrishami et al. “Identification of developmental delay in infants using wearable sensors: Full-day leg movement statistical feature analysis,” IEEE journal of translational engineering in health and medicine, vol. 7, pp. 1–7, 2019.
2. Centers for Disease Control and Prevention, “Developmental disabilities,” 2021, https://www.cdc.gov/ncbddd/developmentaldisabilities/index.html
3. Zablotsky et al. “Prevalence and trends of developmental disabilities among children in the united states: 2009–2017,” Pediatrics, vol. 144, no. 4, 2019.

Major childhood disorders

- Major childhood disorders
  - Autism spectrum disorder (ASD)
    - Social , cognitive, language and communication
  - Cerebral Palsy (CP)
    - Impaired motor development
  - Anxiety disorders
    - Mental disorder
  - ADHD
    - Attention deficit hyperactivity disorder

Why childhood disorders?

- Main reasons for developmental delays[3]
    1. Heredity
    2. complications during pregnancy
    3. premature birth
    4. Low birth weight
    5. unknown

3. Zablotsky et al. “Prevalence and trends of developmental disabilities among children in the united states: 2009–2017,” Pediatrics, vol. 144, no. 4, 2019.

Existing clinical diagnosis

- Self/Parent reporting feedback
- Trained physician consultation
- Milestone checks at each stage
  - Does the baby reached a milestone by the age

- Disadvantages
  - Observer dependent
  - Subjective
  - Time intensive

Mobility as a diagnostic feature

Mobility as a feature for diagnosis

- Early motor delays - initial signs of later developmental impairment
- Mobility of autistics child vs healthy child
  - Lower mobility profile
  - Stereo type movements
  - Lack of variable movements

Mobility as a feature for diagnosis

TD

- Typically developing
- Variable and complex movements

AR

- At-risk
- At risk of developing a disorder
- Lower mobility

NDD

- Neurodevelopmental disorder
- Diagnosed with disorder
- Lower complex and monotonous movements

Window of opportunity for AR kids

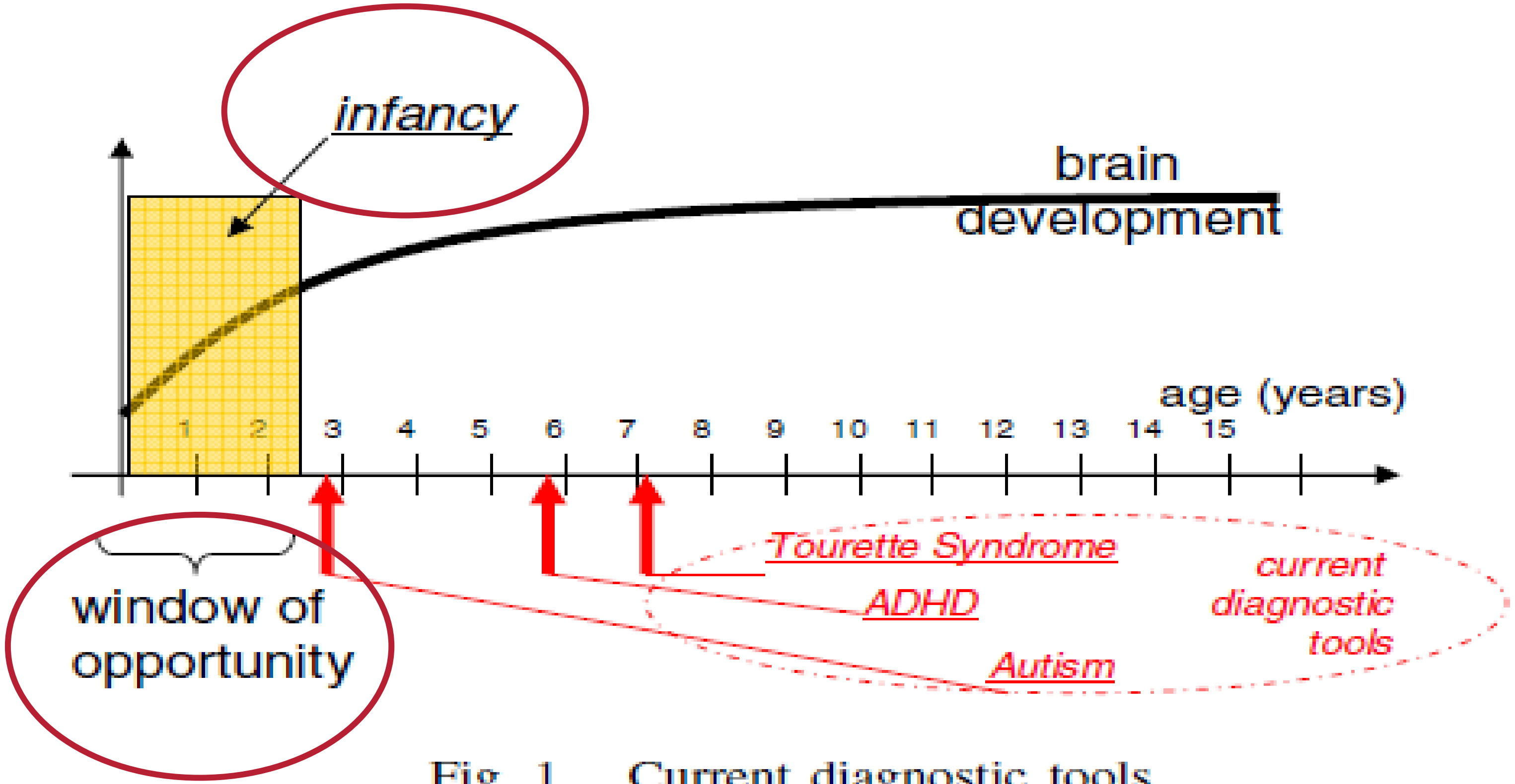


Fig. 1. Current diagnostic tools

Campolo, D., Taffoni, F., Schiavone, G., Laschi, C., Keller, F., & Guglielmelli, E. (2008). A novel technological approach towards the early diagnosis of neurodevelopmental disorders. Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual International Conference, 2008, 4875–4878. https://doi.org/10.1109/IEMBS.2008.4650306

Mobility-based diagnostic methods

Mobility – based diagnostic methods

Qualitative

- Subjective
- Scales are used to assess the severity
- Observer-dependent

Quantitative

- Objective
- Quantifies the mobility to assess the severity
- Observer-independent

Qualitative diagnostic methods

- AIMS scale (Alberta Infant Motor Scale)[4]
  - An observational assessment scale
  - Gross motor skills assessment of weight-bearing, posture and antigravity movements
- Prechtl's assessment for Cerebral Palsy (CP)[5]
  - General movements assessment (GMA)
  - Record a video of infant in supine position for 60 minutes
  - Trained consultant can assess on the general movements (GM) and decide whether child has CP

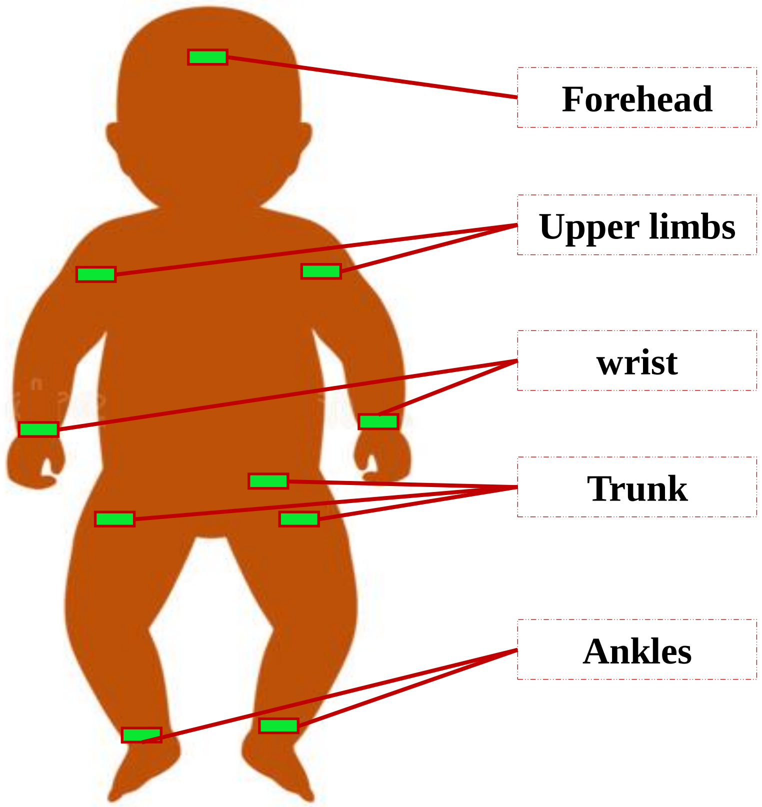
4. Piper, M. C., Darrah, J., Maguire, T. O., & Redfern, L. (1994). Motor assessment of the developing infant (Vol. 1). Philadelphia: Saunders
5. Einspieler, C., & Prechtl, H. F. (2005). Prechtl's assessment of general movements: a diagnostic tool for the functional assessment of the young nervous system. Mental retardation and developmental disabilities researc

Qualitative diagnostic methods

- Observer dependent
- Accuracy?
- Frequent clinical visits
- Increased human effort

Quantitative methods using wearable sensors

Sensor position



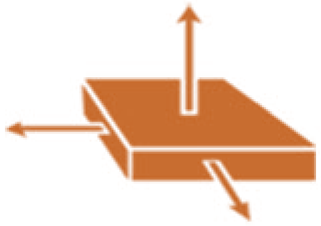
Impaired movements

- Repetitive
- Cramped
- Asymmetrical limbs
- Lower variability
- Lower movement acceleration
- Stereotyped

Major disorders

- Autism
- Cerebral Palsy
- ADHD
- Down syndrome

Data and devices



- Sensors
  - Accelerometer – commonly used sensor
  - Combination of sensors (IMU)
- Sensor instruments
  - Skin adhesive
  - Sensors embedded in clothes
  - Cloth wrapper leg warmer sensors
- Others
  - Gaze tracking
  - Motion tracking devices

Biomarkers
(what mobility parameters are assessed)

- Limb movements
- General Movements (GM) vs abnormal movements
- Variability and repeatability
- Frequency
- Stereo typical movements vs variable movements

Data Collection challenges

- Subjects are infants or kids
- Pacifying crying child
- Cumbersome of wires, sensors
- Duration of sensor attachment

Data processing

- Wear time and Duration of data collection is often ranging from hours to days
- Processing challenges
- Noise elimination
  - Infant vs adult subjects
- Data storage
  - Minimal internal memory
  - Cloud storage
  - Latency due to cloud communication

Techniques

- Predominantly Machine learning techniques
  - Random Forest
  - Support vector Machine
  - Decision trees
- Statistical techniques
- Discriminant analysis

Quantitative approaches

- Using Wearable Sensor Technology to Measure Motion Complexity in Infants at High Familial Risk for Autism Spectrum Disorder
    - Wilson, R.B.; Vangala, S.; Elashoff, D.; Safari, T.; Smith, B.A. Using Wearable Sensor Technology to Measure Motion Complexity in Infants at High Familial Risk for Autism Spectrum Disorder. *Sensors* 2021, *21*, 616. https://doi.org/10.3390/s21020616

- Sensor - Accelerometer
- Wear time – 8 to 13 hours
- Computed Motion complexity (MC) – a measure of infant's movements profile
- Result
    - TD infant's MC is higher than AR
    - movements are complex and variable
- MC measures complexity level of the movements to classify group of infants into TD and AR

Quantitative approaches

- Sample Entropy Identifies Differences in Spontaneous Leg Movement Behavior between Infants with Typical Development and Infants at Risk of Developmental Delay.
  - Smith, B. A., Vanderbilt, D. L., Applequist, B., & Kyvelidou, A. (2017). Sample Entropy Identifies Differences in Spontaneous Leg Movement Behavior between Infants with Typical Development and Infants at Risk of Developmental Delay.

- Sensor - Accelerometer and gyroscope
- Wear time – 8 to 13 hours
- Sample entropy is a measure of infant's variability and repeatability of spontaneous leg movements
- Result
  - Sample entropy values are higher for TD, lower for AR

Summary of Quantitative methods

Reference	Purpose	Sensor	Sensor placement	Wear time (in hours)	Setting	Disorder	Movement type	Subjects	Age (in months)
[7]	Classify TD and AR	IMU	Ankles	8-13	Natural	NA	Spontaneous leg movements	12 TD 19 AR	1-15
[14]	Early diagnosis	IMU	Wrist and ankles	NA	Clinical	ASD	Spontaneous leg and arm movements	NA	NA
[19]	Classify TD and AR	IMU	Ankles	8-13	Natural	NA	Spontaneous leg movements	12 TD 19 AR	1-16
[20]	Diagnose ASD	IMU	Ankles	8-12	Natural	ASD	Spontaneous leg movements	5	3-12
[21]	Diagnose CP	Accelerometer	Ankles and wrist	20 min	Clinical	CP	Spontaneous leg and arm movements	19 TD 4 AR	<10
[18]	Diagnosis CP	IMU	Forehead, ankles, and wrist	1 min	Clinical	CP	Spontaneous head, leg, and arm movements	1 TD	3-5
[22]	Quantify leg movements	Inertial sensor	Ankles	8-13	Natural	NA	Spontaneous leg movements	12 TD	1-12
[4]	Predict impaired motor activity	Accelerometer	Head, ankles, and wrist	1	Clinical	CP	Spontaneous head, leg and arm movements	10 AR	<3
[23]	Number of days required for assessment	IMU	Ankles	5 days	Natural	NA	Spontaneous leg movements	16 AR	2-14
[15]	Measure variability of movements	IMU	Ankles	8-13	Natural	NA	Spontaneous leg movements	11 TD 20 AR	6-9
[24]	Assess leg movements	accelerometer	Right ankle	48 hrs. x 4 times	Natural	DS	Spontaneous right leg movements	8 TD 8 AR	3-6
[16]	Predict motor disorder	Accelerometer and gyroscope	Trunk, upper and lower limbs	4	clinical	CP, stroke	Predefined body movements	4 AR	9-12 years
[17]	Clinical vs motor assessment	Accelerometer	wrist	75	Natural	CP	Spontaneous upper arm movements	26 TD 26 AR	1-17 years

Thank You

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