

# 近红外技术在脑科学的应用和案例分析

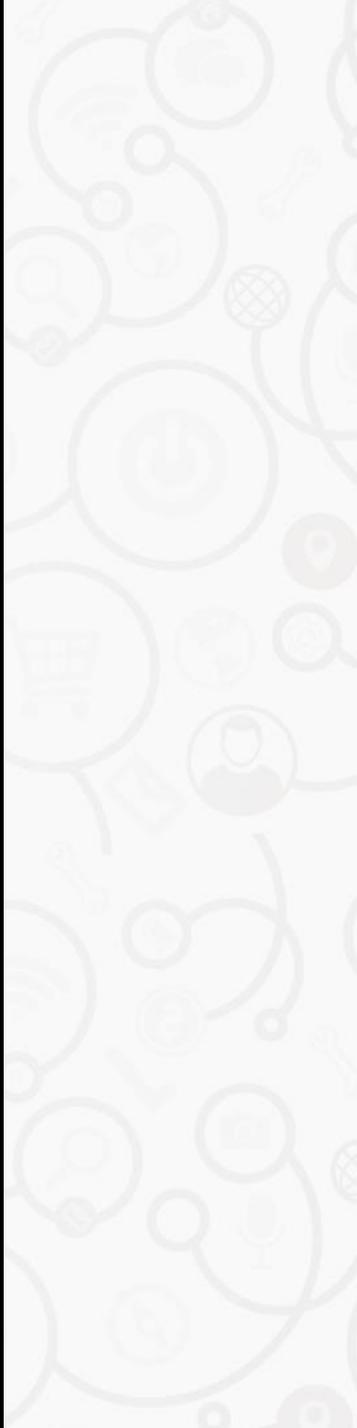
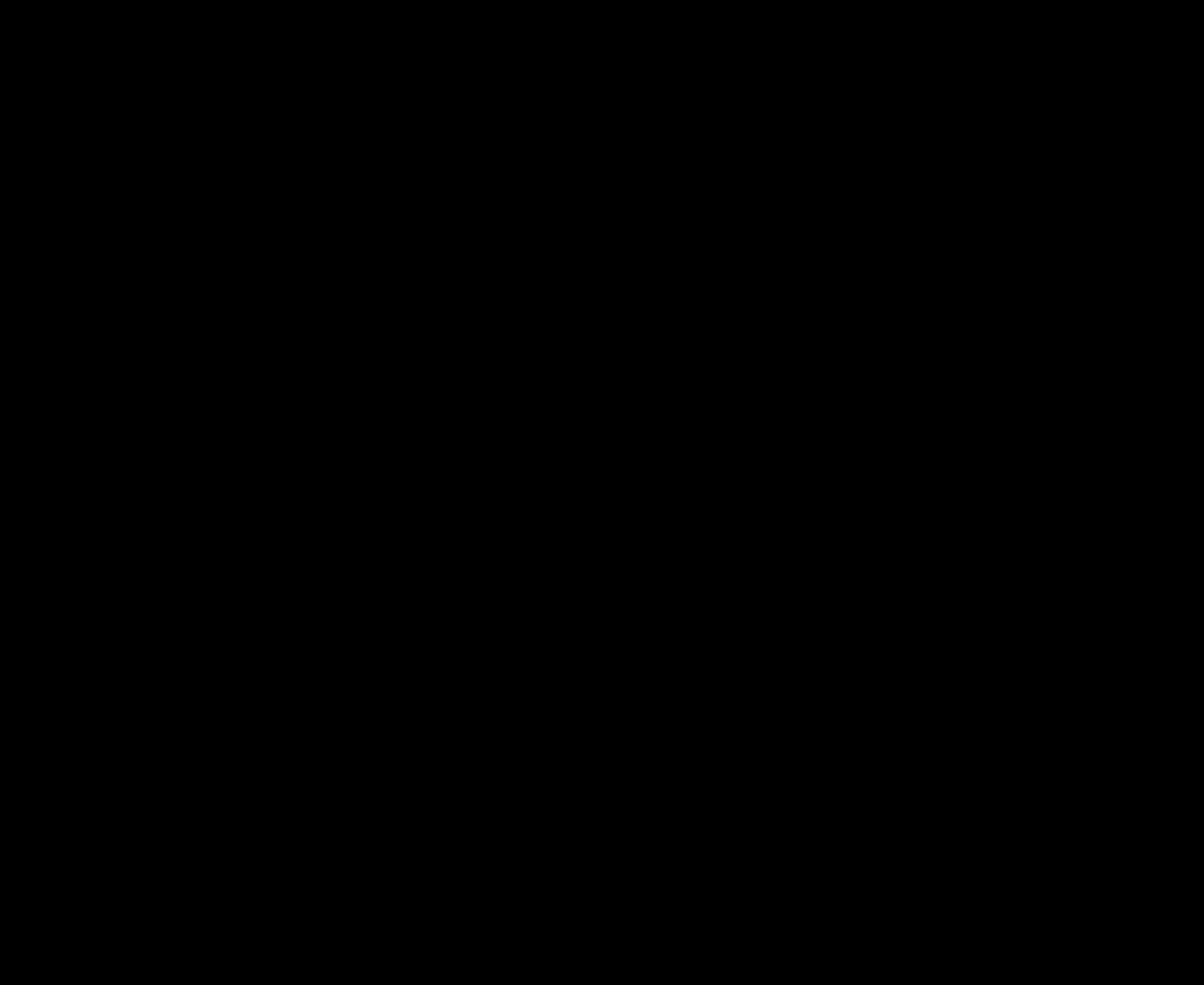
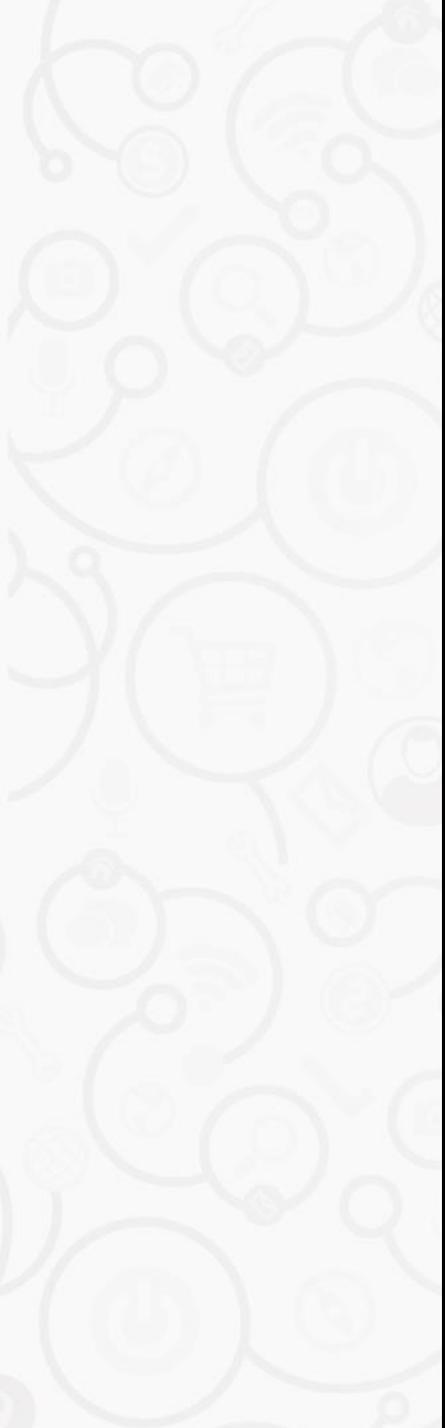
崔旭

Stanford University

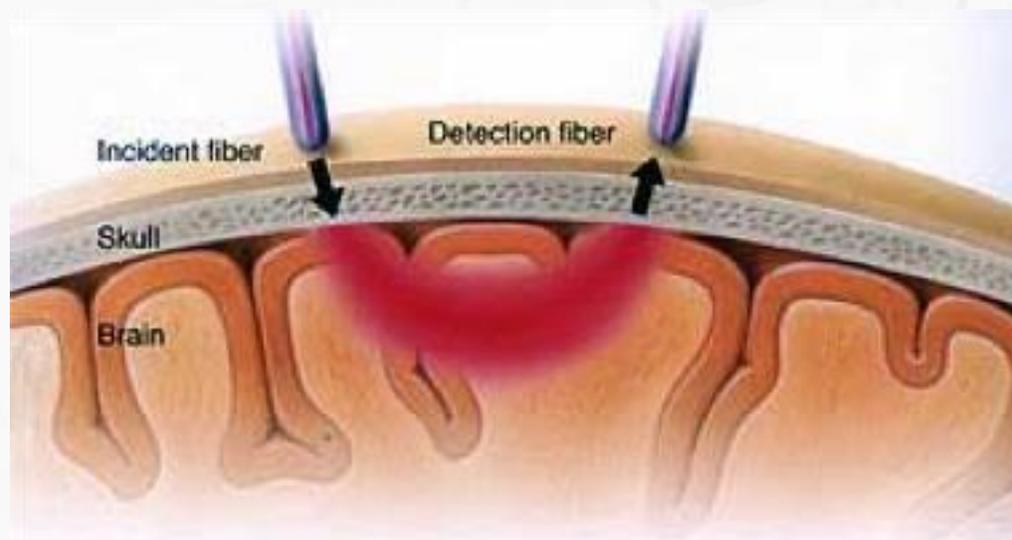
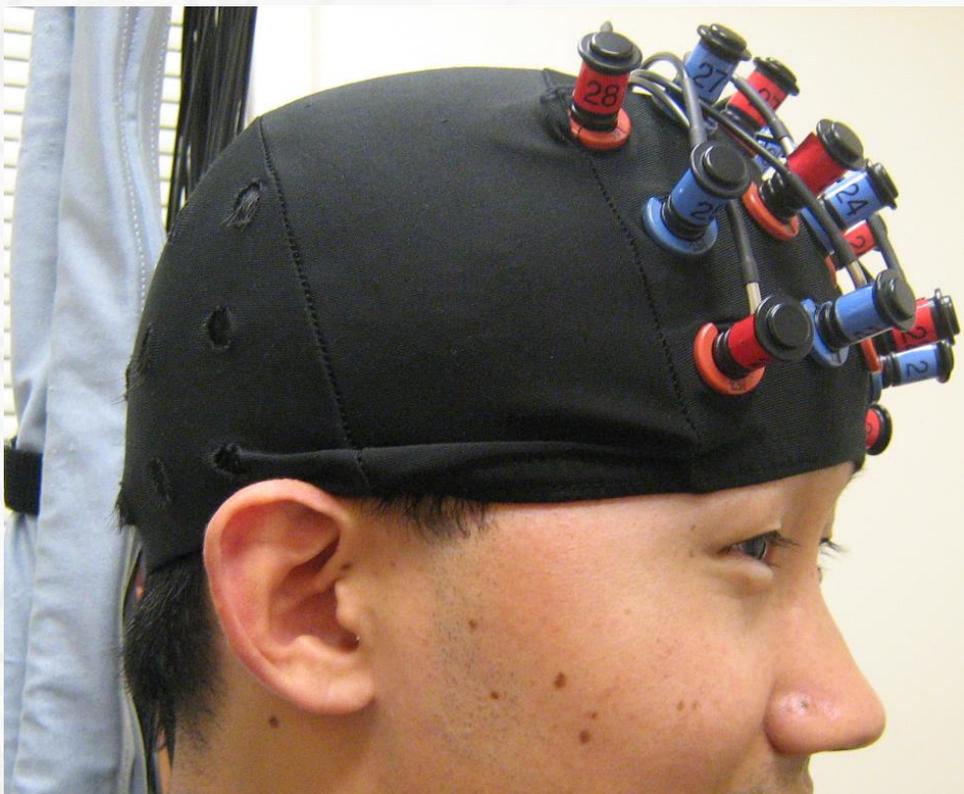
2020/03/18





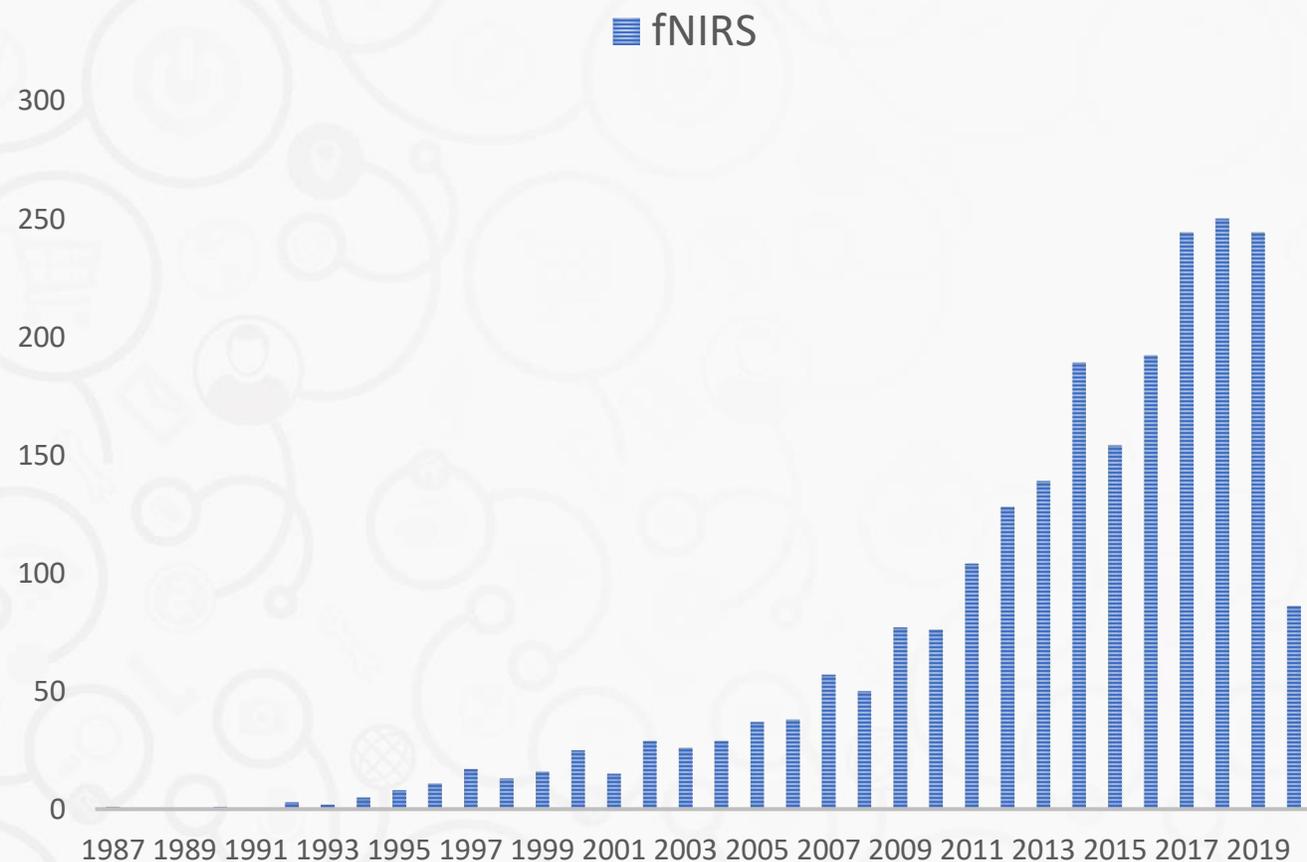


# 近红外技术基本原理



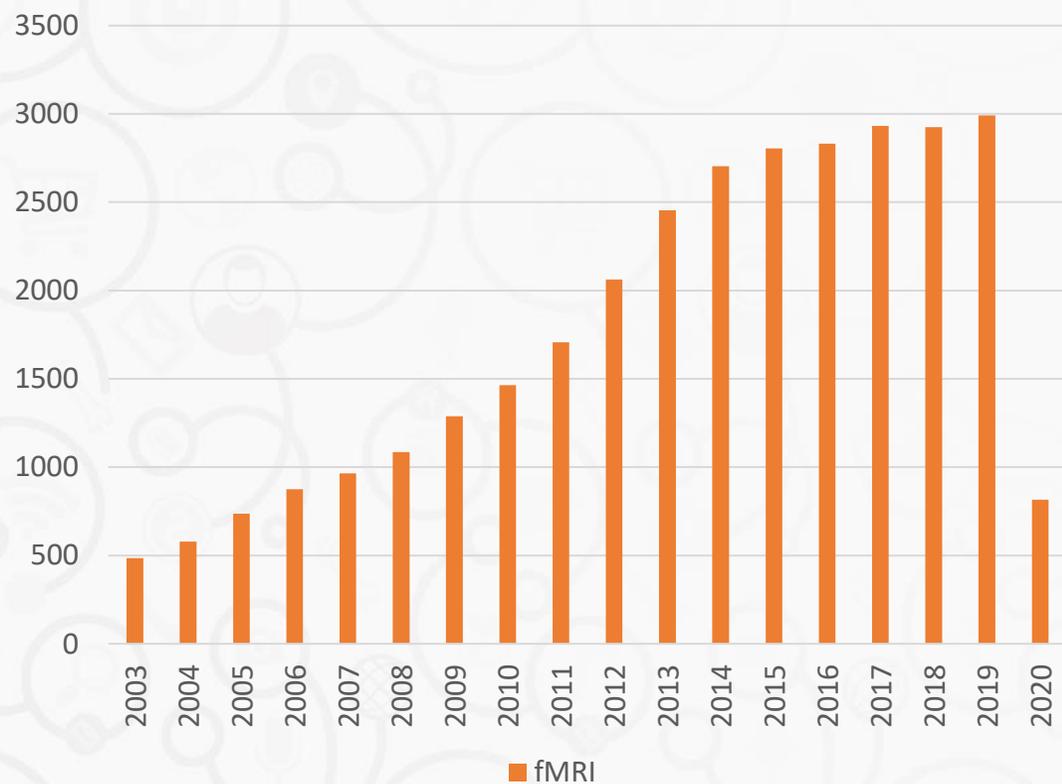
	fNIRS	fMRI	
Measurement	both oxy- and deoxy-Hb	BOLD signal	That means you get two number per location at a time in NIRS
Temporal resolution	10Hz	0.5Hz	In fMRI TR is usually 2s
Spatial resolution	30mm	2-4mm	
Measurable region	Only surface	Entire brain	
Real-time application	easy	difficult	
Real-life application	easy	difficult	such as exercise, natural conversation etc
Hyperscanning application	easy	difficult	
Cost	Cheaper \$100-500K	Expensive >\$2M	NIRS price largely depends on the number of channels
Maintenance Cost	Cheap	Expensive	NIRS has ~0 maintenance cost; fMRI usually requires a on-site expert
Portability	Can be	No	There are some portable NIRS devices available
Signal to noise ratio	lower	higher	
Subjects with Dental Braces and Retainers, or ear rings	Safe	might not be safe	
Subjects with Pacemaker or metals in brain	Safe	unsafe	

# 近红外在脑科学的应用越来越活跃

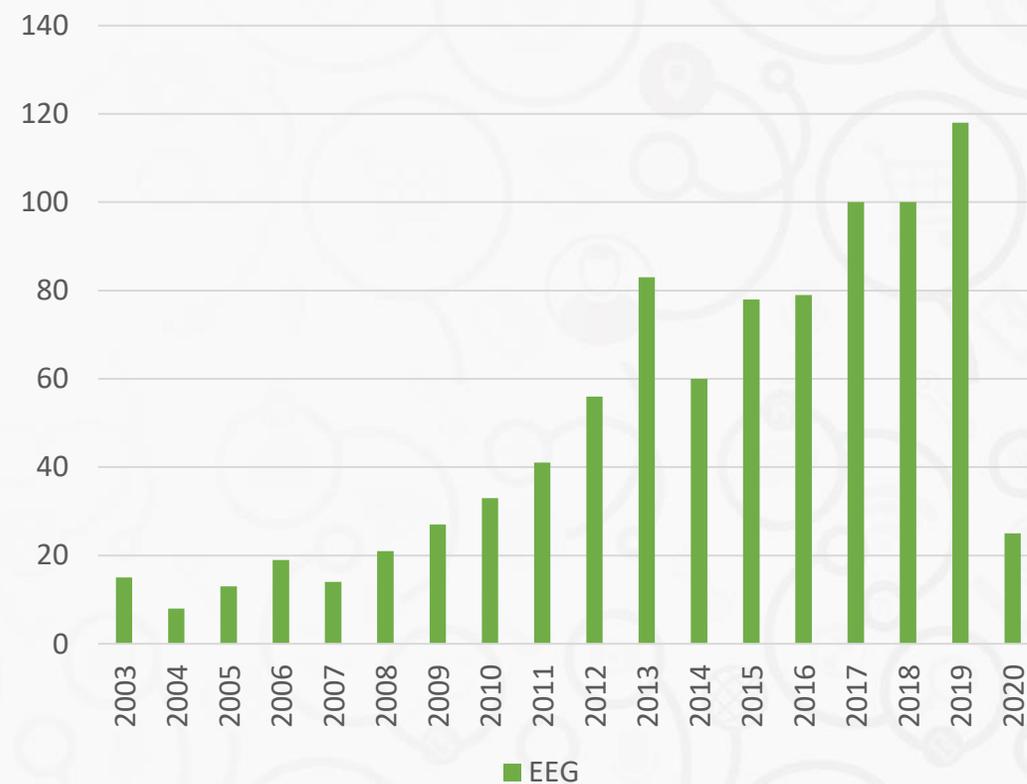


# 近红外在脑科学的应用越来越活跃

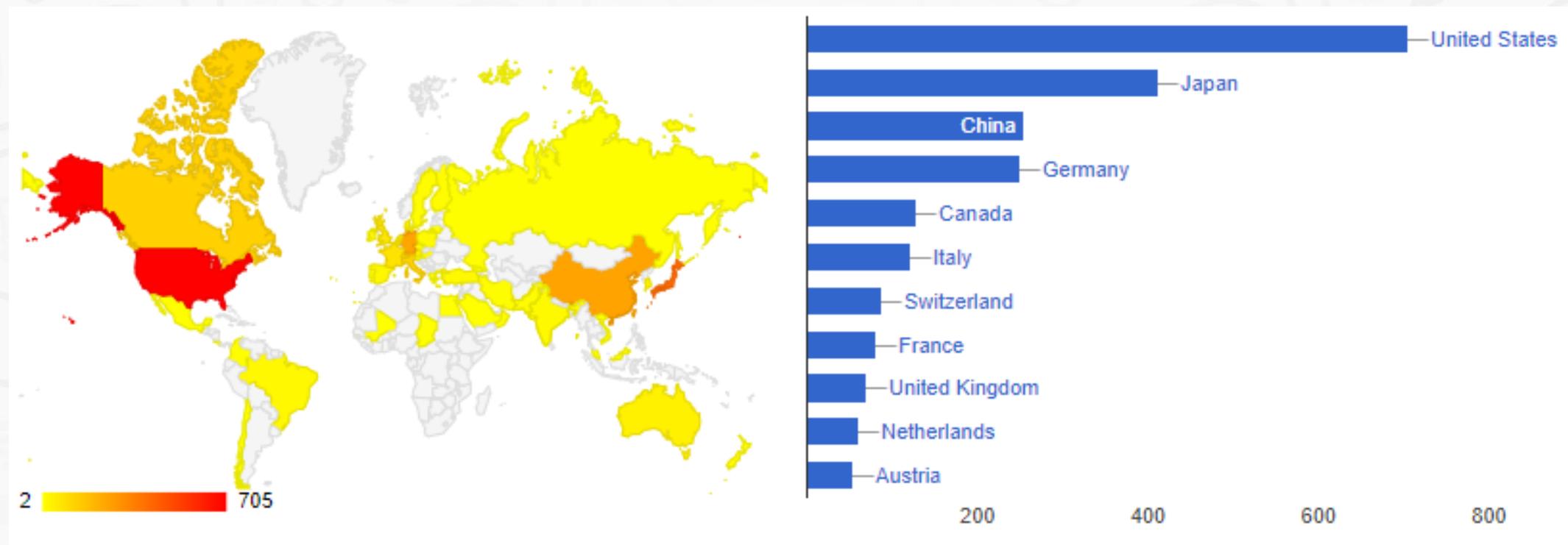
fMRI



EEG



# 国内用近红外研究脑科学很积极



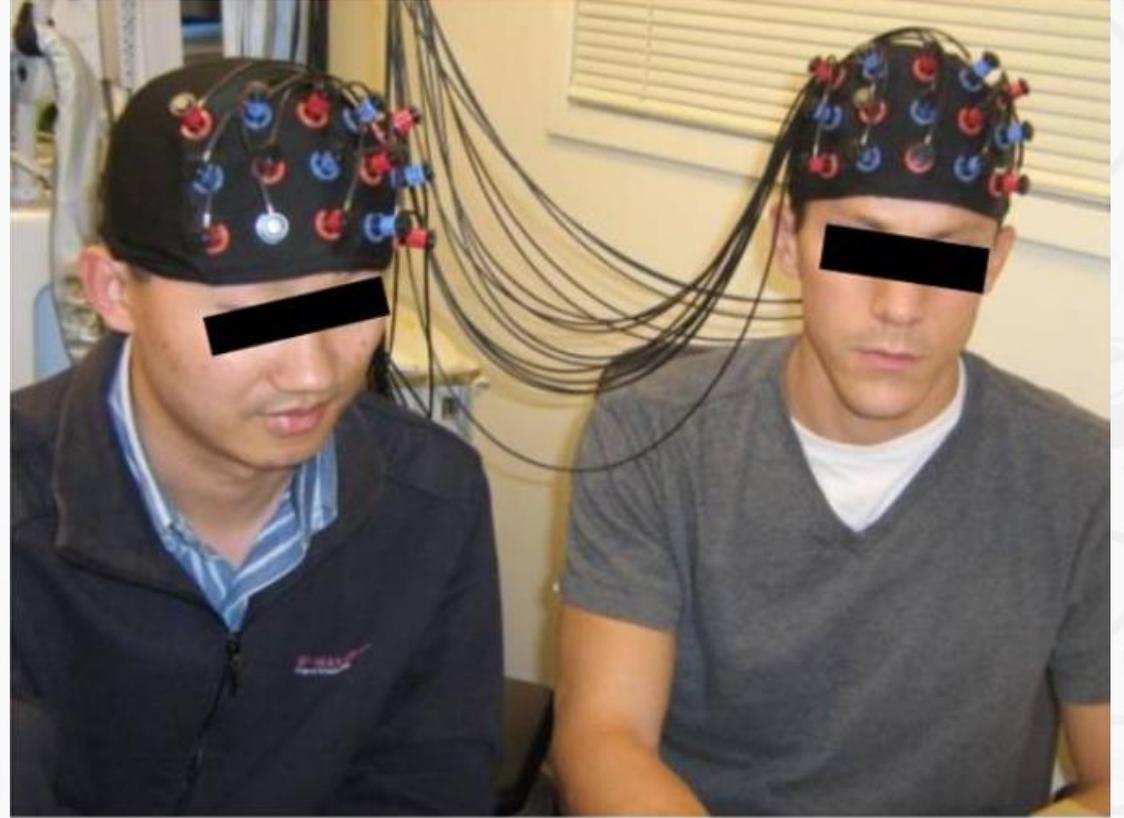


文献鸟软件分析 (storkapp.me)

# 近红外在脑科学的应用

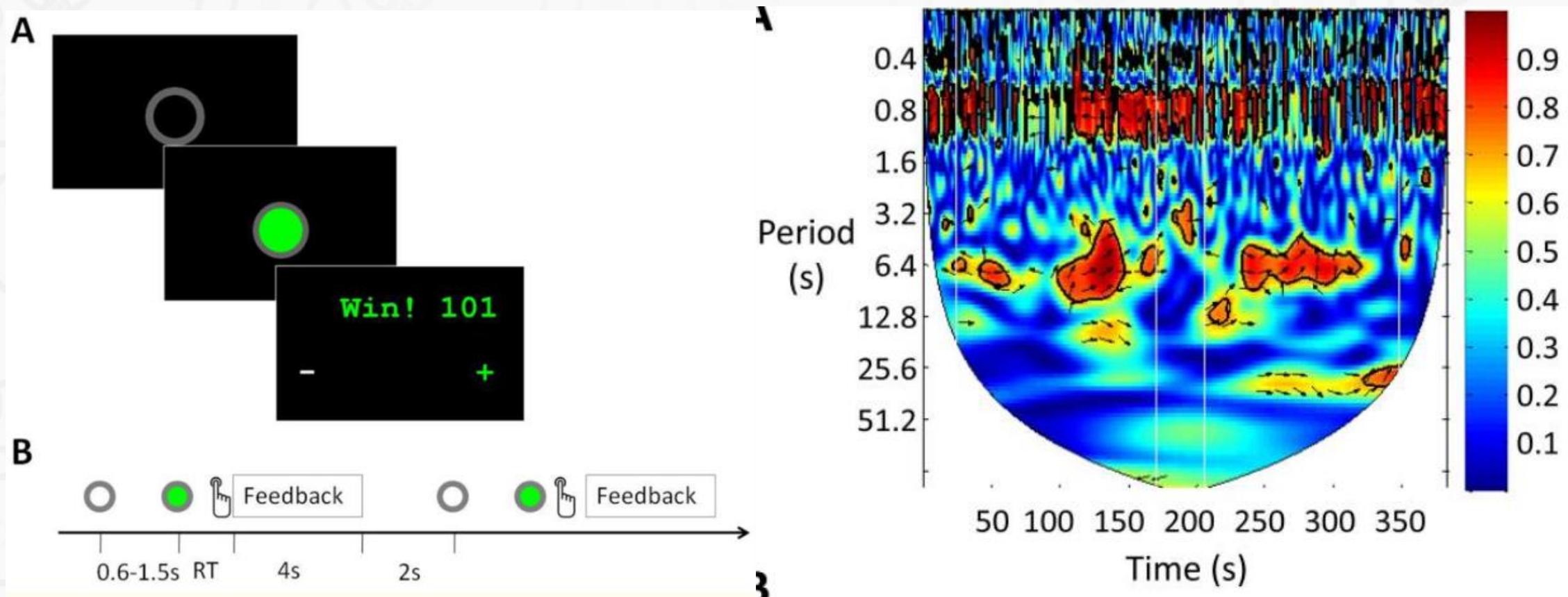
1. 超扫描
2. 运动、体育研究
3. 婴儿
4. 老年人
5. 田野研究
6. 脑疾病研究 (PTSD、自闭等)
7. 脑机接口
8. 诊断
9. 治疗

# 【案例】超扫描：同时测量两人大脑



Cui, Bryant, Reiss (2012) NIRS-based hyperscanning reveals increased interpersonal coherence in superior frontal cortex during cooperation *NeuroImage* 59(3) 2430-7

# 【案例】超扫描：同时测量两人大脑



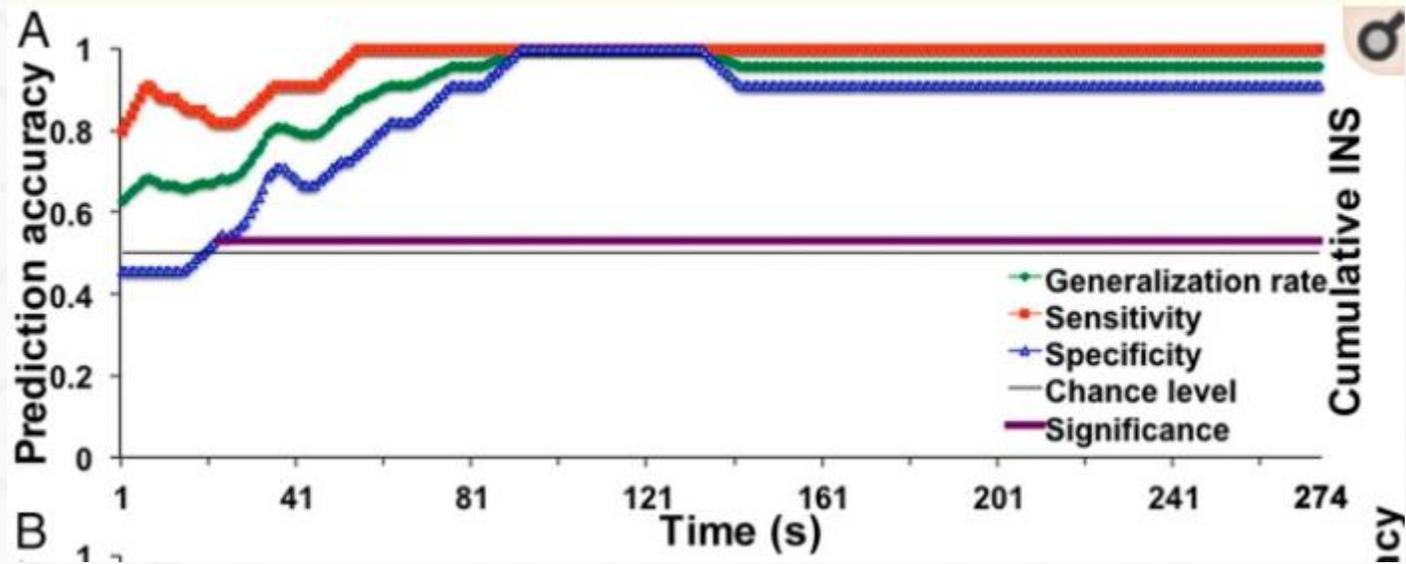
Cui, Bryant, Reiss (2012) NIRS-based hyperscanning reveals increased interpersonal coherence in superior frontal cortex during cooperation *NeuroImage* 59(3) 2430-7

# 【案例】超扫描：同时测量多人大脑



讨论“一架飞机坠毁在一个荒岛上。只有6人幸存：一名孕妇，一名发明家，一名医生，一名宇航员，一名生态学家和一名流浪者。您认为应该给谁一个唯一的单人热气球离开该岛？”

# 【案例】超扫描：同时测量多人大脑



Jiang, Chen, Dai, Shi, Ding, Liu, Lu (2015) Leader emergence through interpersonal neural synchronization *PNAS* 112(14) 4274-9

# 【案例】超扫描：同时测量多人大脑

9人



25人

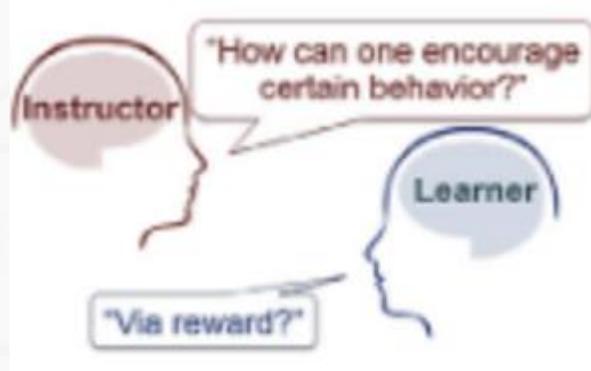


Duan, Dai, Xiao, Sun, Li, Zhu (2015) Cluster imaging of multi-brain networks (CIMBN): a general framework for hyperscanning and modeling a group of interacting brains *Frontiers in neuroscience* 9() 267  
Ikeda, Nozawa, Yokoyama, Miyazaki, Sasaki, Sakaki, Kawashima (2017) Steady Beat Sound Facilitates both Coordinated Group Walking and Inter-Subject Neural Synchrony *Frontiers in human neuroscience* 11() 147

# 【案例】超扫描：多样的社会关系



恋人



老师学生



表演者和听众



母亲和孩子

Pan, Cheng, Zhang, Li, Hu (2017) Cooperation in lovers: An fNIRS-based hyperscanning study *Human brain mapping* 38(2) 831-841

Pan, Dikker, Goldstein, Zhu, Yang, Hu (2020) Instructor-learner brain coupling discriminates between instructional approaches and predicts learning *NeuroImage* 211() 116657

Hou, Song, Hu, Pan, Hu (2020) The averaged inter-brain coherence between the audience and a violinist predicts the popularity of violin performance *NeuroImage* 211() 116655

Miller, Vrtička, Cui, Shrestha, Hosseini, Baker, Reiss (2019) Inter-brain synchrony in mother-child dyads during cooperation: An fNIRS hyperscanning study *Neuropsychologia* 124() 117-124

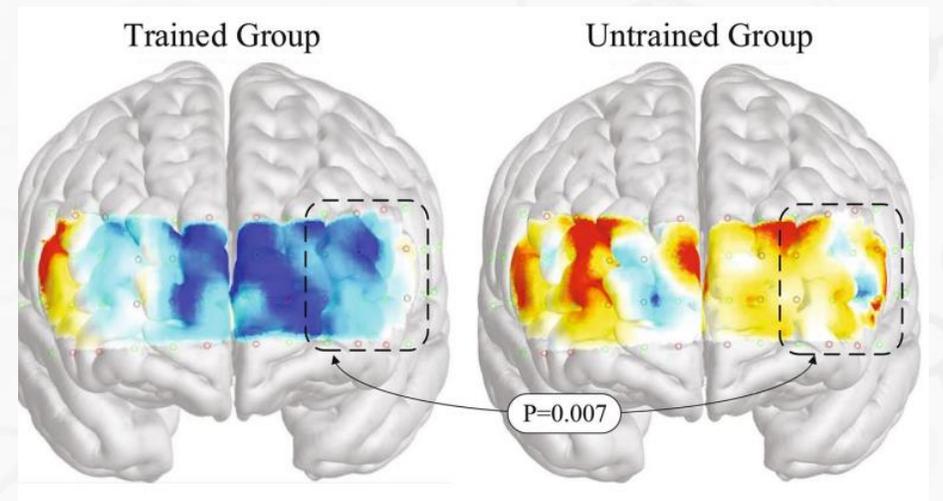
# 【案例】 运动中的测量



Khoe, Low, Wijerathne, Ann, Salgaonkar, Lomanto, Choi, Baek, Tam, Pei, Ho (2020) Use of prefrontal cortex activity as a measure of learning curve in surgical novices: results of a single blind randomised controlled trial *Surgical endoscopy*

## 模拟外科手术时前脑的变化

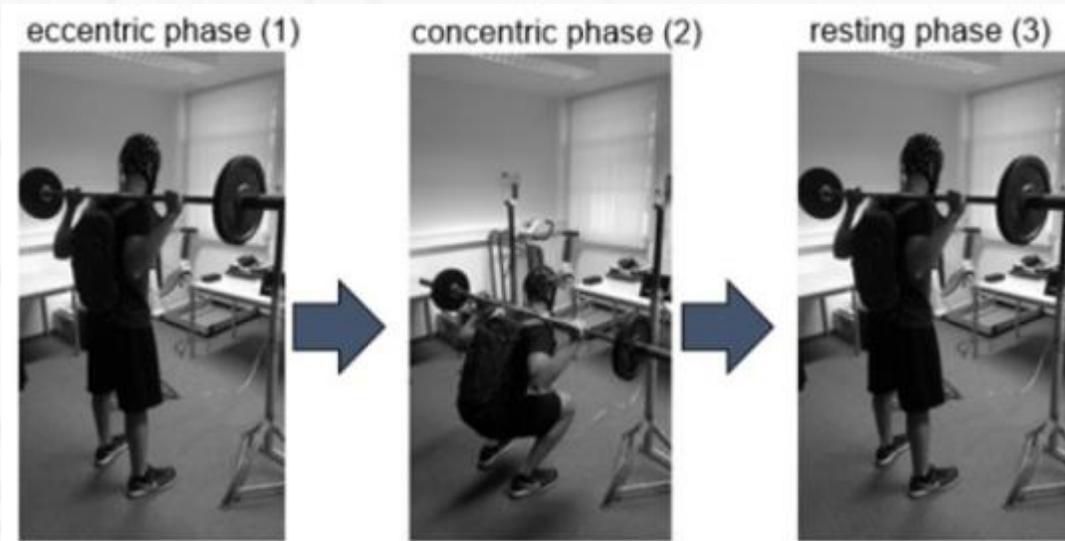
医学院的学生  
两组。一组受到一对一培训，另一组没有培训  
与未培训组相比，培训组在“精密切割”任务中的左PFCA活跃度降低。



# 【案例】 运动中的测量

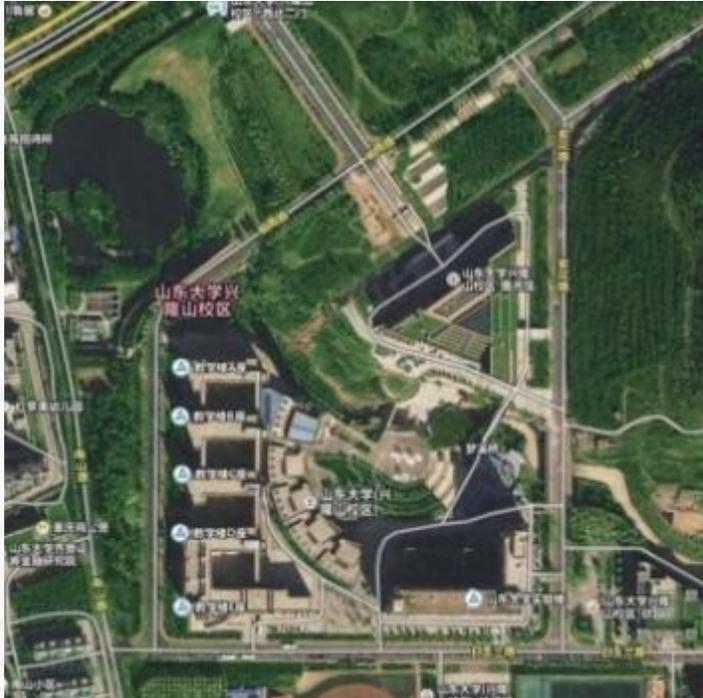
## 研究人在杠铃负荷时大脑变化

功能性近红外光谱 (fNIRS) 可作为一种有前途的工具, 用于在体育科学背景下检查血液动力学反应的变化。本研究旨在调查在执行杠铃深蹲 (BS) 时, 人类运动系统内的大脑活动如何根据不同的杠铃负荷条件改变其处理过程。当比较不同的负荷水平时, 在双侧上顶叶 (SPL) 内, 有氧血红蛋白 (HbO<sub>2</sub>) 信号发生了改变, 而对于脱氧血红蛋白 (HHb) 没有。



Kenville, Maudrich, Carius, Ragert (2017) Hemodynamic Response Alterations in Sensorimotor Areas as a Function of Barbell Load Levels during Squatting: An fNIRS Study *Frontiers in human neuroscience* 11() 241

# 【案例】 运动中的测量



## 驾驶时驾驶员的脑信号

驾驶车辆是一项复杂的活动，需要高水平的大脑功能。这项研究旨在评估休息，简单驾驶和驾车之间大脑网络中前额叶皮层（PFC），运动相关区域（MA）和视觉相关区域（VA）之间的有效连通性的变化。

12名年轻的男性成年人

结果表明，大脑的血液动力学活动水平随认知工作量的增加而增加。

Liu, Zhang, Xu, Huo, Tan, Li, Yuan (2017) Effective Connectivity Analysis of the Brain Network in Drivers during Actual Driving Using Near-Infrared Spectroscopy *Frontiers in behavioral neuroscience* 11() 211

# 【案例】 婴儿研究



## 6个月大的早产儿与足月婴儿比较

足月显示单侧和对侧的激活区域更为均匀，而早产儿的激活反应主要是双侧的。足月组的血液动力学反应潜伏期也比早产组短。左感觉运动区的血流动力学活动与通过 Bayley-III测量的运动表现呈正相关。结果强调了fNIRS足以评估两组之间任务诱导的感觉运动皮层激活的差异。

de Oliveira, de Paula Machado, de Paula, de Moraes, Nahin, Magalhães, Novi, Mesquita, de Miranda, Bouzada (2018) Association between hemodynamic activity and motor performance in six-month-old full-term and preterm infants: a functional near-infrared spectroscopy study *Neurophotonics* 5(1) 011016

# 【案例】 老年人研究

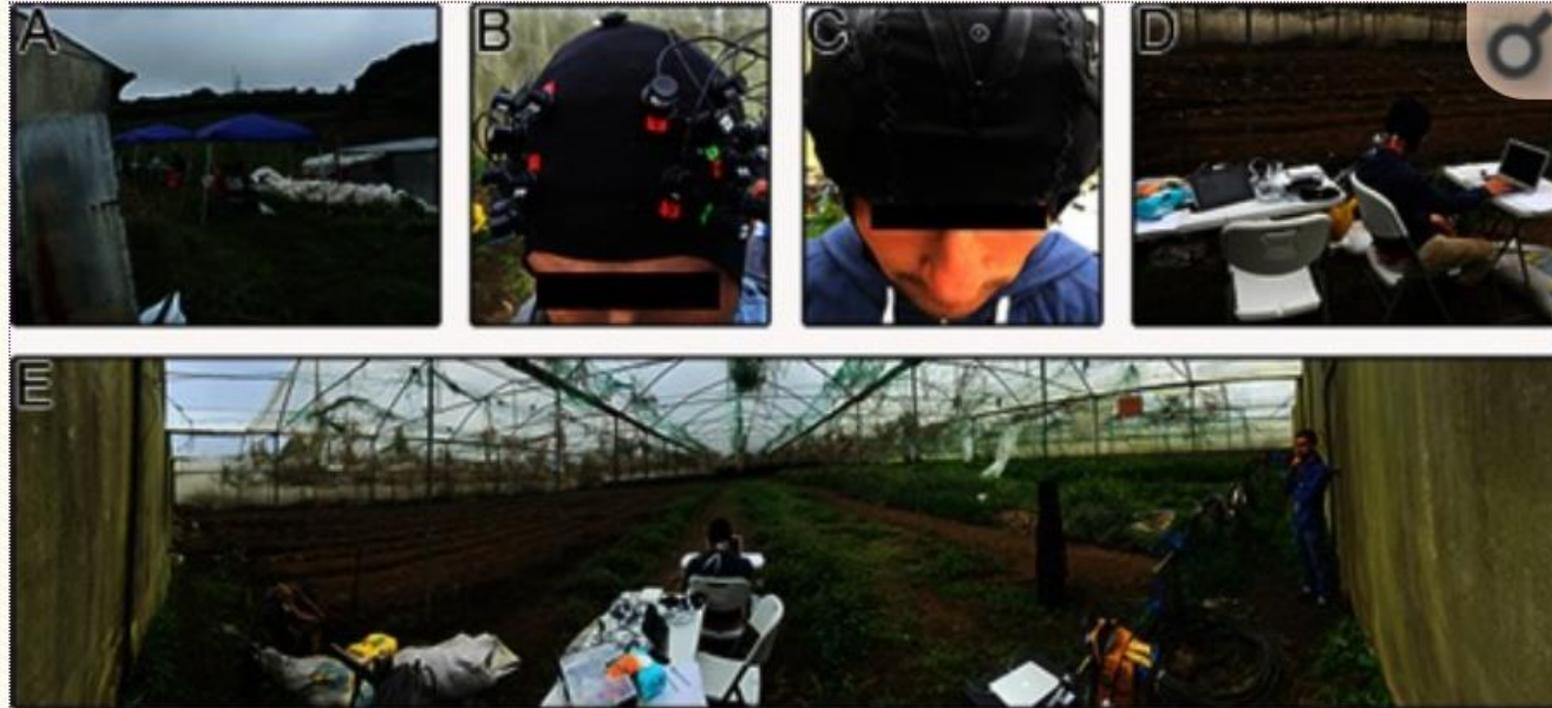


## 60-75岁的老年人，练太极拳的影响

太极拳组反应时更快，前脑的脑信号也更高。

Yang, Chen, Shao, Yan, Yue, Jiang (2019) Effects of Tai Chi Chuan on Inhibitory Control in Elderly Women: An fNIRS Study *Frontiers in human neuroscience* 13() 476

# 【案例】 田野研究

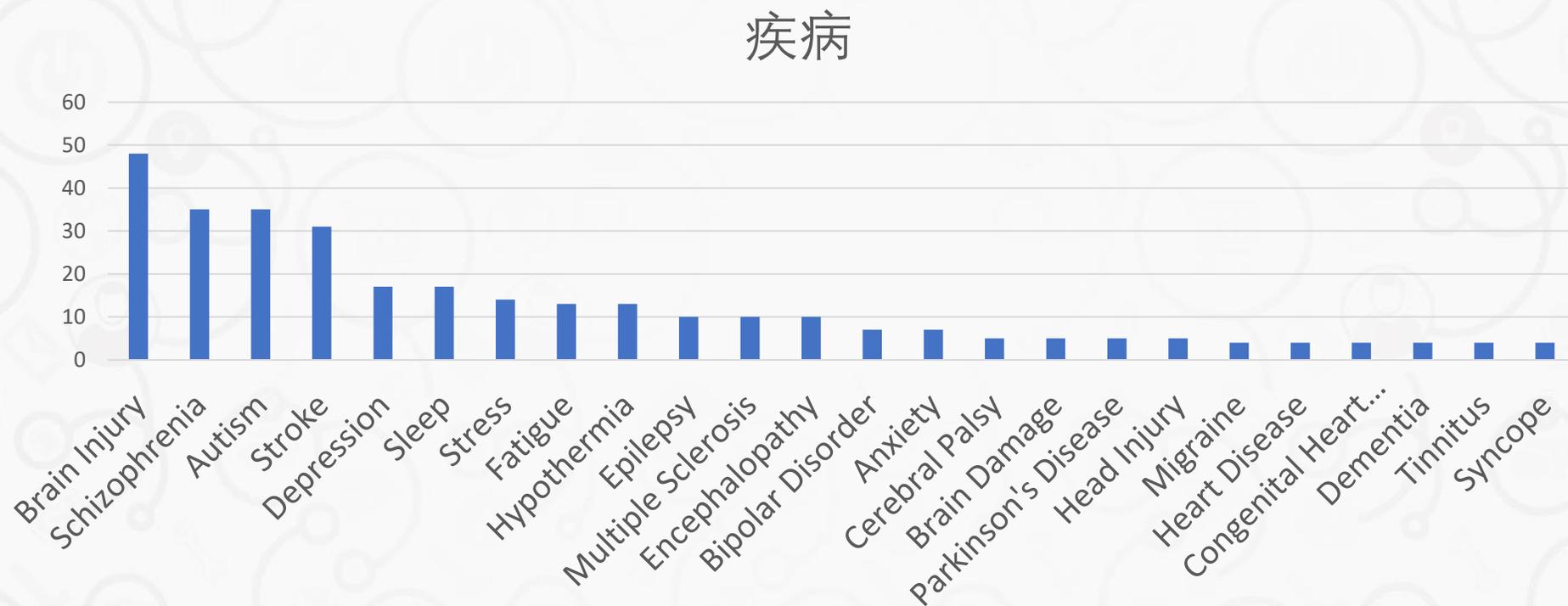


在农场研究农药对健康的影响



Baker, Rojas-Valverde, Gutiérrez, Winkler, Fuhrmann, Eskenazi, Reiss, Mora (2017) Portable Functional Neuroimaging as an Environmental Epidemiology Tool: A How-To Guide for the Use of fNIRS in Field Studies *Environmental health perspectives* 125(9) 094502

# 【案例】 脑疾病研究



文献鸟软件分析 (storkapp.me)

# 【案例】 创伤后应激障碍 (PTSD)

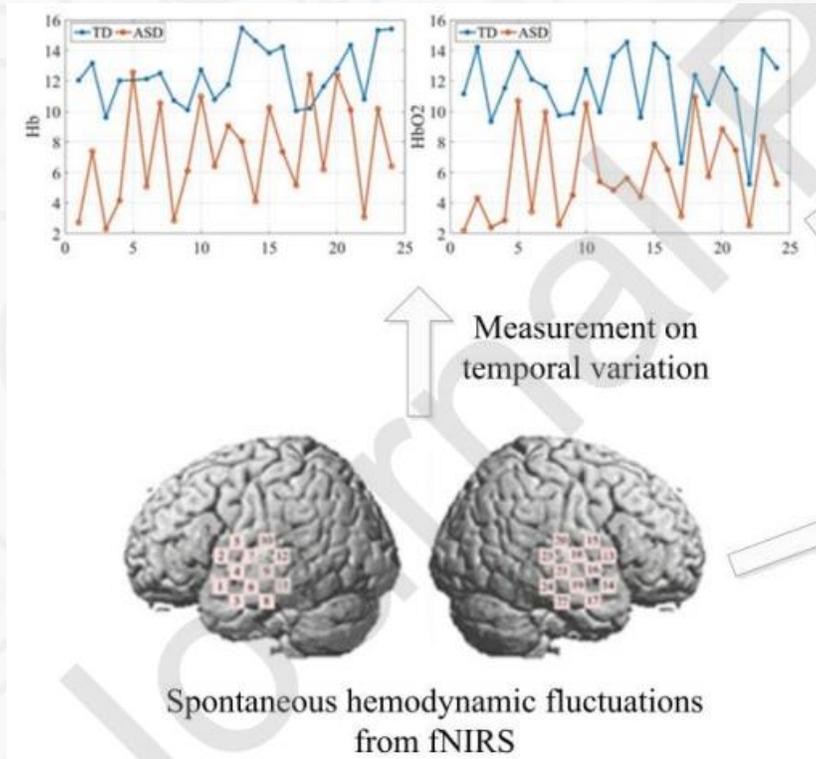


## 创伤后应激障碍 (PTSD) 退伍军人

在记忆任务重，发现患有PTSD的退伍军人在编码过程中具有激活功能，但在检索过程中却具有明显的失活功能。

Tian, Yennu, Smith-Osborne, Gonzalez-Lima, North, Liu (2014) Prefrontal responses to digit span memory phases in patients with post-traumatic stress disorder (PTSD): a functional near infrared spectroscopy study *NeuroImage. Clinical* 4() 808-19

# 【案例】 自闭症



## 自闭症儿童和正常儿童（大约10岁）

用深度学习的方法，用fNIRS测量的自发信号，可以实现高度准确的分类，灵敏度为97.1%，特异性为94.3%。

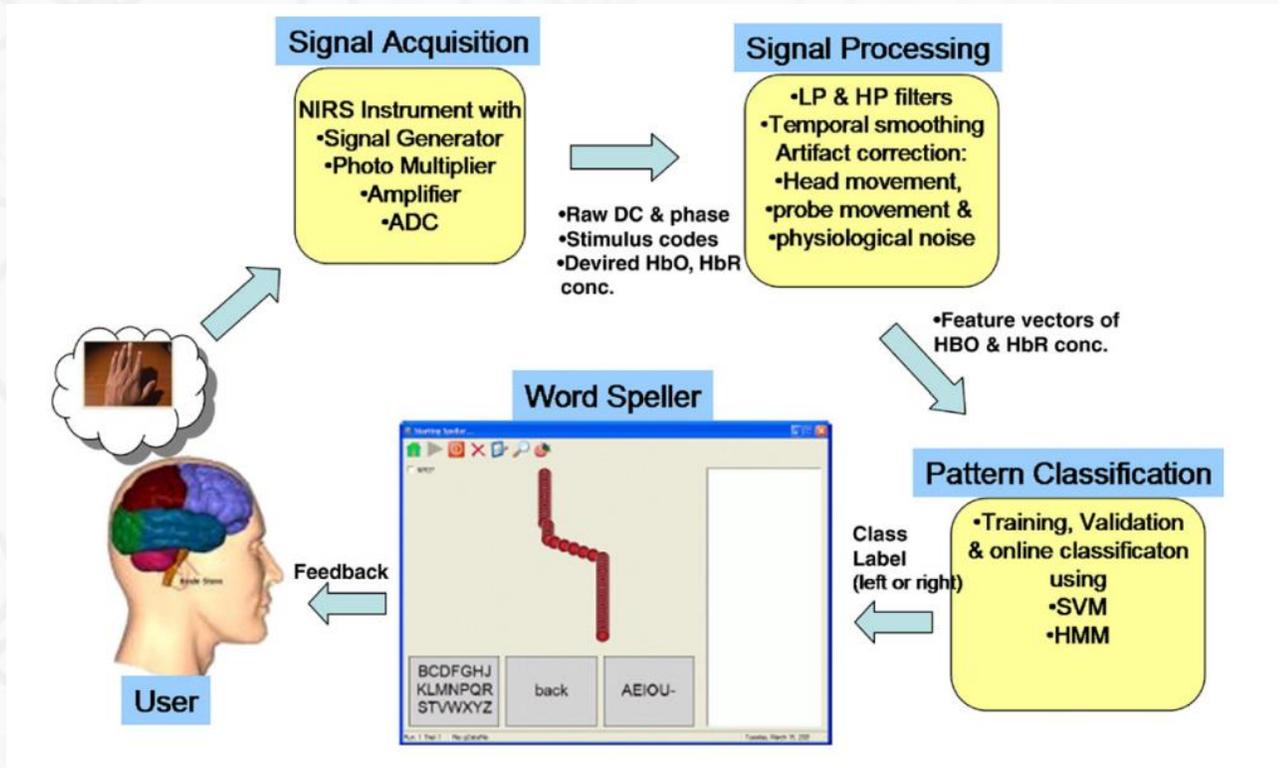
Xu, Liu, Yu, Li, Yu, Cheng, Li (2020) Characterizing autism spectrum disorder by deep learning spontaneous brain activity from functional near-infrared spectroscopy *Journal of neuroscience methods* 331() 108538

上海大学

# 【案例】脑机接口BCI

## 解读用大脑想象左手右手运动

在5名健康志愿者的运动皮层上使用了连续波20通道NIRS系统，以测量左手和右手运动想象期间氧合和脱氧血红蛋白的变化。SVM对所有志愿者从右手想象中对左手想象进行分类，其平均准确率为73%，而HMM的表现更好，平均准确率为89%。我们的结果表明NIRS在BCI的发展中具有潜在的应用前景。



Sitaram, Zhang, Guan, Thulasidas, Hoshi, Ishikawa, Shimizu, Birbaumer (2007) Temporal classification of multichannel near-infrared spectroscopy signals of motor imagery for developing a brain-computer interface *NeuroImage* 34(4) 1416-27

# 【案例】 诊断



Gao, Cai, Wang, Wang, Zhang, Yan (2019) Probing prefrontal cortex hemodynamic alterations during facial emotion recognition for major depression disorder through functional near-infrared spectroscopy *Journal of neural engineering* 16(2) 026026

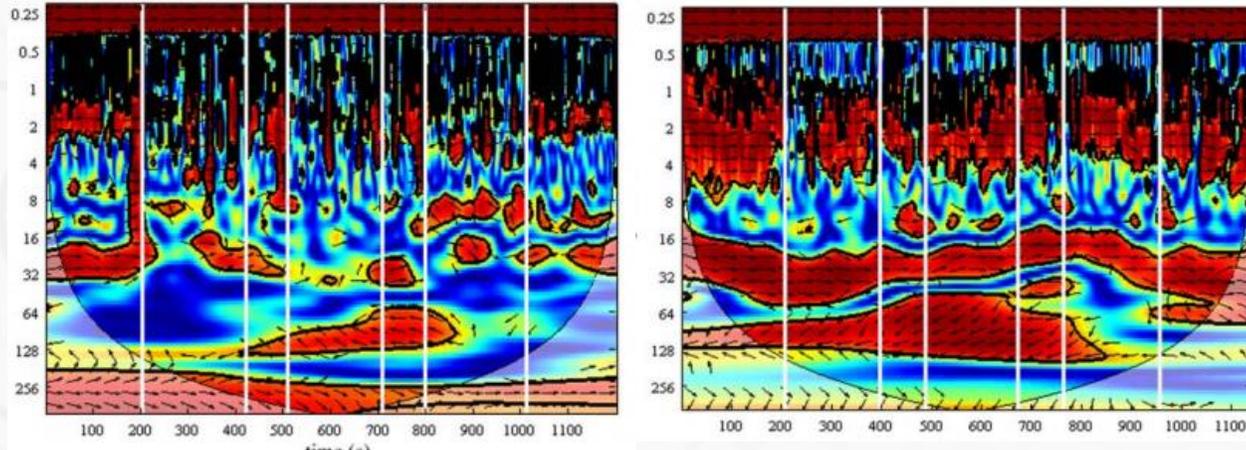
## 重度抑郁症的fNIRS生物指标

精神病学实践中的一个严重问题是缺乏特异性，客观的生物指标来帮助临床医生诊断。重度抑郁症（MDD）的特征在于处理面部情绪表达的能力较差。应用使用近红外光谱仪的便携式神经成像系统，我们研究了27名MDD患者与24名健康对照（HC）相比，在面部表情识别和休息期间前额叶皮层血流动力学激活变化。MDD患者左前额叶皮层上的oxy-Hb和deoxy-Hb之间以及双侧oxy-Hb之间的小波相关性显著低于HC组。这些结果表明，fNIRS信号可为临床诊断抑郁症提供可靠的预测指标，也为使用经颅磁刺激改善病情提供了基础。

# 【案例】 诊断

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重症抑郁症

健康

Gao, Cai, Wang, Wang, Zhang, Yan (2019) Probing prefrontal cortex hemodynamic alterations during facial emotion recognition for major depression disorder through functional near-infrared spectroscopy *Journal of neural engineering* 16(2) 026026 (西安交大)

# 【案例】 治疗



## 经颅红外激光刺激 (TILS)

经颅红外激光刺激 (TILS) 是一种非侵入式脑调节手段。线粒体电子传输链中的末端酶细胞色素c-氧化酶 (CCO) 是主要的细胞内光受体。我们发现TILS上调大脑CCO并引起血液动力学变化。

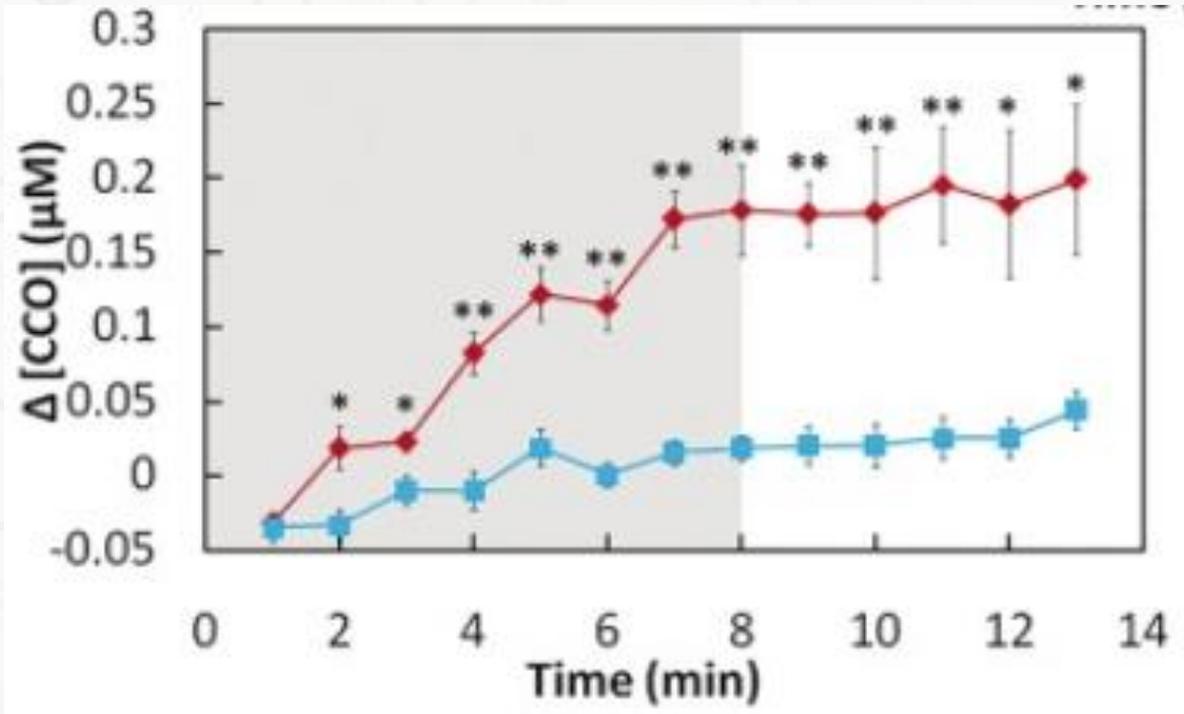
健康参与者 (n = 11)

前额

1064 nm激光刺激

Wang, Tian, Reddy, Nalawade, Barrett, Gonzalez-Lima, Liu (2017) Up-regulation of cerebral cytochrome-c-oxidase and hemodynamics by transcranial infrared laser stimulation: A broadband near-infrared spectroscopy study *Journal of cerebral blood flow and metabolism* 37(12) 3789-3802

# 【案例】 治疗



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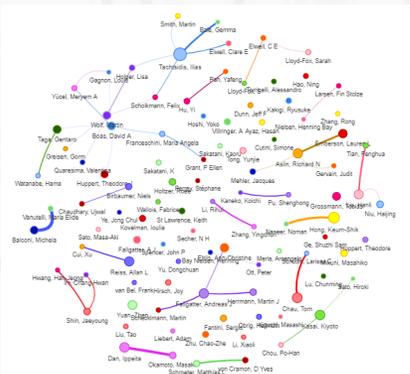
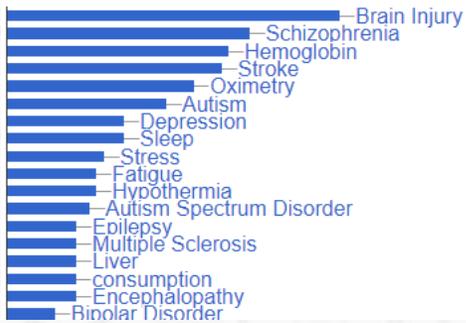
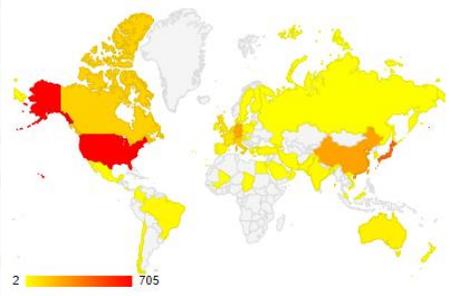
Wang, Tian, Reddy, Nalawade, Barrett, Gonzalez-Lima, Liu (2017) Up-regulation of cerebral cytochrome-c-oxidase and hemodynamics by transcranial infrared laser stimulation: A broadband near-infrared spectroscopy study *Journal of cerebral blood flow and metabolism* 37(12) 3789-3802

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# 文献鸟 Stork

## 小巧的文献追踪分析工具



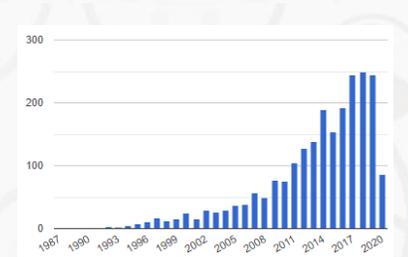
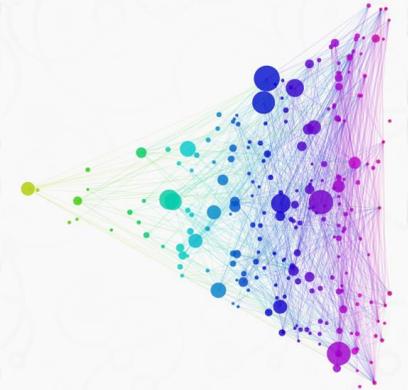
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