

112年人因工程概念與應用推廣課程

人因工程概念與應用

劉品伶 Pin-Ling Liu, Ph.D.
Postdoctoral Researcher
National Tsing Hua University
Hsinchu, Taiwan



Outline

- 人因工程簡介
- 人因工程的概念與範疇：生理、認知、組織
- 常見評估工具介紹與研究分享
- 人因角度之醫療相關應用概念

人因工程

Ergonomics

(ergon)work (nomos) laws

Human Factors

人因工程

E/HF

人類工效學

HF/E

人間工學

- 發現關於人類的行為、能力、限制和其他特性等知識，而應用於工具、機器、系統、任務、工作和環境等的設計，使人類對於它們的使用能更具生產力、安全、舒適與有效 (Sanders and McCormick, 1987)
- 了解人和一個系統內其他元素互動的學科；應用理論、基礎原則、數據與相關方法設計出能優化人類福祉和系統效率的專業
 - A scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance (International Ergonomics Association, IEA)

REF

Sanders, M. S. and McCormick, E. J., 1987. Human Factors in Engineering and Design (6th ed.). NY: McGraw-Hill Book Company
<https://iea.cc/what-is-ergonomics/>

人因工程應用概念



- Human memory capacity

- The magic number (Miller, G. A., 1994)
 - window display ideas for fashion store
 - strategy apply to the design of a telephone book

7±2



- Hand dominance /Hand use behavior/Muscle strength

- for developing hand-controlled devices and systems (Jung, H. S., & Jung, H. S.,2009)
- push button



- Anthropometry

- Industrial settings design (Castellucci et al., 2020)

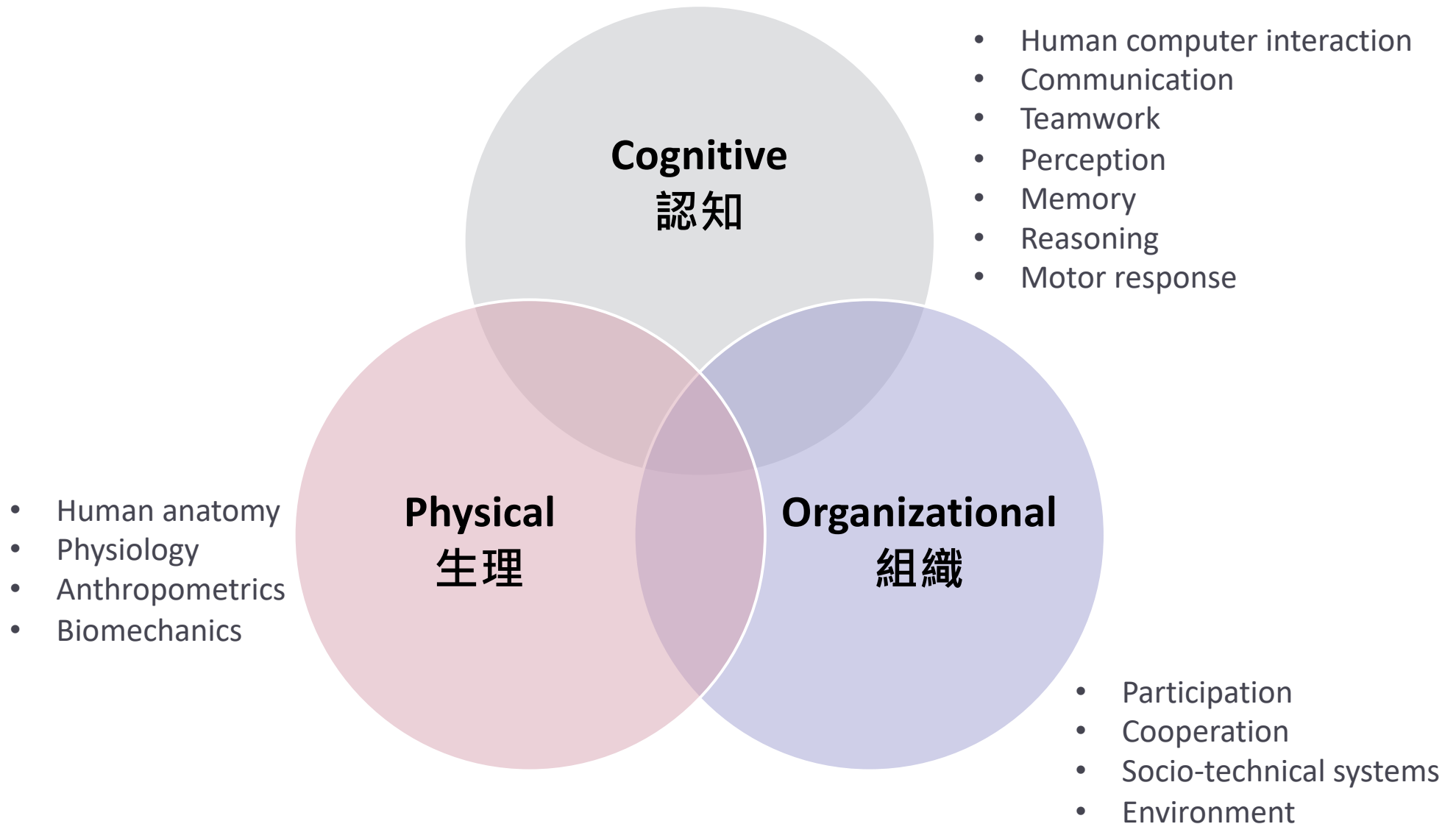
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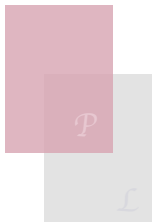
Miller, G. A. (1994). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, 101(2), 343–352.

Jung, H. S., & Jung, H. S. (2009). Hand dominance and hand use behaviour reported in a survey of 2437 Koreans. *Ergonomics*, 52(11), 1362-1371.

Castellucci, H., Viviani, C., Arezes, P., Molenbroek, J. F., Martínez, M., Aparici, V., & Dianat, I. (2020). Applied anthropometry for common industrial settings design: Working and ideal manual handling heights. *International Journal of Industrial Ergonomics*, 78, 102963.

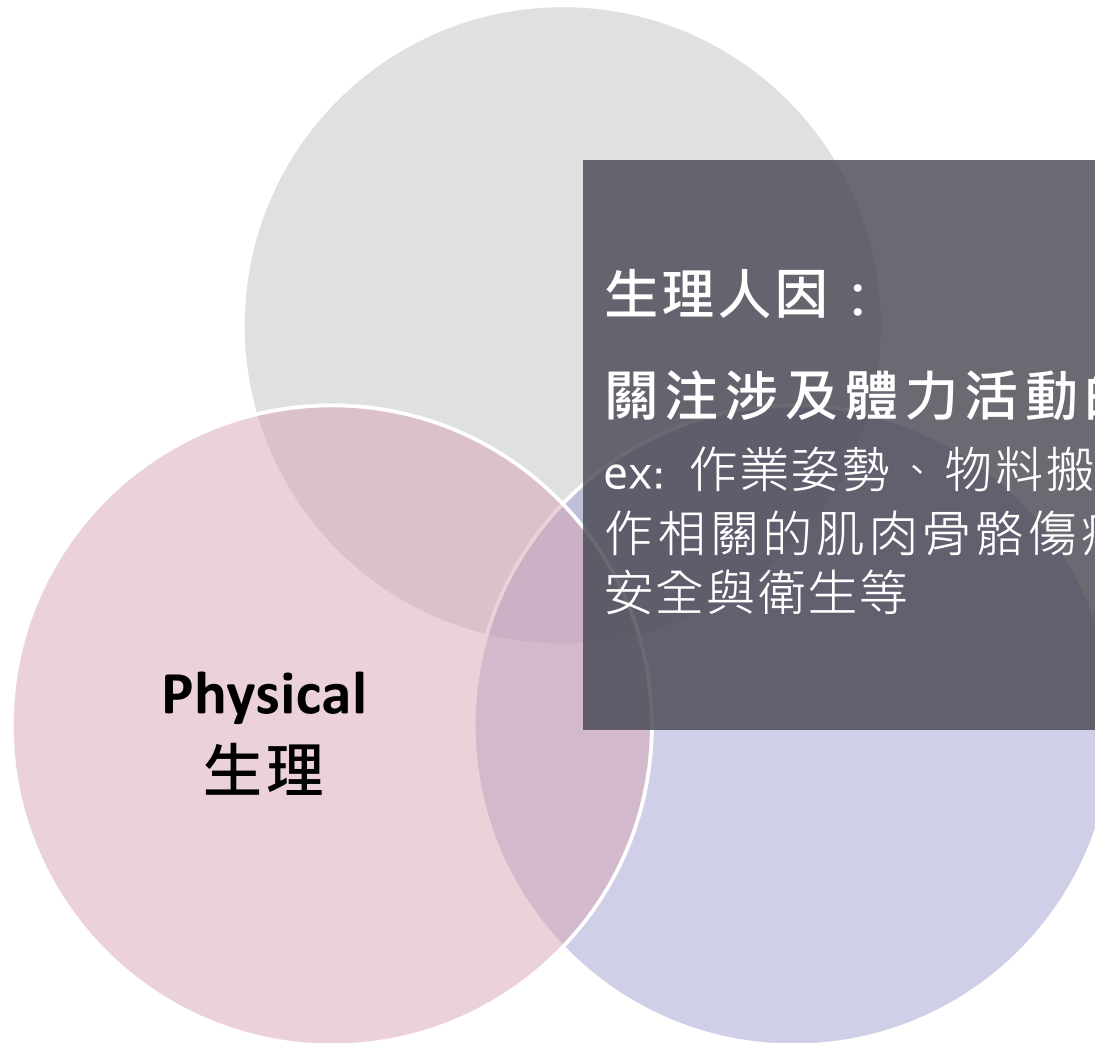
Domains of Human Factors/Ergonomics





Physical Ergonomics

- 人體解剖
- 生理學
- 人體計測
- 生物力學



生理人因：
關注涉及體力活動的人員特徵資訊
ex: 作業姿勢、物料搬運、反覆動作、工作相關的肌肉骨骼傷病、作業場所配置安全與衛生等



Physical Ergonomics Studies/Common Tools

- 人體計測資料量測與分析
 - Body dimensions
- 動作追蹤與生物力學分析
 - Motion data
 - Force/Moment
 - Observational method
- 生理參數量測
 - EMG
- ...



Anthropometry

- 人體計測：量度人員身體各項特徵的學問
 - 直線尺寸 (高度、寬度、長度、深度) 、環圍、彎曲角度、體表面積、肌肉厚度、身體各部位可觸及範圍
 - 傳統手工量測 (Garlie and Choi, 2014) 到全身三維掃描 (Daanen and Ter, 2013)

REF

Garlie, T., & Choi, H. J. (2014). Characterizing the size of the encumbered soldier. ARMY NATICK SOLDIER CENTER MA.

Daanen, H. A., & Ter Haar, F. B. (2013). 3D whole body scanners revisited. *Displays*, 34(4), 270-275.

Mugisa, D. J., Katimbo, A., Sempira, J. E., & Kisaalita, W. S. (2016). Anthropometric characteristics of female smallholder farmers of Uganda—Toward design of labor-saving tools. *Applied ergonomics*, 54, 177-185.



Anthropometry: 設計應用

- EEG headset (Lacko, D., 2017)

- oxygen mask (Lee, W. et al., 2013)

- equipment and clothing for the US Army (Yokota, M. et al., 2005)

REF

Yokota, M. (2005). Head and facial anthropometry of mixed-race US Army male soldiers for military design and sizing: A pilot study. *Applied Ergonomics*, 36(3), 379-383.

Lacko, D., Vleugels, J., Fransen, E., Huysmans, T., De Bruyne, G., Van Hulle, M. M., ... & Verwulgen, S. (2017). Ergonomic design of an EEG headset using 3D anthropometry. *Applied ergonomics*, 58, 128-136.

Lee, W., Jeong, J., Park, J., Jeon, E., Kim, H., Jung, D., ... & You, H. (2013). Analysis of the facial measurements of Korean Air Force pilots for oxygen mask design. *Ergonomics*, 56(9), 1451-1464.



Anthropometry: 醫療相關應用概念

- Low birth weight newborns identification (Sreeramareddy, C. T., et al., 2008)
- Operation room design (Ordóñez-Ríos, M., et al., 2019)

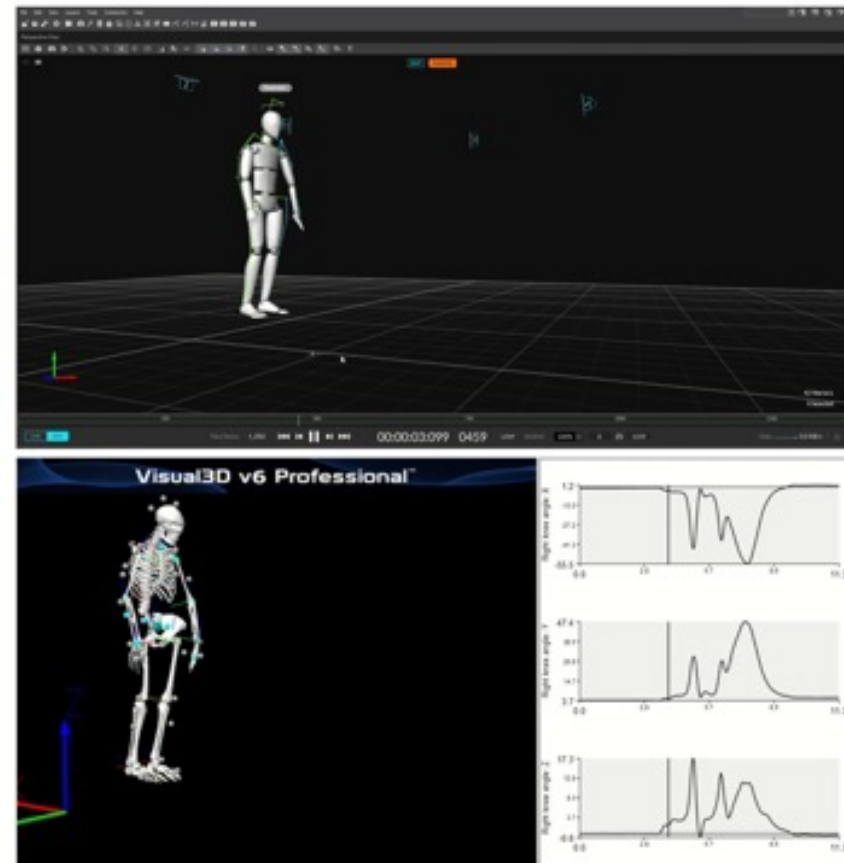
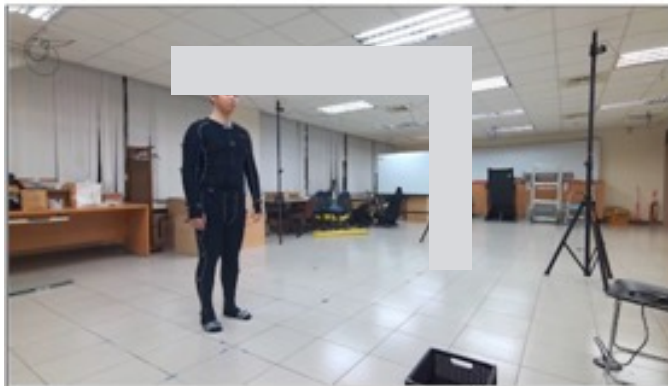
REF

Sreeramareddy, C. T., Chuni, N., Patil, R., Singh, D., & Shakya, B. (2008). Anthropometric surrogates to identify low birth weight Nepalese newborns: a hospital-based study. *BMC pediatrics*, 8(1), 1-6.

Ordóñez-Ríos, M., Salamea, J. C., & Robles-Bykbaev, V. (2019). Anthropometric evaluation and operation room design analysis for laparoscopic surgeries in cuenca, ecuador. In *Advances in Ergonomics in Design: Proceedings of the AHFE 2018 International Conference on Ergonomics in Design, July 21-25, 2018, Loews Sapphire Falls Resort at Universal Studios, Orlando, Florida, USA 9* (pp. 190-200). Springer International Publishing.

Motion Tracking & Biomechanical Analysis

- 藉由人體關鍵點 (如關節中心、軀幹位置等)在空間中的位置，分析人員活動過程中的運動資訊。





Motion Tracking: 評估應用

評估應用

- Design of the door panel of an automobile (Kim, Y., et al., 2019)

醫療相關應用概念

- Assessment method: Post-stroke Gait (Mohan, D. M., et al., 2021)
- Ambulatory system for monitoring elderly (Najafi, B. et al., 2003)

REF

Kim, Y., Choi, E. S., Seo, J., Choi, W. S., Lee, J., & Lee, K. (2019). A novel approach to predicting human ingress motion using an artificial neural network. *Journal of biomechanics*, 84, 27-35.

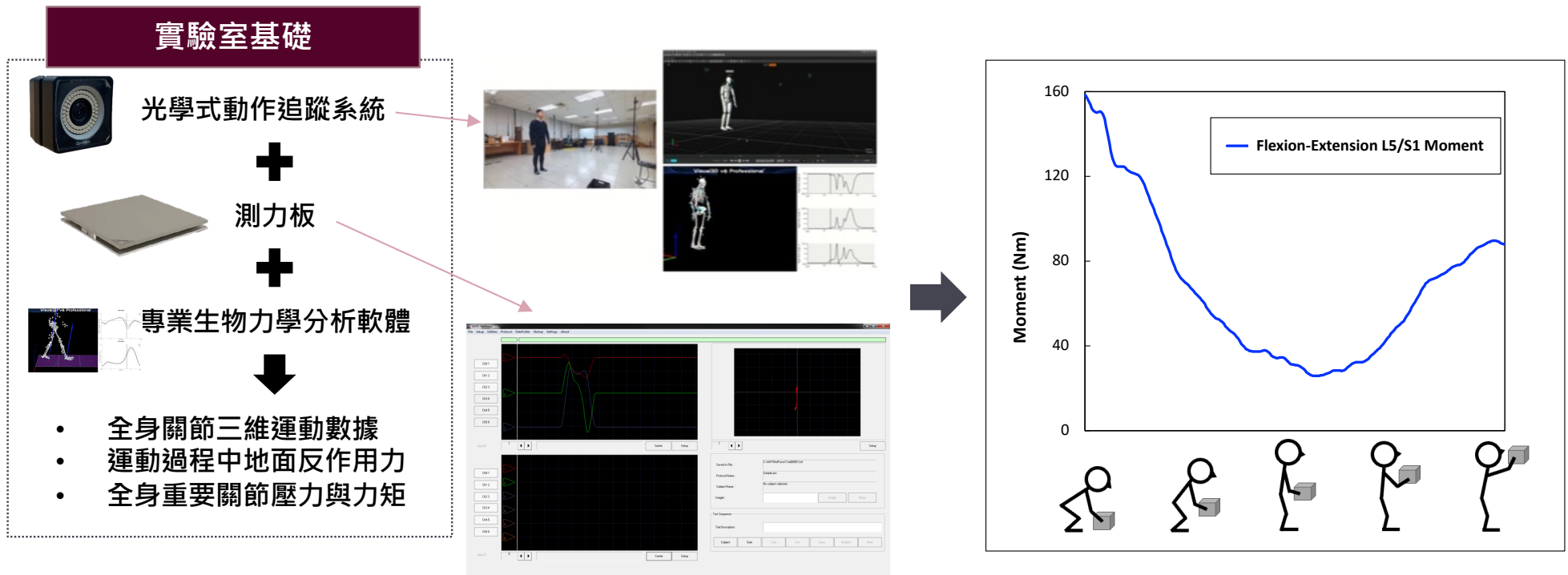
Mohan, D. M., Khandoker, A. H., Wasti, S. A., Ismail Ibrahim Ismail Alali, S., Jelinek, H. F., & Khalaf, K. (2021). Assessment methods of post-stroke gait: A scoping review of technology-driven approaches to gait characterization and analysis. *Frontiers in Neurology*, 12, 650024.

Najafi, B., Aminian, K., Paraschiv-Ionescu, A., Loew, F., Bula, C. J., & Robert, P. (2003). Ambulatory system for human motion analysis using a kinematic sensor: monitoring of daily physical activity in the elderly. *IEEE Transactions on biomedical Engineering*, 50(6), 711-723.

Biomechanical Analysis: 評估應用

- 姿勢資料結合力學數據，代入生物力學模型推算至目標身體區域之負荷程度
 - L5/S1關節區域負荷作為下背受傷風險的評估指標：NIOSH 770/1430lbs

BCF (back compressive force) = $3 \times (BW) \times \sin(\theta) + 0.5 \times (L \times HB) + 0.8 \times ((BW) \div 2 + L)$ (Merryweather, A. S., et al., 2009)



REF

Merryweather, A. S., Loertscher, M. C., & Bloswick, D. S. (2009). A revised back compressive force estimation model for ergonomic evaluation of lifting tasks. *Work*, 34(3), 263-272.



Biomechanical Analysis: 醫療相關應用概念

- Risk evaluation of nursing tasks in the hospital setting (Jang, R., et al., 2007)
- Patient handling strategy (Wiggermann, N., et al., 2021)

REF

Jang, R., Karwowski, W., Quesada, P. M., Rodrick, D., Sherehiy, B., Cronin, S. N., & Layer, J. K. (2007). Biomechanical evaluation of nursing tasks in a hospital setting. *Ergonomics*, 50(11), 1835-1855.

Wiggermann, N., Zhou, J., & McGann, N. (2021). Effect of repositioning aids and patient weight on biomechanical stresses when repositioning patients in bed. *Human factors*, 63(4), 565-577.



Observational Methods

- 專家或相關專業人員，透過觀察並分析現場或影片中之人員動作，結合過往已建立之制式檢核表格，進行風險程度之判斷。
 - RULA- Rapid Upper Limbs Assessment
 - OWAS- Ovako Working Posture Analysis System
 - REBA- Rapid Entire Body Assessment
 - NIOSH Lifting Equation
 - ...

Observational Methods: 評估應用

REBA	RULA	OWAS
建築工人與砂紙機操作工人的作業姿勢	孩童使用電腦之姿勢、辦公室工作人員的日常工作姿勢	製造業與健康照護產業內不良工作姿勢
<ul style="list-style-type: none"> Kulkarni, V.S., Devalkar, R., 2019. Postural analysis of building construction workers using ergonomics. <i>International Journal of Construction Management</i> 19, 464-471. Kusuma, T.Y.T., 2020. Analysis of body posture using Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA) to improve the posture of sand paper machine operators and reduce the risk of low back pain. <i>Biology, Medicine, & Natural Product Chemistry</i> 9, 21-25. 	<ul style="list-style-type: none"> Dockrell, S., O'Grady, E., Bennett, K., Mullarkey, C., Mc Connell, R., Ruddy, R., Twomey, S., Flannery, C., 2012. An investigation of the reliability of Rapid Upper Limb Assessment (RULA) as a method of assessment of children's computing posture. <i>Applied ergonomics</i> 43, 632-636. Widiyawati, S., Lukodono, R.P., Lustyana, A.T., Pradana, I.A., 2020. Investigation of the risk of daily officer work posture based on rapid upper limb assessment (Rula) method. <i>International Journal of Human Movement and Sports Sciences</i> 8, 24-31. 	<ul style="list-style-type: none"> Gómez-Galán, M., Pérez-Alonso, J., Callejón-Ferre, Á.-J., López-Martínez, J., 2017. Musculoskeletal disorders: OWAS review. <i>Industrial health</i> 55, 314-337.



醫療相關作業的風險評估應用？
用於降低不適方案間的比較依據？

- 手術姿勢評估
- 鑑識分析人員上身姿態風險估計
- 辦公室人員長時間進行文書或監控作業
- 護理師協助病患或移動備品之不適風險
- 院內清掃人員之作業風險
- ...

醫療相關應用概念：

Using NIOSH lifting equation to investigate when is it safe to manually lift a patient (Waters, T. R., 2007)

Electromyography (EMG)

- 肌纖維透過動作電位傳遞訊息以完成動作，而肌電圖量測儀 (Electromyography, EMG) 利用收集電位差改變的過程並透過儀器進行數據分析，以代表肌肉活動的程度。
 - 置入肌電圖(indwelling electromyography, iEMG)
 - 表面肌電圖(surface electromyography, sEMG)





Electromyography (EMG) : 評估應用

評估應用

- Supermarket sector handling material (Skals S., et al., 2020)
- Worker performing shingle installation (Dutta A., et al., 2020)

醫療相關應用概念

- Design of an Infusion set connector tool

REF

Skals, S., Bláfoss, R., Andersen, M.S., de Zee, M., Andersen, L.L., 2021. Manual material handling in the supermarket sector. Part 1: Joint angles and muscle activity of trapezius descendens and erector spinae longissimus. *Applied Ergonomics* 92, 103340.

Dutta, A., Breloff, S.P., Dai, F., Sinsel, E.W., Warren, C.M., Carey, R.E., Wu, J.Z., 2020. Effects of working posture and roof slope on activation of lower limb muscles during shingle installation. *Ergonomics* 63, 1182-1193

Garosi, E., Mazloumi, A., Kalantari, R., Vahedi, Z., & Shirzhiyan, Z. (2019). Design and ergonomic assessment of an infusion set connector tool used in nursing work. *Applied ergonomics*, 75, 91-98.



Cognitive Ergonomics



**Cognitive
認知**

- 人機互動
- 溝通
- 協作
- 知覺
- 記憶
- 推理
- 動作反應

認知人因：

關注人們與系統其他元件之交互作用有所影響的心理歷程

ex: 心智工作負荷、決策作成、技能績效、人員電腦互動、人員可靠度、工作壓力、訓練、以及使用者經驗



Cognitive Ergonomics Studies/Common Tools

- 身心理參數量測
 - Heart rate variability
 - EEG
 - Other signals (ex. skin temperature, ...)
- 眼動數據量測與分析
 - Eye movement
 - Attentional resource allocation
- 主觀 / 質性心智負荷調查
 - Task Load Index
- ...



身心理參數量測

- 膚電
 - 交感神經系統作用旺盛、壓力等因素可能導致手部出汗。而濕度增加會使皮膚導電量變化量提高，藉由量測相關生理參數作為人員是否緊張的指標。
- 膚溫
 - 藉由過去研究發現，當人員緊張時會使皮膚表面溫度下降而核心溫度提高。故透過感測器量測微小的溫度變化時常被使用於了解人員壓力狀態的工具之一。
- 脈搏/心跳
 - 脈搏/心跳數據除了反映生存狀態之外，更可被進一步用於計算心律變異率 (Heart Rate Variability, HRV)。HRV被認為與健康與情緒有高度的相關，因此時常被用來做為身心負荷的評估方法之一。
- 腦波
 - 可以觀察大腦動態變化、利用某一個事件所導引的腦電波變化，來探索該實驗情境中的各種特性與相關主題。



身心理參數量測: 評估應用

- Heart rate variability
 - Mental stress evaluation among employees (Orsila, R., et al., 2008)
 - Driver fatigue indicator (Egelund, N., 1982)
- EEG
 - Emotion recognition (Yang, Y., et al., 2021)
 - Sleepiness evaluation for night driving (Papadelis, C., et al, 2006)

REF

Orsila, R., Virtanen, M., Luukkaala, T., Tarvainen, M., Karjalainen, P., Viik, J., ... & Nygård, C. H. (2008). Perceived mental stress and reactions in heart rate variability—a pilot study among employees of an electronics company. *International Journal of Occupational Safety and Ergonomics*, 14(3), 275-283.

Egelund, N. (1982). Spectral analysis of heart rate variability as an indicator of driver fatigue. *Ergonomics*, 25(7), 663-672.

Yang, Y., Gao, Q., Song, Y., Song, X., Mao, Z., & Liu, J. (2021). Investigating of deaf emotion cognition pattern by EEG and facial expression combination. *IEEE Journal of Biomedical and Health Informatics*, 26(2), 589-599.

Koelstra, S., & Patras, I. (2013). Fusion of facial expressions and EEG for implicit affective tagging. *Image and Vision Computing*, 31(2), 164-174.

Papadelis, C., Kourtidou-Papadeli, C., Bamidis, P. D., Chouvarda, I., Koufogiannis, D., Bekiaris, E., & Maglaveras, N. (2006, August). Indicators of sleepiness in an ambulatory EEG study of night driving. In 2006 international conference of the IEEE engineering in medicine and biology society (pp. 6201-6204). IEEE.



身心理參數量測: 醫療相關應用概念

- Indication of surgical team's stress
 - Different surgeries (Rieger, A., et al., 2014)
 - Effect of technique (Conventional/Laparoscopic), function (Surgeon/Assistant), and expertise (Experienced/Less experienced) (Böhm, B., et al., 2001)

REF

Rieger, A., Stoll, R., Kreuzfeld, S., Behrens, K., & Weippert, M. (2014). Heart rate and heart rate variability as indirect markers of surgeons' intraoperative stress. *International archives of occupational and environmental health*, 87, 165-174.

Böhm, B., Rötting, N., Schwenk, W., Grebe, S., & Mansmann, U. (2001). A prospective randomized trial on heart rate variability of the surgical team during laparoscopic and conventional sigmoid resection. *Archives of Surgery*, 136(3), 305-310.



眼動數據量測與分析

- 辨識並且追蹤人眼注視目標，透過分析位置、興趣區域、及所注視之時間長度，進一步瞭解觀看內容、認知過程和注意力資源的分配。
 - Gaze position
 - Area of interest (AOI)

評估應用

- Layout design of print advertisements (Damaskinidis, G., et al., 2018)

醫療相關應用概念

- Developing a simulator to a clinical operating room (Pawelke, C., et al., 2022)

Photo sources:

<https://medium.com/kainos-applied-innovation/eye-tracking-a-new-era-for-vr-or-just-another-gimmick-115f1ad7e441>

<http://www.philjonesgeography.co.uk/blog/hacking-together-an-eye-tracker>

REF

Damaskinidis, G., Kourdis, E., Zantides, E., & Sykioti, E. (2018). Eye-tracking the semiotic effects of layout on viewing print advertisements. *Public Journal of Semiotics*.

Pawelke, C., Merkle, F., Kurtovic, D., Gierig, S., & Müller-Plath, G. (2022). Comparison of a perfusion simulator to a clinical operating room: evaluation of eye tracking data and subjective perception. A pilot study. *Perfusion*, 37(1), 19-25.



主觀 / 質性心智負荷調查

NASA Task Load Index

醫療相關應用概念

- Measuring workload of ICU nurses
 - using NASA TLX (Hoonakker, P., et al., 2011)

Photo sources:

<https://humansystems.arc.nasa.gov/groups/TLX/>
REF

Hoonakker, P., Carayon, P., Gurses, A. P., Brown, R., Khunlertkit, A., McGuire, K., & Walker, J. M. (2011). Measuring workload of ICU nurses with a questionnaire survey: the NASA Task Load Index (TLX). *IIE transactions on healthcare systems engineering*, 1(2), 131-143.



Organizational Ergonomics

組織人因：

關注多人多機所構成的社會技術系統之最佳化。

ex: 通訊溝通、工作設計、工時設計、協同作業、組織文化、品質管理



Organizational
組織

- 參與設計
- 團隊協作
- 社群技術系統
- 環境



Organizational Ergonomics Studies/Concepts

- Known as macro-ergonomics; the scope is large: think big(ger) and think systems (Holden, R. J., et al., 2015)
- Fundamental characteristics (Dul, J., et al., 2012)
 - It takes a systems approach
 - It is design driven
 - It focuses on two related outcomes: performance and well-being

REF

Holden, R. J., Rivera, A. J., & Carayon, P. (2015). Occupational macroergonomics: Principles, scope, value, and methods. *IIE transactions on occupational ergonomics and human factors*, 3(1), 1-8.

Dul, J., Bruder, R., Buckle, P., Carayon, P., Falzon, P., Marras, W. S., ... & van der Doelen, B. (2012). A strategy for human factors/ergonomics: developing the discipline and profession. *Ergonomics*, 55(4), 377-395.



Methods and Approaches: 應用舉例

- Ergonomic Work Analysis (Szenlwar and Hubault, 2015): 公司訂定決策時要考慮到人員實際上的作業活動。
 - knowing what people actually do at work in order to fulfill production goals
 - especially considering that there is always a gap between what was proposed and considered in task design and the real situation
- 以公車司機為例，其工作範圍不只是開車，還需要確保乘客和其他用路人安全、確保行車路線及到站時刻、回答乘客問題、協助不便旅客、甚至面對暴力或其他特殊事件
 - 應該要了解整個系統運作後進行工作設計，而非分成數個單一議題作逐一探討跟規劃

醫療相關應用概念 from organizational ergonomics perspective

- Patient safety interventions
 - Conceptual framework based on principles of organizational ergonomics (Schutz, A. L., et al., 2007)

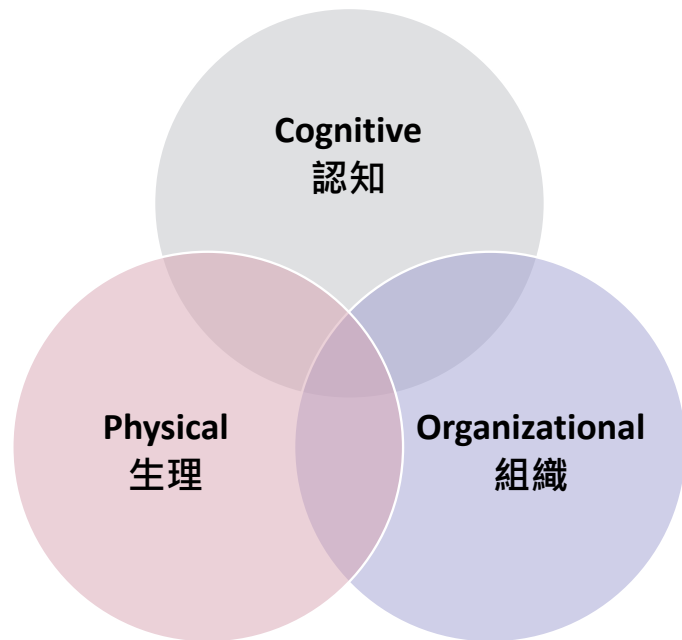
REF

Szenlwar, L. I., & Hubault, F. (2015). Work activities as a resource for work organization design and for strategic decisions?. IIE Transactions on Occupational Ergonomics and Human Factors, 3(1), 37-44.

Schutz, A. L., Counte, M. A., & Meurer, S. (2007). Assessment of patient safety research from an organizational ergonomics and structural perspective. Ergonomics, 50(9), 1451-1484.



Summary



- 人因工程學科涉及所有與「人」相關的議題，各專業環節間環環相扣
- 不同研究目標或任務導向所適合的實驗設計不同，人因學者也會針對研究所得給予相對應的解讀方式
- 在基礎認識之後，可找出人因與相關應用的連結，進而發想研究/發展方向



THANK YOU FOR LISTENING

✉ **劉品伶 Pin-Ling Liu, Ph.D.**

pinling.liu@mx.nthu.edu.tw

millaliu.pl@gmail.com

2023/04/14 @國立臺灣大學醫學院附設醫院兒童醫院