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A pilot investigation on the effects of combination transcranial direct current stimulation and speed of processing cognitive remediation therapy on simulated driving behavior in older adults with HIV ☆

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ABSTRACT

Cognitive impairments seen in people living with HIV (PLWH) are associated with difficulties in everyday functioning, specifically driving. This study utilized speed of processing cognitive remediation therapy (SOP-CRT) with transcranial direct current stimulation (tDCS) to gauge the feasibility and impact on simulated driving. Thirty PLWH (M_{age} = 54.53, *SD* = 3.33) were randomly assigned to either: sham tDCS SOP-CRT or active tDCS SOP-CRT. Seven indicators of simulated driving performance and safety were obtained. Repeated measures ANOVAs controlling for driver's license status (valid and current license or expired/no license) revealed a large training effect on average driving speed. Participants who received active tDCS SOP-CRT showed a slower average driving speed ($p = 0.020$, $d = 0.972$) than those who received sham tDCS SOP-CRT. Non-significant small-to-medium effects were seen for driving violations, collisions, variability in lane positioning, and lane deviations. Combination tDCS SOP-CRT was found to increase indices of cautionary simulated driving behavior. Findings reveal a potential avenue of intervention and rehabilitation for improving driving safety among vulnerable at-risk populations, such as those aging with chronic disease.

1. Introduction

1.1. HIV, aging, and mobility

By the year 2020, 70% of the individuals currently living with HIV are expected to be 50 years old and older (High et al., 2012) due to medical advances such as combination antiretroviral therapy (cART) and better knowledge and care for the

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disease (Sheppard et al., 2017). Declines normally associated with the aging process are accompanied with deficits in cognition, including processing speed, or the rate at which an individual processes and uses information from the environment (Glisky, 2007). With HIV, the discussion of premature aging is of interest as studies show evidence of both age-related deficits at younger ages (i.e., accelerated aging) and exacerbated age-related deficits in age-normative declines (i.e., accentuated aging; Sheppard et al., 2017). Furthermore Greene et al. (2015) found that people living with HIV (PLWH) aged 50 and older reported high rates of geriatric syndromes (e.g., diseases, problems, frailty, or syndromes normally associated with aging), including impairments with mobility, cognition, and difficulties with instrumental activities of daily living (IADL).

1.2. Driving rehabilitation

One common IADL, rated high in importance for older adults, is driving. Driving is a complex task that involves multiple cognitive, behavioral, and environmental factors (Anstey, Wood, Lord, & Walker, 2005; Pope, Bell, & Stavrinos, 2017; Pope, Ross, & Stavrinos, 2016). Driving cessation has been associated with a multitude of negative health outcomes including decreased engagement in social activities (Marottoli et al., 2000), poorer psychological well-being including higher ratings of depression and lower life satisfaction (Siren, Hakamies-Blomqvist, & Lindeman, 2004), and declines in physical functioning (Edwards, Lunsman, Perkins, Rebok, & Roth, 2009). Prior research has focused heavily on clinical populations such as those living with traumatic brain injury (TBI; Ortoleva, Brugger, Van der Linden, & Walder, 2012), dementia (Reger et al., 2004), and HIV (Marcotte et al., 1999) as they have shown driving performance deficits that vary with disease severity when compared to healthy controls. Specifically, for PLWH who had cognitive impairment, higher failure rates on simulated driving scenarios, more simulated driving collisions, and higher likelihood of being rated as unsafe on driving evaluation scores were seen when compared to those with HIV who did not show cognitive impairment (Marcotte et al., 1999; Marcotte et al., 2006; Marcotte et al., 2004). Furthermore, a pilot study by Vance, Fazeli, Ball, Slater, and Ross (2014) also found a significant association between various HIV related variables (CD4 count), self-reported driving history (days driven per week), simulated driving performance (reaction time, speeding, divided attention), and cognitive performance (speed of processing [SOP], attention, memory, cognitive flexibility) adding to the multifactorial processes linked with driving.

Studies investigating the neural mechanisms underlying driving behavior and performance suggest activation of multiple brain areas such as the pre-motor, cerebellar, and frontoparietal areas (Graydon et al., 2004; Spiers & Maguire, 2007), depending on the driving behavior or task at hand. One such area includes the ventral attention system, which encompasses the temporoparietal junction and the ventral frontal cortex (Fox, Corbetta, Snyder, Vincent, & Raichle, 2006; Vossel, Geng, & Fink, 2014) and is associated with the salience network (Sridharan, Levitin, & Menon, 2008). Neural activation corresponds to unexpected stimuli which diverts or cues resources away from the focus of spatial attention (Vossel et al., 2014). Spiers and Maguire (2007) found neural evidence suggesting the activation or role of the ventral frontal cortex during various driving maneuvres such as turning and stopping. These findings add support for the investigation into rehabilitative interventions that include the cognitive processes related to driving such as SOP, attention, and cognitive control.

1.2.1. Speed of processing cognitive remediation therapy (SOP-CRT)

An innovative and frequently studied form of driving rehabilitation is speed of processing cognitive remediation therapy (SOP-CRT; Ball, Edwards, & Ross, 2007; Ball, Edwards, Ross, & McGwin, 2010; Edwards, Myers, et al., 2009; Roenker, Cissell, Ball, Wadley, & Edwards, 2003). This type of CRT utilizes a paradigm of visual SOP and attentional control processes to target processing speed abilities (Ball et al., 2007). Individuals who received 10 sessions of SOP-CRT in the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) clinical trial (Ball et al., 2002) showed SOP training gains which were maintained over 2 years and lower rates of at-fault motor vehicle collisions (MVCs) 6 years after the initial training (Ball et al., 2010). Furthermore, Vance, Fazeli, Ross, Wadley, and Ball (2012) found that SOP-CRT in PLWH was associated with better SOP and performance on a timed IADL task at post-test when compared to the no-contact control group.

1.2.2. Non-invasive brain simulation – Transcranial direct current stimulation (tDCS)

Non-invasive brain stimulation via transcranial direct current stimulation (tDCS) is a safe, common, and widely studied neuro-modulation technique (Ahn et al., 2017; Bikson et al., 2016; Fazeli, Woods, Pope, Vance, & Ball, 2017; Nitsche & Paulus, 2000; Priori, Berardelli, Rona, Accornero, & Manfredi, 1998; Szymkowicz , McLaren, Suryadevara, & Woods, 2016; Woods et al., 2016; Woods et al., 2014). tDCS is thought to modulate cortical neuronal membrane potentials which may alter cortical activity such as spontaneous neuronal activity or changes in neurotransmitters (Woods et al., 2016). Sub-threshold stimulation is administered to the scalp, targeting relevant cortical areas and neuronal networks, yet when using conventional electrodes (in contrast to high-definition) focality is limited and widespread effects are expected (Kessler et al., 2013; Minhas et al., 2010; Minhas, Bikson, Woods, Rosen, & Kessler, 2012; Woods et al., 2016). Membrane polarization and observed behavioral effects are conditional to whether stimulation is anodal (positive charge) or cathodal (negative charge) and the specific tDCS placement (i.e., montage) used (Scheldrup et al., 2014; Woods et al., 2016).

The behavioral findings regarding tDCS on cognitive and motor task outcomes are mixed, with effect sizes depending on methodological design and tDCS factors such as polarity and selected montages (Hsu, Ku, Zanto, & Gazzaley, 2015; Jacobson, Koslowsky, & Lavidor, 2012; Nilsson, Lebedev, Rydström, & Lövdén). Less investigated, is the role of tDCS with complex, real-world behavior such as driving (Scheldrup et al., 2014). Beeli, Koeneke, Gasser, and Jancke (2008) showed immediate changes in simulated driving performance, with individuals who received 15 minutes (min) of 1 milliamp (mA) anodal tDCS