FINAL YEAR PROJECT 1

(EDB 4012)

Extended Proposal

on

Development of Measuring Technique to Study Synchronization in Learning Using fNIRS

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CHAPTER 1: Introduction

1.1 Background

The functional study of neural activities between multiple brains has become an increasing popular study especially in the field of social cognition as shown in Appendices. Nowadays, there are several measuring techniques developed to analyze the brain responses toward social interaction. "Hyperscanning" is one of the new techniques to measure Interpersonal Neural Synchronization (INS) level of multiple brain simultaneously by normally using separated Functional Magnetic Resonance Imaging (fMRI) or Electroencephalogram (EEG) (Nozawa, et al., 2016).

In this project, a new approach is developed by implementing Functional Near-Infrared Spectroscopy (fNIRS) as a solution for learning improvement. The application fNIRS-based hyperscanning is used for simultaneous recording of hemodynamic activities of multiple brains among interacting individuals (Liu et al., 2016). However, there is a need of more findings and accumulation of analysis to prove the feasibility of fNIRS hyperscanning. Therefore, this approach is studied and applied to measure the Interpersonal Neural Synchronization (INS) between instructor and students to improve the effectiveness of classroom learning. A demonstration of classroom teaching and learning is carried out in order to collect the specific data which can be used as important variables and elements in the science of learning.

1.2 Problem Statement

According to Berliner in 2001 (as cited in Stockero, Rupnow & Pascoe, 2017) the most important key which distinguishes novice and expert teachers is how they observe their students' thinking and understanding in classroom. Based on the research findings on more than 1000 classrooms from Smith (1998) and Frey, Fisher and Allen (2009) (as cited in Hurst, Wallace & Nixon, 2013), students had extremely low interaction with teachers who were talking 90% in the class but what students did were only sitting, taking notes and answering the questions from teachers. Comparing to expert tutors, novice teachers only focus on classroom management without drawing attention from students. Hence, interaction is important in the classroom to enable two-way communication for delivery of messages from teachers to students and feedback from students to teachers.

However, it is not easy for tutors to observe students' feedback all the time especially the university lecturers who have to face more than hundred students in a complex class situation. Therefore, this project is proposed to measure Interpersonal Neural Synchronization (INS) level by using fNIRS during the interaction in the classroom.

This new approach can be a real-time monitoring technique which will be useful in development of modern science of learning. Lecturers can identify the most suitable by easily observing students' understanding based on the data obtained such as the level of attention, INS and hemoglobin oxygenation level.

1.3 Objectives and Scopes of Study

1.3.1 Objectives

1. To design a protocol to measure oxygenation level of multiple brains in classroom learning.
2. To measure Interpersonal Neural Synchronization (INS) level of multiple brains among teachers and/or students.
3. To perform statistical analysis on Functional Near-Infrared Spectroscopy (fNIRS) data with a comparison with behavioral assessment to identify the most effective approach in classroom learning.

1.3.2 Scopes of Study

The study is designed to measure Interpersonal Neural Synchronization (INS) of multiple brains during the interaction in classroom teaching and learning. By using fNIRS, the INS level obtained can be a useful data in various studies of social-interactive behavior such as oral communication between individuals (Liu, 2016).

By carrying out four different tasks using fNIRS hyperscanning, the INS level of multiple brains during classroom learning, INS level of brain without interaction and INS brains level during cooperation and understanding level after learning will be taken and analyzed using MATLAB based on the oxygen synchronization level on the prefrontal cortex of the brain.

However, this study aims to design a primary development for fNIRS hyperscanning. Hence, the advancement of post-experiment study is not taken in consideration and yet to be developed in the future study. For example, as mentioned by Hiroyasu Yoshida and Yamamoto (2015), the investigation of region of interest (ROI) using machine learning and generic algorithm which is a good method to improve the accuracy in fNIRS data analysis is yet not included in this study. Besides, the motor neuron skill learning which is one of the most famous study (Liu & Yuan, 2015) will also not included in this protocol study. This is because these neural mechanism studies require data in detail from more experiments in advance.

CHAPTER 2: LITERATURE REIVEW AND THEORY

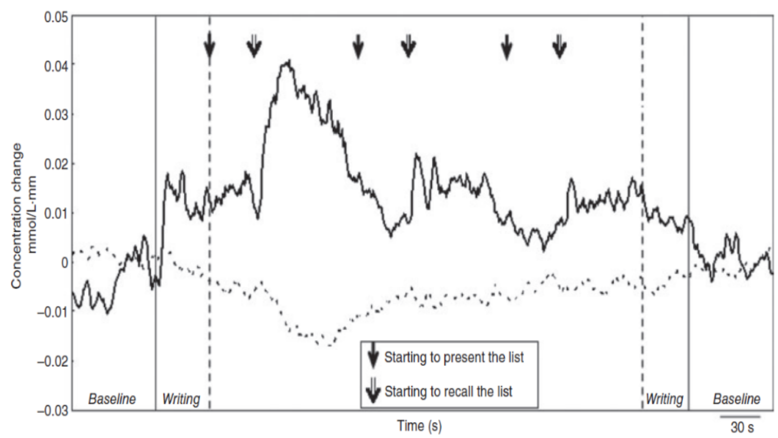
This project aims to produce an fNIRS hyperscanning method to measure the INS level of multiple brains between instructor and students to establish a new effective science of learning. By implementing this project, instructor or teacher is able to measure level of understanding of students and find out the most effective way to draw the attention of the students. In prior to the project, there are several studies need to be carried out to understand the basic concept of this project.

2.1 Hyperscanning

Hyperscanning is a method that enables simultaneous recording of brain neural activities while there is interaction between multiple brains. In this project, hyperscanning is used to measure the level of Interpersonal Neural Synchronization (INS) to analyze the cooperation and verbal communication among individuals.

Based on Duane and Behrendt in 1965 and Montague in 2012 (as cited in Liu et al., 2016), the initial study of hyperscanning was based on the study of neuroimaging modalities techniques of Electroencephalogram (EEG) and followed by Functional Magnetic Resonance Imaging (fMRI). However, there are some limitations of using EEG and fMRI as hyperscanning tools. For example, the application of fMRI is limiting users in a motionless position which is unable to provide real-time social interaction. Besides, the implementation of EEG in hyperscanning is having difficulties to provide precise location for neoruelectrical signal origin (Cui, 2011). Therefore, fNIRs, which is cost effective and providing better wireless portability and temporal resolution will be a preferable alternative to be implemented in this project.

Implementation	Findings	Source
Comparison on Hyperscanning Neuroimaging Technique using EEG, fMRI and fNIRS	1. EEG is good at inter-brains interaction effect recording but difficult to localize the epicenter of inter-brain effect. 2. fNIRS is better in temporal resolution and portability than fMRI. It also creates natural environment for hemodynamic level measuring.	Koike, T., Tanabe, H. C. & Sadato, N. (2014). Hyperscanning neuroimaging technique to reveal the "two-in-one" system in social interactions. *Neuroscience Research*. 90, 25–32.
Study on NIRS-Based Hyperscanning to measure INS level during cooperation in Jenga Game	The highest INS level was measured in right middle, superior frontal gyrus and prefrontal cortex cooperation stage in Jenga Game.	Liu, N. et al. (2016). NIRS-Based Hyperscanning Reveals Inter-brain Neural Synchronization during Cooperative Jenga Game with Face-to-Face Communication. *Frontier in Human Neuroscience*. 10 (82).

<table>
<tr><td>Study on fNIRS-based Hyperscanning to Measure Interpersonal Coherence Level in Superior Frontal Cortex Based on Competition, Cooperation and Single Tasks</td><td>The Wavelet Transform Coherence (WTC) level of individual is highly dependent on cooperation level but competition and individual tasks did not show significant increase in coherence level.</td><td>Cui, X. et al. (2011). NIRS-based hyperscanning reveals increased interpersonal coherence in superior frontal cortex during cooperation. NeuroImage. 59, 2430–2437.</td></tr>
<tr><td>Study of fNIRS in prefrontal cortex activation during memory learning tasks</td><td>1. There was large change of hemoglobin level during memory task (encoding stage).
2. There was no significant change of hemoglobin level during task repetition (retrieval stage).

</td><td>Matsui, M., Tanaka, K., Yonezawa, M. & Kurachi, M. (2007). Activation of the prefrontal cortex during memory learning: Near-infrared spectroscopy study. Psychiatry and Clinical Neurosciences, 61, 31–38</td></tr>
</table>

Study of fNIRS on Brain Connectivity During Imitation by Performing Paced Finger-Tapping Task (PFT) Between Instructor and Imitators	1. Larger Wavelet Transform Coherence (WTC) level was found during imitation (IM) condition as compared to control (CO) condition. 2. Greater extent of G-Causality existed in imitation of stimulus paced finger tapping compared to self-paced finger tapping.	Holper, L., Scholkmann, F. & Wolf, M. (2012). Between-brain connectivity during imitation measured by fNIRS. *NeuroImage.* 63, 212–222.
Experiments on fNIRS to Enable Routine Functional Brain Imaging: This study implemented High Density and wearable fNIRS and advanced signal processing techniques to enhance fNIRS performance.	1. High Density fNIRS provides more accurate brain activity and resting state mapping over different cortical regions. 2. Wearable fNIRS provides natural environment and more efficient brain monitoring system.	Yücel, M. A. et al. (2017). Functional Near Infrared Spectroscopy: Enabling Routine Functional Brain Imaging. *Current Opinion in Biomedical Engineering.*

Several studies have been done based on the past research on fMRI, EEG and fNIRs and it is compared as shown in the table above. Based on the study table, it is found that wearable fNIRS can be a reliable tool for hyperscanning due to its portability which is suitable to be carried. Besides, comparing to EEG and fMRI, fNIRS is preferable to create a natural environment for brain monitoring to allow real-time data can be taken easily (Koike, T., Tanabe, H. C. & Sadato, N., 2014; Yücel, M. A. et al., 2017).

By implementing portable fNIRS, the study area of hyperscanning can be applied in different field such as social psychological problem, development of social interaction between parents and children and teachers and students (Yucel, et al., 2017) which will be our research target in this protocol. According to Holper, Scholkmann and Wolf (2012), the social interaction can be determined by measuring inter-brain connectivity hemodynamic correlates which also known as Interpersonal Neural Synchronization (INS) level. This can be evaluated by using Wavelet Transform Connectivity (WTC) and Granger Causality on the region of prefrontal cortex of human's brain.

Besides, a hypothesis can be made based on the research that the INS level of multiple brain is highly dependent on the interaction or corporation among individuals (Cui, X. et al., 2011). Comparing to individual and competition task, cooperation task showed larger changes.

2.2 Functional Near-Infrared Spectroscopy (fNIRS)

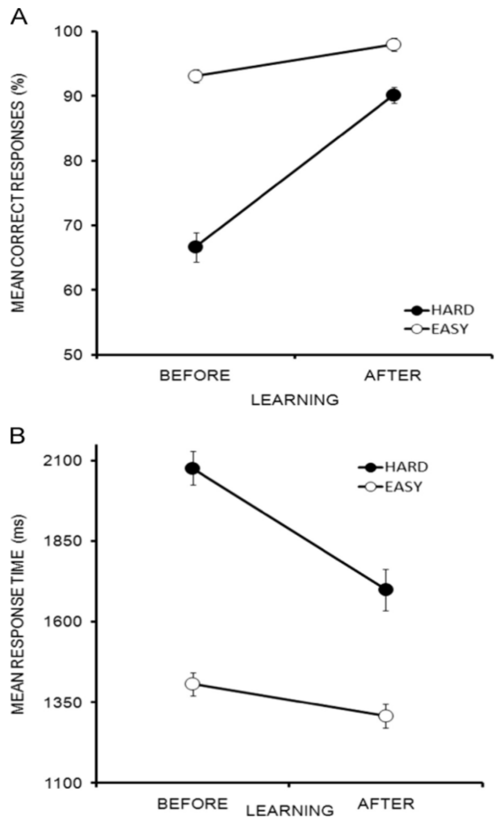
Functional Near-Infrared Spectroscopy (fNIRS) is a non-ionizing method which capture the brain functional hemodynamic response (Yucel, 2017). In this project, fNIRS hyperscanning is implemented as measuring tool of multiple brain neural activities. By applying modified Beet-Lambert Law (MBLL), fNIRS measures the concentration changes of oxy-hemoglobin (oxy-Hb) and deoxy-hemoglobin (deoxy-Hb) by propogating near-infrared radiation through the skull and scalp.

The main purpose of fNIRS is to measure the level of social interaction. This can be done effectively by applying hyperscanning neuroimaging techniques to identify the interbrain effects. Functional connectively and effective connectively will be the main factors indicating the correlation and causal relationship respectively among the multiple brains. Based on the first fNIRS hyperscanning study by Funane, et al. (2011) on two interacting users, the coherence level of the brains was significantly found at the prefrontal cortex of the brains (as cited in Koike, Tanabe & Sadato, 2014).

2.3 Classroom Learning

The process and layout of classroom learning should be understood so that the demonstration of experiments can provide the accurate data to analyze students' performance based on the interaction with tutor in the classroom. A hypothesis is made that students' Interpersonal Neural Synchronization (INS) and coherence level is highly dependent on the interaction while learning in the classroom (Cui et al., 2011). Based on the study (Dziobek et al., 2011 as cited in Cui et al, 2011), the prefrontal cortex is a part of significant brain region which contribute the coherence level measurement by using fNIRS.

Implementation	Findings	Source
Study on Impact of Social Interaction on Student Learning: This study investigate students' perspective based on three courses on how important social interaction in classroom learning is.	Students from all three courses agree that social interaction is important to enhance not only their learning but also problem solving skills.	Hurst, B., Wallace, R. & Nixon, S. B. (2013). The Impact of Social Interaction on Student Learning. *Reading Horizons*. 52 (4).
Study on how the relationship between students and teachers affect academic performance.	Teacher and student relationship is important in emotional and behavioral student engagement.	Lee,. J. S. (2012). The Effects of the Teacher-Student Relationship and Academic Press on Student Engagement and Academic Performance. *International Journal of Educational Research.*
Study on measuring neural coupling between 3 speakers telling stories and 15 listeners using fNIRS and further compare with fMRI	1. Neural coupling and synchronization appear in successful communication and absent when communication is blocked. 2. fNIRS can be a useful tool for neural coupling investigation after comparing with fMRI.	Li, Y., et al. (2017). Measuring speaker–listener neural coupling with functional near infrared spectroscopy. *Scientific Report.*

Study on mathematic learning and neural activities based on EEG frequency effect	1. 67%-90% increase in performance is induced by learning rule. 2. The accuracy is determined by the frequency change in EEG and the response time. 	Skrandies, W. & Klein, A. (2014). Brain activity and learning of mathematical rules- Effects on the frequencies of EEG. Brain Research.

Study on investigating frontalpolar INS in social communication and timescale dependency in INS modulation via Japanese cooperative word-chain game	1. There was no significant change of communication in deep signal and shallow signal compared to neural signal during interaction. 2. Highest INS level exists in prefrontal region during cooperation communication.	Nozawa, T. et al. (2016). Interpersonal frontopolar neural synchronization in group communication: An exploration toward fNIRS hyperscanning of natural interactions. *NeuroImage*. 133, 484–497.
Study on EEG-Based Cognitive Load of 34 participants at multilearning state based on their brain coherence level or Partial Directed Coherence (PDC).	1. Alpha wave is the best to measure the cognitive-load in learning. 2. The accuracy of classification increases as the learning state is repeated thrice.	Moona, M, M., Azrina, A., Aamir, S. M. & Hafeez, U. A. (2017). An EEG-Based Cognitive Load Assessment in Multimedia Learning Using Feature Extraction and Partial Directed Coherence. *Digital Object Identifier*. 10,1109

Several studies were carried out to prove the feasibility of fNIRS application in classroom learning as shown in the table above. Based on the research, fNIRS is feasible to be implemented in classroom learning as it is proven by further comparison with fMRI (Li, et al., 2017).

Regarding to the classroom learning, there are different implementation in order to study the interaction and synchronization between teacher and students in the classroom. The implementations consist of different types of activities such as multilearning, mathematical learning, storytelling, word-chain game and Jenga Game. As what obtained from these implementation, the synchronization between teacher and students is observed when there is successful communication.

Moreover, it is also found that the understanding of students can be determined based on the performance factors such as respond time of imitating, repeating or answering based on what they have learnt (Skrandies & Klein, 2014). By utilizing the analyzed data from the experiments, this protocol helps to identify the most effective approach in classroom learning.

In conclusion, the implementation of EEG, fMRI and fNIRS in learning purpose was studied and compared to come out with a suitable protocol design. It is proven that social engagement and interaction are very important to improve students' performance in classroom learning (Hurst, Wallace & Nixon, 2013; Lee, 2012). The technique of fNIRS-based hyperscanning is suitable to be implemented to improve the efficiency and effectiveness of classroom learning. Besides, the wearable fNIRS provides advantages for simultaneous hemodynamic level recording among multiple brains. As the result of the literature review study, the protocol design for this project is planned based on different tasks which enable different changes of mental states of participants.

CHAPTER 3: METHODOLOGY/PROJECT WORK

2.1 Tools

Tools	Descriptions
Hitachi HOT-1000 fNIRS	Used measure the Interpersonal Neural Synchronization level of multiple brains.
MATLAB	Software used to process the data received by fNIRS.
Classroom Setup	Classroom setup is used to demonstrate the experiment for multiple brains hyperscanning. Further detail is discussed in the section of Research Methodology

2.2 Research Methodology

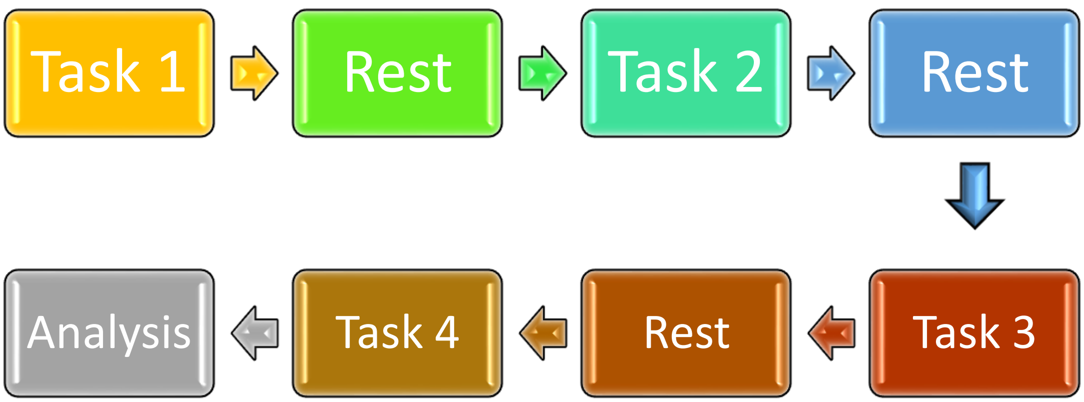
Based on the methodology table shown below, this project aims to measure the Interpersonal Neural Synchronization (INS) of multiple brains via learning a foreign language in classroom. There are 10 participants required that consist of tutor, language experts, language learners with some basic knowledge and new learners. There are four tasks will be carried out in order to investigate how interaction of multiple brains affects the INS level and students' understanding based on different conditions. Between the interval of every task, students are required to take a short break to recover their mental states to normal condition.

The methodology of each tasks and its description are shown in the table below:

Methods	**Learning Foreign Language**	**Descriptions**
10 Participants	1 tutor	Act as instructor.
	3 experts	Students who are able to understand, write and speak the foreign language well.
	3 learners with basic knowledge	Students who are only able to write and pronounce the simple words of the foreign language.
	3 new learners	Students who do not know anything about the foreign language.
Task 1 (Learning)	Classroom Learning	Learning state will be conducted by the tutors to the 9 participants involved in the classroom.
Task 2 (Answering Question)	Answering MCQ	- Students are required to with answer question paper provided based on different difficulty level - Purpose: To measure the level of understanding of students based on the response of answering question with different difficulty
Task 3 (Individual Task)	Pronunciation	- Pronounce the words given as much as possible in 1 minute. - To measure students' INS level without any interaction.
Task 4 (Group Task)	Conversation	- Three group of three learners communicate with each other by giving script and scenario. - To measure students' INS level during interaction and corporation.

Rest State	Stop activity	- Learners are required to close their eyes and rest for 3minutes. - Aims to help learners to recover their mental state back to normal after each task.

The sequence of the protocol is shown in the flowchart below:



Protocol Design (Block Diagram)

Based on the diagram, multiple brain hemodynamic level recording is taken by installing one Hitachi HOT-1000 Wearable fNIRS Headset on each participants. Each participant is required to wear the device along Task 1 until Task 4. All fNIRS are connected simultaneously to computer via Bluetooth. The real time data obtained along the tasks will be analyzed via signal processing by using MATLAB.

2.2 Project Key Milestones

2.2.1 Final Year Project Course Milestones

Week	Key Milestone	Objectives
1	**Final Year Project Title Selection/Proposal**	- To select FYP Title given by coordinator or propose own idea to coordinator.
2	**Project Detail by FYP Supervisor**	- Meet with FYP supervisor to understand about the project detail.
5	**Project Extended Proposal First Draft**	- Submit Project Extended Proposal first draft to FYP supervisor.
6	**Submission of FYP Extended Proposal**	- Submit FYP Extended Proposal to coordinator and Turitin for plagiarism checking.
9	**Proposal Defense and Progress Evaluation**	- Present about project feasibility. - Identify all available tools for the project.
12	**Interim Report First Draft**	- Submit Interim Report first draft to FYP supervisor for checking.
13	**Interim Report Draft**	- Submit Interim Report Draft in hardcopy to supervisor
14	**Project Interim Report Submission**	- Submit FYP Interim Report to coordinator and Turitin for plagiarism checking.

2.2.2 Project Tasks Milestones

Week	Key Milestone	Objectives
1-4	**Literature Review and Feasibility Study**	- To study and research on project related journal and article. - To study on project literature review. - To understand about the project setup and prove its feasibility.
5-7	**Completion of Protocol Design**	- To plan for project methodology and classroom learning layout.
8-9	**Completion of Ethics Approval Application**	- To present project standard requirement and human right involved to UTP ethics approval panels.
10-11	**Completion of Experiment Layout and Materials Setup**	- To prepare all materials required for classroom learning setup - To prepare for project in both software and hardware.
12	**Completion of Experiments**	- To conduct experiments to obtain desired data by using fNIRS.
13	**Post-Experiment Review**	- To review all data obtained from experiments.
14	**FYP2 Preparation**	- To prepare for FYP2 for data processing.

2.3 Project Timeline (Gantt Chart)

Tasks/Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pre-FYP 1														
Project Title Selection														
Meeting with FYP Supervisor														
FYP 1 Study														
Literature Review Study														
Extended Proposal First Draft														
Extended Proposal Submission														
Feasibility Study														
FYP 1 & Evaluation														
Proposal Defense and Project Evaluation														
Completion of Ethics Approval Application														
Completion of Experiment Setup														
Conduct of Experiment														
Post-FYP 1														
Submission of Interim Report Draft														
Post-Experiment Review														
Submission of Interim Report														
FYP2 Preparation														

CHAPTER 4: CONCLUSION AND RECOMMENDATION

4.1 Conclusion

In conclusion, this project aims to establish a new measuring techniques of multiple brains by using hyperscannig in order to find out the most effective way to improve the classroom learning. By using Hitachi HOT-1000 Portable fNIRS as shown in Appendices, it enables simultaneous recording of multiple brains oxygen synchronization level which can be a good alternatives of Electroencephalogram (EEG) and Functional Magnetic Resonant Imaging (fMRI) in hyperscanning. The data captured can be a useful tools for scientists or engineers to find out the reasons of students losing their attention and having low performance and understanding in academic.

4.2 Recommendation

For further development, the experiments can be demonstrated in different field of learning besides learning foreign language such as engineering and psychology. Comparing to learning foreign language, engineering and psychology learning require advancement of study as they require more mathematical thinking, critical thinking and logical thinking instead of just simple understanding.

Besides implementing this study in adult learning, future works can be done on infants or animals learning. Based on the study from Attaheri et al. (2014), an auditory Artificial Grammar (AG) learning was applied in monkey by using EEG. Another study from Benavides-Varela and Gervain (2017), there are application of fNIRS on infants learning to prove that infants are sensitive to words. Further improvement for these studies can be a good way to prove the reliability of fNIRS in the science of learning.

Furthermore, in order to increase the accuracy of analyzed data from the experiments, machine learning can be one useful technique to identify the brain areas for certain task. Based on Hiroyasu, Yoshida and Yamamoto (2015), Support Vector Machine (SVM) which is one of the machine learning classifier are widely used in brain data analysis and gives successful outcome. They also stated that the combination of classified features based on brain function could identify the label in the most accurate way.

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Hiroyasu, T., Yoshida, T. & Yamamoto, U. (2015). Investigation of regions of interest (ROI) through the selection of optimized channels in fNIRS data. 2015 IEEE Congress on Evolutionary Computation (CEC).

Holper, L., Scholkmann, F. & Wolf, M. (2012). Between-brain connectivity during imitation measured by fNIRS. *NeuroImage.* 63, 212–222.

Hurst, B., Wallace, R. & Nixon, S. B. (2013). The Impact of Social Interaction on Student Learning. *Reading Horizons*. 52 (4).

Koike, T., Tanabe, H. C. & Sadato, N. (2014). Hyperscanning neuroimaging technique to reveal the “two-in-one” system in social interactions. *Neuroscience Research*. 90, 25–32.

Liu, F. & Yuan, Z. (2015). Cortical changes of hemodynamic signals during motor skill learning: a functional NIRS study. *TENCON 2015 - 2015 IEEE Region 10 Conference.*

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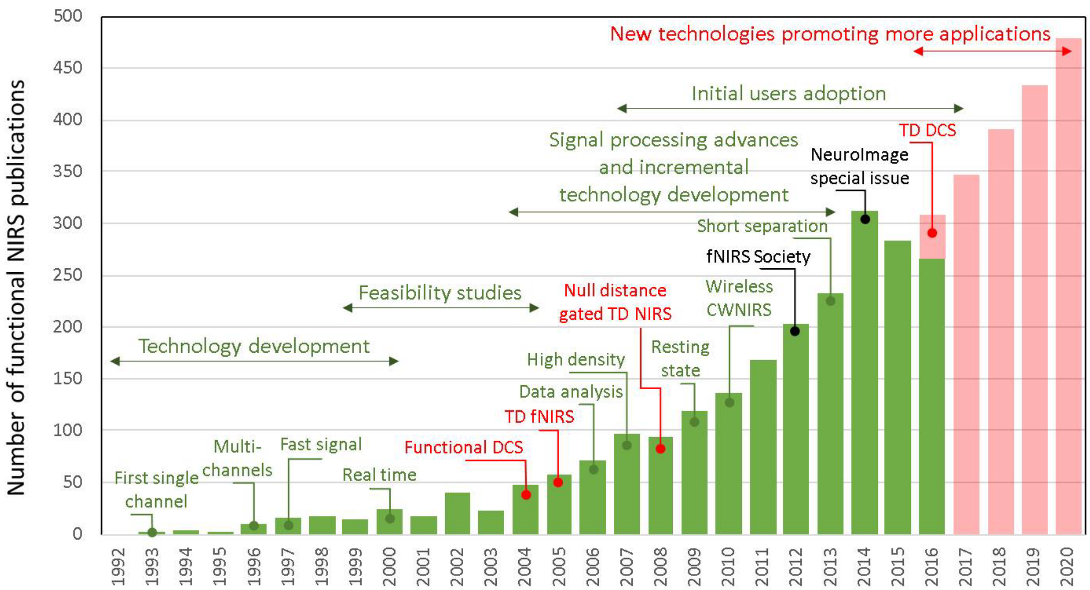
Multimedia Learning Using Feature Extraction and Partial Directed Coherence. *Digital Object Identifier.* 10,1109

Nozawa, T. et al. (2016). Interpersonal frontopolar neural synchronization in group communication: An exploration toward fNIRS hyperscanning of natural interactions. *NeuroImage*. 133, 484–497.

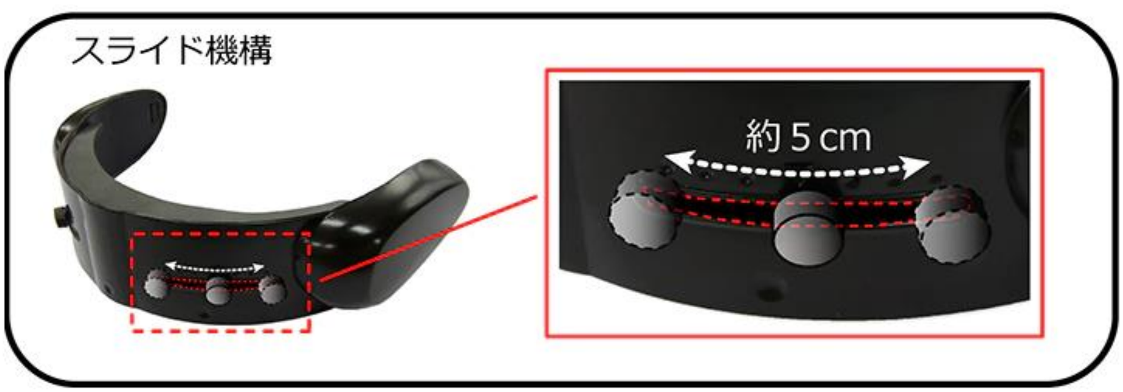
Stockero, S. L., Rupnow, R. L. & Pascoe, A. E. (2017). Learning to notice important student mathematical thinking in complex classroom interactions. *Teaching and Teacher Education.* 63, 384-395.

Yücel, M. A. et al. (2017). Functional Near Infrared Spectroscopy: Enabling Routine Functional Brain Imaging. *Current Opinion in Biomedical Engineering.*

APPENDICES



Number of fNIRS Publication Based on Years



Hitachi HOT-1000 Wearable fNIRS