様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

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研究課題名（和文）Virtual physical training leads to acute cognitive and neural benefits on young and older adults.

研究課題名（英文）Virtual physical training leads to acute cognitive and neural benefits on young and older adults.

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交付決定額（研究期間全体）：（直接経費）　　2,600,000円

研究成果の概要（和文）：若い参加者に関する最初の研究では、自分の仮想体によってのみ実行される仮想トレーニングが、トレーニング中およびトレーニング直後に有益な効果をもたらす可能性があることが証明されました。トレーニング中に、生理学的変化を検出できます（心臓 レートは仮想運動と一貫して増減します）が、さらに重要なことに、トレーニングの直後に、認知（実行機能の速度）および神経（脳関連領域での活性化の増加）の利点も評価できます。
同じ効果は健康な高齢者でも測定できますが、より長いトレーニングで測定できます。実際、急性のトレーニングでは十分ではないようですが、より長いトレーニングは同じ認知と 神経効果。

研究成果の学術的意義や社会的意義
From a clinical perspective, they can be useful for people (especially the elderly, cardiophatics, patients recovering after a long-term disease, etc.) in order to improve cognitive functions (on health population) or to recover lost cognitive abilities (on neurological patients).

研究成果の概要（英文）：The first study on young participants proved that a virtual training performed exclusively by the own virtual body (while the real person's body is still) can have beneficial effects during and right after the training: during the training, physiological changes can be detected (the heart rate increases/decreases coherently with the virtual movements) but more importantly, right after the training also cognitive (speed of executive functions) and neural (increased activation over brain-related areas) benefits can be assessed.
The same effects can be measured on healthy elderly but on a longer training: in fact, while an acute training does not seem to be enough, a longer training (twice a week for 6 weeks, 20 minutes a session) determines the same cognitive and neural effects.

研究分野：cognitive neuroscience

キーワード：virtual reality　body ownership　agency　executive functions　brain imaging

様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９（共通）

１．研究開始当初の背景

Several recent studies have reported that physical activity can improve cardiovascular and metabolic health, but also, surprisingly, cognitive health, showing acute benefits in elderly as well as young adults. These results demonstrate how physical exercises can be beneficial not only for the body itself but also for psychological components and cognition. Unfortunately, in some cases, it is complicated (sometimes even impossible) to perform physical activity, such as aerobic or strength training (e.g., aged population, elderly in frailty conditions, cardiophatic patients, subjects recovering after a long-term disease, sedentary people, etc.). As previously mentioned, this absence of physical training affects negatively body reactions as well as cognitive functions at all ages. The scientific challenge here is to create those conditions necessary for the above-mentioned cases to safely perform a physical activity, in order to enhance (for young people) or to preserve (for elderly) cognitive functions, as important as the physical ones.

For this purpose, innovative technologies and computer-based solutions seem to be very promising. One of the most recent technique for cognitive neuroscience is Immersive Virtual Reality (IVR): it has been shown that in IVR we can move without actually moving: if the subject is completely still, safely sitting on a chair, but the avatar walks, the subject's body reacts exactly as if he's actually walking (for example, heart rate increases). That means we can trick our brain, and so our body, and makes it think he's actually moving, showing the same behavioral and physiological reactions (Kokkinara et al., 2016).

２．研究の目的

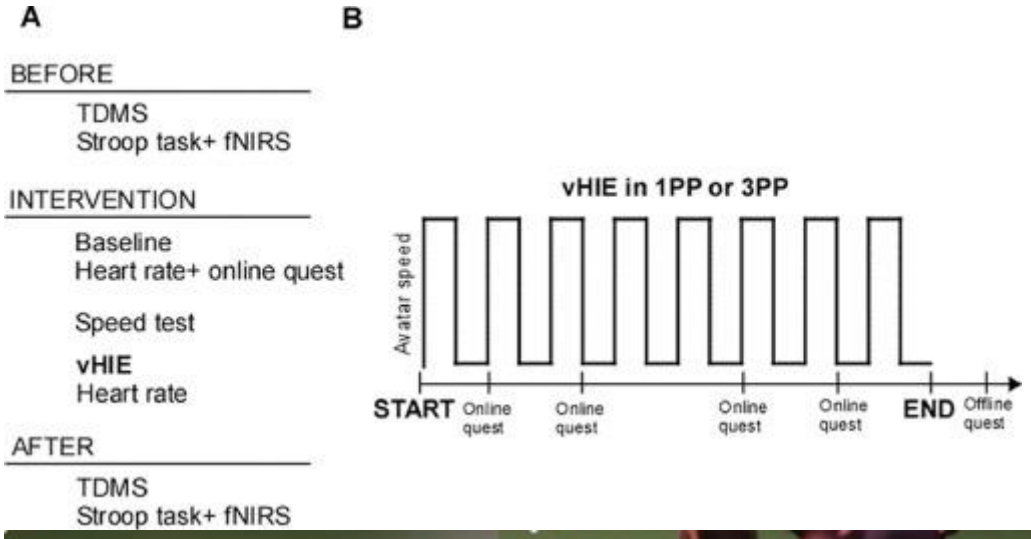
The above mentioned studies, combined together, compose the background of this proposal and open up our crucial experimental question: can a "virtual physical training" performed in IVR have acute beneficial effects on cognition? If cognitive and neural functions can benefit from a high-intensity intermittent physical exercise (HIE) (Kujach et al., 2018), and if the physical body can have physiological consequences after the embodiment of a virtual body (Kokkinara et al., 2016), we can hypothesize that the same training performed with the virtual body (vHIE) (while the real body is still) can have measurable consequences on the physical body (heart rate), on cognition (specifically on executive functions measured by the Stroop Test) and on neural functions (cortical hemodynamic changes recorded by the fNIRS).

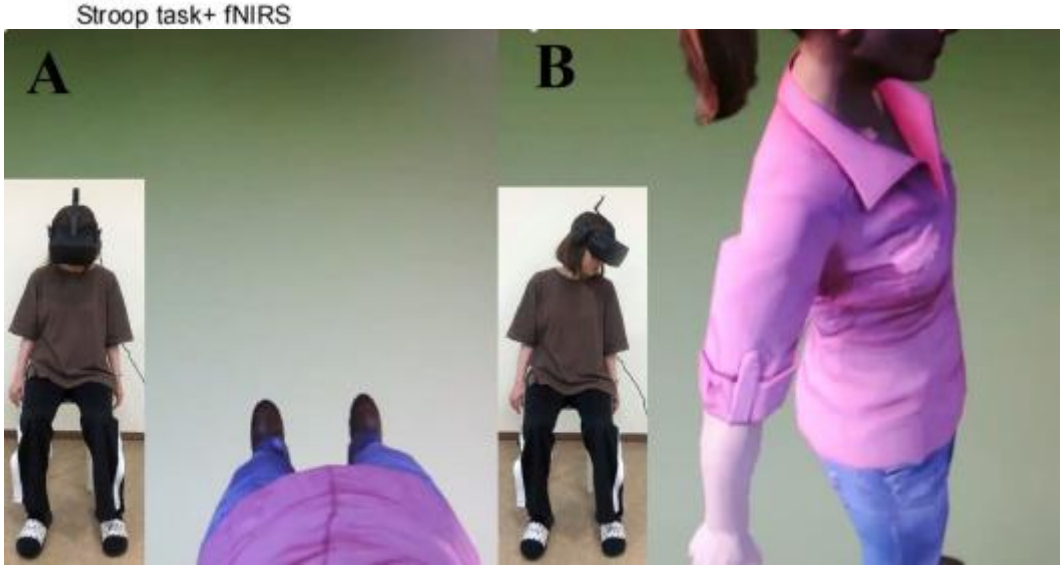
３．研究の方法

Study with young participants

45 healthy young adults (cross-over design) experienced HIE training in IVR (i.e., the virtual body performed eight sets of 30 s of running followed by 30 s of slow walking, while the subject is completely still) in two random-ordered conditions (administered in

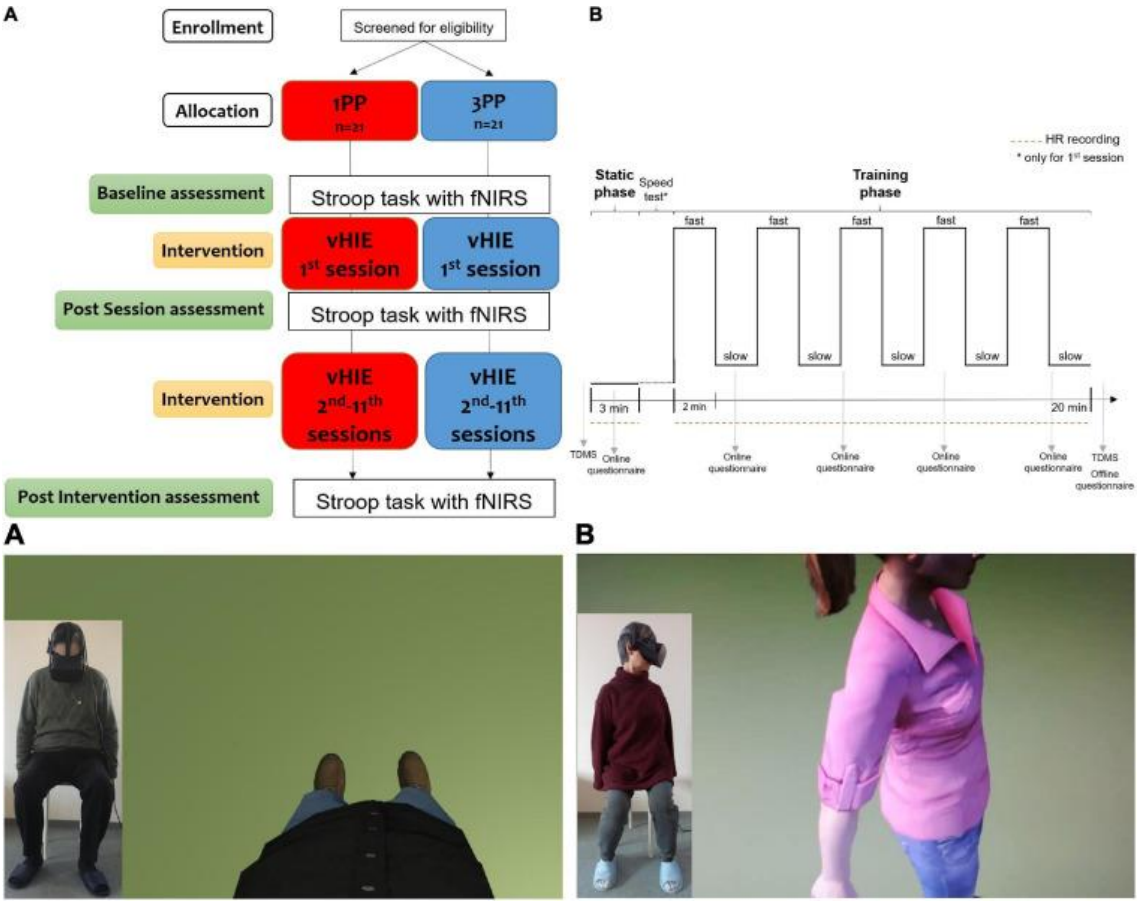
two sessions one week apart): the virtual body is displayed in first-person perspective (1PP) or third-person perspective (3PP). During the vHIE, we recorded the heart rate and subjective questionnaires to confirm the effectiveness of the illusion; before and after vHIE, we measured cortical hemodynamic changes in the participants' left dorsolateral prefrontal cortex (lDLPFC) using the fNIRS device during the Stroop task to test our main hypothesis.





Study with elderly

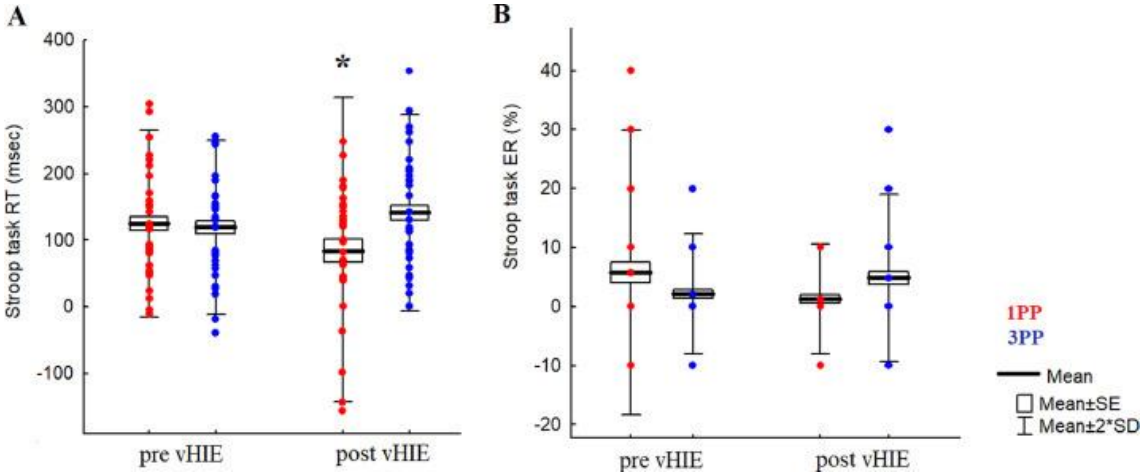
Forty-two healthy older subjects (28 females, average age = 71.71 years) completed a parallel-group randomized controlled trial (RCT; UMIN000039843, umin.ac.jp) including an adapted version of the virtual training previously used: while sitting, participants observed the virtual body in a first-person perspective (1PP) or a third-person perspective (3PP) performing 20 min of virtual high-intensity intermittent exercise (vHIE; the avatar switched between fast and slow walking every 2 min). This was repeated twice a week for 6 weeks. During the vHIE, we measured the heart rate and administered questionnaires to evaluate illusory body ownership and agency. Before the beginning of the intervention, immediately after the first session of vHIE, and at the end of the entire intervention, we evaluated the cognitive performance at the Stroop task with online recording of the hemodynamic activity over the left dorsolateral prefrontal cortex.



4．研究成果

Study with young participants

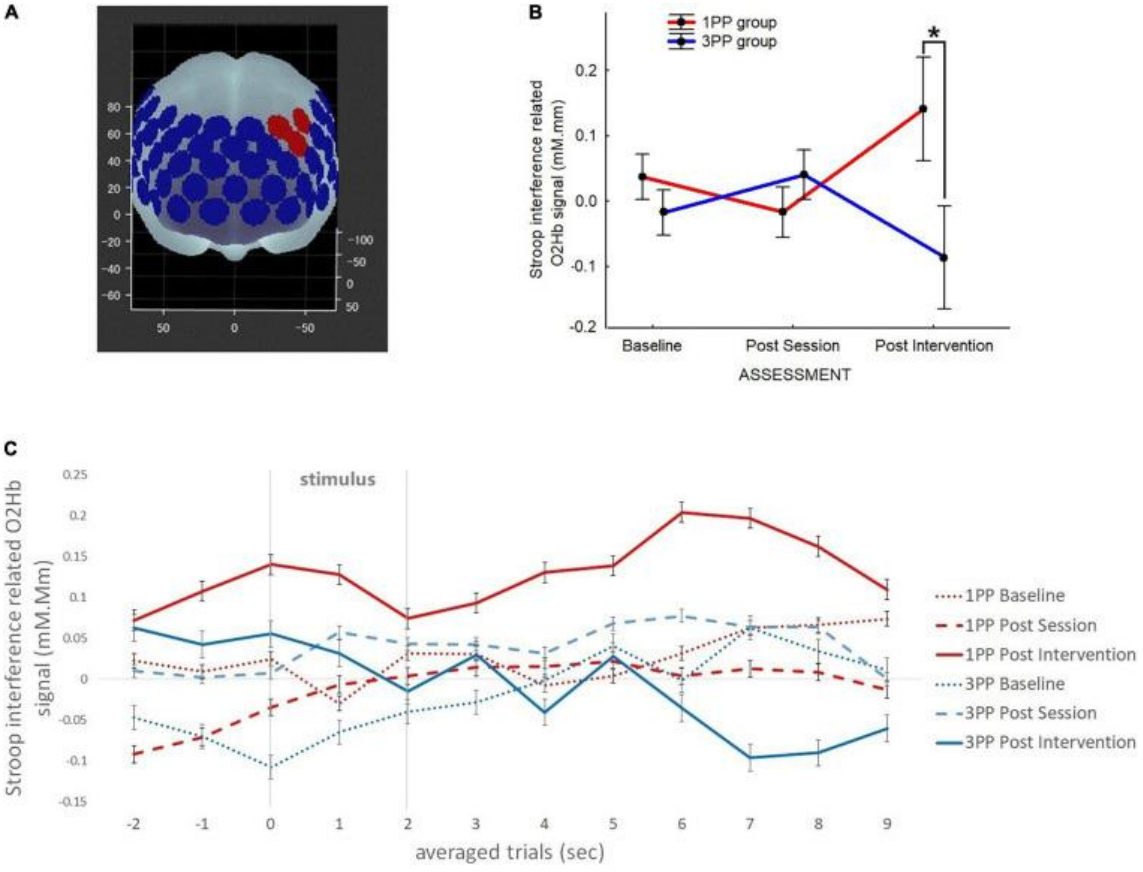
Preliminary, we confirmed that the illusion was effective: during the vHIE in 1PP, subjects' heart rate increased coherently with the virtual movements, and they reported subjective feelings of ownership and agency. Primarily, subjects were faster in executing the Stroop task after the vHIE in 1PP; also, the lDLPFC activity increased coherently. Clinically, these results might be exploited to train cognition and body simultaneously. Theoretically, we proved that the sense of body ownership and agency can affect other parameters, even in the absence of actual movements.



Study with elderly

While we confirm previous results regarding the virtual illusion and its physiological effects, we did not find significant cognitive or neural improvement immediately after the

first vHIE session. As a novelty, in the 1PP group only, we detected a significant decrease in the response time of the Stroop task in the post-intervention assessment compared to its baseline; coherently, we found an increased activation on left dorsolateral prefrontal cortex (lDLPFC) after the entire intervention. While the current results strengthen the impact of the virtual full-body illusion and its physiological consequences on the elderly as well, they might have stronger and more established body representations. Perhaps, a longer and increased exposure to those illusions is necessary to initiate the cascade of events that culminates to an improved cognitive performance.



５．主な発表論文等

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

１．著者名 Burin Dalila、Liu Yingxu、Yamaya Noriki、Kawashima Ryuta	４．巻 222
２．論文標題 Virtual training leads to physical, cognitive and neural benefits in healthy adults	５．発行年 2020年
３．雑誌名 NeuroImage	６．最初と最後の頁 117297～117297
掲載論文のDOI（デジタルオブジェクト識別子） 10.1016/j.neuroimage.2020.117297	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 Dalila Burin, Noriki Yamaya, Rie Ogitsu & Ryuta Kawashima	４．巻 20(1)
２．論文標題 Virtual training leads to real acute physical, cognitive, and neural benefits on healthy adults: study protocol for a randomized controlled trial.	５．発行年 2019年
３．雑誌名 Trials	６．最初と最後の頁 559
掲載論文のDOI（デジタルオブジェクト識別子） 10.1186/s13063-019-3591-1	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 Burin Dalila、Kawashima Ryuta	４．巻 15
２．論文標題 Repeated Exposure to Illusory Sense of Body Ownership and Agency Over a Moving Virtual Body Improves Executive Functioning and Increases Prefrontal Cortex Activity in the Elderly	５．発行年 2021年
３．雑誌名 Frontiers in Human Neuroscience	６．最初と最後の頁 674326
掲載論文のDOI（デジタルオブジェクト識別子） 10.3389/fnhum.2021.674326	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4件（うち招待講演　0件／うち国際学会　3件）

１．発表者名 Burin Dalila
２．発表標題 Virtual training leads to real acute physical, cognitive and neural benefits on healthy adults.
３．学会等名 OHBM Organization of Human Brain mapping conference 2020（国際学会）
４．発表年 2020年

１．発表者名
Burin Dalila

２．発表標題
From virtual to the real! Virtual training leads to real cognitive and neural benefits

３．学会等名
152nd IDAC biannual meeting

４．発表年
2019年

１．発表者名
Burin Dalila

２．発表標題
Virtual training leads to real acute physical, cognitive and neural benefits on healthy adults.

３．学会等名
10th APRU Population Aging Conference 10 13, 2019（国際学会）

４．発表年
2019年

１．発表者名
Burin Dalila

２．発表標題
Virtual training leads to real acute physical, cognitive and neural benefits on healthy adults.

３．学会等名
European Workshop on Cognitive Neuroscience EWCN 2020.（国際学会）

４．発表年
2019年

〔図書〕　計0件

〔出願〕　計1件

産業財産権の名称	発明者	権利者
表示プログラム、表示方法、ヘッドマウントディスプレイ、及び情報処理装置	Burin Dalila	同左
産業財産権の種類、番号	出願年	国内・外国の別
特許、P20190109	2019年	国内

〔取得〕　計0件

〔その他〕

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６．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

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1件

国際研究集会	開催年
European Workshop on Cognitive Neuroscience EWCN 2020	2020年～2020年

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