Dynamic Balance Device

BME 301
February 20, 2026
Client: Mr. Dan Kutschera
Advisor: Professor Monica Ohnsorg

Team: Katherine Sattel, Therese Kalt, Noor Awad, and Freyja Heggeland

Speaker: Therese

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Speaker: Therese

Problem Statement

- ~30% of patients who have suffered from stroke experience Spatial Neglect Syndrome or lose vestibular sense, leading to falls that set back their recoveries [1].
- The client is currently using a yardstick with a bright-colored sticky note at the end
- The client needs a device that can be used to improve visual scanning and balance training that is lighter than his previous design (<0.36kg)

Figure 1: Yardstick with a brightly-colored sticky note at the end

Background

Client Background: Mr. Daniel Kutschera

- Physical therapist, specializes in rehabilitation of stroke patients

- Spatial neglect is most commonly caused from hemispheric stroke and results in impaired spatial attention [2]
- Visuomotor training involves asking the patient to reach toward and object to help their brain better interpret depth perception and spatial relationships [3].

Figure 2: Visuomotor Training [4]

Competing Designs

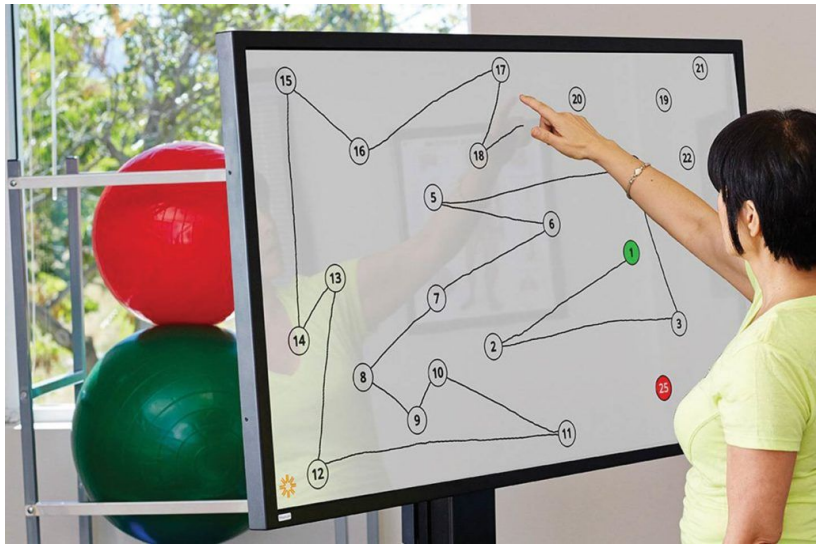

Figure 3: Bioness Integrated Therapy System [5]

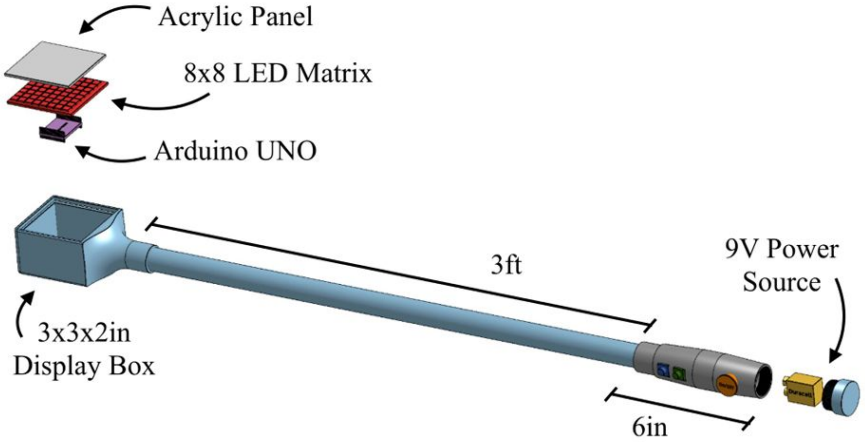

Figure 4: Previous Model from Fall 2024

Speaker: Noor

Product Design Specifications

Speaker: Noor

Product Design Specifications

Client requirements:

- 10% lighter than previous design
- 7.5 cm display
- Various colors and shapes on display
- Functional Reach Test

Cost:

- $500

Size and Weight:

- Min Length = 61 cm
- Max Weight = 0.36 kg

Materials:

- Easily Sanitized
- Durable attachments

Speaker: Noor

Design Matrices

Speaker: Noor

Audio Feedback Systems

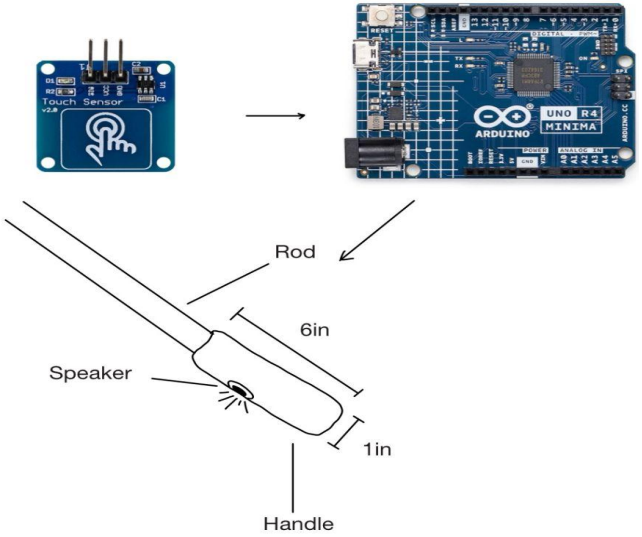

Figure 5: Sensor-Activated Speaker

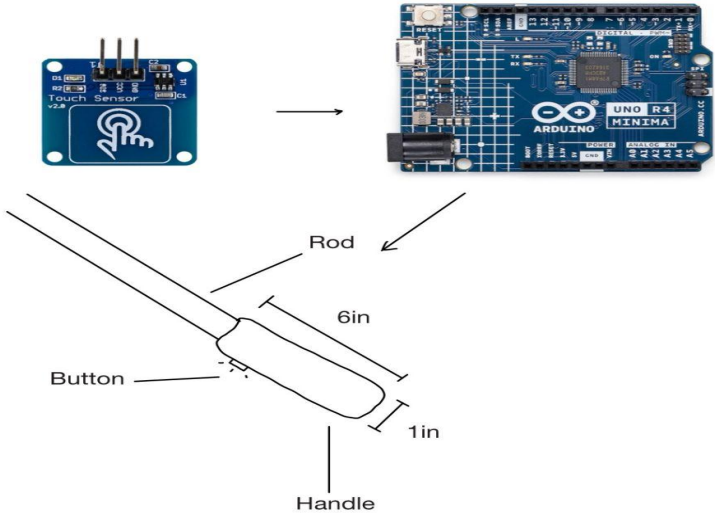

Figure 6: Sensor-Activated Noisemaker

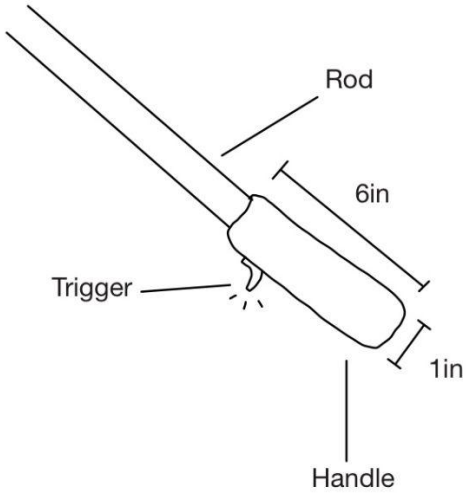

Figure 7: Manual Trigger

Auditory Feedback Design Matrix

Speaker: Noor

Designs		Design 1: Sensor-activated Speaker		Design 2: Sensor-Activated Button		Design 3: Manual Trigger	
Rank	Criteria	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
1	Weight (35)	3/5	21	4/5	28	4/5	28
2	Ease of Use (30)	5/5	30	5/5	30	3/5	18
3	Ease of Fabrication (20)	4/5	16	2/5	8	4/5	16
4	Sound Variability (10)	5/5	10	3/5	6	3/5	6
5	Cost (5)	3/5	3	3/5	3	5/5	5
Total			80		75		74

Table 1: Design Matrix of Auditory Feedback Designs and Weighted Categories

Material Options

Carbon Fiber

- Toughness: 22 MJ/m^3 [6]
- Modulus: 250 GPa [7]
- Cost: $0.03 /gram [8]
- Density: 1.7 g/cm^3 [9]

Figure 8: Carbon Fiber Rods [18]

Aluminum Alloy

- Toughness: 30 MJ/m^3 [10]
- Modulus: 70 GPa [11]
- Cost: $0.002 /gram [12]
- Density: 2.7 g/cm^3 [13]

Figure 9: Aluminum Alloy Rods [19]

PVC Pipe

- Toughness: 30 MJ/m^3 [14]
- Modulus: 55 MPa [15]
- Cost: $0.0008 /gram [16]
- Density: 1.4 g/cm^3 [17]

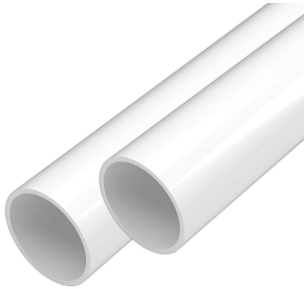

Figure 10: PVC Tubing [20]

Material Design Matrix

Speaker: Freyja

Materials		Design 1: Carbon Fiber		Design 2: Aluminum Alloy		Design 3: PVC Pipe	
Rank	Criteria	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
1	Weight (40)	5/5	40	2/5	16	3/5	24
2	Durability (30)	5/5	30	5/5	30	4/5	24
3	Ease of Fabrication (15)	1/5	3	3/5	9	5/5	15
4	Ease of Engraving (10)	2/5	4	4/5	8	4/5	8
5	Cost (5)	3/5	3	4/5	4	5/5	5
			80		67		76

Table 2: Material Design Matrix with Weighted Values

Overall Design Options

Fixed Length Shaft

- Static length shaft
- Lightweight and mobile
- Switch allows for display

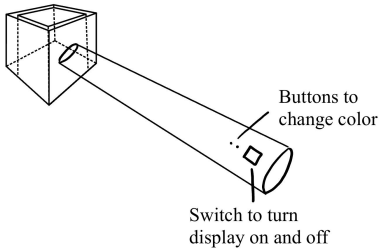

Figure 11: Fixed Length Shaft

Push Button Pin Shaft

- Allows for dynamic length
- Switch-controlled visual
- Lightweight and easily sterilized

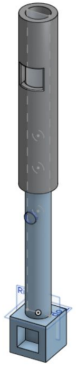

Figure 12: Push Button Pin Shaft

Hands-Free Board

- Allows for hands-free use
- Allows work with other devices
- Less portable than others

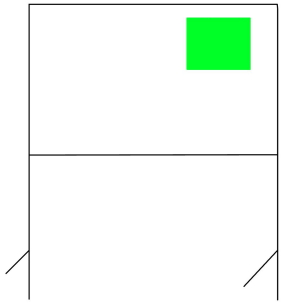

Figure 13: Hands-Free Board

Overall Design Matrix

Speaker: Freyja

Materials		Design 1: Fixed Length Shaft		Design 2: Push Button Pin Shaft		Design 3: Hands-Free Board	
Rank	Criteria	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
1	Weight (25)	4/5	20	4/5	20	5/5	20
2	Durability (25)	5/5	25	4/5	20	4/5	20
3	User Comfort (20)	4/5	16	4/5	16	3/5	12
4	Ease of Fabrication (15)	5/5	15	3/5	9	2/5	6
5	Safety (10)	5/5	10	4/5	8	4/5	8
6	Cost (5)	5/5	5	4/5	4	1/5	1
			81		77		67

Table 3: Overall Design Matrix

Speaker: Freyja

Final Designs

Final Designs

- Fixed-Length Shaft design
- Paired with the Sensor-Activated Speaker
- Shaft constructed with Carbon Fiber
- Bulk of weight centered at the handle
    - Acts as counterweight
    - Lowers the work needed to raise
- Ruler etched on rod to measure reach

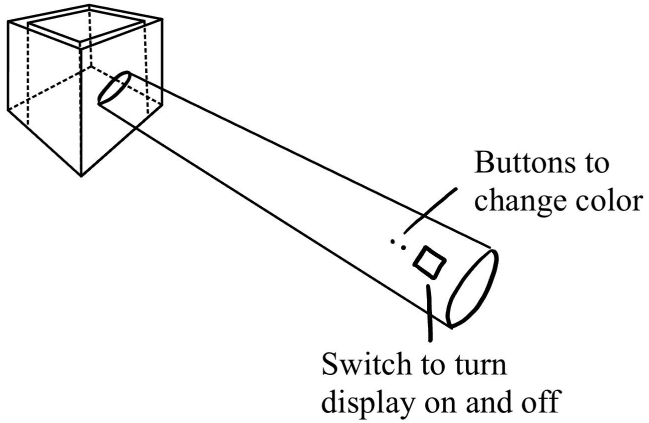

Figure 14: The Fixed-Length Shaft Design

Speaker: Katherine

Testing

Speaker: Katherine

Testing

- Material Properties
  - MTS testing of material components
  - Quantitative strength and elastic modulus values
- Fatigue
  - 5 point scale to measure comfort during typical use
- Battery Life
  - Ensure battery life is suitable for client needs

Future Work

Speaker: Katherine

Future Work:

Short Term:

- Fabrication:
  - Using PVC for preliminary fittings/attachments
  - Update to carbon fiber for final
- Testing and design iteration

Long Term:

- Follow-up on client feedback/usage
- Improved display with higher resolution
- More portable/compact design

References

[1] E. Esposito, G. Shekhtman, and P. Chen, "Prevalence of spatial neglect post-stroke: A systematic review," *Annals of Physical and Rehabilitation Medicine*, vol. 64, no. 5, p. 101459, Sep. 2021, doi: https://doi.org/10.1016/j.rehab.2020.10.010.

[2] K. Li and P. A. Malhotra, "Spatial Neglect," *Practical Neurology*, vol. 15, no. 5, pp. 333–339, May 2015, doi: https://doi.org/10.1136/practneurol-2015-001115.

[3] Y. Wang, L. Huang, Z. Wang, and T. Liu, "Visuomotor Training to Enhance Proprioception of Contralateral Wrist Based on the Cross-Transfer Effect," *CNS Neuroscience & Therapeutics*, vol. 31, no. 9, Sep. 2025, doi: https://doi.org/10.1111/cns.70504.

[4] "Motion Works Physiotherapy & Sports Injury Centre," *Mwphysiostittsville.com*, 2025. https://www.mwphysiostittsville.com/site/blog/2025/01/14/dizziness-vs-vertigo-treatment-for-vestibular-disorders (accessed Feb. 20, 2026).

[5] A. Z. Durfee and A. E. Hillis, "Unilateral Spatial Neglect Recovery Poststroke," *Stroke*, vol. 54, no. 1, pp. 10–19, Jan. 2023, doi: https://doi.org/10.1161/strokeaha.122.041710.

[6] K. Yang *et al.*, "Integrating tough Antheraea pernyi silk and strong carbon fibres for impact-critical structural composites," *Journal Nature communications*, vol. 10, no. 1, Aug. 2019, doi: https://doi.org/10.1038/s41467-019-11520-2.

[7] Epsilon Composite, "The different grades of carbon fiber - Epsilon Composite," *Epsilon Composite spécialisée dans la production de pièces et sous-ensembles en matériaux composites*, 2025. https://www.epsilon-composite.com/en/carbon-fiber-grades (accessed Feb. 19, 2026).

[8] SMITeam, "Carbon Fiber Cost: Factors That Influence The Most," *SMI Composites*, Nov. 10, 2020. https://www.smicomposites.com/carbon-fiber-cost-factors-that-influence-the-most/ (accessed Feb. 19, 2026).

References Continued

[9] http://www.dexcraft.com/articles/author/dexcraft, "Carbon Fiber Composites: properties | manufacturing methods | pros and cons," *Carbon fiber blog*, Nov. 04, 2015. https://www.dexcraft.com/carbon-fiber-composites (accessed Feb. 19, 2026).

[10] AZO Materials, "Properties: Aluminum - Advantages and Properties of Aluminum," *AZoM.com*, 2019. https://www.azom.com/properties.aspx?ArticleID=1446 (accessed Feb. 19, 2026).

[11] Simmal, "Understanding the Modulus of Elasticity of Aluminium | Simmal," *Simmal*, Sep. 26, 2025. https://simmal.com/understanding-the-modulus-of-elasticity-of-aluminium/ (accessed Feb. 19, 2026).

[12] O. Team, "Okon Recycling," *Okon Recycling*, Sep. 19, 2025. https://www.okonrecycling.com/industrial-scrap-metal-recycling/steel-and-aluminum/waste-metal-prices/ (accessed Feb. 19, 2026).

[13] J. R. Davis, "Aluminum and Aluminum Alloys," *Alloying: Understanding the Basics*, 2001, doi: https://doi.org/10.1361/autb2001p351.

[14] A. Rodolfo and V. M. John, "Application of fracture mechanics for the characterization of poly(vinyl chloride) pipes. II . Evaluation of a ring-type specimen for fracture mechanics testing," *Journal of Vinyl and Additive Technology*, vol. 27, no. 4, pp. 806–820, Jul. 2021, doi: https://doi.org/10.1002/vnl.21852.

[15] PVC4PIPES, "The four main different PVC pipe categories," *PVC4Pipes*. https://pvc4pipes.com/pvc-pipes/pvc-pipe-categories/ (accessed Feb. 19, 2026).

[16] Mike, "PVC price index," *businessanalytiq*, Aug. 03, 2020. https://businessanalytiq.com/procurementanalytics/index/pvc-price-index/ (accessed Feb. 19, 2026).

[17] SpecialChem, "Polyvinyl Chloride (PVC) Plastic: Uses, Properties, Benefits & Toxicity," *Specialchem.com*, 2025. https://www.specialchem.com/plastics/guide/polyvinyl-chloride-pvc-plastic (accessed Feb. 19, 2026).

References Continued

[18] Ikan Materials, “Pair of 15mm Carbon Fiber Rods - 8" - Ikan,” *Ikan*, Feb. 13, 2026. https://ikancorp.com/shop/rigs-matte-boxes-follow-focus/elements-rigs-rigs-matte-boxes-follow-focus-2/ikan-ele-15cfr8-p-pair-of-15mm-carbon-fiber-rods-8/?srsltid=AfmBOooWZYg0fvQHpca_lQmXovNofh5nhz8u4UlDdObvLY7bJUoT_7ex (accessed Feb. 19, 2026).

[19] DirectIndustry, “aluminum alloy rod IMPOL D.O.O.,” *http://twitter.com/DirectIndustry*, 2016. https://www.directindustry.com/prod/impol-doo/product-192929-2036081.html (accessed Feb. 19, 2026).

[20] FORMUFIT, “1-1/2 in. Thinwall Furniture Grade PVC Pipe - White,” *FORMUFIT*, 2026. https://formufit.com/products/1-1-2-in-x-5-ft-furniture-grade-thinwall-pvc-pipe-2-pack?srsltid=AfmBOoq1xEceEs0Iq84GobsVLEeFFfbDpF8LoFprApafsqfoB_Z0czbI (accessed Feb. 19, 2026).

Speaker: Katherine

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Questions?