Training older adults to inhibit the automatic attraction to sedentary stimuli: A cognitive-bias-modification protocol

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ABSTRACT

Background: Current interventions aimed at reducing physical inactivity mainly rely on reflective processes that focus on increasing conscious motivation. However, while these interventions are successful in increasing intentions to be active, their effect on actual behaviour is weak. Recent evidence, in line with the Theory of Effort Minimization in Physical Activity (TEMPA), suggests that this inability to translate intentions to be physically active into action may be explained by positive automatic reactions to stimuli associated with sedentary behaviour. These automatic reactions can be particularly strong in older adults, who are more likely to associate physical activity with fear, pain, or discomfort. **Objective**: The objective of this study is to test the effect of an intervention that trains older adults to inhibit their automatic attraction to sedentary stimuli in order to increase physical activity. **Methods**: Older adults will be enrolled in a placebo-controlled, double-blind study with 1, 3, 6, and 12-month follow-up. Participants will be randomised (1:1 ratio) to receive 12 sessions of cognitive bias modification training based on a go/no-go task in an experimental or control (placebo) condition. The primary outcome will be the number of steps per week. Secondary outcomes will include automatic approach-avoidance tendencies toward sedentary and physical activity stimuli, explicit affective attitudes toward physical activity, physical fitness, and quality of life. **Discussion**: The study is expected to inform public health policies and improve interventions aimed at increasing physical activity levels in older adults.

KEYWORDS: Attentional bias, ageing, exercise, health behaviour, sedentary behaviour

Background

Over the past two decades, society has encouraged people to be more physically active [1, 2, 3]. As a result, most people are now aware of the benefits of regular physical activity and have the intention to exercise [4]. However, this intention is not sufficient, as exercise plans are often not carried out [5, 6]. Despite the gradual increase in efforts to promote physical activity over the years, people are becoming less active. From 2010 to 2016, the number of inactive adults worldwide increased by 5%, and currently affects more than 1 in 4 adults (1.4 billion people) [7]. This gap between intention and action is a challenge that health professionals must address to counter the pandemic of physical inactivity [8, 9].

Physical activity is one of the most important contributors to health, reducing rates of cardiovascular disease [10], cancer [11], hypertension [12], diabetes [13], obesity [14], and depression [15]. This wide spectrum of benefits is particularly important for older adults who often experience structural and functional decline in multiple physiological systems. Physical activity can reduce and delay the effects of this age-related health decline [16]. However, more than 60% of older adults in the Americas are physically inactive [17]. Current interventions designed to increase physical activity in older adults rely primarily on reflective processes by providing rational information about the health benefits of a physically active lifestyle [18]. From this perspective, changing conscious goals should lead to substantial change in behaviour [19]. However, meta-analyses indicate that these interventions are more effective at changing intentions than actual behaviour [6, 20]. Thus, new interventions targeting alternative processes (e.g., automatic processes) are needed.

The Theory of Effort Minimization in Physical Activity (TEMPA)

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suggests that an automatic attraction to behaviours that minimize energetic cost could explain the inability to translate intentions to be physically active into actions [21, 22, 23]. The repeated failure to counteract this automatic attraction is thought to partly explain the pandemic of physical inactivity [24]. Consistent with TEMPA, experimental results suggest that avoiding sedentary stimuli requires more inhibitory control than avoiding physical activity stimuli [25]. In addition, other results suggest that avoiding sedentary stimuli requires more brain activity associated with inhibitory control than approaching sedentary stimuli [26]. These results have been supported by large-scale epidemiological studies [25, 27, 28] and are consistent with the notion that these sedentary stimuli are attractive and therefore difficult to avoid [29]. Therefore, as further epidemiological research suggests [30], cognitive resources may be required to avoid sedentary cues and increase the engagement in physical activity.

Engagement in physical activity is governed not only by reflective processes, but also by automatic affective reactions that operate outside of conscious awareness [31]. For example, in active individuals, stimuli associated with physical activity attract attention [32, 33], elicit positive affective reactions [34, 35], and activate approach tendencies [36]. These automatic affective reactions are thought to facilitate the translation of intention into action [37, 38]. From this perspective, physical inactivity is the result of an imbalance between strong negative affective automatic reactions to stimuli associated with physical activity, and a relatively weaker intention to be physically active. This imbalance between reflective and automatic processes can be particularly pronounced in older adults, who are more likely to experience an excessive fear of physical activity [39, 40]. Therefore, older adults may be particularly responsive to, and benefit most from, interventions that target automatic affective responses to physical activity and sedentary stimuli.

Interventions that target automatic reactions to health-related stimuli have been shown to be successful in changing behaviour [41, 42, 43, 44, 45, 46, 47]. For example, interventions have been used to retrain the automatic reaction to alcohol [42]. Using a joystick, patients were repeatedly asked to avoid alcohol-related images on a screen and to approach non-alcohol-related images. Results showed that adding a cognitive bias intervention to regular treatment reduced relapse rates by 9% to 13% one year after discharge [42, 43, 44]. Similar interventions have also been shown to be useful in influencing smoking [45], social anxiety [46], eating [47], and physical activity behaviour [48, 49]. Other types of interventions have been used to improve affective processes and promote physical activity [50, 51, 52]. These interventions have shown mixed results in increasing physical activity, with small effect sizes. However, none of these studies have targeted the processes that inhibit our tendency to minimize effort. The proposed study will fill this gap by testing the effect of a cognitive bias intervention based on a go/no-go task to strengthen the processes that counteract the automatic approach to effort minimization.

Objectives and Hypotheses

The primary objective of this study is to examine the effectiveness of an intervention aimed at training inhibition of automatic attraction to sedentary stimuli to increase usual levels of physical activity (i.e., number of steps per week) in older adults. The secondary objective is to test the effects of the intervention on reflective and automatic processes underlying physical activity behaviour, physical functioning, and quality of life. We hypothesise that, relative to participants in the comparison group, participants in the intervention group will have higher levels of physical activity (pre-intervention vs. 1-week post-intervention) (H1). Moreover, we hypothesize that, relative to participants in the comparison group, participants in the intervention group will decrease their automatic approach tendencies towards sedentary behaviours (H2a) and their automatic avoidance tendencies towards physical activity behaviours (H2b). Finally, we hypothesize that participants in the intervention group will improve their physical fitness (H3a) and quality of life (H3b), compared with participants in the comparison group.

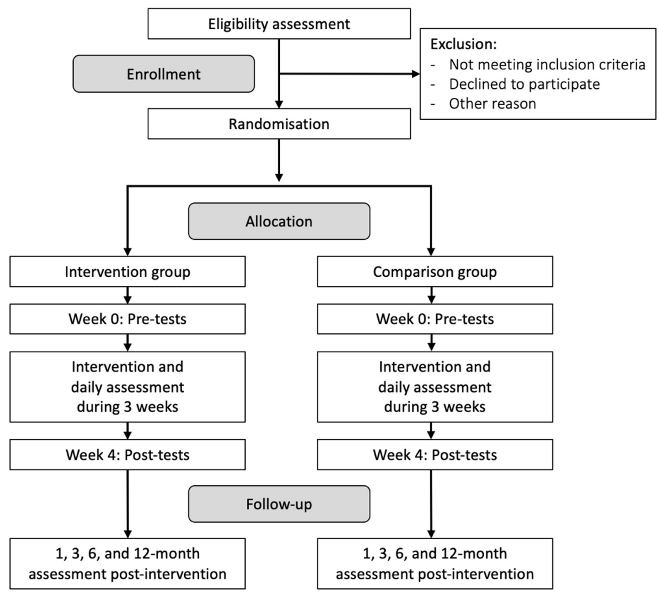

Figure 1 Study design

Methods

Study Design and Settings

Our study follows a placebo-controlled, double-blind design with a 12-month follow-up (**Figure 1**).

Participants

Adults aged 60 years and older will be included in the study [53].

Recruitment

Recruitment will be by emails to senior clubs and groups as well as posters at Non-Governmental Organizations (NGO) and Community centers in the area of Ottawa, Ontario, Canada. Interested participants will be asked to contact the principal investigator of the study. They will then be invited to attend a face-to-face meeting aimed at increasing their intention to be physically active based on the Ask-Assess-Advise approach [18] and to inform them about the study. Participants will receive a copy of the informed consent form prior to the first meeting to inform them about the study. Interested participants will be given the opportunity to ask any questions over the phone or at the meeting before written informed consent is obtained. Consent will only be obtained when the participant fully understands what the study entails and agrees to participate. If they decide to participate, they can withdraw from the research and/or refuse to answer any questions at any time without negative consequences. To assess a potential effect of sex, we will attempt to recruit a similar number of males and females. We will also explore the moderating effect of sex on the effect of the intervention.

Eligibility

To participate in this study, volunteers must be 60 years of age or older and able to understand instructions in English or French. The Mini-Mental State Examination (MMSE) [54] will be used to assess cognitive

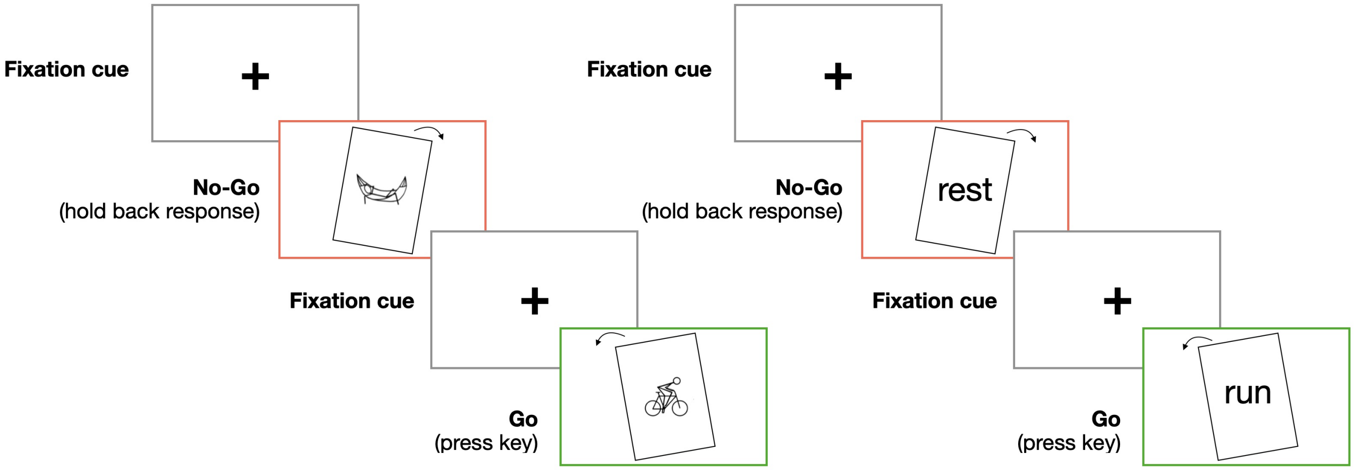

Figure 2 Go/No-go task based on images (left panel) and words (right panel)

function, as poor cognition may affect participants' ability to follow instructions [55, 56, 57]. Potential participants with an MMSE score below 24 will not be eligible for inclusion. Other exclusion criteria are diagnosis of psychiatric disorders or neurological pathologies (e.g. stroke, Parkinson's or Alzheimer's disease, dementia), inability to perform the training program or understand the protocol, motor deficit that requires external assistance to undergo physical activity, physical health status that contraindicates physical activity (e.g. severe cardiac or respiratory disease), and alcohol or drug dependency.

Sample Size Calculation

For power calculation, our intervention implements a between-subject design and random-effects statistical models (i.e., t-tests). The power calculation is based on the primary outcome (i.e., number of steps). Based on estimates of the effect size of interventions using the go/no-go task (g = .39) [47], a desired statistical power of 0.9, and an alpha of 0.05 [58], a sample size calculation in G*Power [59] indicated that a minimum of 140 participants per arm is needed. We expect a loss to follow-up of 10% to 20% at 1 week after the intervention, and a loss of 30 to 40% over 1 year. Thus, a minimum of 392 participants will be recruited.

Ethical Approval and Considerations

This research will be performed in accordance with the Declaration of Helsinki. The study was approved by the University of Ottawa (Canada) Research Ethics Boards (H-09-22-8453). Potential participants will be informed of study details, including procedures, risks and benefits, confidentiality, and the voluntary nature of participation, before signing the consent form. To follow good research practices [59] and to ensure that the research output is quickly and fully accessible to the scientific community and the public, the manuscript will be published as a preprint (e.g., MedRxiv, SportRxiv) and de-identified data, materials and scripts will be made public (e.g., Zenodo) and freely available in open repositories with a Digital Object Identifier (DOI) or another permanent identifier (e.g., Zenodo). Results will be published in scientific journals selected based on their contributions to good research practices [60] and be disseminated at international conferences.

Intervention

Cognitive-Bias Modification Task: The intervention is based on a go/no-go task in which older adults are instructed to quickly decide whether to respond to a stimulus [61]. The task has been adapted to train inhibitory processes that counteract the automatic attraction to sedentary stimuli and promote the automatic approach to stimuli related to physical activity. Specifically, a rectangle containing an image or a word is presented on a screen.

Intervention Group: In the intervention group, older adults are instructed to restrain their actions when the rectangle is tilted to the right and to respond by pressing a key on the keyboard when the rectangle is tilted to the left, irrespective of the content of the rectangle. The rationale for pressing a key on the keyboard solely in response to the direction of the tilt of the rectangle, as opposed to the content of the rectangle, is to ensure that the nature of the training is implicit. To train inhibitory processes that counteract the automatic attraction to sedentary behaviour, 90% of the right-tilted rectangles (counterbalanced across participants) will contain a picture or a word related to sedentary behaviour (**Figure 2**). To promote the automatic attraction to physical activity, 90% of the left-tilted rectangles will contain a picture or a word related to physical activity.

Comparison Group: In the comparison group, the instructions will be identical, but the percentage of physical activity and sedentary stimuli will be equal in each tilt condition (i.e., 50% sedentary stimuli and 50% physical activity stimuli in both right and left-tilted rectangles).

Experimental Protocol: After the face-to-face meeting, the older adults who agree to participate will receive a physical activity tracker (ActiGraph GT9X-BT) [62]. Participants will be trained on the go/no-go task for 3 weeks (4 sessions/week) (**Figure 3**). Each training session will consist of two blocks of 400 trials for a total of 30 min. To assess the effect of the intervention, primary and secondary outcomes will be collected the week before the first session, the week after the last session of the intervention, and 1, 3, 6, and 12 months post-intervention. At each assessment session, secondary outcomes will be assessed in a randomised order across participants.

Allocation and Blinding

Research assistants and participants will be blinded to group allocation. At the end of the trial, the success of the participant blinding will be assessed by asking the participants to guess which group they were in, including a percentage of certainty. The success of research assistants' blinding will be assessed by asking each research assistant if they were able to identify the group (control vs. intervention) when collecting data. Randomisation will be based on computer-generated permuted blocks. To ensure that the research team is blinded to the randomisation, an

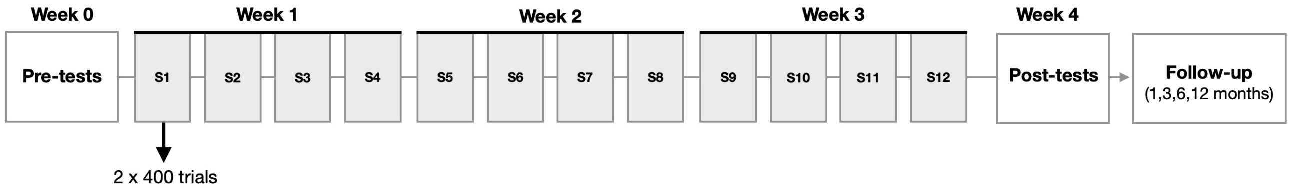

Figure 3 Protocol timeline

independent staff member will perform the randomisation. The participant's identification number will be used to determine the order of randomisation. Participants will be randomised in a 1:1 ratio between the intervention and comparison group. No unblinding is planned during the trial, as we do not see any reasons that would require either the participants or the researchers to know which group the participants were assigned to. However, if requested by the participants, unblinding will be allowed at the end of the trial.

Outcomes

Primary Outcome

The project focuses on device-based measures of physical activity because self-reported measures can be influenced by memory and social desirability [63, 64, 65] and often overestimate time spent in physical activity [66]. In our study, the primary outcome will be step count, which has been shown to be a valid measure of physical activity [67]. Participants will be instructed to wear the ActiGraph accelerometer on their right hip, attached to an elastic belt, all day long for 7 days and to remove it when they go to sleep at night. If wearing time is less than 4 consecutive days, including one weekend day [68], for at least 7 waking hours per day [69], the participant will be excluded from the study. The number of steps measured in the week before and after the intervention, as well as 1, 3, 6, and 12 months after the intervention will be used as the primary outcome. The ActiGraph has shown satisfactory validity and reliability (intraclass correlation = 0.80) [62, 70]. Studies have shown that measures of physical activity using accelerometry in older adults are feasible and provide more valid and reliable data than questionnaires [71, 72, 73].

Secondary Outcomes

The secondary outcomes will allow for the exploration and examination of indirect health effects related to increases in physical activity and decreases in sedentary behaviour. Such exploratory research is important to capture broader effects of the intervention, generate new hypotheses, and guide future interventions.

Reflective and Automatic Processes Underlying Physical Activity : We will assess affective experiences related to physical activity because they are closely related to the perception of effort and could therefore explain the difficulty in engaging in regular physical activity [39].

Explicit Affective Attitudes Toward Physical Activity: Explicit attitudes toward physical activity will be calculated as the mean of two items based on two bipolar semantic differential adjectives on a 7-point scale (unpleasant-pleasant; unenjoyable-enjoyable). The statement begins with "For me, to participate in regular physical activity is …" [74]. The reliability of this measure of explicit attitudes has been validated with a Cronbach's alpha greater than 0.89 [74]. In a recent study of older adults, Cronbach's alpha was 0.92, further supporting the reliability of this measure [36].

Approach-Avoidance Task: A contextual approach-avoidance task will be used to measure automatic approach and avoidance tendencies toward physical activity and sedentary behaviours [26, 36]. Participants will be asked to move a manikin (i.e., an avatar) on the screen "toward" (approach condition) and "away" (avoidance condition) from images depicting physical activity and sedentary behaviours by pressing keys on a keyboard. Each trial will begin with a black fixation cross-presented randomly for 250–750 ms in the centre of the screen with a white background. Then, the manikin will appear in the upper or lower half of the screen. At the same time, a stimulus depicting "movement and active lifestyle" (i.e., physical activity) or "rest and sedentary lifestyle" (i.e., sedentary behaviour) will be presented in the centre of the screen. Participants will be instructed to quickly move the human figure "toward" a stimulus (approach) depicting physical activity or "away" from a stimulus (avoidance) depicting sedentary behaviours, or vice versa. After viewing the manikin in its new position for 500 ms, the screen will be cleared. In case of an incorrect response, an error notification (i.e., a cross) will appear in the centre of the screen. The approach-avoidance task is a reliable and well-validated measure of approach–avoidance tendencies [75, 76]. In terms of validity, this task has shown the most consistent pattern of associations with physical activity outcomes [77]. In addition, this task has shown good reliability (split-half method: r = 0.76) [78].

Physical Effort Scale: The 8-item Physical Effort Scale [79] will be used to capture individual differences in tendencies to approach and avoid physical effort. The relative tendency to approach physical effort will be computed by subtracting the average score for tendency to avoid physical effort from the average score for tendency to approach physical effort [79]. The Physical Effort Scale has shown high internal consistency ($\alpha >$ 0.897) and acceptable test-retest reliability (intraclass correlation > 0.66) [79].

Physical Fitness

6-Minute Walk Test: In this test, the participant is instructed to walk as far as possible for 6 min in a straight 30-m corridor. Standardized encouragement will be provided at each minute. The outcome is the distance walked during the 6 min. The 6-Minute Walk Test requires minimal technical resources [80] and has demonstrated robust test-retest reliability (R ranging from 0.88 to 0.94) and acceptable convergent and construct validity [80, 81]. The minimum clinically important difference is 20 m [81].

Hand Grip Strength: Grip strength will be assessed using a JAMAR dynamometer. Participants will perform the test with their dominant hand in a seated position, shoulder and wrist in a neutral position, elbow flexed at 90º. Two tests will be performed by each participant and the higher value will be recorded as the outcome [82]. This measure has shown acceptable validity and excellent reliability (intraclass correlation coefficient = 0.95) [83]. The minimum clinically important difference is 5 kg [84].

Quality of Life

World Health Organization Quality of Life – Brief Version (WHOQOL-BREF): This scale assesses quality of life in four domains: Physical health (7 items), psychological health (6 items), social relationships (3 items), and environmental health (8 items). Scores for each domain can range from zero to 100, with higher scores indicating better quality of life [85]. Cronbach's alpha values for the different domains range from 0.66 (for domain 3) to 0.84 (for domain 1), indicating good internal consistency [86]. The minimum clinically important difference of the WHOQOL-BREF for each domain is as follows: Physical = 1.5, psychological = 1.3, social relationships = 1.3, environment = 1.1 [87].

Data Collection and Management

All information will be collected by the research assistant. Each participant will be given a unique confidential identification code at the time they accept to participate in the study. The confidentiality of the information collected will be guaranteed by using this unique confidential code for data storage and analyses. Data will be kept on the University of Ottawa OneDrive account of the principal investigator, with access limited to team members. This system is protected by multi-factor authentication, meets Personal Health Information Protection Act (Ontario, Canada) requirements, and is serviced by the University of Ottawa cybersecurity team. Storage will be maintained for 10 years after the end of the study.

Data Analyses

Primary Analyses: Statistical analyses will be conducted according to the intention-to-treat principle and the Consolidated Standards of Reporting Trials (CONSORT) guidelines. A sequential analysis will be conducted with an interim analysis after 50% of the data is collected and the other analysis after all data is collected [88]. Based on the Pocock boundary, the threshold for significant p-values will be .0294 [89]. If the effect is significant at the interim analysis, thereby indicating that the data provide support for the hypothesis, data collection will be terminated. Mean, standard deviation, median, and range values will be used to summarise the continuous data. The primary outcome (number of steps per week) will be analysed using multiple linear regressions. Specifically, we will test whether the physical activity level (number of steps) of participants in the week after the end of the intervention is higher in the intervention group compared to the comparison group, after adjustment for covariates (i.e., age as a continuous variable, sex). In addition, we will test whether participants' automatic tendency to approach physical activity is higher in the intervention group compared to the comparison group and whether participants' automatic tendency to approach sedentary behaviours is lower.

Secondary Analyses: The continuous outcomes will be analysed using linear mixed-effects models, which account for the nested structure of the data (i.e., multiple observations within a single participant), thereby providing accurate parameter estimates with acceptable type I error rates [90]. To examine the effect of the intervention on the changes in physical activity and sedentary behaviour, models will include interaction terms between group (intervention group vs. comparison group) and number of days within or after (follow-up) the intervention. We will treat the continuous secondary outcomes similarly to the primary outcome. R software will be used for all analyses.

Discussion

Most people are aware of the health benefits of regular physical activity and have good intentions to exercise. Yet, 1.4 billion people worldwide are inactive, suggesting that transforming intention into action can be challenging. Recent findings shows that the intention-action gap could be explained by negative automatic reactions to stimuli associated with sedentary behaviour [21, 22, 23, 24, 25, 26, 27, 28, 29, 30]. This gap is of particular concern in older adults, who are more likely to spontaneously associate physical activity with fear, pain, or discomfort [40]. Current physical activity interventions largely focus on providing rational information to change conscious goals [18]. However, these strategies have been shown to be insufficient in changing behaviours [6, 20]. Therefore, to promote physical activity, the current project proposes to train older adults to counteract their automatic attraction to sedentary stimuli and to respond positively to physical activity stimuli. The intervention is expected to reduce physical inactivity during the intervention and at follow-up. More broadly, the output of this program has the potential to develop an evidence-based, large-scale, and low-cost intervention that would complement current reflective approaches in older adults to improve their quality of life. Finally, the results will inform public health policies aimed at addressing a global health problem: The pandemic of physical inactivity.

Strengths of this protocol include procedures that limit the potential for questionable research practices (i.e., pre-registration, power analysis, pre-printing, data sharing plan) [60]. However, potential limitations should be noted. First, due to the longitudinal nature of our design, we cannot exclude the possibility of selection bias related to attrition. Second, voluntary participation may favour the selection of participants with better health status or higher motivation to engage in physical activity.

Authors' Contribution

Based on the Contributor Roles Taxonomy (CRediT), individual author contributions to this work are as follows:

- Ata Farajzadeh: Writing – Original Draft; Writing – Review and Editing
- Miriam Goubran: Writing – Review and Editing
- Layan Fessler: Writing – Review and Editing
- Boris Cheval: Writing – Review and Editing
- Zack Van Allen: Writing – Review and Editing
- Matthieu P Boisgontier: Conceptualization; Writing – Original Draft; Writing – Review and Editing; Supervision; Project Administration; Funding Acquisition.

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