RGC Ref. No.:
UGC/FDS15/M03/20
(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

Is time perception band-pass filtered? An examination of the aftereffect of time adaptation with rTMS

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)	Dr. CHANG Dorita Hue-fung / Assistant Professor	Department of Psychology, The University of Hong Kong
Co-Investigator(s)	Prof. 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	1/1/2021	N/A	N/A
Project Completion Date	31/12/2022	31/12/2023	2/11/2022

Duration *(in month)*	24	36	2/11/2022
Deadline for Submission of Completion Report	31/12/2023	31/12/2024	2/11/2022

4.4 Please attach photo(s) of acknowledgement of RGC-funded facilities / equipment.

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. Testify the Channel-Based Duration Model of time perception
2. Re-examine the aftereffect of time adaptation on perceived duration with a time production task
3. Examine the sensitivity of time perception after time adaptation
4. Study the underlying mechanisms of sub- and supra-second perception with a time adaptation paradigm
5. Examine how rTMS influences sub- and supra-second perception
6. Explore whether subjective discomfort of rTMS associates with subjective time perception
7. Provide research experience in cognitive neuroscience to undergraduate students

5.2 Revised objectives

Date of approval from the RGC: N/A

Reasons for the change: N/A

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. *Testify the Channel-Based Duration Model of time perception*

The Channel-Based Duration Model hypothesizes that populations of neurons are responsive to band pass tuned duration, and are devised to explain time adaptation effect. The present study tested this hypothesis against an alternative continuum model. The findings are inconclusive, based on the durations we tested (ranging from 200ms to 3200ms), it seems that there are only two distinct observable duration ranges, roughly corresponding to sub- and supra-second durations. Additionally, sub- and supra-second durations showed different responses to time adaptation and rTMS, but their perceptual processes also interacted (Appendix 1 and 3).

2. *Re-examine the aftereffect of time adaptation on perceived duration with a time production task*

A time bisection task is a common technique used in subjective time perception, however, it is possible that the reference duration presented after the time adaptation phase is influenced by the aftereffect. Also, time bisection task cannot help in disentangling the effect on the mental references or the perceptual reference. The findings suggest that the time adaptation effect likely influences the perceptual reference rather than the mental reference (Appendix 1 and 3).

3. *Examine the sensitivity of time perception after time adaptation*

Sensory adaptation is believed to enhance perceptual sensitivity. In contrast, time adaptation does not significantly improve sensitivity in the present study, demonstrating its fundamental difference from other sensory adaptations. Given previous studies showing cross modules' time adaptation, its mechanism is multi-modal and of a different level from other sensory adaptations, (e.g. orientation and motion adaptation). A manuscript is submitted to *Scientific Reports* (Appendix 1) and is currently under review.

4. *Study the underlying mechanisms of sub- and supra-second perception with a time adaptation paradigm*

Long before the proposition of a band-pass tuned duration mechanism, there has been a debate concerning the mechanism of sub- and supra-second perception. Among the 1000 ms bisections, adapting to 500 ms resulted in a relative increase in PSEs, while adapting to 1000 and 2000 ms led to a reduction. The aftereffect followed the classical perceptual adaptation model, where perception after adaptation deviated from the adapted duration. However, there is no clear evidence of finely tuned band-pass filters. Further, the time production task supports a Bayesian continuum model. Nevertheless, there is evidence of a transfer of time adaptation effects between durations below and above one second, which calls for further investigation of this mechanism. The team reanalyzed their data archive in search of neurological support for a continuum model or a supra-second perception model. The paper has been submitted to Science and is currently under review (Appendix 2). Among the models tested, preferential evidence for a unifying models are shown.

5. *Examine how rTMS influences sub- and supra-second perception*

While the results are not significantly affected by rTMS on rDLPFC, the adaptation effect of 500 ms is disrupted by rTMS on the cerebellum. By integrating the findings of Objectives #1-4, it becomes clear that rTMS affects the perceptual stage of subjective time perception for durations within the sub-second range. However, mental time references are not significantly affected by rTMS perturbation (Appendix 4).

6. *Explore whether subjective discomfort of rTMS associates with subjective time perception*

Despite the participants reporting clear discomfort after undergoing rTMS, their subjective ratings do not significantly correlate with their performance in a time production task and a time bisection task. This suggests that both tasks are relatively unaffected by subjective discomfort, making them suitable for measuring subjective time perception in future studies.

7. *Provide research experience in cognitive neuroscience to undergraduate students*

A total of six students, four UG majoring in Psychology, one MPhil candidate and one PhD candidate, 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. Testify the Channel-Based Duration Model of time perception	✓	100%
2. Re-examine the aftereffect of time adaptation on perceived duration with a time production task	✓	100%
3. Examine the sensitivity of time perception after time adaptation	✓	100%
4. Study the underlying mechanisms of sub- and supra-second perception with a time adaptation paradigm	✓	100%
5. Examine how rTMS influences sub- and supra-second perception	✓	100%
6. Explore whether subjective discomfort of rTMS associates with subjective time perception	✓	100%
7. Provide research experience in cognitive neuroscience to undergraduate students	✓	100%

6. Research Outcome

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

Background

The research team conducted two series of studies to examine whether time perception operates through a band-pass filter mechanism that is finely tuned to different durations. The first set of studies employed the time adaptation paradigm, while the second set incorporated rTMS techniques. An alternative hypothesis posited a continuum Bayesian model. Additionally, the team assessed the mental references of time, which form the foundation of the classical attentional gate model but have received limited systematic investigation.

Hypothesis 1.1 A time adaptation aftereffect will be found among all time production measurements

Unlike bisection tasks, production tasks do not include a perceptual process of any physical reference in the post-adaptation phase. A significant increase to the 500 production task is reported regardless to the adapting duration contradictory to a band-pass filter hypothesis. In contrast, it supports a continuum Bayesian model that presents longer prior (i.e. 1000 and 2000 ms) increases subsequent perceived duration.

Hypotheses 1.2 An increased sensitivity of participants around the adapted duration

Time production and time bisection do not show a systematic increase to sensitivity after adaptation, but a decrease in some conditions. The results indicate that time adaptation mechanism potentially different from other sensory adaptations, which is deemed possible given the multi-model properties of time perception.

Hypothesis 1.3 Adapting to a time duration will induce a bias to time bisection task

In general, the time adaptation effect is weaker than in previous studies because all participants were naïve to the study objectives in the present setup. In Series 1, only the 1000 ms bisection task shows a weak adaptation effect, conforming to the hypothesis that PSEs deviate from the adapted duration. In Series 2, adapting to a longer duration significantly reduces the PSEs of the 500 ms bisection task. In other words, the hypothesis is confirmed only in some tested conditions.

Hypothesis 1.4 Adapting to various time durations will induce a bias to time production tasks

As mentioned in 1.1., only a significant main effect is found in the sub-second duration (i.e. 500 ms production task), and there is no significant difference among adapting duration.

Hypothesis 1.5 Adaptation to sub- and supra-second duration will transfer to the other group of duration

A transference of adaptation effect between sub-second and supra-second supports the hypothesis.

Hypothesis 2.1 Applying rTMS to rDLPFC would reduce the produced supra-second duration.

Hypothesis 2.2 Applying rTMS to the cerebellum would reduce the produced sub-second duration.

Applying rTMS to rDLPFC and the cerebellum does not lead to any significant change to the time production task, sub- and supra-second duration. Together with the results in Series 1 and support the notion that mental time references do not seem to be affected by the tested manipulations in a laboratory setup as much as perceptual time references.

Hypothesis 2.3 rTMS influences time perception differently with and without adaptation

Adaptation causes a significant reduction of PSEs in 500ms time bisection task in the sham TMS condition, regardless of the adaptation durations. rTMS on the cerebellum disrupt the adaptation effect leading to an increase in PSE in the 500ms adapting condition The results aligns with previous findings that the cerebellum is responsive to sub-second duration and support the hypothesis showing that rTMS on the cerebellum perturb the perceptual process of sub-second range stimuli.

Hypothesis 2.4 Subjective discomfort to rTMS negatively correlates with produced duration

The participants' discomfort was collected in terms of perceived pain, annoyance and irritation. None of these rating predicts produced duration in any condition.

Discussion and Conclusion

The mechanism of time adaptation works differently from other sensory adaptations. There is no direct evidence supporting a finely tuned band-pass filter model for time perception, while sub- and supra-second perceptions are separated but interact. Time production task provides a viable measurement to the mental references of time and shows that most tested manipulations influence the perceptual process of time references. In the future studies, both time production and bisection tasks can serve as measurements relatively free from the perceived discomfort of rTMS.

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

Overall, the results consistently support the existence of a difference in perception between sub-second and supra-second intervals under various conditions. However, no evidence of finer tuning was found. Additionally, the study did not observe the repulsion effect that has been reported in other sensory adaptations, suggesting that time perception involves a higher-order module that integrates multiple sensory inputs. This study is the first to compare the performance of time production and bisection tasks under the influence of time adaptation and repetitive transcranial magnetic stimulation (rTMS). The time production task reflects the mental references and does not involve a prominent perceptual state. By combining Series 1 and 2, the experimental manipulations of adaptation and rTMS were found to have minimal influence on participants' mental references, indicating that most manipulations primarily affect perceptual processes. Future research could focus on exploring factors that may influence the mental references of time, which may be more personalized characteristics rather than experimental manipulations. Lastly, despite the discomfort reported by participants during rTMS, our results demonstrate that subjective time perception, as measured behaviorally, remains unaffected. This finding provides support for other related studies in this field.

7. Layman's Summary

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

The research team study subjective perception of time using a time adaptation paradigm and rTMS to test whether its mechanism is band pass tuned or in a continuum. The team also utilize a time production task to test whether the manipulations influence the mental time reference or the perceptual process.

Theoretical The results support interacting but separate sub- and supra-second perceptual mechanism but finely tuned bands are not evident. Time adaptation also exhibits different characteristics from other sensory adaptation, supporting time perception involves integrating multi-modal sensory information.

Methodological Both time adaptation and rTMS elicits different influences towards the time production and the time bisection tasks. Time production, without a perceptual process, is believed prompting to the mental references more closely and potentially provide alternative cognitive behavioral measurement in future study.

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.

Study protocols, analyses and data are made available on journal repository or open science framework for future studies in subjective time perception and non-invasive transcranial stimulation.

(Words count: 193)

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)*						
		✓		Wang On, Li*, Kenneth Sung Lai, Yuen, Dr. CHANG Dorita Hue-fung, Calvin Kai-Ching, Yu	Studying the aftereffect and changes in sensitivity to physical and mental time references using a time adaptation paradigm, *Scientific Report*	**N/A**	**Yes [Appendix 1]**	**Yes**	**No**
		✓		Kenneth Sung Lai, Yuen*, Wang On, Li	Empirical testing of the striatal beat frequency (SBF) model of temporal processing in the human brain, *Science*	**N/A**	**Yes [Appendix 2]**	**Yes**	**No**
			✓	Wang On, Li*, Kenneth Sung Lai, Yuen, Dr. CHANG Dorita Hue-fung, Calvin Kai-Ching, Yu	Is time perception band-pass filtered? An examination of the aftereffect of time adaptation with rTMS	**N/A**	**No**	**Yes [To be included]**	**No**

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)*
Mar/2024/ Tokyo, Japan	A Time Adaptation Study on Time Production Task and Its Potential Influence on Mental Time Reference and Perceptual Sensitivity	The Asian Conference on Psychology and Behavioral Science	NA	**Yes [Appendix 3]**	**Yes**	**Yes**
June/2025/ Sydney	A Study Using the Time Adaptation Paradigm: Does rTMS Influence Time Perception or Time Reference?	Australasian Experimental Psychology Conference and Asia Pacific Conference on Vision – Joint Meeting 2025	NA	**Yes [Appendix 4]**	**Yes [To be included in presentation]**	**No**

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 of Time Perception to the course introducing the theoretical frameworks for time perception, its theoretical models and neural correlates. Results of the present study were also used as teaching materials.

CP518 Research Workshops and Seminars in Counselling Psychology: The PI has incorporated the Open Science Framework (OSF) experience into a module, Power Analysis, Replication Crisis and OSF, is introduced to the course. This module familiarizes students with the evolution of OSF and emphasizes the significance of conducting a priori power analysis and planned statistical analyses.

Research Postgraduates and Undergraduate Research Internship: Six students participated in the data collection process as interns. None of them incorporated transcranial direct current stimulation into their research theses due to concerns regarding its safety. Two interns developed a passion for research and decided to pursue postgraduate degrees in the field. One of them is currently conducting research on cognition, with their principal supervisor being the PI.

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**

	Master of Philosophy in Psychology/ Doctor of Philosophy	September 2019	N/A (see #10)
	Bachelor of Social Sciences in Psychology	September 2020	N/A (see #10)
	Bachelor of Social Sciences in Psychology	September 2020	N/A (see #10)
	Bachelor of Social Sciences in Psychology/ Master of Philosophy	September 2020	N/A (see #10)
	Bachelor of Social Sciences in Psychology	September 2022	N/A (see #10)
	Bachelor of Social Sciences in Psychology	September 2022	N/A (see #10)

12. Other Impact

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

Data and Protocols Availability: Series 1 data has been submitted together with its manuscript for public access. Series 2 experimental protocols are registered on Open Science Framework.

International Collaboration: The team has attracted invitation from overseas research team in collaboration. and , the GhepLab at Ghent University, Belgium invite the team to contribute to their study about transcranial stimulation to the prefrontal cortex. In addition, (PI) and , both at Leibniz Institute for Resilience Research (LIR) collaborate with the team to test the hypothesis of striatum as the central hub (based on Striatal Beat Frequency model, another prominent subjective time perception model) using a large resting state EEG dataset (n=120). Connectivity between striatum with a couple of a priori defined ROIs were tested by Granger causality analysis, but only insula show significant connectivity in striatum in the gamma band.

Future Study: The team will submit a FDS proposal about a meta-analysis specifically contrasting continuum and band-passed filter models. Given the experiences with time production and time bisection tasks in the present study, the meta-analysis will also take task natures into account.

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	3	2	0	0	Type	No.
					Student interns trained	6
					Online Resources	2
					International collaboration	2
					FDS Proposal	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.