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Daily Physical Activity: Relation to Everyday Memory in Adulthood

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Abstract

We examined the relationship between daily physical activity and everyday memory using an eight-day diary design with young, middle-aged, and older adults. Contrary to expectations, age differences were not reported in the frequency of memory failures and daily physical activity at the between-person level. Multilevel modeling, however, indicated that on days when adults engaged in leisure exercise (physical activity performed during leisure or free time) they reported fewer memory failures, and this was most apparent for older adults. Lagged analyses indicated that when leisure activity was reported on one day, fewer memory failures were reported the next day, and this was especially true for older adults. Thus, findings demonstrate that the benefits of physical activity for memory in later life are observable on a short-term daily basis.

Problems with memory are commonly reported in adulthood, especially in later life (Erber, Szuchman, & Rothberg, 1992; Lachman, 2004). Extensive research efforts are devoted to identifying factors that could contribute to enhanced memory in later life (e.g., Gilewski, Zelinski, & Schaie, 1990). Given that there are large individual differences in the nature and extent of memory declines, there is interest in modifiable behavioral factors that could minimize memory loss in later life. One promising behavioral factor is physical activity. There is widespread evidence that exercise is associated with better cognitive functioning (e.g., Colcombe & Kramer, 2003). Some of this work is based on experimental studies (Barnes, Yaffe, Satariano, & Tager, 2003) or randomized trials (Lachman, Neupert, Bertrand, & Jette, 2006), but it is not known if the relationships between such exercise interventions and cognitive tests are also manifested at the daily level in everyday physical activity and memory functioning. The bulk of previous work has been conducted using correlational designs. Thus, it is unclear whether activity influences cognition or whether those with good cognitive functioning are more likely to be active (Hultsch, Hertzog, & Dixon, 1999). Even those few studies that are longitudinal have not reached clear conclusions, in part because the reports of exercise or memory are based on retrospective accounts asking participants to recall memory failures or exercise over the period of a month or longer (Ghisletta, Bickel, & Lövdén, 2006). The present study used a within-person daily diary design examine whether factors typically found related to memory in the lab or over longer time periods would also be related to performance on a daily basis. Specifically, we

were interested in whether daily variations in physical activity would be related to daily memory functioning. While previous work has found that daily reports of memory failures are related to daily stress in older adults (Neupert, Almeida, Mroczek & Spiro, 2006a), variations by age or the role of physical activity in daily memory functioning have not been examined.

Everyday Memory

Identifying measures able to tap into the realm of memory failures encountered on a daily basis has received considerable attention in recent years. While psychometric tests performed under laboratory conditions allow for changes in participants cognitive performance to be followed, researchers have argued that these results may not be relevant to everyday or daily memory failures (e.g., Sunderland, 1990; Sunderland, Harris, & Baddeley, 1983). For example, research has provided evidence for a discrepancy between psychometric tests and subjective reports of everyday forgetting (Newcombe & Artioli i Fortuny, 1979; Pollina, Greene, Tunick, & Puckett, 1993).

Given these discrepancies, a greater effort to examine the underlying mechanisms of everyday memory has been put forth. One such way to tap into day-to-day memory functioning is to ask participants to provide self-reports. The inherent problem surrounding self-reports of everyday memory functioning is how well people can accurately record their own memory performance. Instead, this self-report is considered to be metamemory (Hickox & Sunderland, 1992), or a person's beliefs of his or her memory. Research related to self-evaluations of memory suggests that as people age, perceptions about overall memory become more negative (Berry & West, 1993). Additionally, older adults' complaints about memory have also been linked to such variables as depression, self-efficacy, and personality (Pearman & Storandt, 2004). Given this research, Hultsch, Dixon, and Hertzog (1985) suggested that the divergence between laboratory measures and self-report questionnaires may be more an artifact of older adults' inaccurate beliefs about their actual memory performance rather than errors in self-reports.

Still, other researchers have offered alternate explanations. Sunderland and colleagues (1986) have suggested that because demands from the environment may be an important factor in everyday memory (such as an individual's lifestyle), everyday memory may not be necessarily well-represented by traditional cognitive tests. Indeed, research has suggested that a relationship between self-reports and test performance exists for older but not younger adults (Zelinski, Gilewski, & Thompson, 1980). Such evidence suggests that administering self-report questionnaires is a suitable technique for assessing memory failures in older adults.

Additionally, the methodology used in the current study was such that participants were not asked to recall memory failures more than 24 hours after they had occurred. By reducing the interval between the incidence and report of the memory failure, there is a greater likelihood of increasing the reliability between assessments of everyday subjective and objective memory (Hickox & Sunderland, 1992). Research on everyday problem solving and cognition has also suggested the importance of tapping into the realm of everyday

functioning and examining everyday memory as a construct in and of itself (Allaire & Marsiske, 2002).

Physical Activity and Memory Functioning

Past work has focused on the benefits of physical activity for the cognitive functioning of older adults based on cognitive test performance (e.g., Hultsch, Hertzog, Small, & Dixon, 1999; Schuit, Feskens, Launer, & Kromhout, 2001). This line of research, using both cross-sectional and longitudinal designs, suggests that engaging in an active lifestyle is linked to higher cognitive functioning (Newson & Kemps, 2005). However, past work has not considered the role of physical activity in cognitive functioning from an everyday or daily perspective, or the role of individual differences in intraindividual variability (Ghisletta, Nesselroade, Featherman & Rowe, 2002).

When considering the relationship between physical activity and cognition, it is important to note the limitations of past research regarding directionality. While some research suggests that greater engagement in activities promotes cognitive function, the data are primarily cross-sectional (e.g., Ghisletta, Bickel, & Lövdén, 2006; Smits, Van Rijseelt, Jonker, & Deg, 1995). Even with longitudinal data there are questions about whether activity promotes the development or maintenance of cognitive abilities, or whether cognitively capable people tend to participate in environments that are cognitively or physically demanding. Using longitudinal data, Hultsch et al. (1999) found a reciprocal relationship with both directions supported. Although the current study was not able to fully resolve this issue of directionality, we were able to examine the direction of the relationship between physical activity and cognition on a more micro level. By examining lagged analyses, or how activity on one day relates to memory functioning the next day, we were able to assess the short-term effects of physical activity on cognition; that is, whether physical activity on a given day was associated with changes in memory the following day.

The goals of the current study were threefold. The first goal was to examine age differences in daily memory failures and physical activity. It was hypothesized that older adults would have a higher incidence of memory failures (Erber et al., 1992) and be less likely to engage in physical activity across an eight day period (Barnes & Schoenborn, 2003). The second goal was to examine the relationship between memory failures and physical activity. On days when participants were more physically active, they were hypothesized to display fewer memory failures based on research suggesting that exercise may buffer against decline in cognitive functioning (Hultsch et al., 1999). The final goal was to examine whether the effect of daily physical activity on the report of memory failures varied by age. It was hypothesized that on days when older adults were more physically active, they would report fewer memory failures, whereas performing physical activity was not expected to result in fewer memory failures among younger adults, who were not expected to have many memory failures.

Method

Sample

Participants were drawn from a probability sample from the greater Boston area. A sampling firm was used in order to obtain the names, addresses and telephone numbers of people within a 20-mile radius of the university. Participants were stratified according to age, gender, and education. There were 28 males (47.5%) and 31 females (52.5%), with 19 participants in the younger age group (22–39 years, 53% female), 19 participants in the middle age group (40–59 years, 53% female), and 21 participants in the older age group (60–85, 52% female). The mean number of health problems reported was 1 ($SD = 1.36$; range 0–6). The response rate for participants recruited over the telephone was 84% (59 out of 70 participants agreed to participate). The compliance rate for number of days the diary was completed was 99% (465 out of a possible 472 days). When considering diary data, it is important to note that both the number of days as well as the number of participants is considered in the analyses. Therefore, data from 59 people reporting on 465 days were used in the present analyses. Eighty-eight percent of participants were Caucasian. The educational mean was 8.56 (scored from 1 [*some grade school*]–12 [*professional degree*]), or about a Bachelor's degree.

Measures

Everyday Memory Failures—Everyday memory failures were assessed through a shortened version of an everyday memory questionnaire developed by Sunderland, Harris, and Baddeley (1983). The shortened version of the Sunderland et al. questionnaire has been effectively used elsewhere (Neupert, Almeida, Mroczek, & Spiro, 2006a; 2006b). Three items were selected from this measure. Further information on this scale can be found in Neupert et al. (2006b). In addition to the Sunderland et al. items, seven additional items were selected (Lachman, Weaver, Bandura, Elliott, & Lewkowicz, 1992). See the Appendix for a complete list of the items. Items were scored as 0 (did not experience memory failure) or 1 (did experience memory failure). Items were presented as a checklist where participants were asked to indicate yes or no to whether they had experienced each memory failure that day. Daily composite scores were created by summing the total number of memory failures (from 0 to 10) for each day.

Daily Physical Activity—The physical activity measure was taken from the second wave of the Midlife in the United States (MIDUS II) mail questionnaire (<http://www.midus.wisc.edu/midus2/>). Participants were then asked to respond separately “no” (scored as 0) or “yes” (scored as 1) to whether they had performed physical activity while at their paid job (job activity), while doing chores in and around the house (home activity), or during their leisure or free time (leisure activity). Three daily physical activity scores were created using the frequency for each category (0 or 1 for job, home, or leisure). A measure of total physical activity was also generated using the frequency of the combined exercise scores (0–3 for each day).

Cognitive Functioning—To assess individual differences in cognitive functioning, the Brief Test of Adult Cognition over the Telephone (BTACT; Tun & Lachman, 2006), a

computerized battery administered over the telephone, was administered at the beginning and end of the week. The tasks included in the BTACT are designed to measure a wide variety of cognitive functions believed to decline with age: episodic verbal memory, reasoning, speed of processing, working memory span, and executive function. In order to eliminate practice effects, two versions of the BTACT were administered in randomly counterbalanced order (now referred to as Tact 1 and Tact 2). Tact 2 was designed by the first author as a parallel form. For further description of the BTACT, refer to Tun and Lachman (2006). A measure of overall cognitive functioning was created from both administrations of the Tact 1 and Tact 2 and is represented by a standardized z-score in Table 1. Scores on all of the tasks were standardized and then summed together for each person (Tact 1, $\alpha = .77$; Tact 2, $\alpha = .74$). The correlation between Tact 1 and Tact 2 was significant, $r = .75, p < .0001$.

Demographics—The sample was divided into two education groups; low (no college degree) and high (Bachelor's degree or higher). Health was assessed by asking participants to indicate "yes" (scored as 0) or "no" (scored as 1), to whether they had experienced or been treated for a variety of 12 medical conditions. Means and standard deviations for all variables described above are reported in Table 1.

Procedure

Participants for the current study were recruited over the telephone and asked to volunteer to be part of a study examining the daily activities among adults. The study was approved by the university Institutional Review Board, and eight separate diary booklets labeled Days 1 through 8 were sent to each consenting participant. Eight days was selected as the study period because this allowed for a full week's worth of data and the start date could vary across persons. Moreover, past work has found that this time period provides adequate within-person variability in daily memory failures (e.g., Neupert et al., 2006a). Before and after the diary period, participants were randomly administered one of two versions of the cognitive battery over the phone. The cognitive battery was administered over the phone by the first author using the computer program Media Lab. Each phone call was recorded through the computer using the program Audacity. After completing the first phone interview, participants were asked to complete their first diary booklet the next night 30 minutes before going to bed. For eight consecutive evenings, participants answered short semi-structured questionnaires about their daily experiences. After completion of the diary booklets, participants were administered the second cognitive battery the following day by telephone. Participants received \$20.00 for their efforts. Data collection was completed during the summer months.

Results

Data Analysis

In order to address the first hypothesis of whether there were age differences in daily memory failures, physical activity levels, and cognitive ability, analysis of variance (ANOVA) was conducted for each variable. Education differences were also examined. In order to test the second and third hypotheses regarding the relationship between physical

activity and memory failures, multilevel modeling was used. This technique allows for the simultaneous examination of interindividual differences in intraindividual variability, as will be explained below. The alpha level for all analyses was set at .05

Age and Education Differences

In order to determine whether there were age and education differences in daily memory failures, physical activity (job, home, leisure, and total), and cognitive ability, 3 (age group: young, middle, old) $\times$ 2 (education: low and high) ANOVAs were conducted for each dependent variable. Contrary to predictions, age and education differences were not significant for total memory failures or the physical activity variable. Age differences were found for overall cognitive ability, $F(2, 52) = 7.92, p < .001$. Participants in the young and middle age groups ($M = .22; .21$, respectively) had significantly higher scores compared with participants in the old age group ($M = -.46; p < .01, p < .01$, respectively). In addition, a main effect of education was found, $F(1, 52) = 11.12, p < .002$. Participants in the high education group ($M = .26$) had higher cognitive ability scores than participants in the low education group ($M = -.28$). Further, there was a relationship between cognitive ability and everyday memory failures ($r = -.42, p = .001$). When performed separately by age group, this relationship was significant only among older adults ($r = -.58, p = .01$).

Relationships between Physical Activity and Memory Failures

In order to examine the second and third hypotheses, multilevel modeling was implemented for the analyses using SAS Proc Mixed. We explored whether there was a relationship between memory failures and physical activity levels and whether this relationship varied by age. In these analyses, age was treated as a continuous variable while education was dichotomous (low and high). Multilevel modeling is a suitable technique for analyzing diary data, as it examines individual change/variability using a two-level hierarchical model (Hawkins, Guo, Hill, Battin-Pearson, & Abbott, 2001). At Level 1, each person's variability is represented by an individual regression equation while at Level 2, these individual parameters are used as the outcome variables. In other words, the data at Level 1 represent the within-person daily observations (such as memory failures, activity levels), while the data at Level 2 represent the between-person characteristics (such as age and education). Prior to the analyses, an unconditional model was run in order to permit estimation of the intraclass correlation, or the ratio of between- to within-person variability in memory failures. Results from this analysis indicated an intraclass correlation coefficient of 0.66; 66% of the variability was between people and 34% was within people. There was significant variation within- ($z = 5.07, p < .0001$) and between-people ($z = 14.27, p < .0001$), which provided justification for full model specification to explain the within- and between-person variability. In order to address the second hypothesis, the following model was tested:

$$\text{Level 1: MEMORY}_{it} = \beta_{0it} + \beta_{1it}(\text{JOB ACTIVITY}) + \beta_{2it}(\text{HOME ACTIVITY}) + \beta_{3it}(\text{LEISURE ACTIVITY}) + r_{it}$$

$$\text{Level 2: } \beta_{0i} = \gamma_{00} + \gamma_{01}(\text{AGE}) + \gamma_{02}(\text{EDUCATION}) + \gamma_{03}(\text{COGNITIVE ABILITY}) + \gamma_{04}(\text{GENDER}) + \gamma_{05}(\text{HEALTH PROBLEMS}) + \gamma_{06}(\text{AGE X COGNITIVE ABILITY}) + u_{0i}$$

$$\beta_{1i} = \gamma_{10} + \gamma_{11}(\text{AGE}) + u_{1i}$$

$$\beta_{2i} = \gamma_{20} + \gamma_{21}(\text{AGE}) + u_{2i}$$

$$\beta_{3i} = \gamma_{30} + \gamma_{31}(\text{AGE}) + u_{3i}$$

In Level 1, memory failures for person i on day t is a function of the intercept, β_{0it} , which is defined as the number of memory failures for person i on days of no activity (i.e., $\text{ACTIVITY} = 0$). β_{1it} represents the within-person relationship between job activity and memory failures; β_{2it} represents the within-person relationship between home activity and memory failures, while β_{3it} represents the within-person relationship between leisure activity and memory failures. This model (now referred to as Model 1) addressed the within-person associations between engagement in job, home, or leisure activity with memory failure frequency on a daily basis. In addition, a model was run with the total physical activity score; however this variable was not related to the report of memory failures, and is therefore not reported in the current paper.

In Level 2, age (γ_{01}), education (γ_{02}), cognitive ability (γ_{03}), gender (γ_{04}), and total number of health problems (γ_{05}) were included as covariates at the between-person level; that is, they were used as predictors of the overall number of memory failures. An interaction of age and overall cognitive ability was also assessed, in order to determine whether the relationship between cognitive functioning and memory failures was stronger for older adults. The between-person coefficients (age, cognitive ability, and total number of health problems) were centered around their grand mean, so the grand mean of the sum of the memory failures (γ_{00}) indicates the number of memory failures when the covariates were at their mean and when no activity was reported. In addition, age differences in the within-person relationships (the within-person slopes between activity and memory failures) were examined in Level 2 by adding age to the equations β_{1i} , β_{2i} , and β_{3i} . Age, education, cognitive ability, gender, number of health problems, and the three physical activity measures were not significantly related to daily memory failures. The interaction of age and cognitive ability was not significantly related to the number of memory failures; however, a significant interaction of Age X Leisure Activity was found (see Table 2). On days when participants reported leisure activity, they were less likely to report memory failures compared to days when they did not engage in leisure activity, and this relationship was stronger for older adults (see Figure 1). The Figure represents the change over time between days with no leisure activity and days with leisure activity. The amount of variance explained by the model above was calculated, resulting in 19% of the within-person variability in daily memory failures being explained by the three physical activity measures. In addition, 24% of the between-person variability in memory failures was accounted for by the Level 2 variables.

In addition to assessing the effects of activity on current day memory failures, lagged effects were also examined (Model 2). Lagged effects examine the effect of exercise on the change in memory failures from one day to the next. Model 2 is similar to Model 1 depicted above with the addition of previous day memory failures as a predictor of current day memory failures. Previous day leisure activity was also entered as a Level 1 predictor. Age, education, and general cognitive ability were controlled for in the first Level 2 equation and

age was added to the subsequent Level 2 equations to examine potential age differences in the relationships between leisure activity and change in memory failures (i.e., Age X Leisure Activity interactions). The findings from the lagged analyses support the above result from Model 1 of a negative Age X Leisure Activity interaction for change in memory failures ($\gamma_{11} = -.02, t = -1.97, p < .05$), suggesting with leisure activity on a given day, there was a decrease in memory failures on the next day, and that this relationship was stronger for older adults.

Discussion

The main purpose of this study was to investigate the relationship between age, physical activity, and memory failures. Several novel findings resulted from this investigation. Unexpectedly, the report of daily memory failures and physical activity (job, home, leisure, or total) frequencies did not differ by age group, suggesting that younger and older adults are equally likely to experience memory problems and to engage in physical activity. Nevertheless, consistent with past research, cognitive ability was lower for older adults. This finding was extended by demonstrating that cognitive ability was related to everyday memory failures only among older adults, suggesting that for younger adults memory failures may be tied to factors other than poor cognition. Second, on days when people engaged in leisure activity, fewer daily memory failures were reported compared to days with no leisure activity, and this was especially so for older adults. Lagged analyses indicated that when leisure activity was reported on one day, fewer memory failures were reported the next day, especially for older adults.

Age Differences in Memory and Physical Activity

Contrary to expectations, none of the physical activity variables differed according to age group. While this may seem surprising given the numerous reports suggesting that exercise decreases with age (e.g., Barnes & Schoenborn, 2003), research also suggests that older adults report higher perceived social support for physical activity and are less likely to cite time barriers to exercise (Anderson, Wojcik, Winett, & Williams, 2006). Also of interest was that younger adults reported as many memory failures as the middle-aged and older adults even though older adults demonstrated the traditional deficit on a cognitive test battery. The relationship between everyday memory and traditional cognitive tests varied as a function of age. For older adults everyday memory failures seem to be related to their cognitive ability, whereas this is not the case for younger adults. This may be reflected in the age differences found in the relationship between everyday memory and physical activity.

The Memory-Physical Activity Relationship

The findings from Model 1 (specifically, the Age x Leisure Activity interaction) suggest that leisure activity appears to be particularly beneficial for the everyday memory of older adults. This result supports past research suggesting the positive link between engaging in exercise and improved cognition (e.g., Dustman et al., 1984; Fabre et al., 1999), but also extends past research by demonstrating that daily leisure activity may be more beneficial to older adults' memory than for younger adults'. Although past work has examined the long-term cumulative effects of exercise, little research has examined the effect of daily activity on

memory functioning. Research has, however, examined this relationship from a monthly perspective (Richards et al., 2003). Researchers in England found that physical activity performed over the past month was significantly and positively associated with memory performance, independent of sex, education, and physical and mental health. Not only did these findings strengthen the suggestion of a causal link between physical activity and protection of memory among adults, but they also implied that the cognitive benefit of physical activity may be enhanced by persistent or more recent activity. Our findings fit with those of Richards et al. and extend them from the monthly perspective to the daily perspective. More recent work from Small and colleagues (2006) suggests that cognitive functioning can be improved over the course of a 14-day lifestyle program (incorporating such aspects as physical activity and diet) among a sample of adults with mild self-reported memory complaints.

Interestingly, we only found an association between leisure activity and memory failures—job and home activity were not related, suggesting the potential importance of engaging in activity during one's free time. An examination of the means for the three activities by age group suggests that while the prevalence of job activity was not substantial among the current sample, both home and leisure activities were more commonly reported. More work is needed to understand the specificity of this relationship. It may be that the nature of activity done in the home or at work was not strenuous or physically demanding enough to have cognitive benefits. Research suggests that while energy expenditure for leisure-time activity (i.e., going to a fitness center) has increased over the past decade or so, energy for chores in and around the home has decreased (Bouchard, 2000). This could in part be due to the influx of technological advancements available for home maintenance (such as the development of a robotic vacuum) which have alleviated many of the physical demands (Swinburn, Caterson, Seidell & James, 2004). Another possibility relates to the attention that leisure physical activity receives through such outlets as the media and scientific research. Far more emphasis is placed on the benefits of leisure activity over other types of activity (Prentice & Jebb, 2000), so the potential exists that people are more likely to believe that they will receive the most benefit from activity performed for the sole purpose of staying or becoming fit.

Research from a national longitudinal survey examining health and development in young and middle adulthood suggests that engaging in exercise (measured as sports and recreational activities) in young adulthood was associated with a decreased rate of decline in memory functioning in middle adulthood (Richards, Hardy, & Wadsworth, 2003). Although this research might seem contrary to what was found in the current study, it is important to highlight the daily nature of these findings, in that we only examined activities and their effect on memory across an 8-day period. While it is most likely that physical activity has a beneficial effect on memory regardless of age, it may be more evident among older adults from a micro level. More work is needed to disentangle this relationship. Although the current study did not examine the physiological underpinnings involved in daily activity, research suggests that physical exercise may improve blood flow to the brain and thereby reduce the risk of cognitive decline (van Praag et al., 1999), even after short bouts of exercise are performed. This might offer an explanation as to why daily physical activity frequency was found to have the most impact on older adults. It may also be of importance

to consider daily contextual variables such as whether the person was sick, had a busy day, or had a good night's sleep in order to fully understand the contribution of age and physical activity to memory problems. If younger adult's memory failures were tied to more fluctuant factors such as busyness or mood, then activity itself might not make a difference. In contrast, for older adults, if memory failures are tied more to cognitive deficits, physical activity would be expected to have a positive impact.

The nature of the lagged analysis with physical activity is particularly noteworthy because it suggests that not only are the potential short-term benefits of physical activity associated with reductions in the report of memory failures, but that the effect of the activity performed the day before carries over into the next day. Although the positive effects of exercise have been demonstrated after acute bouts of exercise that are generally performed on the same day (e.g., Mitchell et al., 1990), researchers also believe that the effects of exercise on such processes as memory functioning can last for longer amounts of time than just on the daily level. For instance, higher levels of norepinephrine (believed to play an important role in memory functioning; Kalat, 1992) have been observed among participants even when the exercise was not performed on that day (Poehlman et al., 1992). While the current study is not able to address these physiological responses to physical activity, further work could integrate the biological and psychological aspects of everyday memory and physical activity.

Limitations and Future Research

Although this study provided a unique perspective on the relationship between daily physical activity and everyday memory failures across the adult lifespan, it is important to recognize its limitations. One issue relates to the directionality of the physical activity and memory relationship. Researchers have debated whether those with good cognition are more likely to be physically active, or whether physical activity level leads to changes in cognition (e.g., Hultsch et al., 1999; Pushkar et al., 1999), or whether the two are related because of other shared variables. The methodology of the present study does not allow for this issue to be definitively resolved, but an experimental longitudinal design could help to answer these questions. Other limitations of the present investigation result from the self-reported data. Future research could remedy this limitation by attempting to verify the daily questionnaires, such as asking family members of the participants to validate the responses. Nevertheless, we did find that leisure activity frequency on a given day was related to decreases in memory failures on the following day (i.e., controlling for prior day memory, as in Model 2). While possible that participants could have forgotten to report memory failures experienced due to the daily diary nature of the design, the likelihood of inaccuracies was reduced. Related to this point, the measurement of memory failures and subsequent translation to cognitive functioning is not without limitation. Memory failures tend to tap into the area of encoding and attention, or failures that result from inattention (Sunderland, Harris, & Baddeley, 1983). Further work could explore this limitation by examining memory failures that tap into different domains of cognitive functioning. Additionally, the measure used to assess memory failures needs further validation.

In order to better disentangle the effects of short- and long-term activity, future research could include questions pertaining to length of activity over one's lifetime. This would make it possible to control for how long a person had been physically active, and perhaps shed light on the unique contribution of physical activity performed over a shorter period of time. A final limitation to consider is the season when data were collected. The summer months when this study was conducted may provide more of an opportunity for people to be physically active. Further research should examine whether the same findings hold true during the winter months.

Conclusions

The fact that daily leisure physical activity may be beneficial for older adults' daily memory functioning provides additional evidence to the already lengthy list of benefits derived from physical activity for this segment of the population. Although evidence for the impact of activity on memory functioning among older adults was found, future studies are warranted in order to replicate and extend these findings, possibly looking at longer time periods and more varied forms of memory and physical activity. Continuing to assess physical activity and memory failures as they occur on a daily basis may yield more precise information about mechanisms underlying these relationships and help to identify avenues for optimization and intervention.

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Appendix. Everyday Memory Failure Items

Note: The first three items were adapted from Sunderland, Harris, and Baddeley (1983) and the last seven items were adapted from Lachman, Weaver, Bandura, Elliott, and Lewkowicz (1992).

1. Did you find that a word was ‘on the tip of your tongue.’ You knew what it was but could not quite find it?
2. Did you forget to take your medications?
3. Did you go back to check whether you had done something that you meant to do?
4. Did you forget material or the plot from a movie, show, or something you read?
5. Did you forget where you had put something, or lost something around the house?

6. Did you have trouble remembering someone's name?
7. Did you start to do something, then forgot what it was you wanted to do, maybe saying 'What am I doing'?
8. Did you forget what you went into a room for?
9. Did you forget something you were told yesterday or a few days ago?
10. Did you start to say something, and then forgot what it was that you wanted to speak about?

Figure 1.

Interaction of age and leisure activity for memory failures controlling for education, cognitive ability, gender, and total number of health problems. On days when older adults participated in leisure activity, they experienced a more beneficial effect in terms of a decrease in the number of memory failures compared to younger and middle-aged adults.

Table 1

Means and Standard Deviations for Study Variables According to Age Group

Variable	<i>M</i>	<i>SD</i>	Minimum	Maximum
Age	53.12	16.66	22	83
Education	8.56	2.04	5.00	12.00
Young	8.52	.75	-1.66	1.55
Middle	8.68	1.73	0	7.00
Old	8.48	.28	0	1.00
Cognitive ability	-.02	.75	-1.66	1.55
Young	.22	.33	-.99	1.01
Middle	.26	.72	-.97	1.55
Old	-.47	.73	-1.66	.93
Memory failures	2.00	1.73	0	7.00
Young	1.73	1.47	0	5.38
Middle	1.60	1.43	.13	4.50
Old	2.60	2.07	.38	7.00
Job activity	.27	.28	00	.88
Young	.35	.33	0	.88
Middle	.29	.28	0	.75
Old	.17	.19	0	.63
Home activity	.57	.33	0	1.00
Young	.49	.34	0	1.00
Middle	.57	.33	0	1.00
Old	.66	.33	0	1.00
Leisure activity	.51	.36	0	1.00
Young	.52	.35	0	1.00
Middle	.43	.38	0	1.00
Old	.57	.34	0	1.00
Total physical activity	1.36	.66	0	2.75
Young	1.36	.67	.25	2.75
Middle	1.29	.75	0	2.50
Old	1.41	.61	.50	2.50

Note. Education coded from 1 (*some grade school*) to 12 (*professional degree*). Cognitive ability is a composite z-score based on the two BTACT administrations.

Table 2

Multilevel Modeling Estimates and Standard Errors Predicting Memory Failures

Fixed effects	Coefficient (se)
Intercept, β_0	
Overall memory failures, γ_{00}	1.97*** (.22)
Age, γ_{01}	.00 (.01)
Education, γ_{02}	.06 (.12)
Cognitive ability, γ_{03}	.03 (.88)
Gender, γ_{04}	-.35 (.46)
Total number of health problems, γ_{05}	.08 (.12)
Age X Cognitive ability, γ_{06}	-.02 (.01)
Sum job exercise slope, β_1	
Intercept, γ_{10}	-.71 (.56)
Age, γ_{11}^a	.02 (.01)
Sum home exercise slope, β_2	
Intercept, γ_{20}	-.65 (.58)
Age, γ_{21}^a	.00 (.01)
Sum leisure exercise slope, β_3	
Intercept, γ_{30}	.84 (.60)
Age, γ_{31}^a	-.02* (.01)

$n = 59$ participants, 465 days.

*
 $p < .05$.

**
 $p < .01$.

 $p < .001$.

^aDenotes interaction with above slope.