様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科学研究費助成事業　　研究成果報告書

令和　６ 年　 ６ 月 １４ 日現在

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研究種目：基盤研究(B)（一般）
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課題番号：２１Ｈ０３４７５

研究課題名（和文）Para-esports: defining player motor and cognitive performance metrics and creating competitive-gaming interfaces for amputees

研究課題名（英文）Para-esports: defining player motor and cognitive performance metrics and creating competitive-gaming interfaces for amputees

研究代表者

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研究成果の概要（和文）：パラeスポーツにおいて高パフォーマンスを達成するために必要な指標について調査し、前腕（断端）の空間方向を使用することで高い帯域幅（bits/sec）のインタフェースが示され、モータ学習の進展をもたらした(Hassan 2022)。また、筋電位信号の使用は高テンポ（actions/sec）インタフェースに適した候補であることも示された（Ccorimanya 2023)。認知的要因も調査され、バイオシグナルがパートナーの社会的存在感を効果的に増強することが示された(Hassan 2024)。さらに、この結果をリハビリ分野に転用するプラットフォームの開発・検証を行った(Kennard 2024)。

研究成果の学術的意義や社会的意義
We demonstrated the potential for persons with upper limb amputation to participate in esports, inclusion in online and cyber spaces, and to qualify for jobs that require intensive use of computers. Cognitive aspects are also expected to contribute to inclusion and performance in cyber spaces.

研究成果の概要（英文）：We have investigated the motor performance metrics needed to achieve high performance in para-esports and controlling cyber spaces. The research showed that a high bandwidth (bits/second) interface for persons with amputation is possible using the spatial orientation of the forearm (remaining limb) as a pointing device. The forearm yielded bandwidth higher than a joystick in healthy persons and amputees, and the headway for motor learning (Hassan et al. IEEE Access 2022). The project results also showed that using bioelectrical signals is a good candidate for a high-tempo (actions/second) interface (Ccorimanya et al. SII 2023). Cognitive aspects of online communication in esports were also investigated, showing that biosignals can effectively augment the perceived social presence of a partner (Hassan et al. IEEE Access, 2024, in-press). A platform to transfer the findings of this project to physical rehabilitation has been investigated as well (Kennard et al. Front. Robot. AI, 2024).

研究分野：Human Interface and Wearable Robotics

キーワード：Human Interface　Assistive Robotics　Motor Control　Cyber Interfaces

様　式　Ｃ－１９、Ｆ－１９－１（共通）

１．研究開始当初の背景

Persons with physical disabilities such as upper limb loss or deformation, suffer from handicaps not only in physical activities at home and work but also in accessing technological activities that require the dexterous manipulation of a computer or digital device. To coin a phrase, this can be considered as “digital exclusion”, where interfaces designed for two-handed persons pose a handicap to those who can only use one hand or none. Although accessible control interfaces have been investigated by several researchers, all have considered access, and none has considered performance, to the best of our knowledge.
E-sports serves as a perfect vessel for investigative research in this field. E-sports athletes are likely the most dexterous humans to manipulate a computer or a digital environment, with impressive manipulation abilities in terms of bandwidth (bits per second), tempo (actions per second), and cognitive abilities such as visuospatial attention, memory, selective attention, and eye-hand coordination.

２．研究の目的

This project aims to investigate para-esports as a vessel for “digital inclusion” of persons with upper limb loss or deformation. The goals are to: ① investigate and define motor performance metrics in esports, ② investigate and define cognitive performance metrics in esports, ③ develop and verify user interfaces for persons with upper limb loss or deformation with high performance in terms of bandwidth (bits/sec) and temp (actions/sec).

３．研究の方法

(1) Motor performance:

The research was conducted through comparative studies of healthy individuals (no upper limb loss or disability, no cognitive disability, able to use standard computer input devices and gaming controllers) using different control interfaces to achieve given computer control tasks. For this study, we recruited 6 participants. We used a driving simulator (CARLA) with a custom-designed interface. Performance of the difference modalities was then compared in terms of cross-track error (m), clicks per seconds (cps), and Throughput (bps), and a questionnaire.

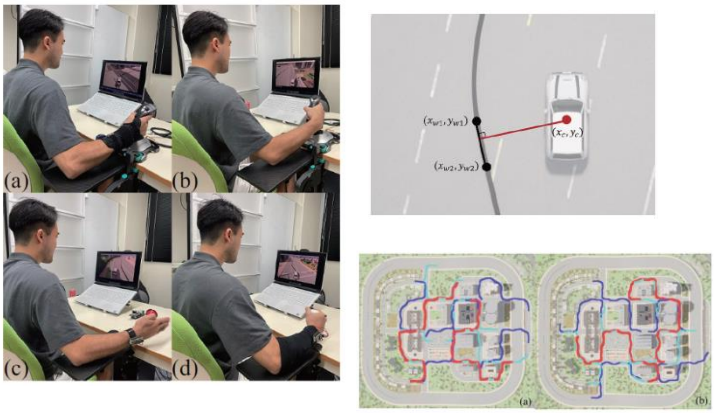

Fig.1 Left: Measurement of motor performance using different modalities (Ccorimanya et al. IEEE SII 2023). Right top: map designed for the test in the driving simulator CARLA. Right bottom: measurement of cross-track error (m).

(2) Social aspect:

The research was conducted through comparative studies of healthy individuals (no upper limb loss or disability, no cognitive disability, able to use standard computer input devices and gaming controllers). A system for sharing Heart Rate (HR) biosignals was designed from scratch to capture the HR signal or a player and visualize it on the opponent’s screen in real-time. Measures of Social presence and co-presence were then obtained using questionnaires. 20 participants (10 pairs) were recruited for these studies, and 5 different experimental conditions were considered:

- Base Line **(BL)**: co-located setting with the participants sitting in the same room

- (figure below)
- No Overlay **(NO)**: playing online without any information about the opponents
- Bio-information Overlay **(BiO)**: playing online with HR overlay (visual) of the opponent
- Video-information Overlay **(ViO)**: playing online with face video overlay (visual) of the opponent
- Bio- and Video-information Overlay **(BViO)**: playing online with face video overlay (visual) of the opponent

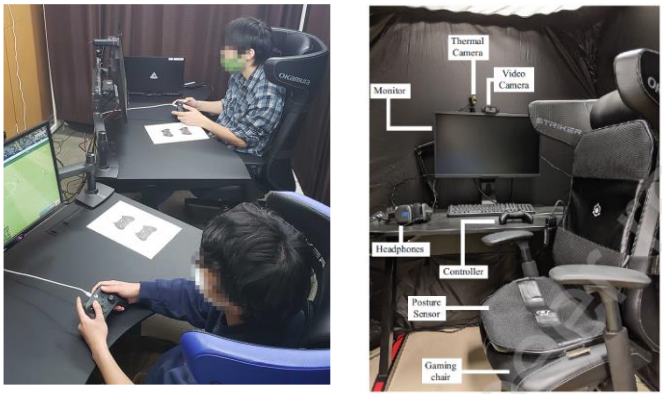

Fig.2 Left: a scene from the experimental setup for measuring the sense of social presence in a co-located setting. Right: set up for the online setting. (Hassan et al. IEEE Access, 2024 (in press))

(3) Prosthesis game controller:

We developed a prosthetic controller based on the findings of this project that enables high throughput control of a 2-dof input device (pointer: i.e. mouse or joystick) using the posture of the forearm (or stump). For this experiment, we recruited 11 healthy individuals and one end user with upper limb amputation on the right hand. We compared the throughput (bps: bits per second) of the developed prosthesis controller, a commercial game console controller (thumb joystick), and a computer mouse. In addition, we measured the latency difference between the controllers and participants' subjective evaluations of the controllers through a longer gaming session.

Fig.3 Left: A scene of a person with upper limb amputation using the developed interface for controlling a video game. (Hassan et al. IEEE Access 2022). Right: setup for measurement of throughput of the prosthesis controller.

(4) Translation to rehabilitation:

We developed and investigated a universal platform for mapping muscle activation and body movements to game control actions, to translate the findings of this research to the field of rehabilitation. To evaluate this platform, we conducted a study with 10 medical professionals at the rehabilitation department of the University of Tsukuba Hospital. The study instructed medical professionals to create rehabilitation exercises using the platform by mapping body actions into game actions. The exercises were, simple, medium, and difficult. We then asked them to answer custom questionnaires and a system usability scale (SUS) questionnaire to evaluate the system.

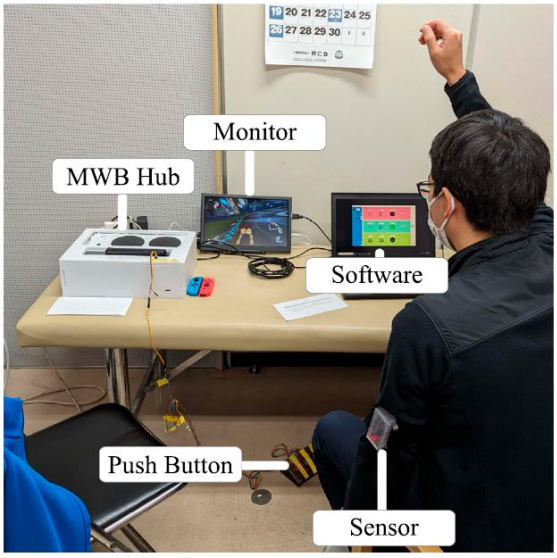

Fig. 4 Translation of research findings to the field of rehabilitation. Left: experimental setup for testing universal platform for gamification of rehabilitation, Right: images of hardware and software implementation. (Kennard et al. Front. Robot. AI 2024)

４．研究成果

(1) Motor performance:

Experiments on motor performance produced very important guidelines for the realization of high-performance accessible interfaces.

A. using muscle activity yields higher tracking error and lower bandwidth than using posture

B. using posture yields higher bandwidth, but higher tracking error than force

C. using EMG as a discrete input yields a higher tempo (actions per second) than posture or EMG as a continuous input

These findings guide the investigation and implementation of high-performance interfaces for persons with physical disabilities. Mapping the appropriate modality, or latent capability, of the user for the suitable input will yield the highest possible performance for that individual, before accounting for learning and habilitation effects.

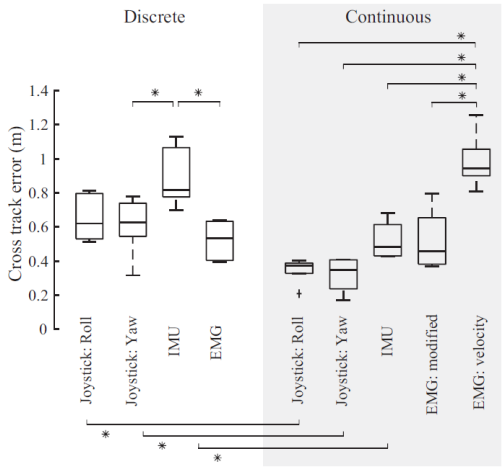

Fig.5 Boxplots of the Cross-track error in the discrete and continuous input modes

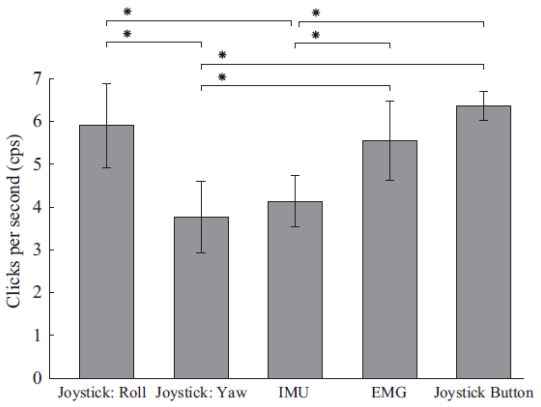

Fig.6 Clicks per second (cps) test results

(2) Social aspect:

Experiments on augmenting the social presence in online gaming through the use of biosignals showed that using the Heart Rate can augment a player's perception of their gaming partner. The bio-information overlay increased the sense of social presence in online gaming compared to the no overlay conditions. However, improvement was most pronounced when the bio-information overlay was combined with the video-information of the gaming partner. Regarding co-presence, the proposed information overlays did not produce the hypothesized differences from playing online without the information overlay of the gaming partner.

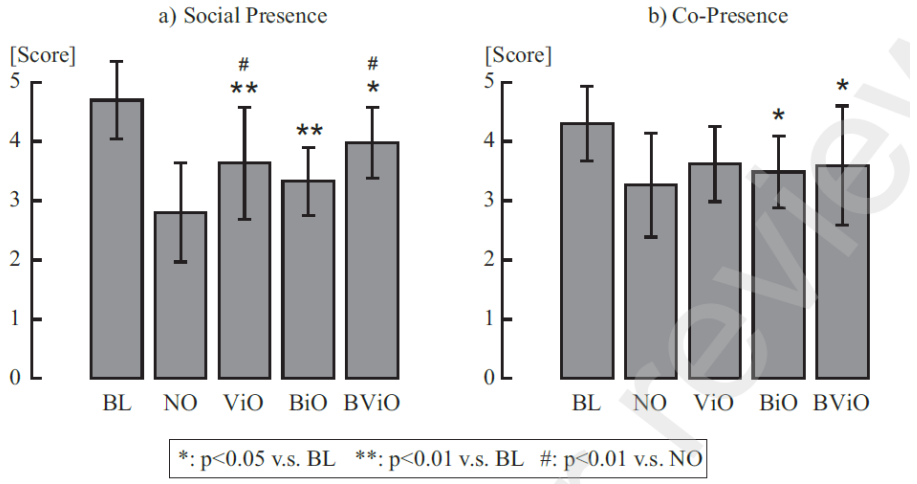

Fig.7 Calculated a) Social Presence and b) Co-Presence scores for each of the experimental conditions. (BL: BaseLine, NO: No Overlay, ViO: Video information Overlay, BiO: Bio- information Overlay, BViO: Bio- and Video information Overlay).

(3) Prosthesis game controller:

Testing the developed gaming prosthesis with 11 typical users on one end user showed that it can produce throughput higher than the thumb joystick of a commercial gaming controller. This is important for the realization of para-esports because it shows that high performance with accessible controllers designed for persons with upper limb loss or deformation is indeed possible. The gaming prosthesis, however, still lacks behind the computer mouse. The computer mouse enjoys a high familiarity factor, traction on the mouse pad, and is controlled by the controlled synergy of the shoulder, elbow, wrist, and fingers. Thus it makes sense to have a gold standard-level throughput. Further tests of the gaming prosthesis with the end user showed headway for the learning effect, with a 25% improvement in performance over 4 sessions, two weeks apart.

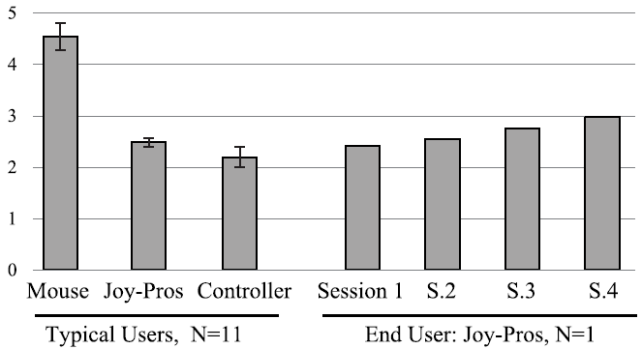

Fig. 8 The average throughput for the all the participants using the gaming mouse, Joy-Pros, and game controller.

(4) Translation to rehabilitation:

The universal platform design to enable using commercial video games for physical rehabilitation was tested with university students and medical specialists. The medical specialists were able to configure easy, medium, and hard tasks with the platform with an average time of less than 4 minutes, faster than the university students. This is likely due to their familiarity with the target exercise, and body joints and muscles. They also gave the system a SUS score of 76, which is similar to other telerehabilitation devices.

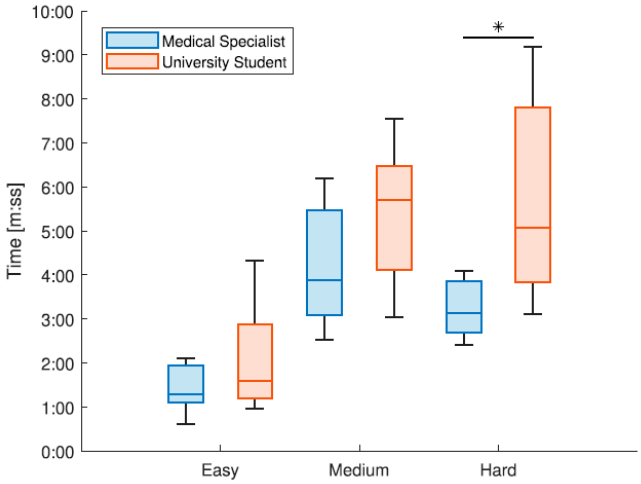

Fig. 9 Comparing the median times needed to complete each of the three tasks between the university students and medical specialists.

These results show that the developed platform is promising for implementation in physical rehabilitation. A key advantage of this platform compared to previous works on gamification of rehabilitation is that it enables using commercial games, which gives access to a large library of fun and engaging video games that can be utilized to maintain the patient's engaged in the rehabilitation program.

Summary:

This project investigated the motor performance metric, social aspects of online esports, a gaming prosthesis controller that enables high performance similar to a joystick, and finally, a platform for gamification of rehabilitation. The contributions of these works help establish objective metrics for understanding the human and interface function in esports, and the interface requirements for para-esports. This work also helps in augmenting esports and other online activities with enhanced sense of social presence, and translate esports into technology that assists physical rehabilitation. The cognitive performance in esports in still under investigation by the PI, due to various complexities in understanding the cognitive function and how it differs in a wide spectrum of end users. This is also expected to further contribute to the fields of esports and game-based rehabilitation.

５．主な発表論文等

〔雑誌論文〕　計4件（うち査読付論文　4件／うち国際共著　4件／うちオープンアクセス　3件）

１．著者名 Ccorimanya Luis、Hassan Modar、Suzuki Kenji	４．巻 1
２．論文標題 Comparison of Accessibility Game Control Interfaces Performance to Enable Para-Esports for Persons with Upper-Limb Deficiencies	５．発行年 2023年
３．雑誌名 IEEE/SICE International Symposium on System Integration (SII)	６．最初と最後の頁 1～7
掲載論文のDOI（デジタルオブジェクト識別子） 10.1109/SII55687.2023.10039333	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 該当する

１．著者名 Hassan Modar、Shimizu Yukiyo、Hada Yasushi、Suzuki Kenji	４．巻 10
２．論文標題 Joy-Pros: A Gaming Prosthesis to Enable Para-Esports for Persons With Upper Limb Deficiencies	５．発行年 2022年
３．雑誌名 IEEE Access	６．最初と最後の頁 18933～18943
掲載論文のDOI（デジタルオブジェクト識別子） 10.1109/ACCESS.2022.3151094	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

１．著者名 Kennard Maxwell、Hassan Modar、Shimizu Yukiyo、Suzuki Kenji	４．巻 11
２．論文標題 Max Well-Being: a modular platform for the gamification of rehabilitation	５．発行年 2024年
３．雑誌名 Frontiers in Robotics and AI	６．最初と最後の頁 -
掲載論文のDOI（デジタルオブジェクト識別子） 10.3389/frobt.2024.1382157	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

１．著者名 M. Hassan, M. Kennard, S. Yoshitake, K. Ishac, S. Takahashi, S.K. Kim, T. Matsui, M. Hirokawa and K. Suzuki	４．巻 -
２．論文標題 Augmenting the Sense of Social Presence in Online Video Games Through the Sharing of Biosignals	５．発行年 2024年
３．雑誌名 IEEE Access	６．最初と最後の頁 -
掲載論文のDOI（デジタルオブジェクト識別子） なし	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

〔学会発表〕　計0件

〔図書〕　計0件

〔出願〕　計1件

産業財産権の名称 仮想空間制御装置およびプログラム	発明者 廣川　暢一、松井　崇、ハサン　モダル、他	権利者 同左
産業財産権の種類、番号 特許、2022-173185	出願年 2022年	国内・外国の別 国内

〔取得〕　計0件

〔その他〕

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6．研究組織

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7．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

8．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関