Neurobehavioral mechanisms influencing the association between generativity, the desire to promote well-being of younger generations, and purpose in life in older adults at risk for Alzheimer's disease

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Abstract

Objectives: Generativity, the desire and action to improve the well-being of younger generations, is associated with purpose in life among older adults. However, the neurobehavioral factors supporting the relationship between generativity and purpose in life remain unknown. This study aims to identify the functional neuroanatomy of generativity and mechanisms linking generativity with purpose in life in at-risk older adults.

Methods: Fifty-eight older adults (mean age = 70.8, *SD* = 5.03, 45 females) with a family history of Alzheimer's disease (AD) were recruited from the PREVENT-AD cohort. Participants underwent brain imaging and completed questionnaires assessing generativity, social support, and purpose in life. Mediation models examined whether social support mediated the association between generativity and purpose in life. Seed-to-voxel analyses investigated the association between generativity and resting-state functional connectivity (rsFC) to the ventromedial prefrontal cortex (vmPFC) and ventral striatum (VS), and whether this rsFC moderated the relationship between generativity and purpose in life.

Results: Affectionate social support mediated the association between generative desire and purpose in life. Generative desire was associated with rsFC between VS and precuneus, and, vmPFC and right dorsolateral prefrontal cortex (rdlPFC). The vmPFC-rdlPFC rsFC moderated the association between generative desire and purpose in life.

Discussion: These findings provide insight into how the brain supports complex social behavior and, separately, purpose in life in at-risk aging. Affectionate social support may be a putative target process to enhance purpose in life in older adults. This knowledge contributes to future developments of personalized interventions that promote healthy aging.

Keywords: Self-transcendence, Prosociality, Resting-state fMRI, Ventromedial prefrontal cortex, Ventral striatum

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1. Introduction

Alzheimer's disease (AD) is a progressive neurodegenerative disease characterized by a decline in behavioral and cognitive abilities, such as memory, learning, and reasoning. Identifying disease prevention strategies is crucial, as delaying the onset of AD by 5 years could reduce its prevalence by 50% (Brookmeyer et al, 1998). One risk factor associated with a 1.26x increased risk of dementia is social isolation (Shen et al, 2023). Older adults who have high levels of perceived social support show higher cognitive abilities and a reduced risk of dementia, even in cases of preclinical AD or mild cognitive impairment (Marioni et al., 2015). This suggests that social support plays a vital role in preventing or delaying AD-related cognitive decline.

There is growing evidence that older adults undergo a 'prosocial goal shift' where behaviours aimed at benefitting the well-being of others become increasingly rewarding with age (Isaacowitz, 2021). A key aspect of social motivation is generativity, which involves both the desire to contribute to the well-being of younger generations (referred to as generative *desire*) and actions directed towards increasing their well-being (referred to as generative *achievement;* Gruenewald et al., 2016). Originally defined by Erikson (1950) in his psychosocial development theory, generativity is a stage at midlife that arises from a desire to be needed. Erikson proposed that generativity in midlife evolves into "grand-generativity" during older adulthood characterized by a reflective evaluation of one's life and legacy. Prior studies have shown that generativity remains stable or even increases in older adulthood (Isaacowitz, 2021). Moreover, it is associated with life satisfaction, well-being, participation in productive activities, self-efficacy, and physical health (Gruenewald et al, 2012; Pinazo-Hernandis et al., 2023).

The relationship between generativity and well-being in older adulthood aligns with the predictions of Socioemotional Selectivity Theory (SST; Carstensen, 2006). SST posits that an individual's perception of their time horizons influences their prioritization of social goals (Carstensen, 2006). In young adulthood when time is perceived as open-ended, goals involving knowledge acquisition are prioritized. In contrast, in older adulthood when time is perceived as limited, goals that enhance

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socioemotional well-being in the present take precedence. Generativity, by promoting the well-being of future generations, can serve as a means for older adults to maximize their socioemotional well-being. Notably, SST seems to apply to older adults in the preclinical and early stages of AD where mental states that promote prosocial behavior, including positive affect, social attention, and empathic concern, are preserved or enhanced compared to age-matched controls (Sturm et al., 2019). These findings raise the intriguing possibility that social factors may be particularly important intervention targets for AD prevention.

Generativity can be enhanced in older adulthood through parenting, grandparenting, or volunteer work that establishes intergenerational connections (Villar et al., 2021). For instance, the Baltimore Experience Corps Trial (BECT) is an intergenerational program where older adults volunteer to help elementary school students with reading. Compared to a control group, participants in this program showed significantly increased generative desire and achievement following the intervention, and this effect was sustained after 24 months (Gruenewald et al., 2016). Additionally, older adults who participated in the program demonstrated improved physical, social, and cognitive functioning compared to a control group (Carlson et al., 2009; Tan et al., 2006). A subgroup of older adults in this study who were at the greatest risk of cognitive impairment (i.e., Mini-Mental State Examination score < 24 or diminished executive function at baseline) showed the greatest improvement in memory, executive function and prefrontal activation following the intervention (Carlson et al., 2009; Carlson et al., 2008). This suggests that intergenerational programs promoting generativity might be particularly effective for older adults at a greater risk of cognitive decline.

Generative desire and achievement are significantly shaped by cultural influences. One study compared generativity across diverse cultural contexts, revealing that Cameroonians had higher generative goals and Germans had lower prosocial motivation than their counterparts, possibly due to the impact of collectivist (i.e., Cameroonian) and individualistic (i.e., German) cultural influences on generativity (Hofer, 2007). In contrast to Western values where preserving individual legacy is

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paramount, Alaskan Indigenous communities instead prioritize the transfer of spirituality and traditions to younger generations to preserve their community and cultural identity (Lewis, 2023). In Asian cultures where multigenerational households are common, generativity is associated with increased social interaction with children and grandchildren as well as participation in grandparenting activities (Dohlman et al., 2023). Finally, in Ibero-American contexts, family and intergenerational relationships carry significant socio-historical and cultural importance, marked by frequent intergenerational contact. In Chilean older adults, it was found that the quality of intergenerational relationships, rather than the extent of grandparenting childcare responsibilities, was associated with older adults' subjective well-being (Herrera et al., 2022). Thus, cultural factors influence the significance of family relationships and the frequency of intergenerational contact, thereby impacting older adults' desire to be generative and the nature of generative behaviours in which they engage.

Converging behavioral studies have demonstrated the positive association between generativity and purpose in life in older adults (de St. Aubin, 2013). Purpose in life is a subfacet of psychological well-being defined as having goals, directedness, and feelings that give one's life meaning (Boyle et al., 2010). According to McAdams and de St. Aubin's (1992) generativity model, the integration of generativity into older adults' lives allows them to construct a meaningful identity and life story, leading to purpose in life (Kruse & Schmitt, 2012). This life purpose is associated with many facets of successful aging, including increased physical health, greater engagement in health behaviors, and a reduced risk of AD and dementia (Boyle et al., 2010; Pinquart, 2002). A longitudinal analysis by Serrat et al. (2018) demonstrated that generativity at baseline predicted older adults' eudaimonic well-being (i.e., fulfilling personal goals and realizing one's full potential), including purpose in life, after retirement. Another study revealed that the association between generative concern and purpose in life was mediated by generative goals across diverse cultural samples (Hofer et al., 2014). The role of generativity in enhancing older adults' purpose in life has also been demonstrated in randomized controlled trials. In one study, older adults attended a life review writing workshop followed by a session where they shared their writing with students

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(Chippendale & Boltz, 2015). Increased purpose in life was observed in these older adults compared to those who attended the writing workshop alone. Another randomized controlled trial had older adults write life advice for assisting younger adults (generativity condition) or write about neutral topics (control condition; Moieni et al., 2020). Those in the generativity condition showed increased well-being and participation in social activities compared to age-matched controls.

Older adults who demonstrate higher levels of generativity are more likely to reported greater social support compared to those with lower generativity levels (Hart et al., 2001). High generativity fuels both the desire for social participation as well as translates it into actions that establish and sustain supportive relationships (Cruse & Schmitt, 2012; Moieni et al., 2021). An intervention specifically tailored to enhance generativity demonstrated notable increases in social well-being (Moieni et al., 2021). Intergenerational relationships are thought to play a pivotal role in providing older adults with multifaceted support that contributes to a heightened social identity and purpose (Rossi et al., 2014). Older adults high in generativity are more likely to participate in community-oriented compared to self-oriented activities (Pinazo-Hernandis et al., 2023), broadening opportunities for building and maintaining supportive social relationships. Moreover, there appears to be a reciprocal relationship between giving and receiving social support in intergenerational relationships. It was previously shown that older adults providing support to younger individuals predicts the older adults' subsequent receipt of financial and emotional support from younger adults (Murayama et al., 2022). Prior research also underscores how social support received is positively associated with older adults' purpose in life, with machine learning techniques revealing that higher perceived social support and social engagement can predict older adults' purpose in life (Mei et al., 2021). Despite these observations, research has yet to investigate whether social support mediates the effect of generativity on purpose in life.

It is imperative to identify modifiable behaviors that can predict purpose in life, especially among older adults at risk for AD. This is crucial considering that purpose in life tends to decrease with age (Pinquart, 2002), yet it is associated with slower rates of cognitive decline, a reduced risk of AD, and

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mitigating effects of AD pathology on cognition (Boyle et al., 2012). Additionally, social isolation affects approximately one quarter of American adults over 65 and ranks among one of the major risk factors for AD (Ren et al., 2023). Generativity and social support emerge as modifiable behaviours that are positively associated with purpose in life in older adulthood, making them promising targets for behavioral interventions aimed at AD prevention. Despite cognitive decline, individuals with mild cognitive impairment and mild to moderate AD often demonstrate preserved or enhanced socioemotional processing (Sturm et al., 2019). Additionally, individuals with early AD retain the ability to regulate negative emotions by seeking emotional support (Frezza et al., 2022). Therefore, strategies aimed at enhancing generativity and social support might prove to be particularly effective for older adults with an elevated risk of AD.

Understanding the neural mechanisms supporting generativity is a crucial step in comprehending and potentially modifying this behaviour. To date, no studies have examined the functional neuroanatomy of generativity, making it an important area of research for developing brain-based interventions to promote health and resilient aging. Resting-state functional connectivity (rsFC) is a powerful method for studying the functional organization of the brain and the networks supporting internal mental processes and behavior (Stevens & Spreng, 2014). Based on prior research, it is possible that generativity relies on brain systems implicated at the intersection of value-based decision making and self-transcendence. A coordinate-based meta-analysis identified the ventromedial prefrontal cortex (vmPFC) and ventral striatum (VS) as nodes of the reward network implicated in value-based decision making by representing the subjective value of decision options (Bartra, 2013). The vmPFC is particularly important in considering emotional content during subjective valuation and demonstrates higher activity when older adults attend to positive relative to negative stimuli (Mather, 2016; Vaidya et al., 2018). Rademacher et al. (2014) found that there was enhanced activity in the VS for social compared to monetary rewards for older adults, while activity in the VS was higher for monetary compared to social rewards in younger adults. These results highlight the potential involvement of the vmPFC and VS in social motivation,

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including generativity. Moreover, self-transcendence, the process of shifting one's focus from self-interests to the well-being of others and humanity, is closely related to generativity. Previous research has shown that self-transcendence and prosocial behaviour are associated with activity in the vmPFC and VS (Kang et al., 2018).

Individual differences in rsFC of regions of the reward network could serve as a crucial neural moderator influencing the link between generativity and purpose in life. It is established that goals and behaviours that are aligned with one's personal values are associated with a higher sense of purpose (McGregor & Little, 1998). Activity of the valuation network, particularly the vmPFC, supports the emotional value of decision options and behaviors that hold emotional value are known to contribute significantly to older adults' life purpose and overall well-being (Carstensen, 2006). The vmPFC is a region that integrates conceptual and affective information, supporting self-transcendence (Cascio et al., 2016) and the generation of emotional meaning (Roy et al., 2013), processes vital for well-being. Another component of the reward network, the VS, is implicated in the assessment of social rewards and goal pursuit (Braams et al., 2014; Kawamichi et al., 2016; Rademacher et al., 2014). Importantly, the VS is crucial for affirming personal values (Cascio et al., 2016), and its activity has been shown to predict greater purpose in life (Heller et al., 2013). Given that intergenerational relationships hold emotional value for older adults (Isaacowitz, 2021; Lyndon & Moss, 2022) and emotionally significant relationship contribute to older adults' life purpose and well-being (Carstensen, 2006), individuals demonstrating higher rsFC of the vmPFC and VS may display a stronger relationship between generativity and purpose in life.

This study has two primary aims. The first aim is to identify a behavioral mechanism that explains how generativity enhances purpose in life in at-risk older adults. First, it is hypothesized that generativity will be positively associated with purpose in life, thus replicating prior findings in a sample of older adults at risk of AD. Given that generativity enhances supportive relationships, and social support has been shown to predict purpose in life in older adulthood, it is hypothesized that social support will

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mediate the relationship between generativity and purpose in life. The second aim of this study is to identify the functional neuroanatomy supporting generativity and purpose in life in older adults at risk of AD. It is hypothesized that generativity will be positively associated with rsFC to the vmPFC and VS, key regions at the convergence of reward valuation and self-transcendence. It is additionally hypothesized that rsFC to the vmPFC and VS will moderate the association between generativity and purpose in life, providing insight into the neural mechanisms influencing the relationship between generativity and purpose in life.

2. Methods

2.1 Participants

Participants consisted of 58 cognitively unimpaired older adults (M_{age} = 70.78, 45 female) from the PResymptomatic EValuation of Experimental or Novel Treatments for Alzheimer's Disease (PREVENT-AD) cohort at McGill University (Tremblay-Mercier et al., 2021). A Monte Carlo power analysis (Schoemann et al., 2017) determined that a sample size of N = 58 was required for detecting an indirect effect with power of 80%, correlations of .40 for the *a* and *c'* paths, and a correlation of .50 for the *b* path. Fifty participants from the original sample had MRI data available and were included in the rsFC analyses. G*Power version 3.1 (Faul et al., 2007) was used to conduct power analyses for the moderation analysis. The analysis showed that a sample size of N = 50 was required for detecting an interaction with a small-to-medium effect size of f^2 = 0.13 and power of 80%. The PREVENT-AD cohort consists of adults 55 years and older who are cognitively unimpaired at the time of enrollment and have a first-degree family history of AD. Participants were considered *APOE ε4* carriers if they had at least one *ε4* allele. All inclusion and exclusion criteria are shown in Table 1. Participant demographics for the full and MRI sub-samples are shown in Table 2.

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2.2 Procedure

MRI scans were collected from the PREVENT-AD cohort in 2021, two years prior to the collection of the cognitive tests and questionnaires in this study. The Repeatable Battery for Assessment of Neuropsychological Status (RBANS; see Supplementary Materials) was administered to the PREVENT-AD cohort in 2022, and these data were used to calculate a measure of global cognition to include as a covariate in the statistical models. All study procedures were approved by the McGill University Research Ethics Board. Participants from the PREVENT-AD cohort were recruited for an optional sub-study by contacting them via phone and email and by sending flyers in the mail. All eligible participants then attended a videoconferenced meeting with a member of the research team where they were provided with detailed information about study procedures and were given the opportunity to ask any questions. All participants provided written informed consent in accordance with the Declaration of Helsinki. Thereafter, all participants completed computerized cognitive assessments (see Supplementary Materials) and an online battery of questionnaires, described below.

2.3 Behavioral Inventories

The BECT Generativity Questionnaire (Gruenewald et al., 2016). This measure was used to assess generative desire and achievement. Participants rated the extent to which they agree with seven generative desire statements (e.g., "I want to make a difference in the lives of others.") and six generative achievement statements (e.g., "I feel like I make a difference in my community.") on a 6-point Likert scale ranging from *strongly disagree* to *strongly agree*. Scores for the generative desire subscale ranged between 7 and 42, with higher scores indicating greater generative desire. Scores for the generative achievement subscale ranged between 6 and 36, with higher scores indicating greater generative achievement.

The Medical Outcomes Study Social Support Survey (Sherbourne & Stewart, 1991). This measure consists of 19 items that assess the availability of four types of social support. The emotional and informational support subscale consists of eight items that measure how often individuals have someone to

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listen to them, confide in, and provide them with advice and information. The tangible support subscale consists of four items that measure the frequency of support in daily tasks such as chores and preparing meals. The affectionate support subscale consists of three items that measure how often individuals have someone to show them love and affection. Finally, the positive social interaction subscale consists of three items that measure how often individuals have someone to spend time and do enjoyable things with. Each item is scored on a Likert scale of 1 to 5 where 1 = *none of the time* and 5 = *all the time*. Scores for each subscale are obtained by calculating the mean score across its items. All scores range between 1 and 5, with higher scores indicating a higher availability of social support.

The Psychological Well-Being Purpose in Life subscale (Ryff et al., 2007). This inventory consists of seven items that measure the extent to which individuals have goals, a sense of directedness, and beliefs that give life meaning (e.g., "Some people wander aimlessly through life, but I am not one of them."). Each item is scored using a Likert scale from 1 to 7 where 1 = *strongly disagree* and 7 = *strongly agree*. Negatively worded items are reverse coded, then scores on all items are summed to create a total score. Total scores range between 7 and 49, with higher scores indicating greater purpose in life.

2.4 Analyses

2.4.1 Behavioral Analyses

First, two linear regression models were conducted to determine whether generative desire or achievement predicted purpose in life, while controlling for age, sex, *APOE ε4* carrier status, and overall cognition. Then, Model 4 of the PROCESS macro for SPSS, version 4.0 (Hayes, 2022) was used for the mediation analyses. Generative desire and generative achievement were entered as predictor variables in separate models, with purpose in life included as the outcome variable in each. Sex, age, and *APOE ε4* carrier status, and overall cognition were included as covariates in all mediation models. Affectionate social support and positive social interactions scores were significantly correlated with generative desire, generative achievement, and purpose in life ($ps < .05$). Therefore, four separate models were computed with

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affectionate social support and positive social interactions included as mediators and generative desire and generative achievement included as predictors of purpose in life. The indirect effects were tested using a percentile bootstrapping method with 1000 samples. Because four separate mediation models were computed, we applied a Bonferroni correction and used 99% confidence intervals for detecting significant indirect effects.

2.4.2 Functional Brain Imaging Analyses

Information concerning MRI acquisition and preprocessing can be found in the Supplementary Material. Seed-to-voxel rsFC analyses were performed using the CONN toolbox (Whitfield-Gabrieli & Nieto-Castanon, 2012). Two regions of interest (ROIs) in the vmPFC and VS were functionally defined using seeds from Batra et al.'s (2013) meta-analytic conjunction analysis on the neural correlates of subjective value. The average time series in the vmPFC and VS ROIs were extracted. First-level correlation maps were obtained by extracting product-moment correlation coefficients between the average time series in each ROI and the time series of all other voxels. Correlation coefficients were then Fisher transformed to z-scores to increase normality prior to the second-level general linear models. Seed-to-voxel maps for the vmPFC and VS are included in Figures 1 and 2 of the Supplementary Materials. Two general linear models were computed for each ROI, with generative desire and generative achievement included as the covariates of interest. Age, sex, mean head framewise displacement, and *APOE ε4* carrier status were included as nuisance variables in the general linear models. All analyses were performed with voxel level $p < .001$ and a cluster-size $p < .05$ family wise error (FWE) corrected cluster-extent threshold to correct for multiple comparisons.

Next, a moderation analysis using Model 1 of the SPSS PROCESS macro was conducted to examine the interactive effect between rsFC and generative desire on purpose in life. Fisher-transformed z-scores were extracted from the rsFC analyses. Generative desire and rsFC values were mean centered to reduce multicollinearity. A generative desire x rsFC interaction term was computed and entered as a predictor of purpose of line in the regression models.

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3. Results

3.1 Behavioral Analyses

Separate linear regression models controlling for age, sex, *APOE ε4* carrier status, and overall cognition revealed that generative desire (β = 0.29, SE = 0.14, 95% CI [0.02, 0.56], p = .039) and generative achievement (β = 0.43, SE = 0.14, 95% CI [0.15, 0.70], p = .003) were significant predictors of purpose in life. The model with affectionate social support included as the mediator between generative desire and purpose in life was statistically significant (Figure 1). In particular, the direct effect of generative desire on purpose in life was no longer statistically significant after controlling for the effect of affectionate social support (β = 0.16, SE = 0.13, 99% CI [-0.20, 0.51], p = .241). Furthermore, the indirect effect was statistically significant (β = 0.13, SE = 0.06, bootstrapped 99% CI [.005, .30]. This suggests that affectionate social support fully mediated the effect of generative desire on purpose in life. The mediation models with generative achievement as the predictor or positive social interactions as the mediator variable did not reveal statistically significant indirect effects.

3.2 Functional Brain Imaging Analyses

As shown in Figure 3A, generative desire was associated with enhanced rsFC between the vmPFC seed and a cluster in the right dorsolateral prefrontal cortex (rdlPFC; $t(45) = 4.43$, voxel $p < 0.001$ uncorrected, cluster p-FWE < 0.05, peak voxel MNI coordinates = [24, 32, 44], k = 54). Generative desire was also positively associated with rsFC between the VS seed and a cluster in the right precuneus, (Figure 3B; $t(45) = 5.55$, voxel $p < 0.001$ uncorrected, cluster p-FWE < 0.05, peak voxel MNI coordinates = [06, -58, 54], k = 154). A bivariate product-moment correlation analysis showed that generative desire was not significantly correlated with mean head framewise displacement, r = .151, p = .333. Seed-to-voxel analyses with generative achievement included as the covariate of interest were not statistically significant.

The interaction between generative desire and rsFC between the vmPFC and rdlPFC on purpose in life was also statistically significant (Figure 2A; β = 1.69, SE = 0.58, 95% CI [0.51, 2.87], p = .006).

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Simple slopes for the association between generative desire and purpose in life at low (-1 standard deviation (SD) below the mean), moderate (mean), and high (+1 SD above the mean) levels of rsFC are shown in Figure 2B. Simple slope tests revealed statistically significant associations between generative desire and purpose in life at high rsFC values (β = 0.79, SE = 0.25, 95% CI [0.28, 1.29], p = .003) and moderate rsFC values (β = 0.43, SE = 0.18, 95% CI [0.07, 0.80], p = .021). The simple slope was not statistically significant at low rsFC (β = 0.08, SE = 0.18, 95% CI [-0.28, 0.45], p = .649). The interaction between generative desire and VS-precuneus rsFC approached but failed to reach statistical significance, p = .078.

4. Discussion

The aim of the present study was to identify neurobehavioral factors influencing the relationship between generativity and purpose in life in older adults who are at risk for AD. This research builds upon prior work indicating an association between generativity and purpose in life in older adults (de St. Aubin, 2013). The current findings expand upon this by revealing that the availability of affectionate social support mediated the relationship between generative desire and purpose in life. Additionally, there was a significant association between generative desire and heightened vmPFC-rdlPFC and VS-precuneus rsFC. The strength of vmPFC-rdlPFC rsFC moderated the association between generative desire and purpose in life.

The behavioral mediation analysis revealed a positive association between generative desire and affectionate social support, which in turn was positively associated with purpose in life. The relationship between generative desire and affectionate social support aligns with the broaden-and-build theory, which posits that intrinsic motivation (i.e., generative desire) can augment positive emotions that allow individuals to build greater social resources, amplifying the availability of social support (Fredrickson, 2001). Thus, it is possible that older adults with higher generative desire cultivate more relationships that provide them with love and affection, resulting in greater life purpose. The current results are also consistent with motivational lifespan theories, such as SST, that propose that as individuals age, they

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prioritize goals that optimize their socioemotional well-being. Given prior research showing that generativity is a modifiable psychological state (Gruenewald et al., 2016), the current results suggest that increasing generative desire could be a means for older adults to enrich their socioemotional state (i.e., their perceived love and affection from others), thereby enhancing older adults' ability to experience a sense of direction and life purpose. Enhancing older adults' perceived social support and purpose in life is vital given that they tend to decline in old age, partly due to life changes such as retirement and widowhood (Pinquart, 2002). Moreover, high social support and purpose in life during aging have been shown to protect against cognitive decline and mental and physical health issues (Boyle et al., 2010; Pinquart, 2002; Ren et al., 2023).

To our knowledge, this is the first study to investigate various domains of social support and their relationships with generativity and purpose in life. The finding that only affectionate social support and positive social interactions were associated with these variables can be understood in light of socioemotional changes in aging (Carstensen, 2006). In intergenerational family relationships, close and affectionate social support from adult children has been shown to be particularly beneficial for older adults' well-being (Merz et al., 2009). In contrast, excessive tangible and informational support can have negative effects on older adults' well-being due to perceived reductions in autonomy and increased feelings of dependency (Djundeva et al., 2015). Another study found that emotional, but not tangible, support from children predicted older adults' well-being (Merz & Huxhold, 2010). Moreover, compared to younger adults, older adults report being motivated to participate in intergenerational programs due to the pleasure and satisfaction derived from the program and the establishment of positive intergenerational relationships (Cohen-Mansfield, 2022). These findings align with the predictions of SST suggesting that older adults are more likely to pursue emotionally meaningful relationships and attend to positive over negative information (Carstensen, 2006). Both affectionate social support and positive interactions elicit feelings of being loved and positive affect, respectively (Jakubiak & Feeney, 2017; Macdonald et al., 2021). In contrast, the tangible and informational domains of social support involve providing practical

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assistance, advice, and information, which are less emotive in nature and therefore may not contribute significantly to older adults' purpose in life.

The findings of vmPFC-rdlPFC and VS-precuneus rsFC being positively associated with generative desire can be understood in light of prior fMRI and neurostimulation studies. Our findings highlight how generative desire is associated with functional coupling between task-negative and task-positive brain networks. The vmPFC is a region within the reward and default mode networks that is active during internally-directed, passive cognitive tasks such as reward valuation and self-transcendent processing (Bartra et al., 2013; Kang et al., 2018). Conversely, the dlPFC is a hub in the executive control network, involved in functions like planning and working memory during externally-directed tasks (Petrides, 2005). Similarly, the precuneus is a region of the default mode network, implicated in higher-order cognitive functions such as self-referential processing, episodic memory retrieval, and mental imagery (Cavanna & Trimble, 2006), while the VS is a subcortical region activated during reward anticipation and reinforcement learning (Bartra et al., 2013). Both the vmPFC and VS exhibit heightened activity during reward anticipation and self-affirmation, particularly when affirmations focus on future experiences as opposed to past ones (Cascio et al., 2016). Additionally, increased mPFC activity is linked to imagining future positive events compared to negative ones (D'Argembeau et al., 2008). The finding that rsFC to both of our hypothesized ROIs was associated with generative desire but not achievement may reflect the distinction between desire, which involves contemplating future-oriented episodes and goals, and achievement, which instead emphasizes reflection on past episodes.

The enhanced vmPFC-rdlPFC in those with higher generative desire aligns with the default-executive coupling hypothesis of aging proposed by Spreng and Turner (2019) and the finding of diminished anti-correlation between medial prefrontal cortex and dlPFC in aging (Keller et al., 2013). According to this neurocognitive model of aging, there is an age-related shift in goal-directed cognition characterized by a decline in cognitive control abilities and an accumulation of semantic knowledge. The model suggests that the increased reliance on semantic knowledge in aging is associated with concurrent

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heightened executive control network activity (e.g., lateral PFC) and reduced suppression of the default mode network (e.g., medial PFC). This coupling has also been shown to extend to regions within the reward network during goal simulation. In an fMRI study by Gerlach et al. (2014), participants mentally simulated the process of achieving a goal and, subsequently, the experience of achieving that goal. They showed that simulating the goal achievement process resulted in enhanced functional connectivity between default mode and executive control network regions, whereas simulating the experience of achieving the goal involved enhanced connectivity between default mode and reward network regions. Future research should therefore examine whether generative desire in older adults involves a heightened reliance on semantic knowledge rather than cognitive control processes when cultivating future goals. This might suggest that the default mode network supports older adults' ability to access internal mental representations of themselves and the world when envisioning goals that promote the well-being of future generations.

In addition to goal setting, vmPFC-rdlPFC connectivity has also been observed in prosocial decision making. In one study, participants who underwent transcranial magnetic stimulation (TMS) to the rdlPFC rejected selfish options in favour of costly options that benefited others (Baumgartner et al., 2011). The prioritization of others over the self was associated with enhanced connectivity between vmPFC to rdlPFC. The authors concluded that the rdlPFC might exert top-down executive control over the vmPFC, thus preventing the impulse to act selfishly in favour of a prosocial alternative. These results highlight how enhanced vmPFC to rdlPFC rsFC in those with higher generative desire might support older adults' ability to suppress self-serving impulses or tendencies, thereby facilitating the pursuit of prosocial, generative goals. This aligns with Erikson's (1950) definition of generativity as the "ability to transcend personal interests to provide care and concern for younger and older generations."

Generative desire also exhibited an association with heightened rsFC between the VS and precuneus. This finding aligns with prior research showing increased VS-precuneus connectivity in tasks of social cognition and social reward. In a study where older adults were tasked with deciding whether

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different words characterized themselves or someone close to them, enhanced connectivity between the default mode network and the VS was observed, compared to vowel and motor tasks. This suggests a close link between self-referential processing and reward in aging (Grady et al., 2012). Similar to the vmPFC, the precuneus is implicated in prosocial decision-making. A study by Dubey et al. (2020) demonstrated increased activity in the precuneus and vmPFC when participants decided to watch social movies and during the viewing of such movies compared to movies depicting objects. The authors suggested that the precuneus and vmPFC play roles in evaluating social stimuli, encompassing both the "wanting" and "liking" aspects of social motivation. Moreover, connectivity between the VS and the precuneus is positively correlated with the frequency of social engagement and varies with individuals' preferences for interacting with others (Kawamichi et al., 2016), indicating a neural correlate of social reward. Research has shown that the VS is more active when receiving rewards compared to losses for others, while the precuneus is more active when receiving rewards for others compared to rewards for the self, underscoring the involvement of these regions in prosocial behavior (Braams et al., 2014). Thus, increased VS-precuneus rsFC may be associated with older adults' ability to experience reward from social stimuli, thereby fostering the desire to enhance the well-being of future generations.

We additionally found that connectivity between the vmPFC and rdlPFC moderated the association between generative desire and purpose in life, with high rsFC (+1 SD above the mean) demonstrating the strongest, positive relationship between generative desire and purpose in life. This highlights how individual differences in brain connectivity might influence older adults' ability to derive life purpose from generative desire. In particular, it underscores how there is a need to consider individual differences in order to develop the right interventions to enhance generativity and purpose in life for the right individual at the right time. Moreover, it highlights how future research using therapeutics (e.g., rTMS) that increase vmPFC-rdlPFC rsFC could potentially bolster the relationship between generative desire and purpose in life, particularly in older adults at risk of AD. This presents an interesting avenue for future research.

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Nonetheless, the present study does have certain limitations. The brain imaging data were acquired two years prior to the collection of the behavioral data. Given that generativity and rsFC are impacted by age-related processes, this presents a putative temporal confound. While all participants in this study are at risk of AD due to a first-degree family history, no participants in this study were diagnosed with mild cognitive impairment (MCI) or early dementia. A potential avenue for future research would be to examine the presence of AD biomarkers (e.g., PET amyloid-tau) in the vmPFC, rdlPFC, VS, and precuneus of individuals with MCI or early dementia and their impact on generative desire over the disease course, thereby offering insights into the relationship between generativity, AD biomarkers, and cognitive functioning.

Moreover, this study has limitations due to the disproportionate representation of women and individuals of Caucasian ethnicity in the current sample. Research indicates gender differences in generativity, with women more likely to express generativity through caregiving or volunteering, placing a higher value on social connectedness and others' needs, whereas men are more inclined to demonstrate generativity through teaching and passing on knowledge and skills (Chen et al., 2022). As a result, it is conceivable that the mediation effect of social support on the relationship between generative desire and purpose in life may be more applicable to women than men. Consequently, future research should explore sex and gender differences in the mechanisms linking generativity to purpose in life. Furthermore, generativity varies across ethnicities and cultural contexts. For instance, studies have shown that generative desire and achievement, social support, and the provision of wisdom through parenting were higher in African Americans than Caucasians (Hart et al., 2001). Therefore, to enhance the generalizability of the findings, it is essential to replicate these results in more diverse samples. Future research should also take into account other variables, such as education level, health status, cultural background, quality of support networks, and emotional regulation, to better understand the influence of these factors on generativity in aging and their relationships with social support and purpose in life. This

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comprehensive approach will provide crucial insights into the individual differences in the expression of generativity during aging.

In summary, this study demonstrated that generative desire was associated with greater rsFC between the vmPFC and rdlPFC as well as the VS and precuneus, regions implicated in goal-directed cognition and prosociality. Moreover, vmPFC-rdlPFC rsFC and affectionate social support were found to moderate and mediate the relationship between generative desire and purpose in life, respectively. The results of the current study have practical implications for promoting the health and well-being of at-risk older adults. Interventions designed to enhance generativity and affectionate social support may be effective to increase purpose in life in older adults at risk for cognitive impairment (Gruenewald et al., 2016). Future interventions might increase their efficacy by implementing familial intergenerational strategies that enhance feelings of love, appreciation, and affection in older adults. Prior research has demonstrated that older adults in early stages of AD experience preserved socioemotional functioning (Sturm et al., 2019), suggesting that such interventions might also be effective for those with early functional impairment. Finally, a deeper understanding of the brain basis of generativity is crucial to understand the cognitive processes and brain mechanisms that support healthy aging. These findings may guide the development of personalized interventions and circuit-based strategies to promote resilient aging.

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Conflict of Interest

The authors have no conflicts of interest to disclose.

Data Availability

All data and materials can be made available upon request. The analyses in this study were not preregistered.

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Tables

Table 1

Inclusion and exclusion criteria for the study sample

Inclusion criteria	Exclusion criteria
• Age 60 years or older • Self-reported parental or sibling history of Alzheimer-like dementia • Adequate vision to complete the computerized cognitive tasks • Ability to read, speak, and write in English or French	• History of a major psychiatric illness (schizophrenia or attention-deficit/hyperactivity disorder [ADHD]) • Current treatment for cancer (excluding non-melanoma skin cancer) • Diagnosis of a neurological disorder (multiple sclerosis, Parkinson's, dementia, stroke) or moderate to severe traumatic brain injury • Current treatment for congestive heart failure, angina, uncontrolled arrhythmia, deep vein thrombosis (DVT), or other cardiovascular condition • A cardiac event that occurred in the past six months (e.g., myocardial infarction, coronary artery bypass grafting, angioplasty) • Any change in an antipsychotic, anti-depressant, anti-anxiety, or attention deficit disorder / attention deficit hyperactivity disorder medication in the past six months • Current alcohol, barbiturate or benzodiazepine abuse/dependence

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Table 2

Demographics, neurobehavioral inventory scores, and computerized cognitive assessment scores for the full sample and MRI sub-sample

Demographic Variable	**Full Sample (*N* = 58)**	**MRI Sub-Sample (*n* = 50)**
Sex, *n* (%)		
Male	13 (22.4%)	10 (20%)
Female	45 (77.6%)	40 (80%)
Age (years), *M* (*SD*)	70.78 (5.03)	70.44 (5.10)
Education (years), *M (SD)*	15.79 (2.96)	15.98 (2.90)
***APOE ε4* Carrier Status, *n* (%)**		
Carrier	20 (34.5%)	17 (34%)
Non-carrier	38 (65.5%)	33 (66%)
Ethnicity, *n*, (%)		
Caucasian	57 (98.3%)	50 (100%)
African American	1 (1.72%)	
Social Support, *M* (*SD*)		
Total	4.18 (0.62)	4.18 (0.63)
Emotional / Informational	4.13 (0.78)	4.15 (0.79)
Tangible	4.11 (0.99)	4.04 (1.04)
Affectionate	4.20 (0.75)	4.21 (0.72)
Positive interactions	4.19 (0.74)	4.20 (0.69)
Generativity, *M (SD)*		
Generative desire	30.26 (6.58)	30.68 (6.86)
Generative achievement	22.41 (6.26)	22.82 (6.19)
Purpose in Life, *M (SD)*	36.33 (6.89)	36.56 (7.05)
RBANS, *M (SD)*		
Total	100.67 (9.31)	101.54 (9.05)
TMB Digital Neuropsychology Toolkit, *M* (*SD*)		
Simple Reaction Time	381.96 (78.20); Z = -0.69 (1.22)	380 (81.12); Z = -0.65 (1.22)
Choice Reaction Time	1258.66 (539.64); Z = 0.15 (1.24)	1228.26 (423.87); Z = 0.26 (0.98)
GOCP (Discrimination)	2.68 (0.84); Z = 0.11 (0.84)	2.69 (0.87); Z = 0.03 (0.81)
GOCP (Impulsivity)	0.38 (0.42); Z = 0.20 (1.07)	0.41 (0.42); Z = 0.16 (1.12)
Matrix Reasoning	21.96 (6.82); Z = 0.03 (1.04)	22.76 (6.04); Z = 0.07 (0.98)
Forward Digit Span	6.48 (1.92); Z = 0.20 (1.12)	6.35 (1.83); Z = 0.14 (1.09)
Backward Digit Span	5.19 (1.85); Z = 0.23 (1.00)	5.27 (1.92); Z = 0.22 (1.01)
Visual Paired Associates	14.35 (4.33); Z = 0.22 (0.96)	14.54 (4.20); Z = 0.15 (0.91)
Digit Symbol Matching	35.96 (8.72); Z = -0.31 (0.61)	35.61 (8.73); Z = -0.42 (0.69)

Note. MRI = magnetic resonance imaging; GOCP = Gradual Onset Continuous Performance Test. Social support scores come from The Medical Outcomes Study Social Support Survey (Sherbourne & Stewart, 1991). Generativity scores come from the Generativity Questionnaire (Gruenewald et al., 2016). Purpose in life scores are derived from The Psychological Well-Being Purpose in Life subscale (Ryff et al., 2007). TMB refers to TestMyBrain Digital Neuropsychology Toolkit (Singh et al., 2021) and RBANS refers to The Repeatable Battery for the Assessment of Neuropsychological Status (Randolph et al., 1998), with both described in the Supplementary Material.

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Figures

Figure 1

Diagram of the Mediation Model Results Between Generative Desire and Purpose in Life.

Note. The *a* path represents the effect of generative desire on affectionate social support; the *b* path represents the effect of affectionate social support on purpose in life; the *c* path represents the total effect of generative desire on purpose in life; the *c'* path represents the direct effect of generative desire after controlling for affectionate social support; the *ab* path represents the indirect effect. *p < .05, **p < .01.

Figure 2

Ventromedial Prefrontal Cortex (vmPFC) to Right Dorsolateral Prefrontal Cortex (rdlPFC) Resting-State Functional Connectivity (rsFC) Moderating the Effect of Generative Desire on Purpose in Life.

Note. Panel A shows a diagram of the model and Panel B shows the interaction effect. Generative desire and resting-state connectivity values are centered to their means. Purpose in life was regressed on generative desire at low (-1 standard deviations), moderate (mean), and high (+1 standard deviations) levels of resting-state functional connectivity. vmPFC = ventromedial prefrontal cortex; rdlPFC = right dorsolateral prefrontal cortex. **p < .01, *p < .05.

Figure 3

Ventromedial Prefrontal Cortex to Right Dorsolateral Prefrontal Cortex and Ventral Striatum to Right Precuneus Resting-State Functional Connectivity is Associated with Generative Desire.

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Note. Panel A displays the ventromedial prefrontal cortex seed (blue) to right dorsolateral prefrontal cortex connectivity (yellow). Panel B displays the ventral striatum seed (blue) to right precuneus connectivity. Clusters are overlaid on a standard template and are corrected for multiple comparisons.

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Figure 1

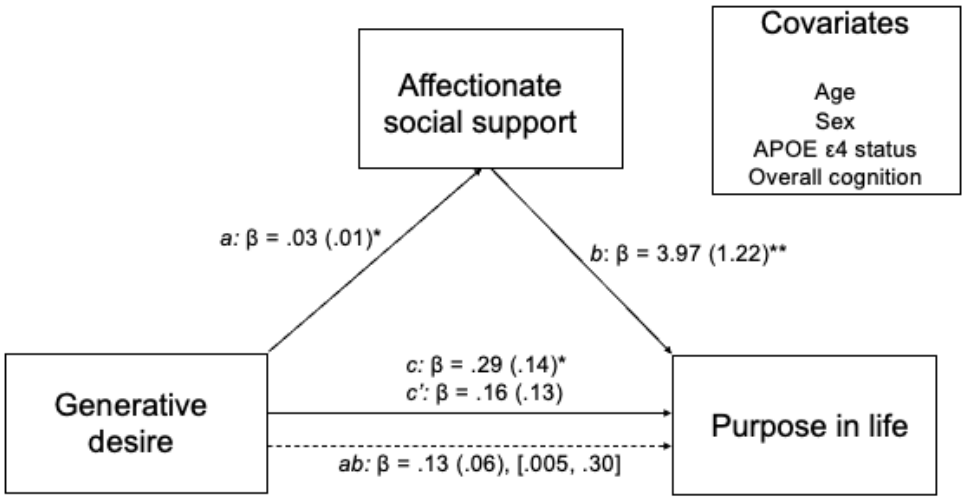

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Figure 2

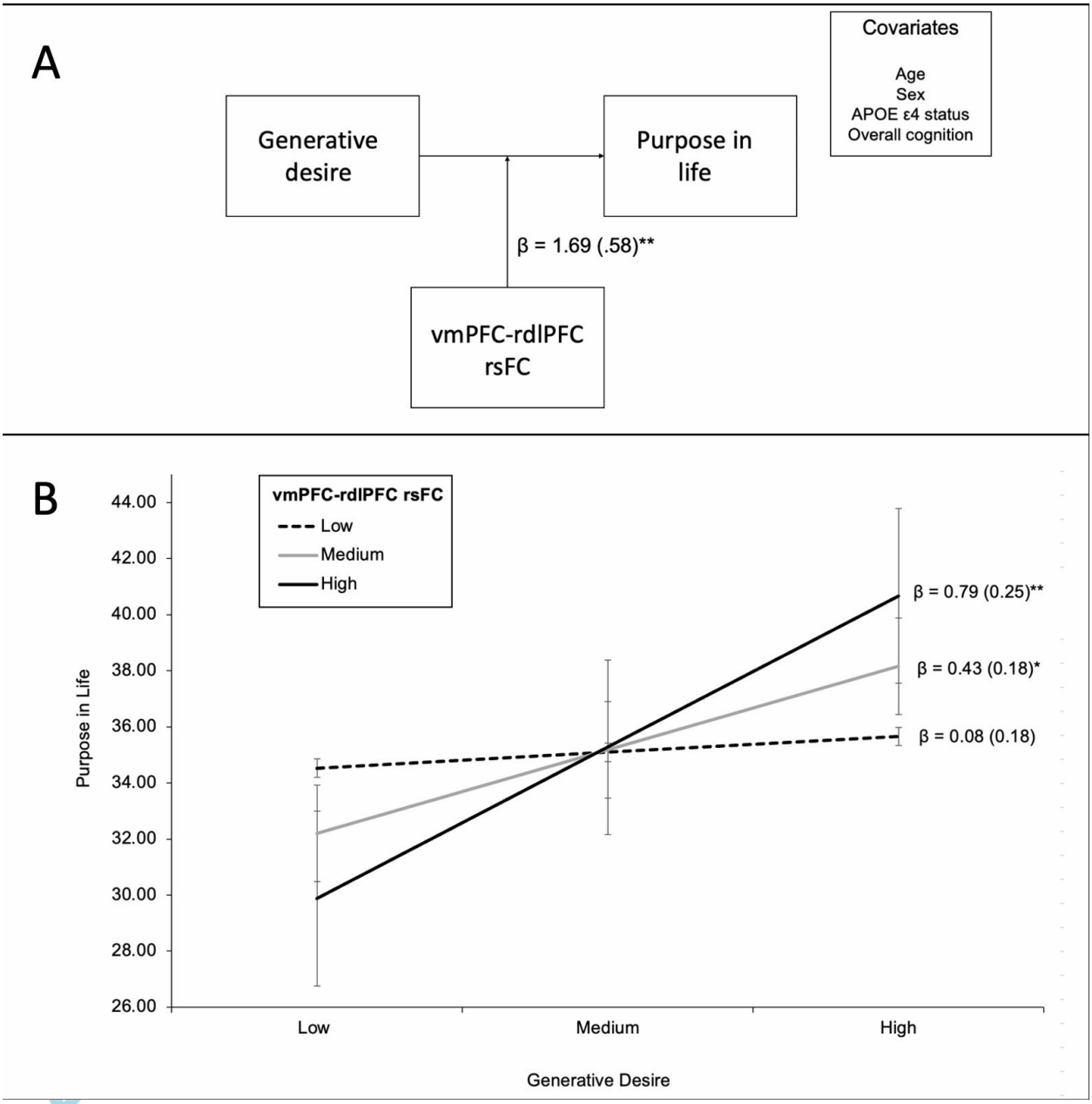

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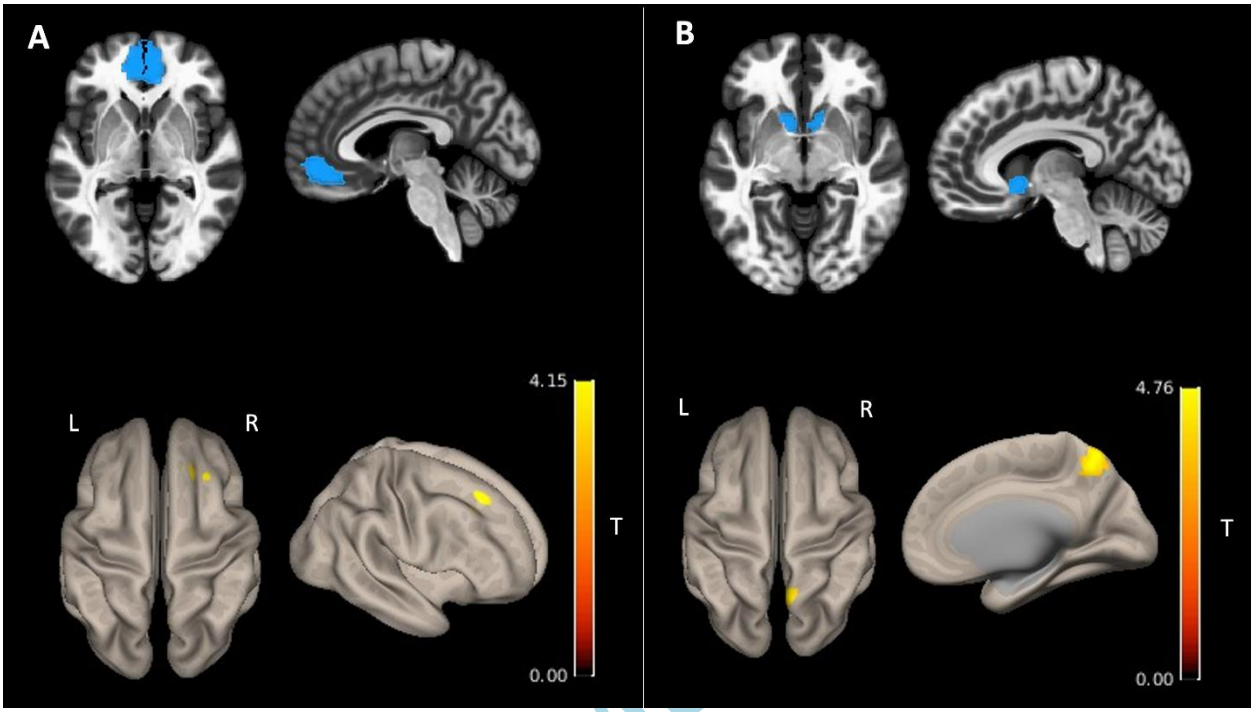
Figure 3



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