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成果報告書

採択者：山崎稜一郎
（政策・メディア研究科後期博士課程）

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著者名：Ryoichiro Yamazaki, Junichi Ushiyama
発表形式：会場でのポスター発表

報告内容：

ISEK 2024（第24回国際電気生理運動学会）は、三十を超える国と地域から約五百人の研究者が参加した、人間の運動・筋肉・神経系について扱う大規模な国際学会であった（中京大学. 「ISEKが愛知で開催。スポーツ科学部渡邊教授が大会長」. https://www.chukyo-u.ac.jp/news/2024/07/024086.html, 2024年8月20日参照. ）。ポスター発表の演題数は二百を超え、ポスターセッションは三日間にわたりおこなわれた（予稿集および大会プログラムを参照）。

採択者は、最新の研究成果についてポスター発表をおこなった。内容は、前庭感覚系に電気刺激を与えることでリズム運動の安定性を向上させる効果を見出した、という電気生理学・神経科学・実験心理学を組み合わせた実験の結果を報告するものであった。学会全体としては筋電図を扱う研究が多いなか、筋電図を使用していない研究でありながら国内外の多くの参加者と議論を交わした。これまで採択者は自身の研究と分野やスコープが合致する学会を主として参加してきたが、今回のようにスコープを少し異にする学会への参加したことで、共通の背景知識の少ない相手との議論によって得られる新たな気づきや視点の重要性を再確認した。また、川上泰雄先生（早稲田大学スポーツ科学学術院）や野坂和則先生（School of Medical and Health Sciences, Edith Cowan University）といった日本の研究者が国際学会である本学会でkeynote lectureで講演をおこなっており、世界水準の研究としてのロールモデルを目にした。今回の学会でのディスカッションで得られた視点や、講演を視聴して得た新たな知見については、発表した研究の原著論文執筆における考察や構成に取り入れることを予定している。

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Rhythmic galvanic vestibular stimulation modulates sensorimotor synchronization to auditory syncopation

Ryoichiro Yamazaki [1], Junichi Ushiyama [2,3]

[1]Graduate School of Media and Governance, Keio University, Kanagawa, Japan; [2]Faculty of Environment and Information Studies, Keio University, Kanagawa, Japan; [3]Department of Rehabilitation Medicine, Keio University School of Medicine, Tokyo, Japan

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Summary

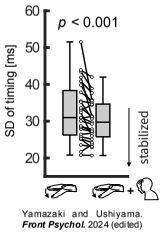
Purpose: We investigated the effects of galvanic vestibular stimulus (GVS) on sensorimotor synchronization to auditory syncopated rhythms

Findings: GVS tended to improve the timing stability of movements.

Background

The vestibular system is known to be implicated in the perception of auditory rhythms (Trainor et al. ***Cortex***. 2009; Tichko and Large. ***Ann N Y Acad Sci.*** 2019; Tichko et al. ***Dev Sci.*** 2021). However, it has been unclear whether the vestibular system is involved with motor execution synchronized to auditory rhythms (sensorimotor synchronization, SMS).

We recently found that SMS in the head to auditory rhythms stabilized SMS in the finger to the same rhythms (Yamazaki and Ushiyama. ***Front Psychol.*** 2024). As well, our data implied that this stabilization was not the same phenomenon as a bimanual advantage. Given these findings, the stabilization of SMS by head movements would be due to (1) vestibular inputs synchronized with the rhythms or (2) increased proprioceptive feedback from neck muscles (Bravi et al. ***Front Integr Neurosci.*** 2017).



Yamazaki and Ushiyama. ***Front Psychol.*** 2024 (edited)

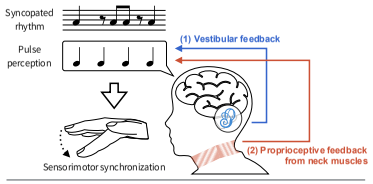


Figure. 1 | Two possible mechanisms causing the stabilization of sensorimotor synchronization during head movements.

To address this issue, we replicated the vestibular feedback from head movements by applying electrical stimulation to the vestibular system (i.e., GVS) concurrently with the auditory beats while participants synchronized finger flexion with the same beats in experiment 1. In addition, to confirm that the effect of electrical stimulation on the performance was specific to GVS, we applied the same stimuli to the left shoulder in experiment 2. We compared the modulation of synchronization performance between two experiments.

References

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There is no competing interest to be declared for this study.

Methods

- **Participants**: Healthy young right-handed adults (35 in experiment 1 and 14 in experiment 2)
- **Motor Task**: Flexing the right index finger in synchrony to 64 perceived beats (i.e., 4/4 meters) in 12 trials
- **Auditory stimuli**: 10 syncopated auditory rhythms (the duplicates of a previous study (Chapin et al., ***Front Psychol.*** 2010))
- **Conditions**: Real stimulation condition and sham stimulation condition within individuals (single-blinded)
- **Stimuli**: Direct current (square waveform of 10ms duration; 90% intensity of the cutaneous threshold) coinciding with the onsets of the 4/4 meters of auditory stimuli
  - Electrodes were placed over the bilateral mastoids process (experiment 1) or the left shoulder (experiment 2)
- **Evaluation**: Coefficient variation of inter-flexion intervals (CV_{IFI})

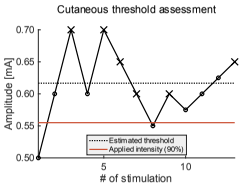

Figure. 2 | The procedure of cutaneous threshold assessment. The intensity gradually increased until participants perceived it and decreased until their perception vanished. The average of 6 intensities at which the increase/decrease direction flipped was calculated as the threshold.

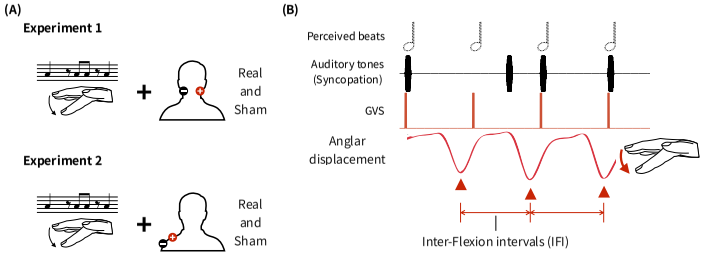

Figure. 3 | The procedure of experiments. **(A)** Experiment 1 tested the effect of GVS on sensorimotor synchronization, while experiment 2 served as the control for experiment 1. **(B)** Inter-flexion intervals (IFI) was defined as the temporal distance between adjacent flexions. **(C)** In both experiments, real and sham stimulating condition were provided alternately. Each of 6 syncopation patterns were presented for both conditions.

Results

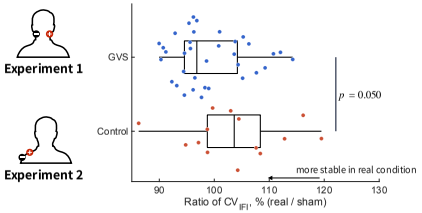

Figure. 4 | The modulation of the timing stability of movements in experiment 1 (top) and 2 (bottom). The x axis represents the timing stability modulation by stimulus application, the ratio of CV_{IFI} in real condition to sham. Each dot indicates individual data (averaged across trials).

- In experiment 1, GVS application tended to improve the timing stability of movements
- In experiment 2, stimuli on shoulder did not affect the timing stability of movements

➡ The modulation of performance might be specific to the stimulation to the vestibular system

Discussion

- Previously, the contribution of the vestibular system to auditory perception is suggested to be due to the enhanced connectivity between auditory and vestibular network by Hebbian plasticity (Tichko and Large. ***Ann N Y Acad Sci.*** 2019; Tichko et al. ***Dev Sci.*** 2021)
- The present experimental design was not likely to induce the connectivity reinforcement by Hebbian plasticity
  - Since each condition was provided alternately, the performance in both conditions would have enhanced if supposing the reinforcement by Hebbian plasticity

➡ The observed stabilization of rhythmic movements may reflect the direct interaction of the vestibular system with rhythmic movements

- We used a novel method of GVS (short-duration, repetitive, parallel with auditory stimuli), which is expected to help rhythmic movement execution
  - Previous studies adopted different waveforms (e.g., sinusoidal or stochastic), higher intensity, and longer duration (Trainor et al. ***Cortex***. 2009; Aoyama et al. ***Sci Rep***. 2015; Piccolo et al. ***PLoS One.*** 2020)
- Changing such parameters might boost or diminish the observed effect or deteriorate the performance