RGC Ref. No.:
UGC/FDS15/M01/17
(please insert ref. above)

RESEARCH GRANTS COUNCIL
COMPETITIVE RESEARCH FUNDING SCHEMES FOR
THE LOCAL SELF-FINANCING DEGREE SECTOR

FACULTY DEVELOPMENT SCHEME (FDS)

Completion Report
(for completed projects only)

Submission Deadlines:
1. *Auditor's report with unspent balance, if any: within **six** months of the approved project completion date.*
2. *Completion report: within **12** months of the approved project completion date.*

Part A: The Project and Investigator(s)

1. Project Title

A systematic examination of the neural correlates of subjective time perception with fMRI and tDCS

2. Investigator(s) and Academic Department(s) / Unit(s) Involved

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	Dr. LI, Wang-on (Associate Professor)	Department of Counselling and Psychology, Hong Kong Shue Yan University
Co-Investigator(s)	Dr. YUEN, Kenneth Sung-lai (Scientist)	Neuroimaging Center Mainz (NIC), Johannes Gutenberg University Medical Center
Co-Investigator(s)	Professor YU, Calvin Kai-ching (Professor)	Department of Counselling and Psychology, Hong Kong Shue Yan University

3. Project Duration

	Original	Revised	Date of RGC / Institution Approval *(must be quoted)*
Project Start Date	1 Jan, 2018	N/A	N/A
Project Completion Date	31 Dec, 2019	31 Mar, 2022	22 Feb, 2021
Duration *(in month)*	24	51	22 Feb, 2021

Deadline for Submission of Completion Report	31 Dec, 2020	30 Sept, 2022	22 Feb, 2021

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. Study subjective time perception with tDCS

2. Examine the viability of manipulating subjective time experience causally with tDCS
3. Examine the effect of tDCS to attention components according to Attention Network Test
4. Testify the correlation of attention with subjective perception of duration per the attentional gate model
5. Provide internship opportunities for students to receive hands-on experience in psychological and neurophysiological studies

5.2 Revised objectives

Date of approval from the RGC: N/A

Reasons for the change:

1.

2.

3. ....

5.3 Realisation of the objectives
(Maximum 1 page; please state how and to what extent the project objectives have been achieved; give reasons for under-achievements and outline attempts to overcome problems, if any)

1. *Study subjective time perception with tDCS*

The team registered the Stage 1 protocols with the open-science framework (https://osf.io/rgjzk/) and conducted two studies series. Two regions of interest were identified: right DLFC and cerebellum, confirming with findings in previous studies that these two cortical regions are responsive to subjective time perception. Study Two applied tDCS to these two regions has weak effects on subjective time perception. The effect is not significant after correction for multiple comparisons (see pt 2 of the same section). All experimental protocols follow the Stage 1 preregistered report closely and the team successfully complete the experiments. Stage 2 registered report is published in NeuroImage (Scopus: CiteScore 11.2, 5/107 in Cognitive Neuroscience).

2. *Examine the viability of manipulating subjective time experience causally with tDCS*

tDCS were applied to the two regions of interest identified in fMRI (Study 1). tDCS perturbation to the cerebellum does not influence subject time experience systematically (also see #4). Perhaps, the test duration does not fall into its critical regions, which is shorter than the test duration (1000ms). With a bilateral stimulation setup, cathodal stimulation to the right DLPFC (i.e. anodal stimulation to the left DLPFC) produced a marginal underestimation effect on subjective time perception – participants tended to judge an interval shorter than its physical duration (see #1). The bilateral setup avoids spreading tDCS current to the cerebellum, another tested region. The stimulation may have cancelled out each other since Study 1 showed that both right and lateral DLPFC were responsive to subjective time perception. A commonly agreed belief about tDCS is its anodal simulative and cathodal inhibitory effect on the neural circuit. A bilateral tDCS setup to DLPFC, thus, may stimulate and inhibit DLPFC circuits responsive to subjective time perception. A direct comparison shall be conducted in future studies.

3. *Examine the effect of tDCS to attention components according to Attention Network Test*

Besides the subjective time perception task, Study 2 includes the Attention Network Test (ANT) to study the effect of tDCS on attention. ANT was chosen to provide measurements on alerting, orienting and executive control, which corresponds to components in the Attentional Gate Model (i.e., pacemaker, gate and switch). There was no significant difference in the three ANT sub-scores after tDCS, cathodal stimulation to the right DLPFC induces a reduced reaction time in ANT. The sensitivity of ANT is perhaps insufficient in showing the tDCS effect in the chosen stimulation settings using bilateral stimulation (see pt 2 of the same section) and relatively large electrodes ($25cm^2$).

4. Testify the correlation of attention with subjective perception of duration per the attentional gate model

The team formulated hypotheses based on the Attentional Gate Model explaining subjective time perception in terms of attention and working memory that tDCS influencing subjective time experience shall also affect attention and working memory simultaneously. Cathodal stimulation to the right DLPFC (i.e. anodal stimulation to the left DLPFC) produced a marginal overestimation effect to subjective time perception. However, there is no significant difference among conditions in attention and working memory. The correlation of attention with the subjective perception of duration is not as straightforward as the hypotheses.

Nonetheless, executive control scores in ANT were found to significantly predict PSE after tDCS. The analysis in the sham condition was not significant. The tDSC perturbation has either strengthened the relationship between the attention processes and subjective time perception or induced changes to attention and subjective time perception simultaneously through stimulating their common neural correlates. None of these explanations supports the Attentional Gate Model.

5. Provide internship opportunities for students to receive hands-on experience in psychological and neurophysiological studies

A total of four students, two UG majoring in Psychology and two MPhil candidates, received hands-on experience in assisting the reported study (see Section 10).

5.4 Summary of objectives addressed to date

Objectives *(as per 5.1/5.2 above)*	**Addressed** *(please tick)*	**Percentage Achieved** *(please estimate)*
1. Study subjective time perception with tDCS	✓	100%
2. Examine the viability of manipulating subjective time experience causally with tDCS	✓	100%
3. Examine the effect of tDCS to attention components according to Attention Network Test	✓	100%
4. Testify the correlation of attention with subjective perception of duration per the attentional gate model	✓	100%
5. Provide internship opportunities for students to receive hands-on experience in psychological and neurophysiological studies	✓	100%

6. Research Outcome

6.1 Major findings and research outcome
(Maximum 1 page; please make reference to Part C where necessary)

Background

In the present study, the team tested the attentional gate model, a classical conceptual framework in studies of subjective time perception. An fMRI study was conducted to confirm whether the dorsolateral prefrontal cortex (DLPFC) and cerebellum are responsive to subjective time perception (Hypothesis 1). Then, two mixed-design tDCS and behavioural studies were conducted to test hypotheses formulated according to the attentional gate model (Hypothesis 2 and 3).

Hypothesis 1 - The right DLPFC and cerebellum respond to the time discrimination task with the time reference at 1000ms.

25 participants were scanned. After excluding one subject without replacement due to a suboptimal fit of psychometric curves on their behavioural performance, the neural activation during the time discrimination task of a final sample of 24 subjects was analysed. The results showed significant activations in both a priori ROIs, right DLPFC, and right cerebellum, confirming Hypothesis 1.

Hypothesis 2 - Anodal tDCS applied to the right DLPFC leads to the overestimation of duration, magnification of the alerting effect, an overall reduction in reaction time (RT), and enhance n-back task performance

The stimulation on the right DLPFC showed a very weak difference in the PSE of the rDLPFC stimulation condition. The direction of the effect is aligned with Hypothesis 2 but are not statistically significant after a correction of multiple comparisons. There was no significant difference in the ANT scores, including alerting, orienting and executive control, but there was a significant difference in the overall reaction time. Cathodal stimulation to the right DLPFC increased subjects' reaction time compared to anodal stimulation and sham stimulation. The ANT results partially align with Hypothesis 2 regarding the overall reaction time but not in other ANT and n-back task performance.

Hypothesis 3 - Anodal tDCS applied to the cerebellum results in the overestimation of duration, improve executive control performance in ANT, an overall increase in reaction time, and improve 3-back task performance

The stimulation to the right cerebellum did not produce any significant differences in all planned ANOVA. In other words, the results do not support Hypothesis 3.

Hypothesis 4 – Behavioral measurements of attention and working memory predicts the subjective perception of time

The behavioural measurements of working memory and attention marginally predict PSE obtained in the time discrimination task after tDCS stimulation to the right DLPFC. In contrast, working memory and attention task outcomes only significantly predict PSE when anodal stimulation is applied to the right cerebellum. The working memory and executive function ability (i.e. ability to inhibit distractions) positively predict PSE. In other words, the perceived duration is overestimated. The prediction is in line with the Attentional Gate Model that a better ability to count mental ticks would result in an overestimated time. Nevertheless, the regressions are only significant after tDCS that the stimulation potentially enhancing the linkage among attention, working memory and subjective time perception.

Discussion and conclusion

The results provide support to both the right DLPFC and cerebellum as the neural correlates of subjective time perception, and they are responsive to a time discrimination task of 1000ms. The results of the tDCS studies show marginal differences in PSE and reaction time in ANT among different stimulation to right DLPFC. However, both are non-significant after correction for multiple comparisons. In other words, the hypotheses derived from the Attentional Gate Model is not supported. The results of the regression analyses, together with the imaging results, support that subjective time perception shares a similar neural circuit with attention. Nonetheless, their roles are not as straightforward as the relationship hypothesised by the Attentional Gate Model. The Stage 2 registered report is published in NeuroImage (See Part C #8).

6.2 Potential for further development of the research and the proposed course of action *(Maximum half a page)*

The reported study has confirmed the regions of interest of subjective time perception. Unfortunately, COVID has delayed data collection and restricted travelling. The plan to present the findings at an international conference was delayed. The team has already submitted an abstract to European Congress of Psychology 2023 organised by The British Psychological Society (BPS) (See Part C #9).

Further, the present study provides supportive evidence for the neural correlates of the chosen subjective time perception task. The team would continue to study how DLPFC and cerebellum play a role in subjective time perception. The non-invasive transcranial stimulation experimental protocols used in the reported study have enlightened the team in conducting another study with repetitive Transcranial Magnetic Stimulation (rTMS). In this ongoing study, a time adaptation paradigm is used to study whether subjective time perception is subdivided into different neural mechanisms based on duration, for example, sub- and supra-second perception. Further, experiments are conducted to study how rTMS would influence the two time-perception tasks (i.e. time production and time bisection) in time adaptation. The results shall help us to understand the mental representation of time references. This project is funded by another FDS (UGC/FDS15/M03/20).

Further, the team is working on a related meta-analysis extending from this project. The completed project studied the neural correlates of subjective time perception, and its foundation is based on the classical meta-analysis by Wiener, Turkeltaub, and Coslett in 2010. We are working on a manuscript tentatively entitled, Revisiting the neural correlates of time perception: an updated fMRI meta-analysis.

7. Layman's Summary

(Describe <u>in layman's language</u> the nature, significance and value of the research project, in no more than 200 words)

<u>Nature</u>

The research team tested the attentional gate model of subjective time perception with functional magnetic resonance imaging (fMRI), transcranial direct stimulation (tDCS) and behavioural tasks. The behavioural tasks included time discrimination, Attention Network Test and n-back.

<u>Significance</u>

Theoretical The results provide supportive evidence that DLPFC and cerebellum are the neural correlates of subjective time perception. However, the results do not support the hypotheses derived from the attentional gate model. Future research shall continue to study the roles of these two regions in subjective time perception.

Methodological Both bilateral and unilateral setups are commonly used in tDCS studies. A bilateral setup, placing the two electrodes on the contralateral hemispheres of the same regions, may stimulate and inhibit responsive regions at the same time if the fMRI shows both hemispheres are responsive to the task.

Teaching The present study informs teaching in cognitive psychology and research methods that relevant modules are developed. It also helped its research interns gain research experience and cultivate interest in further studying perception, neuropsychology and related fields.

<u>Value</u>

The protocols and scripts for scanning, data analyses and simulations are available online for future studies in subjective time perception and non-invasive transcranial stimulation.

(Words count: 196)

Part C: Research Output

8. Peer-Reviewed Journal Publication(s) Arising Directly From This Research Project

(Please attach a copy of the publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				Author(s) *(denote the corresponding author with an asterisk*)*	Title and Journal / Book *(with the volume, pages and other necessary publishing details specified)*	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this Report *(Yes or No)*	Acknowledged the Support of RGC *(Yes or No)*	Accessible from the Institutional Repository *(Yes or No)*
Year of Publication	**Year of Acceptance** *(For paper accepted but not yet published)*	**Under Review**	**Under Preparation** *(optional)*						
2022	**N/A**	**N/A**	**N/A**	**W. O., LI* K. S.-L., YUEN, & C. K.-C., YU**	**A systematic examination of the neural correlates of subjective time perception with fMRI and tDCS, *NeuroImage* (https://doi.org/10.1016/j neuroimage.2022.119368)**	**2018 (Stage 1 protocol)**	**Yes (Appendix 1)**	**Yes**	**Yes**

9. Recognized International Conference(s) In Which Paper(s) Related To This Research Project Was / Were Delivered

(Please attach a copy of each conference abstract)

Month / Year / Place	Title	Conference Name	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this Report *(Yes or No)*	Acknowledged the Support of RGC *(Yes or No)*	Accessible from the Institutional Repository *(Yes or No)*
2023/ Brighton, UK	A tDCS study in predicting subjective time perception with performance in attention and working memory tasks	18th European Congress of Psychology	No	Yes (Appendix 2a and 2b)	No*	No

*The poster is still pending. Acknowledgement will be included in it

*

10. Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning

(Please elaborate)

PSY310 Advanced Cognitive Psychology: The PI gave a guest lecture on Time Perception to the course introducing the theoretical frameworks for time perception and its neural correlates. Results of the present study were also used as teaching materials.

CP516 Research Methods in Counselling Psychology: The PI has incorporated the Open Science Framework (OSF) experience into his research method classes. A new module, Power Analysis, Replication Crisis and OSF, is introduced to the course. It introduces the students to the development of OSF to better understand the importance of a priori power analysis and planned statistical analyses.

Research Postgraduates and Undergraduate Research Internship: Four students intern helped in the data collection process. Due to its safety issues, none of them uses transcranial direct current stimulation in their independent research studies. After his graduation, an undergraduate intern is studying MPhil at HKU in a related field (i.e. cognition and perception). Another UG has developed an interest in furthering his study in psychology and is currently a student of the Master of Social Sciences in the field of Clinical Psychology (HKU). An MPhil intern has been hired as an FT research assistant for the related FDS project mentioned in Section 6.2. She shares her experiences in non-invasive transcranial stimulation study with new research postgraduate students in the department.

11. Student(s) Trained

(Please attach a copy of the title page of the thesis)

Name	Degree Registered for	Date of Registration	Date of Thesis Submission / Graduation
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

12. Other Impact

(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)

Open Science Framework (OSF): Stage 1 protocols, including the proposal with detailed methodology, are uploaded to OSF before data collection. All simulations, scripts, and anslyses are available in the database. Stage 2 registered report is also available (https://osf.io/rgjzk/).

Timing Research Forum (TRF): TRF is an open academic society promoting multidisciplinary research

on timing and time perception (http://timingforum.org/).
The TRF group tweeted this study and its publication (https://twitter.com/timingforum/status/1543959012546576385?s=21&t=_uAzbnHs4BY4g1oon1zIEQ).

Faculty Development Scheme (FDS): Based on the experience of this project, the team is working on a follow-up project on time perception with repetitive Transcranial Magnetic Stimulation (rTMS) funded by another FDS (UGC/FDS15/M03/20). Dr Dorita H. F., CHANG (HKU) has joined the team in this new ongoing study (see Section 6.2 for details).

13. Statistics on Research Outputs

	Peer-reviewed Journal Publications	Conference Papers	Scholarly Books, Monographs and Chapters	Patents Awarded	Other Research Outputs (please specify)	
No. of outputs arising directly from this research project	1	1	N/A	N/A	Type	No.
					Student interns trained	4
					Online resources of experimental protocols, scripts for simulation and analyses, data	1
					Social Media Mentioned	1
					FDS Grant	1

14. Public Access Of Completion Report

(Please specify the information, if any, that cannot be provided for public access and give the reasons.)

Information that Cannot Be Provided for Public Access	Reasons
Students' names in Section 11	The team does not have the consent to disclose the students interns' identities.