ORIGINAL RESEARCH

Examining cognitive training and executive function in older adults

Meggan Porteous[1], Sheida Rabipour[1] and Patrick Davidson[1*]

Abstract
Studies have shown that cognitive functions decline with increasing age. As the population of older adults (OA) has grown, interest in cognitive training programs (CTP) has steadily expanded. The present study investigated whether CTP can lead to improvements in the performance of OA on cognitive tasks. Thirty-five adults (OA; 60-87 years) were recruited to complete 25 sessions of a CTP over five weeks, with assessments completed before and after the program. Thirty-two young adults (YA; 17-27 years) were also recruited to complete one assessment for baseline comparison with OA. During assessments, participants were evaluated using tasks of executive function, including the N-back task of working memory and Flanker task of inhibition. The response time (RT) and hit rates of YA and OA on these tasks were examined at baseline, as well as changes in OA pre- and post-training. Repeated measures analysis of variance indicated a reduction of pre- and post-training RT for the Flanker task. There was no post-training change in RT on the N-back task. While OA hit rates did not change significantly pre- and post-assessment on the Flanker task, they showed increased hit rates post-training in the N-back task. In both tasks, OA and YA hit rates and RT were significantly different, with YA demonstrating lower RT and hit rate compared to OA. Follow-up studies will determine whether other factors can also lead to improvement. Determining whether CTP can improve cognitive performance in OA can help determine the potential of such approaches to prevent or rehabilitate age-related cognitive decline.

Keywords: Cognitive training programs; Aging; Older adults; Young adults; Expectations; Working memory

Résumé
Certaines études démontrent que les fonctions cognitives diminuent avec l'âge. À mesure que la population d'adultes plus âgés (AA) augmente, on s'intéresse beaucoup plus aux programmes d'entraînement cognitif (PEC). Cette étude examine si les PEC améliorent la performance aux tâches cognitives. On a recruté trente-cinq AA (60-87 ans) qui ont dû prendre part à 25 sessions de PEC pendant cinq semaines, avec des évaluations réalisées avant et après le programme. On a également recruté trente-deux jeunes adultes (JA, 17-27 ans) afin d'avoir un groupe de base contre lequel comparer la performance. Au cours des évaluations, les participants ont été évalués en utilisant des tâches de la fonction exécutive, y compris la tâche N-back de la mémoire de travail et la tâche d'inhibition de Flanker. Le temps de réponse (TR) et les taux de succès des JA et AA pour ces tâches ont été examinés au départ, ainsi que les changements chez les AA avant et après le PEC. L'analyse de la variance des mesures répétées a indiqué une réduction du TR avant et après l'entraînement pour la tâche Flanker. Il n'y a pas eu de changement post-entraînement du TR pour la tâche N-back. Bien que les taux de succès de la performance n'aient pas changé de façon significative avant et après l'évaluation pour la tâche Flanker, ils ont montré des taux de succès accrus après l'entraînement pour la tâche N-back. Dans les deux cas, les taux de succès et les TR des JA et AA étaient significativement différents ; les JA démontraient un TR et un taux de succès inférieurs à celui des AA. Des études subséquentes seront nécessaires pour déterminer si d'autres facteurs peuvent également entraîner une amélioration. Déterminer si les PEC améliorent la performance cognitive chez les AA peut aider à déterminer le potentiel de telles approches pour prévenir ou réhabiliter le déclin cognitif lié à l'âge.

Mots Clés: Programmes d'entraînement cognitif; Vieillissement; Personnes âgées; Jeunes adultes; Attentes; Mémoire de travail

Introduction

Studies have shown that certain cognitive functions decline with increasing age (*1, 2*). With increasing life expectancy and a growing population of older adults (OA), interest in cognitive training programs is steadily expanding. Cognitive training programs may provide an effective, long-term and drug-free aid or solution to OA in need of cognitive improvements. The present study sought to investigate whether cognitive training programs can lead to improvements in the performance of OA on measures of working memory and inhibition. The authors hypothesized that young adults (YA) would perform better than OA, and that OA would demonstrate performance improvements pre- and post-training. This work was part of a larger study investigating the interactions between expectations and cognitive training on cognitive performance and other real-world outcomes in OA.

Methods

Thirty-five OA, 60-87 years of age, were recruited to complete 25 sessions of a cognitive training program over five weeks. The authors also recruited 32 YA, 17-27 years of age, to complete a single forty-minute cognitive training session and one assessment for baseline comparison with OA. The cognitive training program, a commercially-available web-based program called "Activate", comprised multiple games targeting executive functions such as spatial working memory, pattern recognition, and inhibition. The games increased in speed and difficulty depending on participants' results. YA were not required to participate in a five-week training program due to the study's interest being limited to OA data; we assessed OA before and after the program.

Participants were evaluated using tasks of executive function, including the N-back task of working memory and the Flanker task of inhibition (*3, 4*). Both working memory and inhibition were targeted in the Activate games and reflect age-related changes in cognitive function (*5*). They have been shown to decline over time, and therefore are a good indicator of cognitive training effectiveness and improvement (*6, 7*). Participants were seated at a computer, where a fixation point was presented. The researcher then randomly initiated the Flanker or the N-back task. The Flanker task was presented in four trials, each separated in time by a short break. A longer break was provided to allow participants to return to a resting state between tasks. The task required participants to indicate in which direction the center arrow pointed (right or left), while ignoring irrelevant stimuli (other arrows) surrounding the center arrow. If all the arrows pointed in the same direction, the Flanker task was considered congruent. If not, the Flanker task was incongruent. It was administered to the participants in four separate blocks, which included a random order combination of 24 left congruent trials, 24 right congruent trials, 12 left incongruent trials and 12 right incongruent trials.

The N-back task involved a zero-back, one-back, and two-back condition, generated in random order. The task required participants to respond to a specified letter in a series of varied letters. Depending on the condition, participants were instructed to respond when the target letter was shown (zero-back), when the target letter was the same as the previous letter (one-back) or when the target letter was the same as the letter two letters back (two-back). The zero-back and one-back conditions contained 202 letters each, where 98 letters were target letters requiring a response; the two-back condition contained 95 letters in total, where 55 letters were targets

For both tasks, response time (RT; i.e. how quickly the participant responded via key press in milliseconds) and hit rate (i.e. the number of correct responses out of the total number of possible responses) of YA and OA were examined at baseline, as well as post-training for OA, to examine changes in performance over the course of the training.

Results

When comparing OA pre- and post-training RT, repeated measures analysis of variance indicated a reduction of post-training RT for the congruent Flanker task ($F_{1,26} = 11.74$, $p = 0.002$, $\eta = 0.311$), more specifically for trial 1 ($T_{26} = 2.147$, $p = 0.041$, $CI[6.399, 29.453]$), trial 3 ($T_{26} = 4.494$, $p = 0.000$, $CI[15.695, 42.061]$) and trial 4 ($T_{26} = 4.174$, $p < 0.000$, $CI[10.993, 32.326]$). The incongruent Flanker task also showed a reduction of post-training RT ($F_{1,26} = 5.985$, $p = 0.021$, $\eta = 0.187$), specifically in trial 3 ($T_{26} = 3.936$, $p = 0.001$, $CI[17.489, 55.715]$). In contrast, no change was noticed in the RTs for the N-back task.

When comparing OA pre- and post-training hit rates, no significant changes were noted in the congruent and incongruent Flanker tasks. Conversely, OA hit rates did increase post-training in the N-back task ($F_{1,25} = 41.326$, $p = 0.000$, $\eta = 0.623$), notably in the one-back ($T_{25} = -4.91$, $p < 0.000$, $CI[-1.256, -0.514]$) and two-back conditions ($T_{25} = -6.548$, $p < 0.000$, $CI[-5.932, -3.093]$).

When comparing baseline data, repeated measures analysis of variance showed significant baseline RT differences between YA and OA on the congruent ($F_{3,192} = 2.181$, $p = 0.025$, $\eta = 0.047$) and incongruent Flanket tasks ($F_{3,192} = 2.616$, $p = 0.052$, $\eta = 0.039$) (Figures 1 and 2) as well as on the N-back task ($F_{2,124} = 38.124$, $p = 0.000$, $\eta = 0.381$) (Figure 3). Repeated measures

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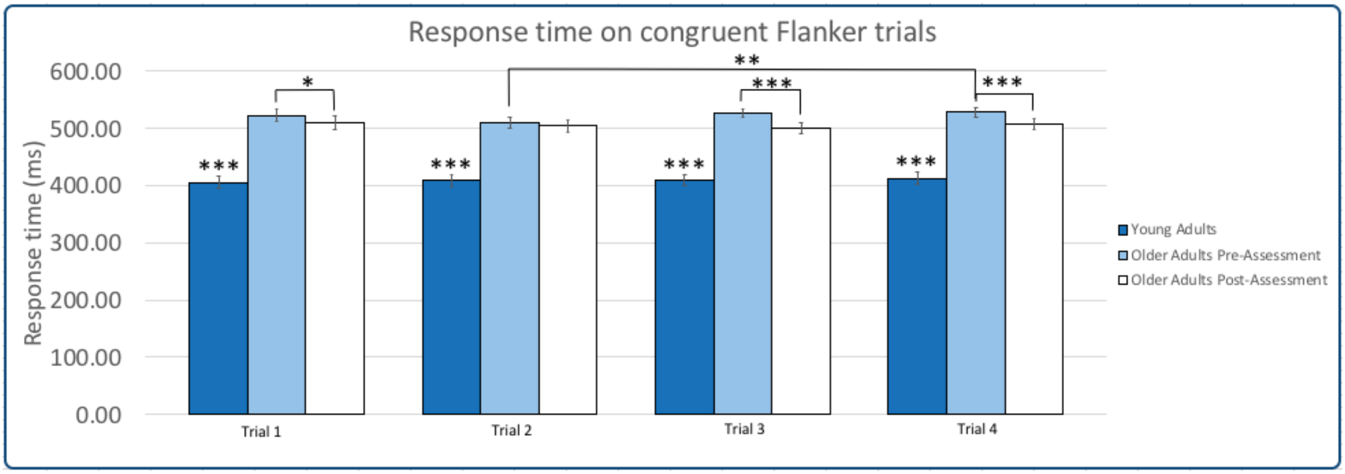

Figure 1: Response time on congruent Flanker trials. RT results of YA and OA (pre- and post-training) on the congruent Flanker trials (1-4). Statistical significance is indicated by "*", where one asterisk indicates p $<$ 0.05, two asterisks indicate p $<$ 0.01, and three asterisks indicate p $<$ 0.001.

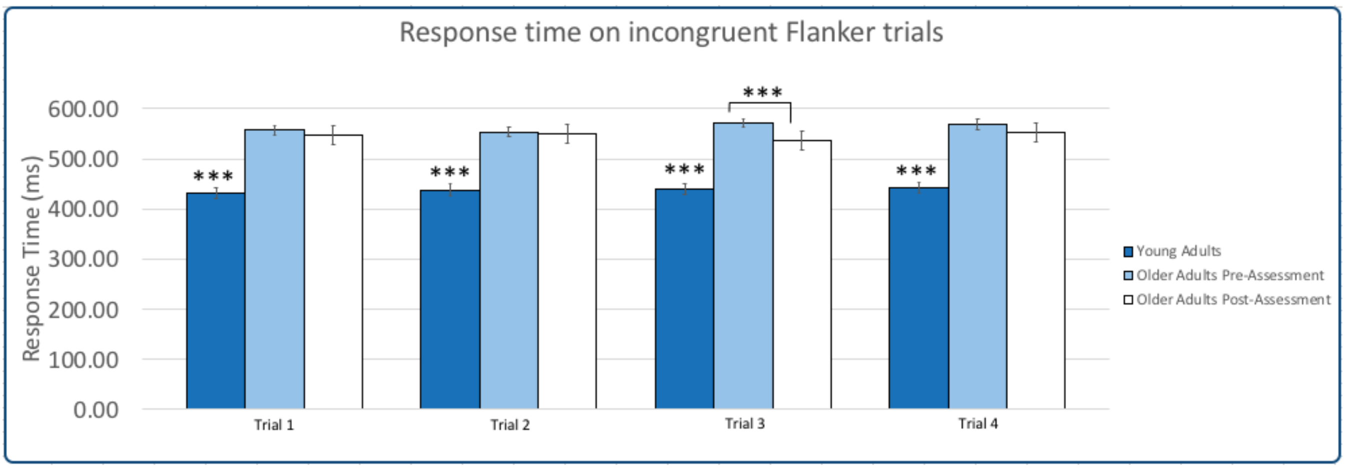

Figure 2: Response time on incongruent Flanker trials. RT results of YA and OA (pre- and post-training) on the incongruent Flanker trials (1-4). Statistical significance is indicated by "*", where one asterisk indicates p $<$ 0.05, two asterisks indicate p $<$ 0.01, and three asterisks indicate p $<$ 0.001.

analysis of variances showed no showed no significant differences between YA and OA hit rates on either Flanker task (Figures 4 and 5). It was, however, significantly different on the N-back task ($F_{2,124} = 51.679$, $p = 0.000$, $\eta = 0.455$) (Figure 6).

Discussion

Overall, YA responded quicker than OA and were also less accurate. After training, results showed a decrease in RT for OA in both the congruent and incongruent trials of the Flanker task. This may indicate that their ability to inhibit irrelevant stimuli improved following inhibition training. However further investigation is required before any definitive conclusions can be made. This effect of time was not present for the hit rate in either the congruent or incongruent Flanker task, which indicates that while response time may be affected by cognitive training, accuracy may not be. The lack of change of accuracy in OA may be due to lack of near-transfer. *Near-transfer* refers to changes in performance caused by cognitive training programs transferring to similar tasks, as is the case with the games in cognitive training and the Flanker and N-back tasks. Near transfer may apply to the inhibition portion of the task, but not to correct answers. The N-back task of working memory showed no significant post-training change in RT, which means that OA did not become quicker after the training. They did, however, become more accurate following training, which may indicate that near-transfer applies in correct answer responses on working memory tasks, where participants are required to maintain and manipulate information before using it. YA had significantly lower RT on both the

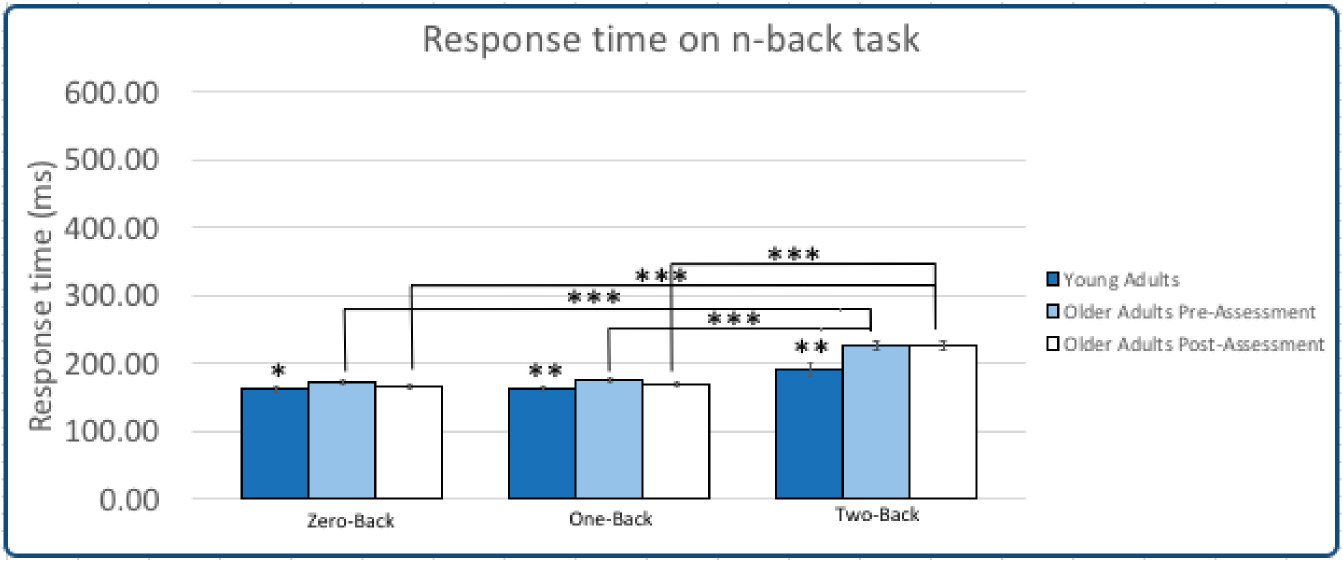

Figure 3: Response time on n-back task. RT results of YA and OA (pre- and post-training) on the n-back task (zero-, one- and two-back). Statistical significance is indicated by "*", where one asterisk indicates $p < 0.05$, two asterisks indicate $p < 0.01$, and three asterisks indicate $p < 0.001$.

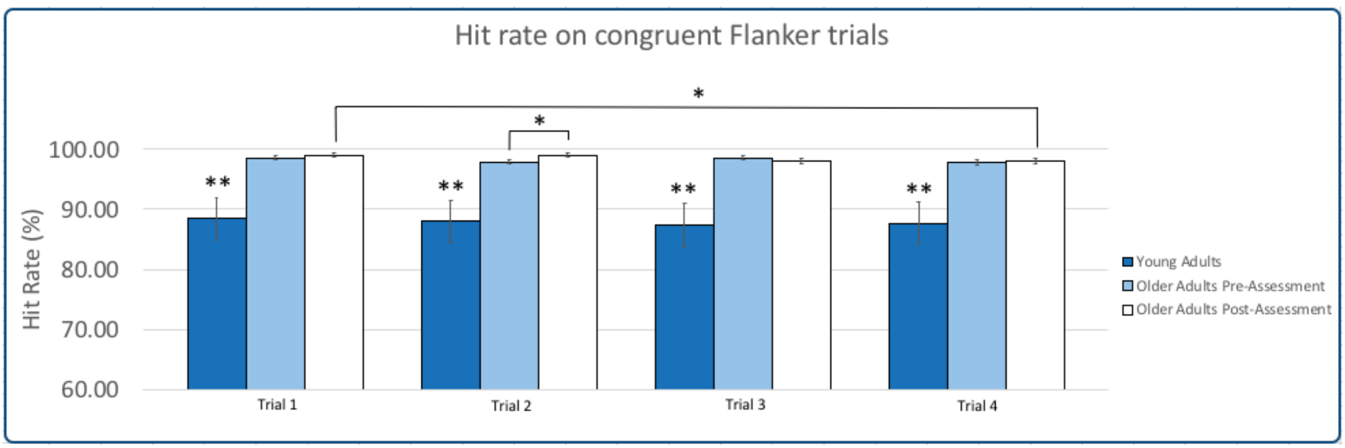

Figure 4: Hit rate on congruent Flanker trials. Hit rate results of YA and OA (pre- and post-training) on the congruent Flanker trials (1-4). Statistical significance is indicated by "*", where one asterisk indicates $p < 0.05$, two asterisks indicate $p < 0.01$, and three asterisks indicate $p < 0.001$.

congruent and incongruent Flanker task, as well as the N-back task. This might indicate that YA are quicker at identifying relevant data and responding to it, as well as maintaining and manipulating information with the purpose of using it. However, this finding could also be explained by impulsive behaviour patterns typically attributed to YA, or lack of motivation and investment in the task and subsequently, in the study. The latter interpretations are supported by the hit rate data, which indicates that while YA are quicker, they are also incorrect more often than OA. Although YA only showed a significant difference of hit rate on the N-back task, both the congruent and incongruent Flanker tasks show significant differences in one or more trials.

In summary, cognitive training may improve RT on inhibitory tasks, while also improving accuracy on memory tasks. This, while in itself not conclusive, justifies further research in the field of cognitive training and executive function. Further investigations could lead to potential discoveries regarding cognitive training in rehabilitation and preventative contexts. Such advances may help improve cognitive function in older adults and, therefore, increase independence and level of functioning. Everything considered, increased mental capabilities may enhance brain capacity longevity and allow for increased cognitive reserve in cases of problematic neuropathological diseases such as Alzheimer's disease, as well as in cases of non-pathological age-related cognitive declines.

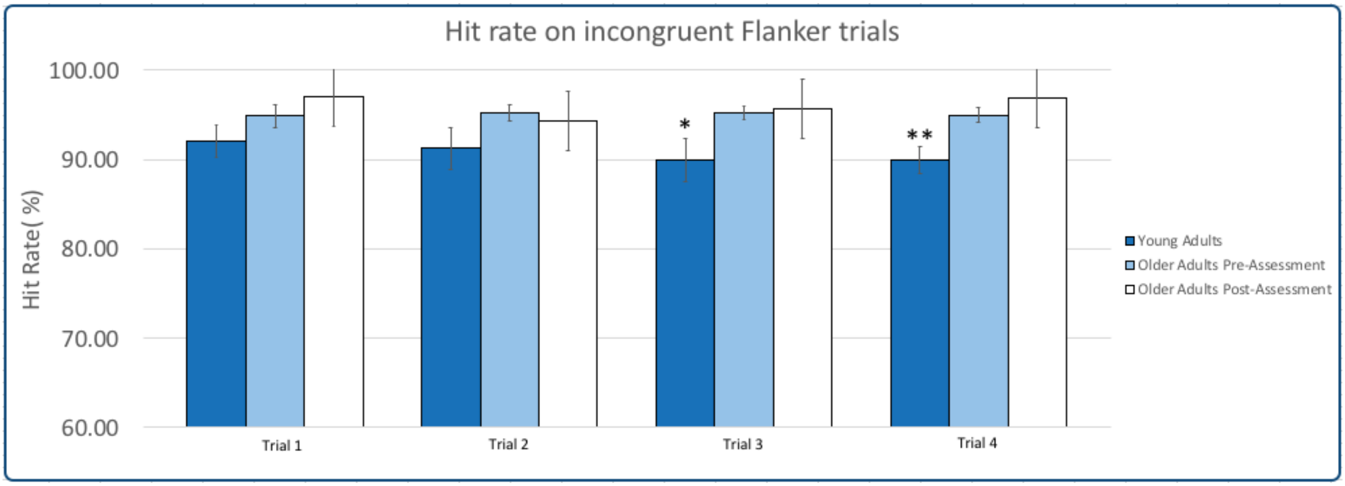

Figure 5: Hit rate on incongruent Flanker trials. Hit rate results of YA and OA (pre- and post-training) on the incongruent Flanker trials (1-4). Statistical significance is indicated by "*", where one asterisk indicates $p < 0.05$, two asterisks indicate $p < 0.01$, and three asterisks indicate $p < 0.001$.

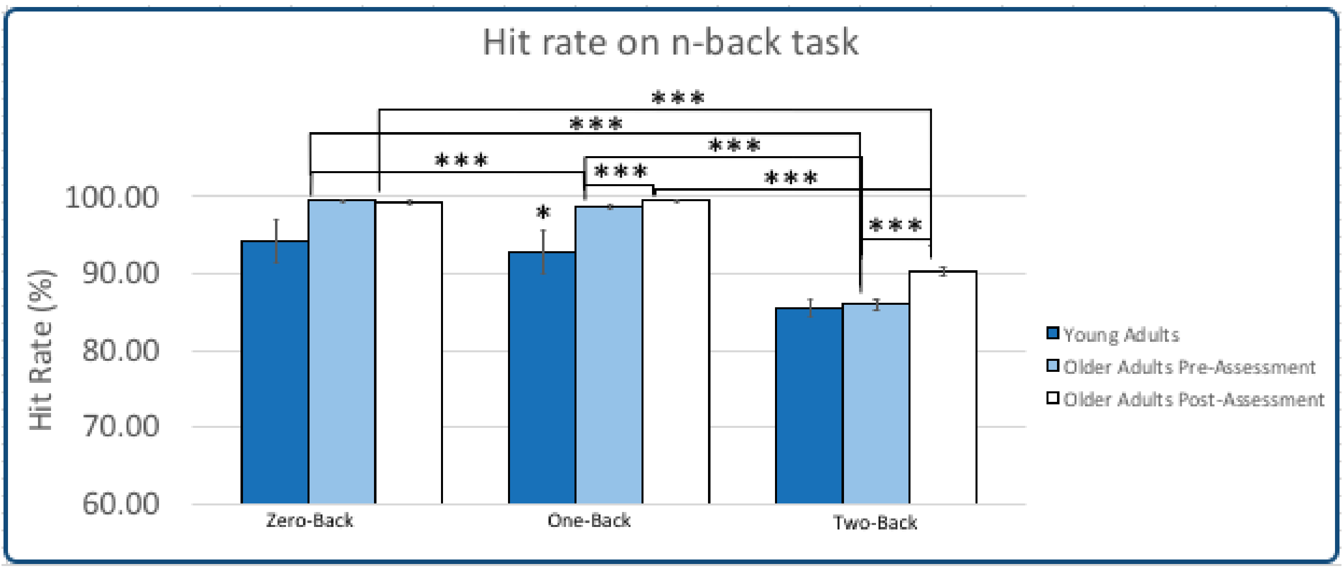

Figure 6: Hit rate on n-back task. Hit rate results of YA and OA (pre- and post-training) on the n-back task. Statistical significance is indicated by "*", where one asterisk indicates $p < 0.05$, two asterisks indicate $p < 0.01$, and three asterisks indicate $p < 0.001$.

Competing interests

The authors declare that they have no competing interests.

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