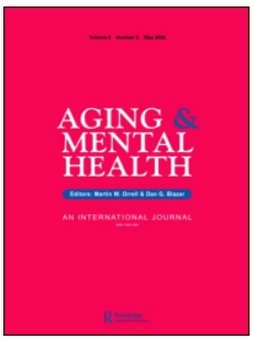

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# Mediators of the relationship between social activities and cognitive function among older Irish adults: results from the Irish longitudinal study on ageing

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**ABSTRACT**

**Objective:** Evidence points to an association between social and leisure activity (SLA) engagement and cognitive outcomes, but the mechanisms underlying this link remain unknown. We aimed to investigate three potential mechanisms: Vascular function, Perceived Stress, and Cognitive Reserve.

**Methods:** With data from 8163 adults aged over 50 in the Irish Longitudinal Study of Ageing, we used a structural equation model to evaluate Vascular Function and Perceived Stress as potential mediators, and Cognitive Reserve as a potential antecedent in the relationship between SLA at baseline (2009), and cognitive outcomes collected at a two-year follow-up point (2011).

**Results:** Cognitive Reserve was strongly associated both with cognitive outcomes ($\beta = 0.306$; $p < 0.001$) and with SLA ($\beta = 0.694$; $p < 0.001$). Perceived stress ($\beta = 0.018$) acted as a significant mediator in the relationships between SLA and cognitive outcomes ($p < 0.001$), although Vascular Function did not ($\beta = 0.000$).

**Conclusion:** These results indicate that SLA may protect cognitive function partly because of its association with cognitive reserve, and partly through its impact on perceived stress. Results have policy implications for those interested in facilitating SLA to protect cognitive outcomes among older adults.

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**KEYWORDS**
Cognitive functioning; social support; epidemiology (mental health); stress

## Introduction

Social engagement is a major predictor of health outcomes in later life (Holt-Lunstad, Smith, Baker, Harris, & Stephenson, 2015), and aspects of social engagement may also be considered as predictors of cognitive function (Bosma et al., 2002; Fratiglioni, Paillard-Borg, & Winblad, 2004; Menec, 2003; Zunzunegui, Alvarado, Del Ser, & Otero, 2003), both in the short-term (Gow, Avlund, & Mortensen, 2014; Saczynski et al., 2006) and over time (Barnes, Mendes de Leon, Wilson, Bienias, & Evans, 2004). While social processes are often described in a unidimensional fashion, Cohen warns that doing so obscures the true relationships between specific social processes and overall functioning (Cohen, 2004). Specific social processes can be considered within a 'causal cascade' model, which frames health outcomes as being related to successive layers of social determinants (Berkman, Glass, Brissette, & Seeman, 2000). 'Mezzo-level' determinants such as social isolation (Bassuk, Glass, & Berkman, 1999; Béland, Zunzunegui, Alvarado, Otero, & del Ser, 2005; DiNapoli, Wu, & Scogin, 2014; Shankar, Hamer, McMunn, & Steptoe, 2013) and social network size (Barnes et al., 2004; Green, Rebok, & Lyketsos, 2008), consistently shown to relate to cognitive functions, may represent contexts in which more 'micro-level' processes such as social support (Ayotte, Allaire, & Whitfield, 2013; Glymour, Weuve, Fay, Glass, & Berkman, 2008) and social activity engagement can take place.

Previous findings demonstrate associations between leisure activities (Ghisletta, Bickel, & Lovden, 2006), cognitively effortful activities (Singh-Manoux, Richards, & Marmot, 2003), social activities (James, Wilson, Barnes, & Bennett, 2011), and cognitive function. Small and colleagues report that cognitive decline precedes declines in social activity (Small, Dixon, McArdle, & Grimm, 2012), so there may be some reciprocity in this relationship.

Bielak has offered suggestions in how to explore the link between activity engagement and cognitive ageing (Bielak, 2010). We frame our current investigation within Bielak's first listed suggestion: trying to understand the mechanisms underlying relationships between activity (specifically social and leisure activity) and cognitive function. It is likely that as well as a direct relationship between social and leisure activity engagement and cognitive function, there are many mediating pathways between the two phenomena (Bielak, 2010; Glass, de Leon, Marottoli, & Berkman, 1999), which may either enhance or suppress the overall association.

Fratiglioni has suggested three pathways mediating the relationship between social, leisure and physical activities, and cognitive outcomes: *Cognitive Reserve*, *Stress*, and *Vascular Function* (Fratiglioni et al., 2004). These pathways are allegedly common to social, mental and physical activities, and may contribute to our understanding of how these activities relate to cognitive decline and dementia.

Cognitive Reserve (CR) is a mechanism likely to underlie the relationship between social activity and cognition in later life (Bielak, 2010; Fratiglioni et al., 2004). CR refers to a theory whereby personal educational and occupational history can build a 'reserve' protecting against the cognitively deleterious effects of brain pathology (Stern, 2002). Notably, activities may help to create CR (Scarmeas & Stern, 2003), specifically,

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leisure and social activities (Verghese, Wang, Katz, Sanders, & Lipton, 2009).

Stress may also mediate the relationship between social activity and cognitive function in later life, due potentially to the 'buffering' effect of social support (Cohen & Wills, 1985). In a similar way, engagement in social and leisure activities may help to 'buffer' the individual against the negative impact of stress on cognitive function (Verghese et al., 2009). Evidence from animal models suggests that social isolation leads to stress-induced hippocampal atrophy, which may relate to the link between social engagement and cognition in humans (Ferragud et al., 2010; Magarinos, McEwen, Flugge, & Fuchs, 1996). Social interaction may buffer directly against the impact of HPA axis activation upon cognitive function and hippocampal integrity (deVries, Glasper, & Detillion, 2003).

Social support and social interaction are related to improved cardiovascular function (Orth-Gomér, Rosengren, & Wilhelmsen, 1993; Uchino, Cacioppo, & Kiecolt-Glaser, 1996). This relationship may represent another biologically plausible pathway through which social activities also impact cognitive function, since vascular function is a known risk factor for cognitive decline and dementia (Gorelick et al., 2011; Kivipelto et al., 2001; T O'Brien et al., 2003).

The aim of the current study was to evaluate these three potential pathways using data from the Irish Longitudinal Study of Ageing (TILDA), a nationally representative cohort study of adults aged over 50 in Ireland. While Fratiglioni's original argument frames CR as a pathway between activity engagement and cognitive outcomes, in the current study, we frame CR as a preceding factor to both activity engagement and cognitive outcomes. This is because our chosen proxy measure of CR temporally precedes both measures of social and leisure activities, and cognitive function.

***Hypothesis***: Perceived stress and vascular health will constitute mediators in the relationship between social & leisure activities and cognitive function, accounting for CR as an exogenous predictor of both social and leisure activities and cognitive function.

## Methods

### *Design*

The TILDA study is a representative, longitudinal cohort study, investigating the dynamics of ageing among 8504 adults aged over 50. Participants were randomly sampled from the population, from all geographical units of the country, and all participants gave informed consent to participate. More information on the design of the TILDA study is available elsewhere (Barrett et al., 2011). Ethical approval for conducting the study was granted by the Research Ethics Committee at Trinity College Dublin. The baseline assessments were collected between 2009 and 2011, with follow-ups every two years since.

### *Participants*

Of the original 8504 TILDA participants, 8175 were originally targeted, and 329 additional interviews were performed with younger spouses or partners of participants. We limited the current analyses to those individuals who were aged over 50 and who had data relevant to this study for both waves 1 and 2 of the study (6985 individuals). The mean age of participants was 63.45 (age range of 50–80; standard deviation = 9.4) and 45.72% were male (see Table 1). Each participant underwent a home-based interview with an assessor, a health assessment in the research centre, where possible, and completed a paper-based questionnaire in their own time.

**Table 1.** Sample characteristics for 6985 participants at baseline, in 2009, taking part in the TILDA study (Republic of Ireland).

| | Mean (SD) or percentage |
|---|---|
| Age | 63.46 (9.5); age range = 50–80 |
| Gender | |
| Male | 45.72% ($n$ = 3194) |
| Female | 54.27% ($n$ = 3791) |
| Education level | |
| No qualification | 28.71% ($n$ = 2005) |
| Intermediate qualification | 40.56% ($n$ = 2833) |
| Tertiary qualification or higher | 30.72% ($n$ = 2146) |
| Perceived stress scale score | 4.19 (3.12, range = 0–16) |
| Mean seated systolic blood pressure | 135.49 (19.78; range = 78.5–222) |
| MMSE score at baseline | 28.39 (2.12) |
| Immediate word recall at baseline | 5.77 (1.71) |
| Delayed word recall at baseline | 6 (2.33) |
| MMSE score at follow-up | 28.45 (2.23) |
| Immediate word recall at follow-up | 5.87 (1.72) |
| Delayed word recall at follow-up | 5.93(2.61) |

### *Measures*

Demographic information (age, sex, physical activity) was collected from all participants. Physical activity was measured as MET (metabolic equivalent of task) minutes calculated from the International Physical Activity questionnaire (Craig et al., 2003). MET minutes are the way of measuring time engaged in a physical activity with regard to the number of METs associated with that task. Current guidelines suggest that older adults participate in 500–1000 MET minutes per week.

Social and leisure activities were evaluated using a list of 14 items (see Supplementary Materials) which were assessed to measure social participation in accordance with the framework set out by House, Robbins, and Metzner (1982). The current analysis instead used all 14 items to create a single measure of Social & Leisure Activity (SLA; see *Data Analysis*). The fourteen items are harmonised broadly with similar items and possible responses in the Health & Retirement Study and in the English Longitudinal Study of Ageing.

Responses were assessed using a Likert scale: 'Daily/almost daily'; 'once a week or more'; 'twice a month or more'; 'about once a month'; 'every few months'; 'about once or twice a year'; 'less than once a year'; 'never'. Scores of 1–8 were given to each response whereby low scores indicate frequent engagement and high scores indicate infrequent engagement in social and leisure activities. For ease of interpretation, however, scores on these items were reverse-coded so that low scores indicated infrequent engagement, and higher scores indicating more frequent engagement in activities.

The main factors of interest in the current study were Cognitive Reserve, Stress and Vascular Function. Education level is often used as a proxy measure of CR (Stern, 2002; Valenzuela & Sachdev, 2006) (but see Jones et al., 2011) and was used as such here. Education level was assessed using the item 'What is the highest level of education you have completed?' with possible responses recoded for analysis as: 'No qualification', 'Intermediate Qualification', and 'Third level Qualification or Higher'. To evaluate Stress, we used a four-item version of the

Perceived Stress scale (Cohen, Kamarck, & Mermelstein, 1983), which previously has been shown to have acceptable reliability and validity and in the current sample had a Cronbach's alpha value of 0.65 (acceptable for a short scale), with item-total correlations (corrected for item overlap and scale reliability) of between 0.43 and 0.63. The four-item scale asks individuals about feelings of being unable to control things in one's life, ability to handle personal problems (which is reverse coded), feeling of things going one's way (reverse coded), and the feeling of difficulties piling up. Each item yields a score of 0–4 and scores are summed to give a total score between 0 and 16 where smaller scores indicate lower levels of perceived stress. Vascular function was measured using the proxy of a mean of two readings of a seated systolic blood pressure (SBP). This measure is frequently used as a marker of vascular function and has good temporal stability (Manuck, 1994; Uchino et al., 1996).

Outcomes of interest were cognitive factors assessed at a two-year follow-up point, and included performance on a 10-word immediate list recall, a delayed recall of the same 10 words, and scores on the mini-mental state examination (Folstein, Folstein, & McHugh, 1975). The latter is an assessment of global cognitive function for older adults and includes assessment of memory, orientation, executive function and praxis. A latent 'cognition' factor was created using scores on these three measures as indicators.

### *Data analysis*

All data analyses were performed using R software. The package 'lavaan' (Rosseel, 2012) was used to construct a structural equation model (SEM) with the latent 'cognition' factor (at follow-up) as the outcome, and mediating pathways specified for Perceived Stress and Vascular Function, measured at baseline. CR was included as an exogenous predictor of SLA and Cognition. SEM is a useful tool when considering mediation pathways since it permits each mediation variable to be both a cause and an effect and allows the simultaneous evaluation of several equations, in tandem with the estimation of latent variables within the mediation analysis (Gunzler, Chen, Wu, & Zhang, 2013). The 'lavaan' package allowed for missing data to be imputed using the full information maximum likelihood method within SEM. To facilitate interpretation and scaling of the latent variables, the variance of the 'social and leisure activities' latent factor was set to 1, and the pathway between cognition as a latent variable and the first indicator (in this case, Immediate Recall) was also set to 1. We report four common fit indices here: the Comparative Fit Index (CFI), the Tucker–Lewis Index (TLI), the root mean square error approximation (RMSEA) and the standardised root mean square residual (SRMR). Lavaan output also includes factor loadings for all latent factors and their items, as well as providing standardised (beta) coefficients for all pathways specified in the model. The mediation (indirect) effects of each of the three mediators are obtained respectively by multiplying the effect from SLA to the mediators by the effect from the mediators to Cognition. The total effect of SLA on Cognition is an aggregation of its direct effect on Cognition and the three indirect effects. These coefficients can be interpreted in the same manner as in regression analyses, as the degree of change in the outcome variable relative to a change of 1 standard deviation in the predictor.

## Results

A model was created with Cognition as the outcome, SLA as the independent variable, CR as a predictor, age, and physical activity as covariates, and Perceived Stress and Vascular Function as putative mediating pathways between SLA and Cognition. Constraints were applied *a priori* and involved constraining the variances of the baseline and follow-up versions of the same measure to be equal, as well as constraining some items of the SLA questionnaire to have equal covariances. Constraints are made based on theory, where one would expect the residuals of two items to be highly correlated (i.e. items from the same scale with identical response options). Factors were not set to be orthogonal. The model converged normally after 63 iterations. Loadings of each of the latent variable items onto their latent factor are described in Table 2.

Fit indices indicated an acceptable fit ($\chi^2_{185} = 2042.89$, $p < 0.001$; CFI = 0.886, TLI = 0.846; RMSEA = 0.05 ($CI_{90} = 0.048$, 0.052), SRMR = 0.045). There was a significant association between SLA at baseline and Cognition at follow-up such that higher levels of SLA were related to better performance in Cognition (see Figure 1). More frequent engagement in SLA was associated with higher levels of CR, lower levels of Perceived Stress, and lower levels of SBP. Higher performance in

**Table 2.** Measurement component of the model, for each of the latent factors (a) social and leisure activities, and (b) cognition, with factor loadings, *Z*-scores, significance and $R^2$ reported. Data pertain to baseline and follow-up assessment (2009–2011) in the TILDA study (Republic of Ireland).

| Latent variables | Estimate | Standard error | *Z*-value | *p* | Factor loading | $R^2$ |
|---|---|---|---|---|---|---|
| Social and leisure activities | | | | | | 0.214 |
| Watch TV | 0.011 | 0.009 | 1.268 | 0.205 | 0.023 | 0.001 |
| Go to films, plays, concerts | 0.808 | 0.025 | 31.836 | <0.001 | 0.621 | 0.385 |
| Attend classes and lectures | 0.847 | 0.032 | 26.113 | <0.001 | 0.495 | 0.245 |
| Travel for pleasure | 0.421 | 0.024 | 17.596 | <0.001 | 0.322 | 0.104 |
| Work in garden, home, or car | 0.379 | 0.029 | 13.18 | | 0.252 | 0.64 |
| Read books or magazines for pleasure | 0.758 | 0.032 | 23.699 | | 0.434 | 0.188 |
| Listen to music or radio | 0.220 | 0.017 | 13.311 | | 0.245 | 0.06 |
| Spend time on hobbies or creative activities | 1.147 | 0.042 | 27.213 | | 0.540 | 0.291 |
| Play cards, bingo, games | 0.495 | 0.038 | 12.878 | | 0.234 | 0.055 |
| Go to the pub | 0.255 | 0.040 | 6.43 | | 0.126 | 0.016 |
| Eat out of the house | 0.582 | 0.027 | 21.91 | | 0.429 | 0.184 |
| Participate in sports or exercise | 1.183 | 0.044 | 26.633 | | 0.492 | 0.242 |
| Visits/phone calls to/from family or friends | 0.242 | 0.019 | 12.521 | | 0.266 | 0.071 |
| Do voluntary work | 0.866 | 0.044 | 19.519 | | 0.410 | 0.168 |
| Cognition | | | | | | 0.329 |
| Immediate Recall 1 | 1.076 | 0.02 | 54.892 | | 0.79 | 0.623 |
| Immediate Recall 2 | 1.224 | 0.02 | 62.277 | | 0.875 | 0.766 |
| Delayed recall | 1.659 | 0.029 | 57.422 | | 0.818 | 0.669 |
| MMSE | 0.792 | 0.023 | 34.387 | | 0.538 | 0.289 |

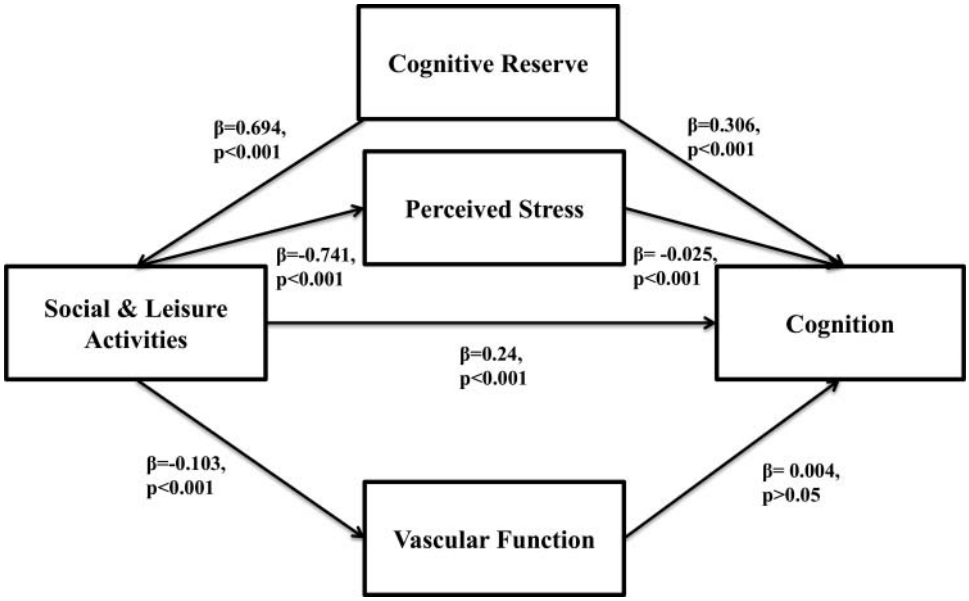


**Figure 1.** Mediation pathways between Social & Leisure Activities and Cognitive Function at wave 2, with standardised coefficients of each pathway. Data pertain to baseline and follow-up assessment (2009–2011) in the TILDA study (Republic of Ireland).

**Table 3.** SEM mediation results for cognition at wave 2 as an outcome, Social & Leisure Activities (SLA) as the independent variable, education level as a predictor of interest, age, and physical activity as covariates, and with (a) perceived stress and (b) vascular function, all at wave 1, as putative mediators. Data pertain to baseline and follow-up assessment (2009–2011) in the TILDA study (Republic of Ireland).

| Regression path | Coefficient ($\beta$) | Standard error | $Z$ | $p$ (significance) |
|---|---|---|---|---|
| **Pathways to SLA** | | | | |
| Cognitive reserve → SLA | 0.694 | 0.028 | 24.766 | <0.001 |
| **Pathways from SLA** | | | | |
| SLA → cognition | 0.240 | 0.023 | 10.516 | <0.001 |
| SLA → perceived stress | −0.741 | 0.049 | −15.1 | <0.001 |
| SLA → vascular function | −0.103 | 0.016 | −6.457 | <0.001 |
| **Pathways to cognition** | | | | |
| Perceived stress → cognition | −0.025 | 0.006 | −4.167 | <0.001 |
| Cognitive reserve → cognition | 0.306 | 0.028 | 10.9 | <0.001 |
| Vascular function → cognition | 0.004 | 0.018 | 0.211 | 0.833 |
| Age | −0.052 | 0.002 | −24.344 | <0.001 |
| Physical activity | −0.027 | 0.018 | −1.562 | 0.118 |
| **Mediating pathways** | | | | |
| Indirect effect via perceived stress | 0.018 | 0.004 | 4.093 | <0.001 |
| Indirect effect via vascular function | 0.000 | 0.002 | 0.210 | 0.833 |
| Total effect | 0.952 | 0.035 | 26.954 | <0.001 |

Cognition was also associated with higher CR, decreasing age, and lower levels of Perceived Stress. Neither SBP nor physical activity were found to be related to performance in Cognition. A significant mediating effect of Perceived Stress ($\beta = 0.018$, $p < 0.001$), but not Vascular Function ($\beta = 0.000$, $p > 0.05$) were found, and the total effect of SLA on Cognition was significant ($\beta = 0.952$, $p < 0.001$; see Table 3; see Figure 1).

## Discussion

We partially supported our hypothesis that perceived stress and vascular health would partially mediate the relationship between social and leisure activities, and cognitive function, accounting for the impact of CR. Our results partially corroborate Fratiglioni's suggestion (Fratiglioni et al., 2004) that social and leisure activities share pathways to cognitive outcomes. We find evidence for perceived stress but not for vascular health as one of these pathways, while CR was found to be an antecedent to both social and leisure activities and cognitive outcomes. Taken together, results suggest that CR may account for both engagement in social and leisure activities in later life, and for cognitive functioning, and that social and leisure activities may in part relate to better performance in cognitive functioning due to its impact in reducing perceived stress levels. It is important to note that we report findings based on education as a proxy for the still-theoretical construct of CR, which as such is difficult to measure directly, and our findings must be interpreted in relation to CR with caution.

The measurement model suggested that a single latent variable of SLA might be a useful metric, although further research is required to investigate the optimal operationalisation of this measure, and to develop a psychometrically sound scale assessing social and leisure activities in older adults.

The association we detected between social and leisure activity engagement and vascular function accords with previous findings of a link between social interaction and vascular function (Uchino et al., 1996). However, vascular function did not relate to cognitive outcomes, and therefore no mediation was possible. While previous research has commonly used the proxy measure of SBP (Uchino et al., 1996), we acknowledge that a more sensitive and holistic measure of vascular function is merited before conclusions can be drawn about the nature of the relationship between social and leisure activities and vascular function.

We also found evidence for a mediating role of perceived stress in the relationship between social and leisure activities. While typically social support is described as a moderator of the relationship between stress and health outcomes (Cohen, 1988) our findings suggest that engaging in social and leisure activities also can improve cognitive functioning because of their mitigating impact on perceived stress levels. This finding also corroborates claims by Glass and colleagues, that psychosocial pathways are likely to exist between activity engagement and health outcomes (Glass et al., 1999).

Since our findings are based on short-term follow-up data, we cannot exclude the possibility that social and leisure disengagement prodromally follows cognitive decline. This possibility has been raised previously (Saczynski et al., 2006) since the prodromal phase of dementia may last for many years (Verghese et al., 2006). Despite the fact that we report findings based on longitudinal results, we cannot conclusively exclude the possibility of some reciprocity in the relationship.

Wang previously differentiated between the contributions of physical, mental and social activities in determining dementia risk (Wang, Karp, Winblad, & Fratiglioni, 2002) and found that mental or psychosocial activities were most effective while physical activities did not appear to influence cognitive function. We collapsed all social and leisure activities together to create a single metric of engagement including an item specific to engagement in sport or exercise, so we cannot comment on the different contributions of these aspects of activity. We controlled for physical activity in our analyses, and it did not appear to be related to cognitive outcomes. As Wang notes, it is very difficult to parse out the individual contributions of these different types of activity since most activities involve overlapping levels of each type of stimulation. We showed a relationship between overall levels of engagement and cognitive function longitudinally. This is a valuable finding since perhaps its suggests that the quantity of overall activity rather than taking the 'right' type of activity could be the most meaningful way in which to reduce dementia risk in later life.

Some previous evidence found more of an effect of social activity on cognitive function than any other type of activity, be it physical, cognitive, or other leisure (Akbaraly et al., 2009; James et al., 2011). Often it appears that social activities are seen as a panacea for protecting cognitive decline in older populations. We suggest that this effect is likely due to the possibility that social activities, or at least, those activities described as 'social' in typical questionnaires, tend to combine aspects of all other types of listed activity, be it physical, cognitive, or leisure related. Other activities are more likely to be unidimensional and involve physical activity only, in the case of solitary fitness pursuits, for instance, or cognitive activity only, as in the case of reading alone. This raises the possibility that the quantity of engagement rather than the type of engagement is most predictive of cognitive functioning. This hypothesis deserves further investigation and perhaps will lead us to a better understanding of the nature of social activity's contribution to wellbeing in later life.

A possible shortcoming of our analysis is that using the SEM approach to mediation does not explicitly invoke the modern counterfactual framework that distinguishes controlled direct effects (which purport to quantify an exposure effect under an intervention that sets the mediator to a specific value for all individuals) and controlled indirect effects (defined as a contrast between the total and the controlled direct effects in the absence of exposure-mediator interaction). Under such a framework the causal effects of interest are defined as contrasts of potential outcomes, or a contrast of outcomes that would be observed under different (possibly counter to the fact) exposure and mediator values (from which 'natural' direct and indirect effects are estimated) (VanderWeele, 2011). However, serious questions have been raised about the utility for policy of this counterfactual approach to mediation (Kaufman, 2009). To the extent that any method must rely on untestable assumptions about the absence of exposure-outcome, mediator-outcome and exposure-mediator confounding, the superiority and utility of counterfactual mediation models is not obvious (Naimi, Kaufman, & MacLehose, 2014).

Our findings have implications at a policy level, such that if CR is low, or perceived stress high, engaging in social and leisure activities may help sustain cognition, a possibility which merits further exploration in future research.

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## Disclosure statement

No potential conflict of interest was reported by the authors.

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