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COGNITIVE TRAINING AS AN INTERVENTION TO IMPROVE DRIVING ABILITY IN THE OLDER ADULT

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16. Abstract

The notion that cognitive and motor skills are plastic and can be improved with training is very exciting, because it opens up the possibility for rehabilitation and amelioration of age-related declines in performance. It has been shown that older adults can improve cognitive processes such as attentional control, memory, and speed of processing with training. Although transfer to other tasks has been reported, it is not clear whether benefits transfer to real-world tasks such as driving. The aging of the baby boomers will bring about new challenges for the safety of older drivers. In the current study, we evaluated whether a five week cognitive training intervention resulted in improvements in measures of cognition, complex motor control, and performance in a driving simulator task for both young and older adults. Young and older adults were assigned to the cognitive training intervention group (young n=29, older adult n =18) and to a knowledge training (vocabulary and trivia) control group (young n = 27, older adult n=18). We have completed enrollment and testing of young adults at this time; enrollment and testing for the older adults is ongoing. Both training groups exhibited improvement on the cognitive training protocol across five weeks of practice. Significant transfer effects were observed for other measures of working memory and processing speed. Although the results for older adults are preliminary as participants are still completing the intervention, they show transfer to the complex motor tasks and the driving simulator measures, particularly under dual task conditions. These results suggest that working memory training may be a useful intervention to improve driving in older adults, but has minimal impact in relatively high functioning young adults.

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FINAL REPORT

Description of the problem

The notion that cognitive and motor skills are plastic and can be improved with training is very exciting because it opens up the possibility for rehabilitation and amelioration of declines that occur with age, disease, or brain injury. It has been shown that with training, young adults can increase working memory (Jaeggi et al., 2008; Olesen et al., 2004), older adults can improve speed of processing (Ball et al., 2007), attention (Bherer et al., 2006), and memory (Buschkuehl et al., 2008), and stroke patients can improve functional motor performance with physical therapy (cf. Hornby et al., 2008). A crucial litmus test of the success of such training programs is whether they transfer to improvements in everyday functional behaviors such as driving.

The aging of the baby boomers will bring about new challenges for the safety of older drivers. Individuals over the age of 75 years have higher driver death rates per vehicle-mile of travel than drivers between the ages of 30 - 59 (Li et al., 2003), pointing to a clear need for interventions. A recent review suggests, however, that prior intervention programs, including physical retraining and visual perception training, have had only limited effectiveness on driving performance (Kua et al., 2007). While educational programs have been shown to improve driving awareness, they do not reduce the number of crashes for older adults (Kua et al., 2007). Marotolli and colleagues (2007) have recently shown that a fitness training program was associated with maintained driving performance for older adults across a period during which controls exhibited declines, but it did not improve driving performance.

In the current project, we evaluated whether progressive working memory training results in improved performance on driving simulator tests for both young and older adults. We had two lines of evidence leading us to believe that we might observe such transfer. The first is that we have already shown that training-related improvements in working memory transfer to other cognitive tasks, including measures of fluid intelligence (Jaeggi et al., 2008) and memory (Buschkuehl et al., 2008). Secondly, research demonstrates that the interdependence between the cognitive and motor systems increases with age (Huxhold et al., 2006; Lindenberger et al., 2000). Thus, we predicted that working memory training benefits would transfer to the performance of complex motor tasks including driving. That is, we believe that this type of cognitive training may be an efficient rehabilitation approach because it has the capacity to improve performance in a range of domains.

We evaluated whether a five week cognitive training intervention improves measures of cognition, complex motor control, and performance in a driving simulator task for both young and older adults. Identifying an intervention which allows older adults to extend their safe driving years would have immense societal benefits. Moreover, it is of theoretical interest to determine whether cognitive training improvements transfer to tasks that are both “near to” and “far from” the training task, because it would provide insight into which aspects of cognition are malleable with practice. It is not clear whether training enhances plasticity in general, or if transfer will only occur to tasks that rely on behavioral and neural processes which overlap with those of the trained task (Dahlin et al., 2008).

Approach

The literature on both cognitive and sensorimotor training has been rapidly expanding, opening new avenues for rehabilitation and self-improvement. Recent work has demonstrated that aspects of cognition previously thought to be unmalleable, such as fluid intelligence, can be improved with training (Jaeggi et al., 2008). Moreover, training benefits have been observed in older adults in a number of domains (Mahncke et al., 2006; Seidler, 2007; Buschkuehl et al., 2008), when it was originally thought that aging was associated with reduced adaptive capacity. Our approach was to build upon this burgeoning literature by determining whether improvements in working memory performance transfer to driving ability. We initially utilized a single blind randomized assignment of participants to control and training groups, but midway through the study we observed large group differences in pre test performance on the driving simulator. We then switched to a blind assignment procedure aimed at equalizing pre test scores. The control condition was a knowledge training intervention in which participants practiced vocabulary definitions and answered trivia questions in a format that was visually similar to that of the working memory training software. We addressed the following aims and hypotheses:

<u>Aim 1:</u> Determine whether a five week working memory training program improves working memory performance for young and older adults.
We have previously shown that working memory training is effective for young (Jaeggi et al., 2008) and older (Buschkuehl et al., 2008) adults; we hypothesized that we would replicate these effects with the currently proposed training parameters.

<u>Aim 2:</u> Determine whether benefits associated with a five week working memory training program transfer to other cognitive and motor tasks thought to rely on working memory processes, including measures of fluid intelligence and complex motor tasks.
We hypothesized that young and older adults would show similar transfer magnitudes. Although older adults have reduced plasticity, this effect may be counteracted by an increase in shared processing resources with age.

<u>Aim 3:</u> Determine whether benefits associated with a five week working memory training program transfer to the complex, real-world skill of driving.
We hypothesized that training would transfer to a driving task for both young and older adults.

Methodology

Participants

Twenty-nine young adults (mean age 21.4 years, 15 women) and 18 older adults (11 have completed training and post testing thus far; mean age 68.4 years, 7 women) were assigned to the dual task working memory training intervention group. Twenty-seven young adults (mean age 20.2 years, 12 women) and 18 older adults (13 have completed training and post testing thus far; mean age 70.4 years, 9 women) were assigned to the knowledge training control group. Individuals were paid for their participation. Recruitment and enrollment for older adults is continuing beyond the expiration of the project support.

Training tasks

The intervention groups engaged in the dual n-back working memory training task that we have previously shown to be successful in increasing working memory capacity, which shows transfer benefits to fluid intelligence (Jaeggi et al., 2008, see Figure 1). During this demanding task, participants are presented two series of stimuli that occur simultaneously at a rate of 3 s per stimulus. One series consists of auditory presentation of single letters (lower row in Figure 1), while the other consists of visual presentation of spatial locations (upper row in Figure 1). Participants are instructed to decide, for each series, whether the current stimulus matches the one that was presented *n* items back in the series (Figure 1 depicts the task for *n* = 2). Participants respond with a left finger keypress for a visual stimulus location match, and with a right finger keypress for an auditory stimulus match. The task changes adaptively based on each individual participant's performance. That is, if performance improves (declines), then *n* increases (decreases) for the subsequent block, with each block lasting just over one minute. Control group participants performed a knowledge training task, which consisted of answering multiple choice questions about vocabulary words and general knowledge. The control task was designed to provide participants with the same experience coming into the lab, interacting with experimenters, and performing computerized tasks as the intervention group.

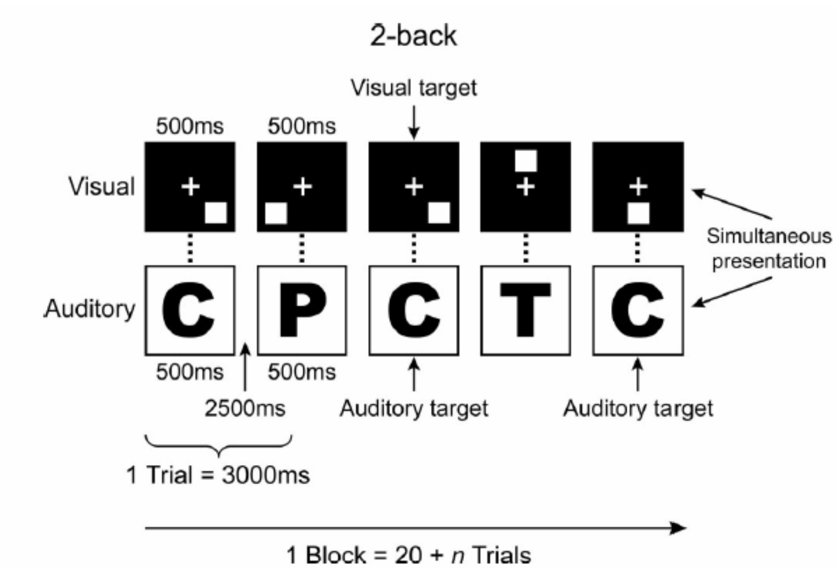


Figure 1. The dual n-back training task, illustrated for the case of n = 2 (taken from Jaeggi et al., 2008).

Working memory training sessions comprised 20 blocks of 20 + *n* trials, resulting in approximately 20 - 25 minutes of training per day. Knowledge training sessions were determined by time, that is, participants trained 23 minutes per training session. Participants were asked to engage in one training session each day, five days per week, for five weeks, resulting in a total of 25 training sessions. All participants completed a minimum of 17 training sessions, with several completing up to the full 25.

Pre and post test assessments

We assessed performance on a variety of measures prior to initiation of the training regimen, at the completion of the five week training period, and at a one month follow up test point. The total assessment battery lasted approximately 3 hours and was conducted in two different sessions (i.e. morning and afternoon in a counterbalanced fashion or over two days). We conducted three types of pre and post test assessments: 1) tests that are functionally close to the working memory training program, allowing us to determine whether improvements in working memory transfer to other working memory measures (Type 1 tests); 2) tests that are functionally less similar to the working memory training program, including measures of fluid intelligence and motor learning, allowing us to determine whether improvements in working memory transfer to other cognitive and motor behaviors (Type 2 tests), and 3) driving simulator tests, allowing us to determine whether working memory improvements transfer to complex, real-world behaviors (Type 3 tests).

Type 1 tests included card rotation (Ekstrome et al., 1976), operation span (Unsworth et al., 2005), and visual array comparisons (Luck & Vogel, 1997), which are three neuropsychological assessments of working memory, and the digit symbol substitution task (from WAIS-R), which is a measure of sensorimotor processing speed. In addition, participants performed single and dual n-back tasks, a visual array comparison test of working memory, the operation span working memory test, and the ANT test of attention (Fan et al., 2005).

Type 2 tests included Raven's matrices (Raven et al., 1990), which is a standardized test of fluid intelligence, and the BOMAT and verbal analogies tests of intelligence (Hossiep et al., 1995). We have previously shown that working memory training transfers to performance on this task (Jaeggi et al., 2008), and we included it here for the sake of replication. Participants also performed a motor sequence learning task and a sensorimotor adapation test as part of the type 2 test items. We have previously shown that measures of working memory correlate with the rate of learning both types of tasks (Anguera et al., in press, Bo & Seidler, 2009), and that aging is associated with declines in both types of skill learning (Seidler 2006). The administration of type 2 tests allows us to determine whether working memory training benefits are restricted to measures of working memory and related cognitive tasks, or if they transfer to tasks which purportedly rely on working memory mechanisms as well.

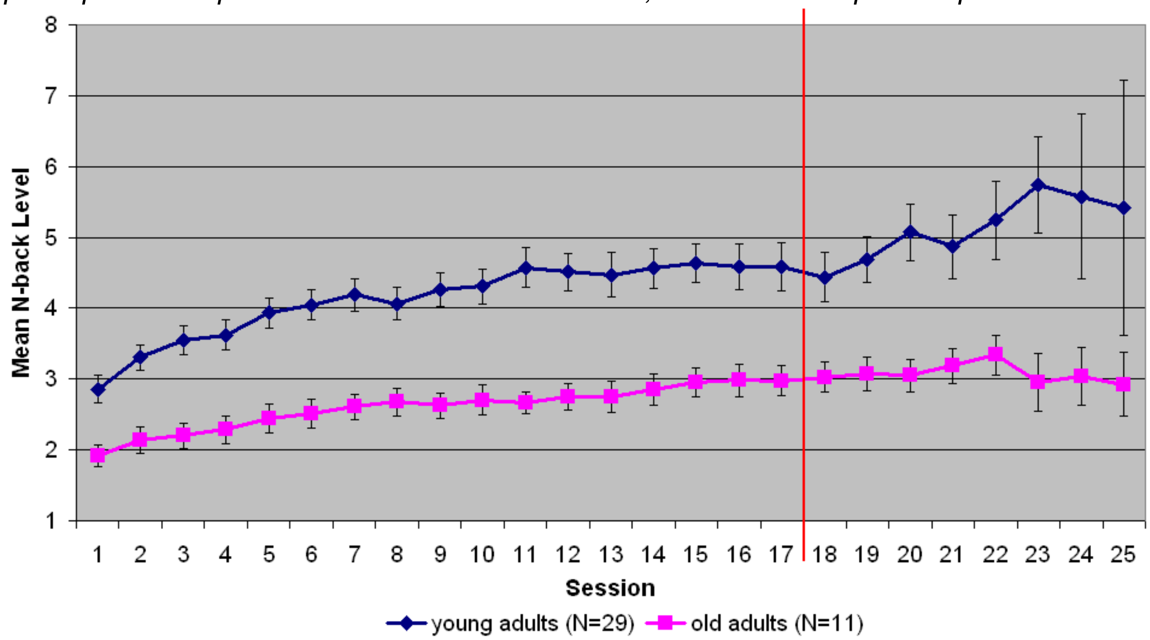
The Type 3 tests were assessments performed with an STISIM Drive driving simulator. Recent studies have shown that tests and training with this system are correlated with real-world, in-car driving performance (Akinwuntan et al., 2005; Freund et al., 2002; Lee et al., 2003). Participants were first given a practice course and then two course driving tests, each lasting approximately 10 minutes. One course included both straight and curved roads, with varying speed limits and traffic requiring steering and braking for avoidance and other complex traffic events. The other course was simpler. Both the easy and hard courses were performed alone and under divided attention conditions. The divided attention condition required pressing a button in response to cues that appeared occasionally on the screen. Performance metrics included number of traffic violations and crashes, speed deviation and lane position deviation, response time to events, and response time and number of missed versus correct responses for the divided attention task.

Findings

Training Gains

Improvements on the dual n-back training task for the two training intervention groups are plotted in Figure 2. Both young and older adults exhibited training-related gains, despite the fact that older adults had poorer performance at the outset.

Figure 2. Training curves for the two dual n-back training groups. The red line indicates the point at which reducing numbers of participants completed additional sessions. That is, all participants completed a minimum of 17 sessions, and some completed up to 25.



Young and older adults in the knowledge training groups had comparable performance, with both groups answering approximately 65% correct on the vocabulary and general knowledge questions throughout the five week training period.

Performance on Type I Assessments- Near Transfer to Other Working Memory Measures

For the young adults, there were significant group (working memory intervention, knowledge training control) by test session (pre, post training) interactions for several of the working memory measures. The dual n-back training group exhibited significantly greater improvements than the knowledge trainer group on the operation span test ($P < .05$), single and dual n-back tests ($P < .05$), and a trend for an interaction on the card rotation test ($P = .07$). There is insufficient data in the older adult participant groups to evaluate transfer at this point.

Performance on Type II Assessments- Far Transfer to Measures of Intelligence and Complex Motor Performance

There were no significant group by test session interactions for the intelligence measures or complex motor tasks for the young adults, although one of the intelligence measures exhibited a trend for transfer effects that scaled with training task gains. Again, there is insufficient data to statistically evaluate these transfer effects for older adults at this point in the study. Figure 3 shows a promising trend in the Walking While Talking task (Verghese et al., 2002), however, with the older adults in the intervention group exhibiting larger improvements on this measure of dual tasking while walking. This is particularly significant given that scores on this assessment are predictive of falls in older adults.

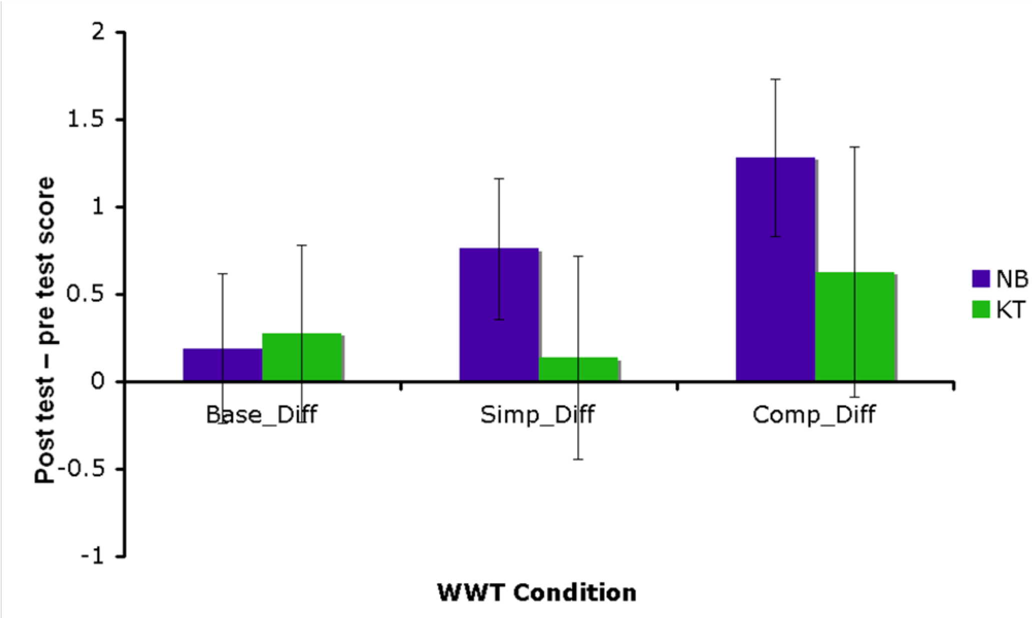


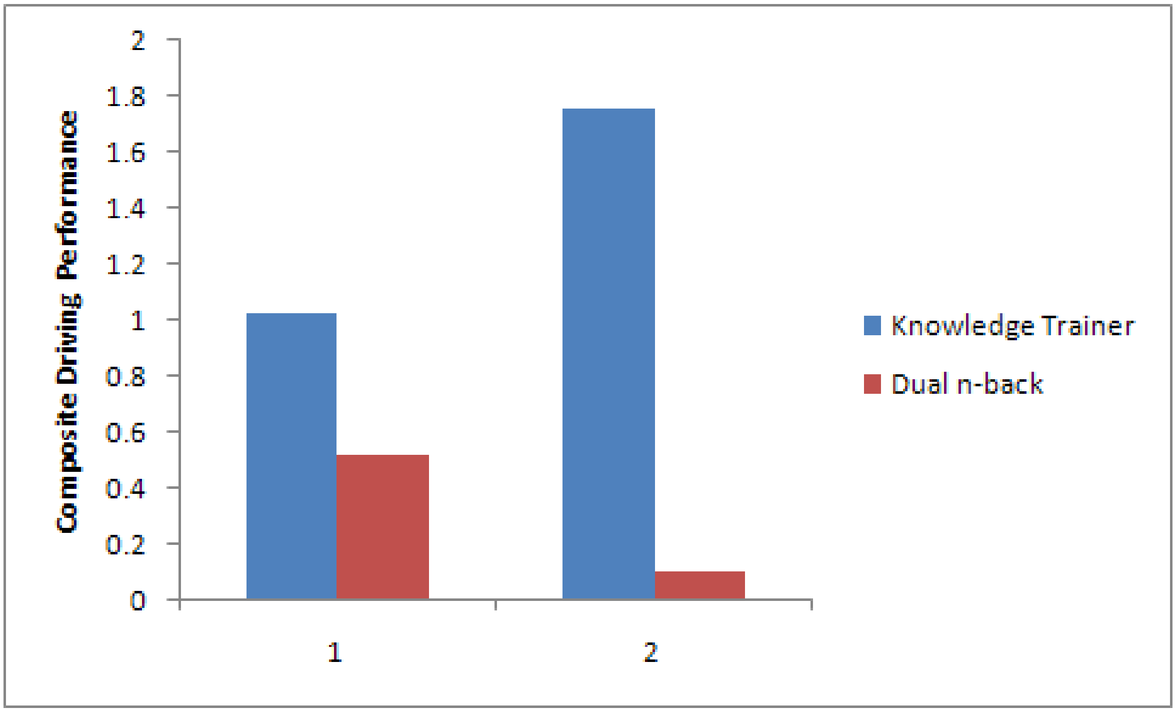
Figure 3. Pre- to post-test change in the walking while talking test for older adults. The dual n back training group (blue) shows greater positive transfer than the knowledge training control group (green), particularly for more the more complex conditions of this test.

Performance on Type III Assessments- Transfer to Driving Simulator Tests

For the young adults, there were no significant transfer effects to the driving courses, either under single or dual task conditions. This was assessed using a composite driving performance measure that takes into account a number of factors including maintaining posted speeds, number of crashes, lane deviations, etc. We are conducting more detailed analyses for the young adults to determine whether any measures in isolation provide evidence for transfer.

The number of older adult participants that have completed pre and post testing on the driving simulator is quite small at this point (N= 6, 7 per group). Unfortunately several of the older participants complained of dizziness and nausea when driving the courses and had to cease testing. We are still training and testing older adult participants to increase this number. For those that have completed testing thus far, there is a trend for improvement on the composite measure when driving under dual task conditions for the working memory training versus the knowledge control group (Figure 4).

Figure 4. Older participants in the working memory training group (depicted in red) show positive transfer of training to driving under dual task conditions, while those in the control group (depicted in blue) do not.



Conclusions

In summary, young adults exhibited substantial performance gains on the dual n-back training task, as we have shown previously (Jaeggi et al., 2008). The training effects transferred to differential improvements for the training group on other measures of working memory and speed of processing. Unlike in our previous work (Jaeggi et al., 2008) we did not observe transfer to measures of intelligence. This may have been a by-product of the rather extensive pre and post test battery of assessments that we performed, particularly given that one of the intelligence measures was always performed last in the sequence of tests. Given this, participants may have been too fatigued and / or unmotivated to perform these tests well. It was somewhat disappointing that training benefits for the young adults did not transfer more broadly to improvements on the complex motor tasks and performance on the driving simulator courses. However, performance for this group on these tasks was quite high to begin with and they may have less room for improvement than the older adults.

We have insufficient power at this point to statistically examine transfer effects for the older adults, but we have a large number of older adult participants that will be completing training and post testing over the next month. The fact that the participants who have completed the intervention thus far exhibit significant training gains and trends for transfer to the complex motor tasks and driving simulator tests is promising. These effects appear to be the largest for dual tasking mobility measures- walking while talking and driving under divided attention.

Recommendations

We are unable to make concrete recommendations at this time, given that we have not quite completed data collection and analysis with the older adult participants. However, if significant transfer to the driving simulator assessments is observed, then further studies which examine transfer to on-road driving situations will be warranted.

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