Leisure Activity, Health, and Medical Correlates of Neurocognitive Performance Among Monozygotic Twins: The Older Australian Twins Study

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Objectives. We aimed to examine associations between each of three leisure activities (Cognitive, Physical, and Social) and performance in selected cognitive domains (Speed, Memory, Verbal ability, and Executive functions) and global cognition. We also aimed to explore associations between medical and health factors and late-life cognition.

Method. Our sample comprised 119 pairs of monozygotic twins from the Older Australian Twins Study. Their mean age was 71 years and 66% were women. We used a discordant co-twin design, with cognitive performance measures as dependent variables and leisure activities as independent variables. Multiple regression analyses were performed, adjusting for potentially relevant medical and health factors.

Results. Discordance in Cognitive Activity and Social Activity participation was positively associated with discordance in performance on some cognitive domains. There were no associations between Physical Activity participation and cognition. Discordance in several cardiovascular, frailty, and sensory variables was associated with discordance in cognitive performance measures.

Discussion. This study identified lifestyle and health-related influences on late-life cognition. Our findings not only help in understanding the neurobiological mechanisms, they also have practical implications for interventions to prevent or slow age-related cognitive decline.

Key Words: Aging—Cognition—Health—Leisure activity—Twins.

Cognitive decline is a characteristic feature of aging and age-related conditions, such as Alzheimer’s disease (AD) and vascular dementia. Both genetic and environmental factors contribute to cognitive decline in late adulthood. The heritability of AD has been estimated from a large population-based twin study to be 79% (Gatz, Reynolds, et al., 2006), and the apolipoprotein E ε4 allele is a strong contributor to this genetic risk (Holmes, 2002). Nongenetic or environmental factors also influence the risk of AD, with those that are modifiable being potential targets for strategies aiming to prevent AD. The same factors are also expected to influence the cognitive decline and impairment preceding the often insidious onset of AD, and understanding these effects is crucial for assessing and optimizing the effectiveness of early intervention strategies.

A potentially important influence on cognitive decline or impairment that has been extensively studied is leisure activity, which encompasses cognitive pursuits, physical exercise, and social engagement. However, the effects of these leisure activities on cognitive functioning in older adults is unclear, with an earlier review finding beneficial effects (Fratiglioni, Paillard-Borg, & Winblad, 2004), but a later one concluding that the evidence is limited (Plassman, Williams, Burke, Holsinger, & Benjamin, 2010). A number of relatively recent studies have reported associations between the three leisure activities and cognition or AD, including social resources and cognitive change (Hughes, Andel, Small, Borenstein, & Mortimer, 2008), physical exercise, and cognition (Langlois et al., 2012; Wilbur et al., 2012), and cognitively stimulating activities and AD (Treiber et al., 2011). Other health, medical, and lifestyle factors have also been implicated in cognitive decline in older adults, both in normal aging and dementia. Declining vision (Clay et al., 2009), olfactory impairment (Wilson, Arnold, Tang, & Bennett, 2006; Wilson et al., 2009), hypertension (Oveisgharan &
Some previous studies have used samples of twins to investigate environmental influences on cognition in later life. Twin studies can help isolate environmental influences by providing a degree of inherent control for genetic influences. The extent of this control is greater for studies using monozygotic (MZ) twins, who share nearly identical genomes and early environmental influences, than for studies using dizygotic twins, who share on average 50% of their segregating genes.

Twin studies have reported relationships between late-life cognitive decline or AD and environmental factors that include education (Gatz et al., 2001; Räähi, Kaprio, Koskenvuo, Rajala, & Sourander, 1998), depression, tooth loss before the age of 35 and short adult height (Gatz, Mortimer, et al., 2006), and lack of physical exercise, less favorable lipid values, poorer grip strength, and “higher emotionality” (Gatz, Reynolds, Finkel, Pedersen, & Walter, 2010). One study particularly using MZ twins found social activity to be significantly associated with cognition (McGue & Christensen, 2007).

Across all types of studies, both positive and negative associations between leisure activity and cognitive functions have been reported. Potential reasons for this include age-dependent and/or activity-specific effects on the neural substrates of cognition, and that may be further complicated by variation across different cognitive domains. This study of associations between leisure activities and cognitive functioning in later life aimed to address some of these issues. To control for genetic influences, we used a discordant MZ twin design, in which discordances (differences) between individuals in a twin pair are the unit of analysis. We examined associations between discordance in each of the three types of leisure activities (Cognitive, Physical, and Social) and discordance in cognitive performance assessed in terms of both separate cognitive domains and a global composite score. In being a well-established and core feature of AD, episodic memory was one of the domains we examined. We also examined processing Speed and Executive functions, which have been postulated (Salthouse, 1996; West, 1996) and empirically supported (Lee et al., 2012) as mediators of relationships between aging and cognition. Verbal performance was included as a further domain, as language impairment is reported to be involved in some dementing processes (Hall, Vo, Johnson, Wiechmann, & O’Bryant, 2012). We augmented our investigation by also analyzing associations between discordances in cognition and some medical and health factors that have been identified as potentially important influences on late-life cognitive function.

Methods

Participants

Our study sample initially comprised 138 MZ twin pairs from the Older Australian Twins Study (OATS). They were aged 65 or older and enrolled at one of the three study centers from three eastern states (New South Wales, Queensland, and Victoria) of Australia. They were sourced from the Australian Twin Registry, media release, and newspaper advertisements. The inclusion criteria were ability to consent to participate, having a consenting co-twin, having completed some education in English, and being of at least low average intelligence (IQ ≥ 80). Exclusion criteria were life-threatening illness, inadequate English to participate in assessments, and acute psychosis. Written consent was provided by the participants, and the study was approved by the ethics committees of the various organizations involved. Details of ethics approval and methodology of the OATS had been reported elsewhere (Sachdev et al., 2009). Zygosity was determined by genotyping with high-density single-nucleotide polymorphism arrays. More than 99% of the co-twins in the OATS were assessed within 6 months of one another. Nineteen MZ twin pairs were excluded from this study because of missing questionnaire data for all three leisure activities, giving a final study sample size of 119 twin pairs.

Measures

1. Leisure activity measures.—Data on leisure activities were collected by interview and a questionnaire adapted from the San Diego Successful Aging Questionnaire (Jeste, 2005; Montross et al., 2006).

Cognitive activity. Participants rated the frequency of their engagement in each of the following 20 activities: knowledge games, board games, crossword puzzles, listening to radio, listening to music, reading newspaper, reading books, reading magazines, letter writing, doing original art, doing kit art, leading discussions, managing investments, routine financial work, visiting museum, computer activities, travelling, attending lectures, doing paid work, and speaking or reading a second language. Two cognitive activity scores were obtained: the total number of activities participated in (maximum score = 20) and the frequency of activities participated in (each coded as 0 = never or not in the past year, 1 = less than once per month, 2 = one to more than five times per month, 3 = daily; maximum score = 60).

Physical exercise. Participants rated their participation in 17 activities. Three physical activity scores were formed: (a) the number of activities participated in during the past 4 weeks; (b) the highest intensity across all activities participated in, coded as 1 (low) for walking leisurely, walking to do errands, stretching/flexibility exercise, and
general conditioning exercise, 2 (moderate) for walking fast, cycling, aerobic machine, stairs machine, swimming gently, water exercise, yoga or tai chi, aerobic exercise/dancing, light strength training, and ball sports, and 3 (high) for jogging or running, swimming moderately fast or fast, and heavy strength training; and (c) the total number of occasions of participation in these activities each week.

Social engagement. Participants provided ratings for the seven social activities: contact family member, contact neighbor, talk to neighbor, contact friends, group activities, church activities, and voluntary work. “Contact” included visits, telephone calls, letters, and electronic mail. Two scores were derived: the number of social activities participated in and the frequency of participation: coded as 0 = never, 1 = few times a year to every month, 2 = weekly, and 3 = daily.

The leisure activities variables used for analysis were component scores derived from a principal components analysis of the two Cognitive Activities, three Physical Activities, and two Social Activity scores. There were three components, with each of these clearly interpretable as representing one of the leisure activities. Root-one criterion and inspection of the plot of eigenvalues, using the scree test, suggested that three components could be extracted. This solution (percent variance explained = 58.9%) is shown in Supplementary Table 1. Cronbach alpha reliability estimates of the component scores, based on composite scales using items defining the component, were 0.944, 0.842, and 0.905 (well above the commonly adopted benchmark value of 0.70; Nunnally, 1978).

2. Cognitive performance measures.—Cognitive assessments were conducted by trained research psychologists and included the following:

Processing speed. Trail Making Test A (Reitan & Wolfson, 1985) and Digit Symbol Coding Test (Wechsler, 1997). The z-scores from these two tests were averaged to form the domain score for “Speed.”

Episodic memory. (a) Logical Memory Story A (Wechsler, 1987), the z-scores of immediate recall and delayed recall were averaged to quantify one component score for verbal memory. (b) Three measures from the Rey Auditory Verbal Learning Test (Rey, 1964): total learning, recall after distraction, and delayed recall. These were combined by averaging their z-scores to form a second component score for verbal memory. (c) Visual memory was assessed with the Benton Visual Retention Test (Sivan & Spreen, 1996). The z-scores from the three episodic memory tests were averaged, and the z-score of their mean formed the “Memory” domain.

Verbal abilities. Z-scores of a verbal fluency test (Controlled Oral Word Association Test; Benton & Hamsher, 1989), a 30-item version of the Boston Naming Test (Kaplan, 2001), and Similarities (Wechsler, 1997), a test of verbal abstract reasoning, were averaged and followed by using the z-score of their mean to form the “Verbal” domain.

Executive functions. Digit Span Backward (Wechsler, 1997) represented working memory, the ratio score of Trail Making Test B/Trail Making Test A indexed cognitive flexibility (Arbuthnott & Frank, 2000), and the ratio score of Stroop interference/Stroop word reading (Delis, Kaplan, & Kramer, 2001) denoted response inhibition. The z-scores from these three tests were averaged, and z-score of their mean formed the “Executive” domain.

Global cognitive function. A General Cognition score was calculated from averaging the four cognitive domain scores, followed by transformation to z-score.

3. Demographic, medical, health, and lifestyle measures.—Information obtained from an interview and a brief medical examination by the research psychologist included the following.

Sociodemographic. Age, sex, and education (number of years). IQ was estimated from the National Adult Reading Test (Nelson & Willison, 1991).

Cardiovascular health and medical history. Previous diagnoses of diabetes, diagnosis of hypertension, current hypertension (systolic and diastolic blood pressures, averaged of three measurements), coronary artery disease (myocardial infarction or angina), atrial fibrillation, other heart disease (any of cardiac arrhythmia, cardiomyopathy, heart valve disease), arthritis, number of general anesthetics, number of head injuries, long-standing kidney disease, and number of falls in the past 18 months.

General health. Body mass index (BMI; kg/m²), hip-to-waist ratio, previous diagnosis of high cholesterol, 6-m walk time (Waite, Broe, Grayson, & Creasey, 2001), and gait (coded 0–4, cannot walk to normal), sit-to-stand time and ability (coded 0–3, incapable to being independent), stability/balance (time standing with eyes closed), odor identification (Brief Smell Identification Test score; Doty, Marcus, & Lee, 1996), self-rated hearing and vision, and visual acuity (obtained using a 3-m Standard Contrast LogMAR chart and calculated as \(1.78 - \log_{10} \) line number, averaged for both eyes).

Mental health. Previous diagnosis of depression, scores from the 15-item Geriatric Depression Scale (Sheik & Yesavage, 1986), and scores from the Goldberg Anxiety Scale (Goldberg, Bridges, Duncan-Jones & Grayson, 1988).

Lifestyle. Alcohol consumption (none, monthly, weekly, daily) over the past year and cigarette smoking (current, past, never).
Statistical Analysis

As stated earlier, 19 twin pairs were excluded from the study for missing data for all three leisure activities. There were small amounts of missing data among the included 119 twin pairs, and for which we imputed values for discordance scores, using the expectation maximization method (Dempster, Laird, & Rubin, 1977). For each of the three activity composites, we imputed scores for between one and five twin pairs. Among the control variables, values were imputed for between 1 and 16 twin pairs. No cognitive variables required imputation, as there was no missing discordance score after the cognitive domains were formed.

Correlations among the leisure activities and cognition scores were examined for each of the Twin 1 (first born) and Twin 2 groups separately. Within-pair Pearson correlations and the means and standard deviations (SD) of the absolute differences between Twin 1 and Twin 2 were also calculated for each of the activity and cognition scores.

Our main analyses aimed at investigating the relationships between discordance in leisure activities and discordance in cognition scores. We considered assigning twin pairs to arbitrarily defined discordance groups as potentially limiting the validity of our results and consequently treated both sets of discordance variables as continuous. Continuous discordance scores were generated by first transforming the three leisure activities (Cognitive, Physical, and Social) and five cognitive (Speed, Memory, Verbal, Executive, and General Cognition) variables to z-scores using the means and SD for the total sample of all individual twins (N = 238). We then calculated the algebraic difference between twins as Twin 1 − Twin 2.

A series of five multiple regressions were carried out with the three activity discordance scores as independent variables and each of the five cognition discordance scores as the dependent variables. To prevent outliers exerting an undue influence on the results, scores greater than three SD from the mean for variables in these analyses were truncated to values of three SD from the mean. Discordance scores for the demographic, medical, health, and lifestyle measures were calculated in a similar manner to those of the activities and cognition discordance scores and were used as control variables in the analyses. Because of the large number of control variables, we used the stepwise procedure (with p for entry and exclusion set to .10 and .11, respectively) to reduce the number of control variables in the equations. The set of control variables present in any of the five reduced models was retained and used as a common set of control variables for the final regression analyses reported. After applying a Bonferroni correction for multiple testing, regression coefficients with p < .01 were considered as statistically significant. We also report a set of regression analyses without any control variables included in the models, and with each of the leisure activities, discordance scores entered separately into the equations.

Results

Demographic characteristics of the sample are shown in Table 1 (for leisure activities, cognitive variable values, and final control variable values see Supplementary Table 2). The mean age, years of education, and estimated IQ of the sample (71.2, 11.1, and 107.2, respectively) were similar to that of the full OATS sample (70.7, 11.0, and 106.0, respectively). The female-to-male ratio of 2:1 was similar to that of other studies of older adult twins. None of the participants had a Mini-Mental State Examination score of less than 24, a generally accepted cutoff for mild dementia, and the mean estimated IQ was at the higher end of the average range. There were no significant differences in the characteristics of the Twin 1 and Twin 2 groups.

Table 2 shows the correlations among the three activities and five cognition variables within each of the Twin 1 and Twin 2 groups. All correlations among the cognition scores were positive and statistically significant, as were all correlations among the leisure activities. Correlations between cognition domain scores and leisure activities were generally lower and not all were statistically significant. Cognitive activity was relatively strongly and significantly correlated with all of the cognitive variables in both the Twin 1 and Twin 2 groups. Compared with the individual cognitive domains, General Cognition had typically higher correlations with the leisure activities. Table 2 also shows intrapair Pearson correlations for the main variables investigated and the mean differences in scores between twins in each pair for each of these (i.e., the means of the absolute discordance). All intrapair correlations were statistically significant, ranging from 0.28 for Physical Activity to 0.76 for General Cognition. The mean differences between twins within pairs ranged from just under half an SD for General Cognition (mean = 0.46) to 0.90 SD for Physical Activity. The SD reported were those for the total sample of 238 individuals.

Table 3 shows the results of regression analyses with leisure activity discordance scores as independent variables and cognitive discordance scores as dependent variables. For Model 1, each of the predictors was entered separately and no control variables were included. For Model 2, all three leisure activity discordance scores were entered.
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simultaneously as predictors and the nine control variables selected in preliminary analyses were also included.

The Model 1 results include statistically significant relationships between discordance scores for Cognitive Activity and Speed (β = 0.39, p < .001) and Social Activity and Memory (β = 0.24, p = .009). Associations between Cognitive Activity and each of the Verbal domain (β = 0.22, p = .011) and General Cognition (β = 0.21, p = .019) were not statistically significant. The main Model 2 results, with control variables included, are statistically significant associations between discordance scores for Cognitive Activity and each of the Speed and Verbal domains (β = 0.41, p = .001 and β = 0.25, p = .005, respectively) and for Social Activity and the Memory domains (β = 0.26, p = .007).

For three of the control variables, discordance was significantly and independently associated with discordance on at least one cognitive variable. Gait during the 6-m walk test was associated with Memory (β = 0.26, p = .002), and odor identification was associated with both the Verbal...
Discordance in participation in Social Activity was associated with discordance in General Cognition domain ($\beta = 0.31, p = .001$). BMI was also associated with the Verbal domain ($\beta = -0.29, p = .001$). There were several other initially significant relationships between control and cognitive variables that did not meet the $p < .01$ criterion adopted to correct for multiple comparisons. These were diagnosis of hypertension and Speed and sit-to-stand time and Speed ($p = .011$ and $p = .012$, respectively), kidney disease and the Verbal domain ($p = .030$), odor identification and the Executive domain ($p = .031$), and gait during the 6-m walk test and General Cognition domain ($p = .018$).

**Discussion**

This study investigated the relationships between leisure activities and late-life cognitive functioning, comparing discordance in cognitive performance with discordance in participation in Cognitive, Physical, and Social activities among older adults’ MZ twins. Influences of medical, health, and other lifestyle factors on these relationships were also investigated.

We found discordance in Cognitive Activity to be positively associated with discordance of performance in both the Speed and Verbal measures, meaning that greater participation in cognitive activities was associated with better performance on these cognitive domains. This lends some support to previous research that suggests cognitive activities protect against AD and other dementias (Fratiglioni et al., 2004). Our findings can also be considered consistent with the “disuse hypothesis” and the axiom “use it or lose it” (Hultsch, Hertzog, Small, & Dixon, 1999). Claims of strong support cannot be made as our research design did not permit the establishment of cause-effect relationships. In contrast, our findings are not supportive of some aspects of the cognitive reserve hypothesis (Stern, 2006). This is because the discordance on variables serving as proxies for cognitive reserve (years of education and IQ estimated with a reading test) did not predict discordance in performance on General Cognition or any of the individual cognitive domains. The finding that there was no association between participation in cognitive activities and episodic memory performance is somewhat unexpected, given that cognitively stimulating activities appear to benefit people with mild-to-moderate dementia (Woods, Aguirre, Spector, & Orrell, 2012). However, it is possible that effects observed in dementia patients do not occur as strongly in individuals with normal cognition. This is similar to the idea that engagement in cognitive leisure activities reduces risks of dementia but has no effects on the rates of normal cognitive aging (Salthouse, 2006).

Discordance in participation in Social Activity was associated with discordance in the Memory domain. This is in keeping with research findings that more socially active older adults experienced less cognitive decline across various cognitive domains, including perceptual Speed (Lovden, Ghisietta, & Lindenberger, 2005) and episodic Memory (James, Wilson, Barnes, & Bennett, 2011). It has been suggested that Social activities provide contact and support that facilitate social competence, enhance mood, and lower stress (Fratiglioni et al., 2004). From a neurobiological perspective, the mechanism linking social engagement and memory might therefore involve the hippocampus, as this plays a role in both the response to stress and episodic memory. It could even be that social engagement induces psychological or physiological changes that affect the hippocampus or other neural substrates of memory. Conversely, social interaction can be dependent on episodic memory. Episodic memory allows a person to reevaluate their past behavior and is an adaptive tool for socialization (Klein et al., 2009). Social Activity was not associated with any cognitive domain other than Memory, which could help explain why there are mixed findings for an influence of this leisure activity on more general measures of cognition in the literature.

Unlike Cognitive or Social Activity, participation in Physical Activity was not associated with performance on any cognitive domain in this study. This is unexpected, given the relatively low intrapair twin correlation ($r = .28$) and thus exerts relatively low concordance in Physical Activity among the twin pairs. This is also at odds with evidence that physical exercise is beneficial for cognitive functioning. For example, a recent meta-analysis of 11 randomized controlled studies found aerobic exercise and resistance training to be beneficial for executive functioning and memory, respectively (Gates, Sachdev, Fiatarone Singh, & Valenzuela, 2013). It may be that relationships between physical activity and cognitive performance are greatest for activities that are structured and/or performed under supervision, such as those in intervention programs. Our null finding could also reflect the broad range of activities (e.g., from light leisurely walking to more vigorous jogging/running) in our Physical Activity factor, particularly if relationships between Physical Activity and Cognition are influenced by activity type, intensity level, and/or cognitive domain. Our results could also have been limited by Physical Activity being self-reported. Though more difficult to obtain, objective measures of Physical Activities have proven to be more accurate than self-report measures (Middleton et al., 2011; Miller, Taler, Davidson, & Messier, 2012).

In addition to discordance in leisure activities, this study found discordance in several health and medical history factors as associated with discordance in cognitive performance. Discordance in odor identification ability was associated with discordance in General Cognition, which is in accordance with previous research and readily accounted for by known relationships between degenerative olfactory changes and both decline in global cognition (Wilson et al., 2006) and cortical neurodegeneration (Christen-Zaech et al., 2003). Discordance in odor identification was also
particularly associated with discordance in performance on the Verbal domain. This association can be considered in the context of the prefrontal cortex being a secondary area of olfactory processing (Westerveld, Ruffolo, & Tremont, 2005), as two of our three Verbal measures involve frontal functions. A verbal semantic memory component to the odor identification task could also have contributed to this association, as correct naming of odor depends on both knowledge and retrieval of odor names (Oberg, Larsson, & Backman, 2002).

Discordance in some physical frailty measures was related to discordance in cognitive performance. This includes better gait during the 6-m walk test being significantly associated with better Memory performance, and tending to be associated with General Cognition. This is in accord with research into the gait and cognition relationship in aging (Bridenbaugh, Monsch, & Kressig, 2012; Ikram, Verlinden, Hofman, van der Geest, & Erasmus, 2012), although memory has not always been found to be associated with various aspects of gait (Ikram et al., 2012). In contrast, there was a tendency for faster sit-to-stand time to be associated with poorer performance on the Speed domain. Although this unexpected relationship is to be interpreted cautiously (given the lack of significance after adjustment for multiple comparisons), it could reflect a reduction in frontal lobe functions, such as inhibition and insight, that leads cognitively impaired older adults having to hurry when performing physical tasks (Van Iersel et al., 2005). Older adults without cognitive impairment may be more cautious (and thus take more time) when performing physical tasks.

We found an inverse relationship between discordance in BMI and discordance in performance on the Verbal domain, reflecting poorer verbal performance with higher BMI. This is in keeping with a previous finding of faster decline in verbal abilities among individuals with higher BMI (Sellbom & Gunstad, 2012). We also identified some cardiovascular factors as tending toward having a significant association with cognition, including a previous diagnosis of hypertension and lower performance on Speed, and higher systolic blood pressure and better performance on the Executive domain. Though counterintuitive, the latter finding is supported by previous reports of higher blood pressure being associated with less risk of cognitive impairment, including dementia, among older individuals (Coley et al., 2008).

The use of MZ twins is a strength of this study, with the sharing of genetic influences between individuals facilitating the identification of unique environmental effects. There are limitations, however, including a reliance on self-report measures that may have particularly affected our results for Physical Activity, as discussed earlier. Limited by the cross-sectional nature of our study, we are not able to establish a causal relationship in the associations. There is also an assumption in cross-sectional studies, such as ours that older identical twins remain genetically similar, but it is likely that epigenetic changes exert an increasing influence with age.

In summary, when optimally controlling for genetic effects, our investigation of relationships between discordance in leisure activities and discordance in cognitive performance found participation in cognitive activities to be associated with performance on Speed and Verbal domains and participation in social activities to be associated with performance on a Memory domain. Participation in physical activities was not associated with cognitive performance. We also found discordance in cognitive performance to be independently associated with discordance in BMI, gait in 6-m walk, and odor identification. Our general findings could be used to help design strategies aiming to maintain or enhance cognitive health among older individuals. Of particular utility are the leisure activities and health factors related to cognition that are potentially modifiable.

Supplementary Material

Supplementary material can be found at: http://psychsocgerontology.oxfordjournals.org/

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