Volunteering and the Improvement of Cognitive Function in Older Adults: Neuropsychological Mechanisms

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Date: 2023-12-25T00:00:00+00:00

Abstract

Breaking away from traditional cognitive interventions that position older adults as passive recipients, this study employs volunteering as an intervention modality to examine older adults as active providers of assistance, investigating how the cognitive, physical, and social activities inherent in the helping process reciprocally influence their own cognitive functioning and the underlying mechanisms. The research will utilize randomized controlled trials, functional magnetic resonance imaging, and data modeling techniques to systematically explore the neuropsychological mechanisms of volunteering interventions on older adults' cognitive functions from a dual hot-cold systems perspective, construct predictive models, and identify adaptive patterns for different older adults to engage in volunteering for cognitive improvement. Centered on the scientific validity of volunteering as a cognitive intervention for older adults, this study aims to harness their subjective agency while enhancing intervention sustainability, thereby providing a reality-grounded approach for protecting cognitive function in older adults.

Full Text

The Improvement of Older Adults' Cognitive Function Through Volunteering and Its Neuropsychological Mechanisms

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Abstract: Moving beyond traditional cognitive interventions that position older adults as passive recipients of help, this study employs volunteering as an intervention modality and examines older adults as active providers of assistance. We investigate how the cognitive, physical, and social activities involved in the helping process subsequently affect volunteers' own cognitive function and the underlying mechanisms. Using randomized controlled trials, functional magnetic resonance imaging, and data modeling techniques, we systematically explore the neuropsychological mechanisms through which volunteering interventions affect older adults' cognitive function from the perspective of hot-cold dual systems. Additionally, we aim to construct predictive models to identify optimal volunteering modalities for different older adults to maximize cognitive benefits. This research focuses on the scientific validity of volunteering as a cognitive intervention for older adults, harnessing their subjective agency while enhancing intervention sustainability, thereby providing a real-world intervention approach for protecting cognitive function in aging.

Keywords: older adults, volunteering, cognitive function, hot-cold cognitive systems, brain modularity

1. Research Significance

"Do not say the sunset is late, for the evening glow still fills the sky." Over a thousand years ago, Liu Yuxi expressed this sentiment about the value of late-life contribution in his poem "In Reply to Letian's Poem on Aging." Enabling willing and capable older adults to remain productive represents a potential solution to tightening human resources while simultaneously serving as an effective "helping others helps oneself" approach to enhancing their own health. According to the *2021 China Active Volunteers Status Survey Report*, active volunteers in China contributed 2.238 billion service hours monthly, equivalent to 42.276 billion yuan in economic value based on the minimum hourly wage of 18.89 yuan. Among these volunteers, the "post-1960s" generation accounted for 24.21%, while the "post-1950s" generation represented 18.60% (Zou & Liang, 2021). However, limited by organizational forms and platforms, older adults in China currently exhibit a "high willingness, low participation" phenomenon in volunteering (Xie, 2017). For older adults, volunteering provides assistance to others and society while simultaneously generating positive effects on their own physical and mental health. Clarifying the scientific validity of volunteering as a cognitive intervention and revealing its neural underpinnings will provide a sustainable, real-world intervention approach for protecting older adults' cognitive function and offer insights for developing innovative elderly care service systems.

Traditional cognitive interventions have demonstrated protective effects on older adults' cognitive function (Reijnders et al., 2013). However, such laboratory-based interventions suffer from several limitations: weak subjective agency among older adults, substantial human resources required for organization and training, limited reach among beneficiaries, and inability to sustain interven-

tions long-term. Volunteering as an intervention approach transforms older adults from passive recipients into active providers of help. The cognitive, social, and physical activities experienced during the helping process subsequently promote volunteers' own cognitive function. This approach effectively avoids the limitations of traditional cognitive interventions by leveraging older adults' subjective agency, enhancing sustainability, expanding beneficiary coverage, and improving ecological validity.

2.1 Volunteering and Cognitive Improvement in Older Adults

Volunteering refers to voluntary, unpaid service activities provided to others or society through relevant organizations. Participation in volunteering effectively enhances older adults' physical and mental health (Bell et al., 2022; Huo et al., 2021), particularly playing an important role in improving cognitive function (Guiney & Machado, 2018). Existing theoretical models propose that volunteering increases three types of activities in older adults' daily lives—cognitive, social, and physical—which in turn exert positive effects on neural and mental health, ultimately improving cognitive function (Guiney & Machado, 2018). Cross-sectional evidence demonstrates that, after controlling for demographic variables, physical health, and lifestyle factors, older adults who volunteer exhibit better overall cognitive abilities compared to non-volunteers (Schwingel et al., 2009; Shmotkin et al., 2003). Longitudinal studies similarly find that older volunteers face significantly lower risks of cognitive decline (Tomioka et al., 2018) and have reduced likelihood of developing cognitive impairment (Hughes et al., 2013). Additionally, research shows both formal and informal volunteering significantly reduce the probability of cognitive impairment in older adults (Wang et al., 2022).

However, only two randomized controlled trials have examined volunteering's impact on older adults' cognitive function. One study implemented a 5-month kindergarten volunteering intervention for older adults with mild-to-moderate dementia, finding that volunteer stress levels decreased significantly and cognitive decline showed a decelerating trend compared to controls, though the difference was not statistically significant due to small sample size (8 vs. 7) (George & Singer, 2011). Another community-based volunteering intervention with older adults demonstrated that after more than four months, volunteers showed significant improvements in executive function and memory, outperforming non-volunteers (Carlson et al., 2008). Importantly, to exclude confounding from the possibility that "older adults with better cognitive function are more likely to choose volunteering," a longitudinal study examined this selection effect, finding that it explained only 4.9% to 29% of the total cognitive improvement effect. After controlling for selection effects, volunteering still demonstrated significant "net gains" in overall cognitive function (Kail & Carr, 2020). Beyond statistically controlling for selection effects through longitudinal tracking, some studies have investigated volunteering among older adults with mild cognitive

impairment and mild-to-moderate Alzheimer's disease (e.g., Chen et al., 2020; George & Singer, 2011; Klinedinst & Resnick, 2016; Piette et al., 2023), suggesting that these individuals can engage in appropriate volunteering activities that effectively slow their cognitive decline.

Current theoretical models suggest that older adults' increased engagement in cognitive, social, and physical activities through volunteering influences their neural and mental health, ultimately improving cognitive function (Guiney & Machado, 2018). However, these models provide a unified overview of all volunteering activities and lack characterization of volunteering types, targeted cognitive systems, and neural mechanisms. In reality, different volunteering activities activate distinct skill sets, making it essential to incorporate volunteering type as a critical variable when examining effects on cognitive function. Research comparing instrumental volunteering with more cognitively demanding activities found that older volunteers in the latter reported higher life satisfaction and fewer depressive symptoms (Lam et al., 2023). Another study examining 11 types of volunteering activities revealed that managerial volunteering produced more positive effects for women, while community service or cultural organization volunteers showed better self-esteem and sense of control (Windsor et al., 2008). Clarifying the effects of different volunteering types has become a primary future research direction in this field (Anderson et al., 2014). Although substantial research demonstrates positive associations between volunteering and cognitive function, we cannot assume all volunteering types produce consistent benefits. On one hand, cognitively demanding volunteering may delay cognitive decline by building greater cognitive reserve (Stern, 2012). On the other hand, socially oriented volunteering may expose older adults to more novel stimuli, helping them better cope with age-related cognitive decline (Salthouse, 2006).

2.2 Domain-Specific Effects of Volunteering on Cognitive Function

Most studies examining volunteering's impact on older adults' cognitive function have used comprehensive cognitive measures such as the Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA) as core outcome indicators. However, both normal and pathological aging exert domain-specific effects on cognitive function, particularly higher-order functions, making comprehensive measures inadequate for domain-specific analysis of volunteering's benefits. A large-scale longitudinal study of over ten thousand middle-aged and older volunteers found that while service duration positively correlated with overall cognitive function, the relationship varied across cognitive domains with increasing service time: associations with working memory and processing speed gradually strengthened, while the relationship with episodic memory gradually weakened (Proulx et al., 2018). Similarly, another study found no difference in MoCA scores between older volunteers and non-volunteers, but monthly volunteering participation directly predicted working memory performance and

indirectly predicted task-switching performance through cognitive activities experienced during service (Guiney et al., 2021). These results demonstrate heterogeneous effects of volunteering on different cognitive domains in older adults, highlighting the necessity of distinguishing cognitive types.

Cognitive function can be categorized into cold cognition and hot cognition based on emotional and motivational involvement (Roiser & Sahakian, 2013; Zelazo & Carlson, 2012). Cold cognition refers to cognitive activities without obvious emotional engagement, such as executive function, processing speed, and memory involving neutral stimuli. Hot cognition involves cognitive activities with emotional and reward processing, such as risky decision-making, social cognition, and processing of emotional stimuli. Research shows volunteering can improve both cold and hot cognitive functions in older adults (Carlson et al., 2008; Guiney et al., 2021; Piercy et al., 2011; Proulx et al., 2018). An intergenerational volunteering study demonstrated that older adults showed improved performance on trail-making tests and complex figure delayed recall tasks after six months of volunteering (Carlson et al., 2008). Another study focusing on hot cognitive function found that middle-aged and older volunteers providing religious and humanitarian services abroad exhibited stronger cultural understanding and empathy, greater self-awareness and understanding of others, and deeper comprehension of human suffering and global issues. Importantly, volunteering provided opportunities to re-examine their motivations, discover life meaning and personal value, and ultimately achieve spiritual growth (Piercy et al., 2011).

2.3 Neural Basis of Volunteering's Effects on Cognitive Function

Research on the brain mechanisms underlying volunteering's effects on older adults' cognitive function remains extremely limited, with only two studies originating from the same program—Experience Corps. This intergenerational volunteering initiative, launched by the American Association of Retired Persons, engages older volunteers in public elementary schools to collaborate with teachers in helping children improve reading skills and classroom performance, requiring 5–15 hours of service weekly during the school term. After six months, researchers examined volunteering's effects on brain function and found that older volunteers showed greater activation in the left prefrontal cortex and anterior cingulate cortex compared to controls when performing an arrow Flanker task, with enhanced neural activity significantly correlated with behavioral performance improvements, suggesting benefits to executive function (Carlson et al., 2009). A subsequent study comparing baseline, one-year, and two-year time points found that volunteers showed significant increases in cortical and hippocampal volumes compared to controls, with effects moderated by gender—protective effects being more pronounced for male volunteers. Changes in cortical volume significantly correlated with improved performance on auditory delayed memory tasks (Carlson et al., 2015). While these neuroimaging stud-

ies provide preliminary exploration of the neural mechanisms, issues regarding result robustness, applicability to different volunteering types, and cognitive domain specificity require further investigation.

Beyond traditional volumetric and task-based activation measures, brain modularity represents a variable closely associated with cognitive function and plasticity. Modules are groups of nodes that can be identified through data-driven approaches using various community detection algorithms or predetermined subnetworks based on functional or structural connectivity (Sporns & Betzel, 2016). Numerous studies demonstrate that brain modularity—both structural and functional—declines with aging (e.g., Chan et al., 2014; Gallen et al., 2016). Importantly, brain network modularity can serve as a biomarker of intervention-related plasticity, showing intervention-induced changes across populations (clinical vs. normal) and intervention modalities (physical activity vs. cognitive training) (e.g., Baniqued et al., 2019; Iordan et al., 2021). Furthermore, research indicates that baseline modularity levels predict cognitive training outcomes (e.g., Baniqued et al., 2019; Gallen & D'Esposito, 2019). A reasoning training study in older adults found that higher baseline modularity predicted greater improvements in strategy learning, a relationship not observed in control groups, revealing intervention-specific predictive value (Gallen et al., 2016). Currently, beyond traditional brain volume and task activation measures, exploration of brain modularity—possessing both intervention plasticity and predictive utility—remains a critical gap.

3. Problem Statement

Existing research has primarily examined volunteering's effects on older adults from physiological and social functional perspectives, showing that participation reduces mortality, lowers C-reactive protein concentrations, and alleviates diurnal cortisol dysregulation (Bell et al., 2022; Huo et al., 2021; Musick et al., 1999). At the social level, volunteering enhances well-being, increases social participation, and builds more effective social support networks (Morrow-Howell, 2010; Pilkington et al., 2012). However, compared to physiological and social functions, research on volunteering's impact on cognitive function remains relatively scarce, with unclear mechanisms. Current research on volunteering interventions for cognitive function in older adults faces several critical issues.

First, although existing studies demonstrate protective effects of volunteering on cognitive function, the mechanisms of different volunteering types remain unclear, limiting generalizability. This study will integrate current theoretical models of volunteering and cognitive function, weighting the cognitive, social, and physical activities involved in different volunteering types to reveal relationships between volunteering type and cognitive change, while examining how these relationships are modulated by volunteers' neuropsychological characteristics.

Second, most research relies on cross-sectional and longitudinal surveys, with

only two randomized controlled trials, yielding insufficiently robust causal evidence. Moreover, studies suggest domain-specific effects of volunteering on cognitive function, making it invalid to discuss such specificity independently of volunteering type. This study will employ randomized controlled trial designs to examine effects of different volunteering types on different cognitive functions from the hot-cold dual system perspective.

Third, the neural mechanisms underlying volunteering's effects on cognitive function remain unclear. Existing neuroimaging studies suggest volunteering can increase cortical volume and executive function-related brain activation, but suffer from limitations including single volunteering type (both from the same intergenerational program), unsystematic cognitive domain coverage, and cross-task constraints on brain measures. Building on previous research, this study will examine effects of different volunteering types on different cognitive systems and their neural basis from the hot-cold dual system perspective. Leveraging brain modularity's plasticity and predictive properties, we will incorporate this measure alongside traditional brain metrics to model intervention effects and predictions.

Finally, current research lacks investigation of individual differences in intervention effects and predictive model construction, resulting in weak intervention specificity. All intervention studies exhibit individual heterogeneity, and ignoring this variable when evaluating intervention effects introduces bias. This study will use latent change models to examine individual differences in volunteering intervention effects, then incorporate psychological factors (including motivation), hot-cold cognitive abilities, personality traits, and brain modularity into machine learning models using classification and regression algorithms to predict optimal volunteering matching and cognitive enhancement.

4. Research Framework

This research series examines the scientific validity of volunteering interventions for older adults' cognitive function, shifting from the traditional perspective of older adults as help recipients to investigating the neural mechanisms through which older adults as help providers improve their own cognitive function. We explore relationships between volunteering and cognitive function from correlational and causal perspectives, establish a hot-cold dual-system neuropsychological model, examine individual differences in intervention effects, and develop predictive models to maximize intervention efficacy. The overall framework is illustrated in Figure 1 [Figure 1: see original paper].

Figure 1. Research framework for volunteering interventions on older adults' cognitive function

4.1 Relationship Between Volunteering and Cognitive Function in Older Adults

Study 1 investigates correlations between cognitively-oriented volunteering, socially-oriented volunteering, and hot-cold cognitive functions. Using hybrid online-offline data collection, we will administer comprehensive neuropsychological assessments to registered older volunteers. First, we will calculate weighted scores based on volunteers' subjective and objective ratings of various volunteering activities across three dimensions—cognitive, physical, and social activities—incorporating both directionality and absolute values to create a directionality-inclusive volunteering "involvement index" to inform volunteering type selection for subsequent intervention studies. Second, we will use multilevel linear models to examine relationships between the volunteering involvement index and hot-cold cognitive functions, exploring cross-level interactions between volunteering involvement and participation intensity. Finally, based on these analyses, we will employ multilevel mediation models to investigate potential moderating effects of volunteers' neuropsychological characteristics (e.g., personality traits, socialization, emotion, sleep) on the relationship between volunteering and cognitive function.

4.2 Neuropsychological Mechanisms of Volunteering's Effects on Cognitive Function

We will recruit community-dwelling older adults and randomly assign them to four groups: cognitively-oriented volunteering, socially-oriented volunteering, active control, and passive control. Different volunteering types will be selected based on the involvement index from Study 1. The active control group will receive physical and mental health education, while the passive control group will have no contact. Assessments will occur at four time points over one year: pre-test, mid-test, post-test, and six-month follow-up. First, we will examine effects of different volunteering types on hot-cold cognitive functions. Second, we will investigate intervention time-dependency through comparisons across the four time points. Third, we will construct competing models to identify the optimal fit for volunteering interventions on cognitive function, clarifying relationships between hot-cold cognitive changes.

Multimodal neuroimaging data, including structural, resting-state, and task-based imaging, will be collected at pre-test and post-test for all four groups. Beyond traditional volumetric and task activation analyses, we will focus on brain modularity as a global metric to reveal the neural basis of volunteering interventions. Previous research indicates this measure shows cognitive intervention plasticity through increased modularity post-intervention, with baseline modularity predicting intervention outcomes. This study will explore volunteering's effects on brain modularity in older adults, whether these effects are modulated by volunteering type, and the feasibility of using modularity as a feature in intervention effect prediction models.

4.3 Individual Differences in Intervention Effects and Predictive Models

As volunteering is a real-world intervention, individual differences may be more pronounced than in laboratory-based cognitive interventions. Building on group-level analyses, we will further examine individual differences in intervention effects using latent change models. Model results will enhance our understanding of intervention efficacy while identifying significant observed variables to inform personalized intervention model construction.

Based on individual difference analyses, we will employ machine learning to construct classification models for determining which volunteering type best suits each older adult, followed by regression models to predict cognitive enhancement from matched interventions. First, classification models will be built based on intervention effectiveness (effective vs. ineffective) for different volunteering types, using pre-intervention baseline information as features, with cross-validation evaluating classification accuracy. After identifying suitable intervention types, regression models will predict cognitive-neural enhancement for matched interventions by calculating improvement scores (post-minus pre-intervention) across cognitive dimensions, using baseline information as features and cross-validation to evaluate prediction accuracy.

5. Theoretical Construction and Innovation

Cognitive intervention represents a key focus in aging research and an effective pathway for promoting active aging. This study examines the scientific validity of volunteering interventions for older adults' cognitive function, exploring causal relationships and brain mechanisms between volunteering and cognitive improvement from a hot-cold dual-system perspective. Using cognitively-oriented and socially-oriented volunteering as interventions, we attempt to ameliorate age-related cognitive decline, construct a dual-system neuropsychological model of volunteering's effects, and reveal domain-specific influences of volunteering type.

(1) Role transformation breaks traditional intervention perspectives. Volunteering as an intervention transforms older adults from passive help recipients into active help providers. This approach effectively avoids limitations of traditional cognitive interventions by leveraging subjective agency, enhancing sustainability, expanding beneficiary populations, and improving ecological validity.

(2) Constructing a dual-system neuropsychological model to explain mechanisms. From the hot-cold dual-system perspective, this project uses cognitively-oriented and socially-oriented volunteering as interventions to examine changes in community-dwelling older adults' cognitive functions and neural basis, constructing a dual-system neuropsychological model (Figure 2 [Figure 2: see original paper]) that reveals domain-specific effects of volunteering type.

Figure 2. Hypothesized dual-system neuropsychological model of volunteering's effects on older adults' cognitive function

(3) Achieving personalized intervention. Beyond traditional group-level analyses, this project employs latent change models to examine individual differences in intervention effects. Feature selection will inform machine learning classification algorithms for optimal volunteering type matching, followed by regression algorithms to predict cognitive enhancement from matched interventions, thereby achieving personalized intervention.

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Note: Figure translations are in progress. See original paper for figures.