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Cognitive resources moderate the adverse impact of poor perceived neighborhood conditions on self-reported physical activity of older adults

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ABSTRACT

Poor neighborhood conditions are associated with lower levels of physical activity for older adults but socio-ecological models posit that physical activity depends on both environmental and individual factors. Older adults' ability to overcome environmental barriers to physical activity may partially rely on cognitive resources. However, evidence on the moderating role of these cognitive resources in the associations between environmental barriers and physical activity is still lacking. We analyzed cross-national and longitudinal data on 28,393 adults aged 50 to 96 years as part of the SHARE. Lack of access to services and neighborhood nuisances were used as indicators of poor neighborhood conditions. Delayed recall and verbal fluency were used as indicators of cognitive resources. Confounder-adjusted generalized estimation equations were conducted to test associations between neighborhood conditions and self-reported moderate physical activity, as well as the moderating role of cognitive resources. Results showed that poor neighborhood conditions reduced the odds of engagement in physical activity. Cognitive resources robustly reduced the adverse influence of poor neighborhood conditions on physical activity. Participants with lower cognitive resource scores showed lower odds of engaging in physical activity when neighborhood conditions were poorer, whereas these conditions were not related to this engagement for participants with higher cognitive resource scores. These findings suggest that cognitive resources can temper the detrimental effect of poor neighborhood conditions on physical activity. Public policies should target both individual and environmental factors to tackle the current pandemic of physical inactivity more comprehensively.

1. Introduction

For > 50 years, it has been recognized that engagement in physical activity (PA) – and its health benefits – are dependent on both individual and contextual factors (Bronfenbrenner, 1979, 1986). Socio-ecological frameworks posit that PA is the result of individuals anticipating and reacting to contextual factors that surround them (Sallis et al., 2015; Sniehotta et al., 2017). For example, although the motivation to engage in PA is an important predictor of PA (Biddle et al., 2007), the decision to cycle versus drive to local stores is also likely

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influenced by variables such as the proximity of these stores and the perceived neighborhood safety. A strong body of evidence supports the facet of socio-ecological frameworks linking PA with environmental factors. Previous studies showed that individuals surrounded by safe areas with well-maintained facilities with public spaces for walking, cycling, and other physical activities are more likely to be physically active than individuals living in a neighborhood without such facilities and spaces (Chastin et al., 2015; Rees-Punia et al., 2018; Van Cauwenberg et al., 2011). However, most relevant research adopting a socio-ecological framework is cross-sectional (Piro et al., 2006; Sallis et al., 2018; Smith et al., 2019; Van Cauwenberg et al., 2014), with only a handful set of longitudinal studies available (Lee et al., 2009; Li et al., 2005; Michael et al., 2010; Xiao et al., 2018), thereby preventing the assessment of contextual factors that may explain PA dynamics (Rebar and Rhodes, 2019).

Furthermore, socio-ecological frameworks' premise that PA is the consequence of a complex interaction between environmental and individual factors has rarely been tested (Ding and Gebel, 2012; Ding et al., 2012; Laatikainen et al., 2019; Perez et al., 2017). Multiple individual-level variables, such as cognitive resources, could moderate the adverse effect of poor neighborhood conditions on engagement in PA (Carlson et al., 2012; Ding and Gebel, 2012; Van Holle et al., 2015). This hypothesis is consistent with recent theoretical (Cheval et al., 2018b), neurobehavioral (Cheval et al., 2018d), and epidemiological (Cheval et al., 2018a) findings showing that cognitive resources are critical in counteracting an automatic attraction to effort minimization, in turn facilitating engagement in PA. However, whether cognitive resources moderate the effect of neighborhood conditions on PA is still unknown (Fig. 1).

This study aimed to investigate, for the first time, whether cognitive resources moderate the impact of neighborhood conditions on engagement in low-to-moderate PA and its trajectory across aging. It was elected to focus on low-to-moderate PA because neighborhood conditions are likely to have the most impact on active transport forms of activity (e.g., walking and cycling), which are typically of low-to-moderate intensity. We investigated two indicators of fluid cognitive abilities: verbal fluency, which is associated with executive functioning (Lezak et al., 2004), and delayed recall, which is an early indicator of cognitive impairment (Zhao et al., 2012). In line with the socio-ecological model (Sallis et al., 2015; Sniehotta et al., 2017) and the theory of energetic cost minimization (Cheval et al., 2018b), we hypothesized that poor neighborhood conditions would be associated with lower engagement in PA (H1a) and faster decline of this engagement across aging (H1b). We also hypothesized that cognitive resources would moderate these effects with weaker associations between neighborhood conditions and PA behavior in individuals with greater cognitive resources (H2a) and an increasing influence of these cognitive resources across aging (H2b).

2. Methods

2.1. Study population and design

Our analyses used data from participants aged 50 years or older, who were included in the Survey of Health, Ageing and Retirement in Europe (SHARE) (Börsch-Supan et al., 2013), a dataset consisting of 6 repeated measurements performed every 2 years between 2004 and 2015. Neighborhood conditions were collected once (either at measurement 1 or 2). Low-to-moderate PA and cognitive function (delayed recall and verbal fluency) were assessed at measurements 1, 2, 4, 5, and 6. Participants with at least one measure of PA, neighborhood conditions, and cognitive functioning were included in the study. Supplemental material 1 provides more details on all the measures described below.

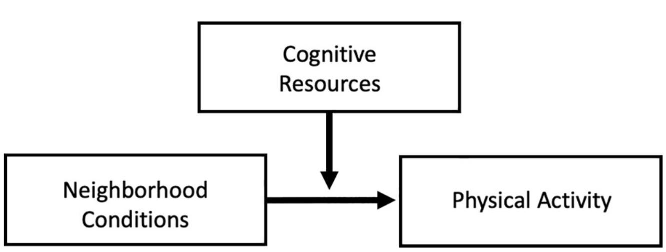

Fig. 1. Diagram illustrating the performed analyses.

2.2. Measures

2.2.1. Physical activity

Low-to-moderate PA was assessed using the following item: "How often do you engage in activities that require a low or moderate level of energy such as gardening, cleaning the car, or doing a walk?". Participants answered on a 4-point scale: 1, more than once a week; 2, once a week; 3, one to three times a month; 4, hardly ever, or never (Boisgontier et al., 2018; Cheval et al., 2018c; de Souto Barreto et al., 2017; Lindwall et al., 2011). Participants who did not answer "1" were classified as "physically inactive". This strategy was used to reduce potential misclassification bias whereby physically inactive participants would be inaccurately categorized as physically active.

2.2.2. Neighborhood conditions

Neighborhood conditions were assessed with four yes/no items. Two items assessed accessibility of services ("*sufficient supply of facilities such as pharmacy, medical care, grocery, and the like within reasonable distance*"; "*sufficient possibilities for public transportation*") and two items assessed neighborhood nuisances ("*pollution, noise or other environmental problems*"; "*vandalism or crime*"). For neighborhood nuisances, participants who answered "yes" to either item were categorized as living in a neighborhood with nuisances. For accessibility to local services, participants who answered "yes" to either item were categorized as living in a neighborhood with access to facilities.

2.2.3. Cognitive resources

Cognitive resources were measured using two indicators (delayed recall and verbal fluency). Delayed recall was assessed using the 10-word delayed recall test (Harris and Dowson, 1982). The delayed recall score is the number of words that the respondent is able to recall, which ranges from 0 to 10. In the verbal fluency test (Rosen, 1980), participants named as many different animals as they could think of in 60 s. The verbal fluency score is the number of correctly named animals. In line with outliers treatment of previous studies using SHARE data (Litwin et al., 2016), scores were top-coded to 45.

2.2.4. Covariates

The covariates and confounders included in the statistical models were gender, education (primary, secondary, tertiary), household's ability to make ends meet (easily, fairly easily, with difficulty, with great difficulty), measurement occasions (1, 2, 4, 5, and 6), birth cohort [war (between 1914 and 1918 and between 1939 and 1945), Great Depression (between 1929 and 1938), no war and no economic crisis (before 1913, between 1919 and 1928, and after 1945)], and chronic conditions (e.g., hypertension, diabetes). Attrition (no dropout, dropout, death) was also controlled for.

2.3. Statistical analysis

Model 1a tested the association between neighborhood conditions and the odds of engagement in low-to-moderate PA. Interaction terms between neighborhood conditions and linear and quadratic age were included in Model 1b to test whether neighborhood conditions moderated the trajectory of PA over age. Model 2a tested whether cognitive resources moderated the association between neighborhood conditions and the odds of engagement in low-to-moderate PA. Three-way interaction terms between neighborhood characteristics, cognitive resources, and linear and quadratic age were included in Model 2b to test whether cognitive resources moderated the influence of neighborhood conditions on PA trajectory across aging. The models were fitted with one indicator of cognitive resources at a time but were also fitted in a fully-adjusted model that included both indicators. Analyses were performed using the geepack R package (Halekoh et al., 2006; R Core Team, 2017).

Four sensitivity analyses were performed: 1) including additional covariates likely to influence both cognitive resources and PA: partner status (living with a partner vs. living alone), smoking behavior (pack-year smoking), body mass index, depression, and self-rated health; 2) excluding participants with dementia; 3) excluding participants who died during the survey; 4) excluding participants who dropped out during the survey. Supplemental material 1 details the covariates used in the sensitivity and main analyses.

Data were analyzed using generalized estimation equations (GEE) with a Poisson log-link and an exchangeable correlation structure. GEE assess changes in the population mean given changes in predictors while accounting for the nested structure of the data (Hubbard et al., 2010). Poisson regression with robust standard errors is recommended to accurately estimate the relative risk (through exponentiation of the coefficient estimates) when testing binary outcomes (Zou, 2004). The models included linear and quadratic terms for age, as well as the a priori covariates and confounders as fixed effects. Age was centered at the midpoint of the sample's age range (73 years) and was then divided by 10. Thus, the coefficients yielded effects of the rate of change in low-to-moderate PA over a 10-year period.

Model 1a tested the association between neighborhood conditions and the odds of engagement in low-to-moderate PA. Interaction terms between neighborhood conditions and linear and quadratic age were included in Model 1b to test whether neighborhood conditions moderated the trajectory of PA over age. Model 2a tested whether cognitive resources moderated the association between neighborhood conditions and the odds of engagement in low-to-moderate PA. Three-way interaction terms between neighborhood characteristics, cognitive resources, and linear and quadratic age were included in Model 2b to test whether cognitive resources moderated the influence of neighborhood conditions on PA trajectory across aging. The models were fitted with one indicator of cognitive resources at a time but were also fitted in a fully-adjusted model that included both indicators. Analyses were performed using the geepack R package (Halekoh et al., 2006; R Core Team, 2017).

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3. Results

Table 1 reports participants' characteristics as a function of their baseline engagement in low-to-moderate PA. The final sample included 28,393 participants living in 15 European countries. Physically active participants showed better delayed recall and verbal fluency, higher education, were younger and less likely to be a woman, to have 2 or more chronic conditions, and to drop out or die during the survey than physically inactive participants. Delayed recall (mean = 3.5 ± 1.9; range 0–10) and verbal fluency (mean = 19.1 ± 7.1; range 0–45) showed a moderate correlation (r = 0.40, $p < 0.001$).

3.1. *Neighborhood conditions and physical activity*

3.1.1. *Level*

Results of Model 1a (Table 2) showed that a neighborhood with poor accessibility to services (relative risk [RR] = 0.98, 95% confidence internal [CI] = 0.97–0.99, $p = 0.002$) and with nuisances (RR = 0.98, CI = 0.96–0.99, $p < 0.001$) was associated with decreased odds of engagement in low-to-moderate PA. These odds were 2.0% lower when services accessibility was poorer or in the presence (vs. absence) of neighborhood nuisances.

3.1.2. *Rate of change*

In Model 1b, the lack of access to local services, but not neighborhood nuisances, was associated with steeper linear and quadratic decrease of the odds of engagement in low-to-moderate PA across aging (RR = 0.95, CI = 0.92–0.97, $p < 0.001$ for linear age effect; RR = 0.98, CI = 0.97–1.00, $p = 0.029$ for quadratic effect) (Table 2). Specifically, the odds of being physically active decreased by 19.3% from 73 (intercept) to 83 years when services were accessible. By contrast, the odds decreased by 23.5% when accessibility to services was poor .

3.2. *Cognitive resources as a moderator of the effect of neighborhood conditions on physical activity*

3.2.1. *Level*

In Models 2a, delayed recall and verbal fluency tempered the negative association between the lack of access to services and the odds of engagement in low-to-moderate PA (RR = 1.02, CI = 1.01–1.02, $p < 0.001$ for delayed recall; RR = 1.01, CI = 1.00–1.03, $p = 0.016$ for verbal fluency) (Fig. 2; Table 2). Simple slopes effects revealed that when delayed recall was low (−1 SD), the odds of being physically active were 4% lower when services were not accessible (vs. accessible) (RR = 0.96, CI = 0.94–0.98, $p < 0.001$). The odds of being physically active were 2% lower in individuals with an average level (mean) of delayed recall (RR = 0.98, CI = 0.97–0.99, $p = 0.002$). By contrast, services accessibility did not influence the odds of being physically active for individuals with high levels (+1 SD) of delayed recall (RR = 1.00, CI = 0.98–1.01, $p = 0.864$). Similar results were observed with verbal fluency with the odds of engagement in PA being 4% and 2% lower in participants with low (RR = 0.96, CI = 0.94–0.98, $p < 0.001$) and average verbal fluency (RR = 0.98, CI = 0.96–0.99, $p < 0.001$), respectively; whereas accessibility did not influence PA in participants with high verbal fluency (RR = 0.99, CI = 0.98–1.00, $p = 0.195$) (Fig. 2; Table 2).

In addition, verbal fluency, but not delayed recall, tempered the negative association between neighborhood nuisances and the odds of engagement in PA (RR = 1.01, CI = 1.00–1.03, $p = 0.009$). Simple slopes effects revealed that in participants with low or average levels of verbal fluency, the odds of being physically active in a neighborhood with versus without nuisances were 4% (RR = 0.96, CI = 0.95–0.98, $p < 0.001$) and 2% lower (RR = 0.98, CI = 0.96–0.99, $p < 0.001$), respectively. By contrast, nuisances did not influence the odds of being physically active for individuals with high levels of verbal fluency (RR = 1.00, CI = 0.98–1.01, $p = 0.568$) (Fig. 2; Table 2). In the fully-adjusted model, delayed recall (but not verbal fluency) moderated the association between services accessibility and the odds of engagement in PA, and verbal fluency moderated the association between neighborhood nuisances and the odds of engagement in PA.

3.2.2. *Rate of change*

Models 2b showed that higher delayed recall or verbal fluency was associated with a less accelerated (although $p = 0.053$ for the quadratic age effect for delayed recall) decrease of the odds of engagement in low-to-moderate PA over aging (Table 2). Delayed recall did not moderate the association between neighborhood conditions and the evolution of

Table 1
Sample characteristics reported by physical activity level at baseline.

	Physically active		Physically inactive		*p* value
Neighborhood conditions					
Neighborhood accessibility					
Access	14,611	72.6%	5821	70.4%	
Lack of access	5519	27.4%	2442	29.6%	< 0.001
Neighborhood nuisances					
Absence of nuisances	14,176	70.4%	5509	66.7%	
Nuisances	5951	29.6%	2754	33.3%	< 0.001
Cognitive resources					
Delayed recall (number of words), SD	3.7	1.9	3.2	1.9	< 0.001
Verbal fluency (number of words), SD	19.9	6.9	17.2	7.0	< 0.001
Covariates					
Age at baseline (years), SD	62.5	9.0	64.4	10.1	< 0.001
Gender					
Women	10,865	54.0%	4701	56.9%	
Men	9265	46.0%	3562	43.1%	< 0.001
Education					
Primary	5347	26.6%	2872	34.8%	
Secondary	10,432	51.8%	4021	48.6%	
Tertiary	4351	21.6%	1370	16.6%	< 0.001
Chronic conditions (> 2)					
Yes	7859	39.0%	4102	49.6%	
No	12,271	60.1%	4161	50.4%	< 0.001
Birth cohort					
After 1945	8646	43.0%	3182	38.5%	
Between 1939 and 1945	4758	23.6%	1688	20.5%	
Between 1929 and 1938	4853	24.1%	2051	24.8%	
Between 1919 and 1928	1873	9.3%	1342	16.2%	< 0.001
Attrition					
No drop out	11,279	56.0%	3987	48.2%	
Drop out	6996	34.8%	3010	36.5%	
Death	1855	9.2%	1263	15.3%	< 0.001

the odds of engagement in PA over aging. By contrast, verbal fluency moderated the association between neighborhood nuisances and the quadratic change of PA over aging (RR = 1.01, CI = 1.00–1.03, $p = 0.041$). The negative association between neighborhood nuisances and the decrease in the odds of engagement in PA over aging was more pronounced in participants with lower verbal fluency.

3.3. Sensitivity analyses

Results of the sensitivity analyses adjusting for additional covariates likely to influence cognitive resources and PA were consistent with the main results. Results excluding participants who dropped out, died, or had dementia were also consistent with the main results (Table S1).

4. Discussion

4.1. Main findings

Results showed that cognitive resources robustly tempered the adverse influence of poor neighborhood conditions on engagement in low-to-moderate PA: poor neighborhood conditions reduced the odds of being physically active among individuals with low or moderate, but not high, levels of cognitive resources. Although a 4% difference in the odds of engagement in PA may be considered a modest effect size, this effect is meaningful when considering a large population. For example, in our sample of 28,393 individuals, this 4% difference represents 1136 individuals. Verbal fluency also moderated the effect of neighborhood conditions on declining trajectories of PA across age: an accelerated decrease in the odds of engagement in PA over age was observed in individuals with lower verbal fluency and living in a neighborhood with nuisances. These effects remained significant after adjusting for multiple socioeconomic and health-related covariates.

4.2. Comparison with previous studies

4.2.1. Neighborhood conditions affect physical activity

Results showed that poor neighborhood conditions were associated with lower odds of engagement in low-to-moderate PA (H1a) and with a steeper and accelerated decline of this engagement across aging (H1b). These associations were observed for both the lack of access to services and neighborhood nuisances. These findings are consistent with the socio-ecological framework of PA (Sallis et al., 2015; Sniehotta et al., 2017) and previous studies showing an association between neighborhood conditions and PA (Chastin et al., 2015; Li et al., 2005; Michael et al., 2010; Piro et al., 2006; Rees-Punia et al., 2018; Sallis et al., 2018; Smith et al., 2019; Van Cauwenberg et al., 2011; Van Cauwenberg et al., 2014; Xiao et al., 2018). Importantly, this large-scale prospective study extends the existing evidence because most of the previous studies were cross-sectional (although, in our study, neighborhood conditions were assessed only once), of more homogenous age ranges, and did not investigate potential individual moderators of the association between neighborhood factor and PA (Van Cauwenberg et al., 2011; Xiao et al., 2018). Overall, our findings confirmed that older adults' PA – and its decline across aging – is not only influenced by individuals' factors, but also by environmental factors (Satariano and McAuley, 2003).

4.2.2. Cognitive resources as a moderator of the effect of neighborhood conditions on physical activity

Results showed that cognitive resources reduced the adverse influence of poor neighborhood conditions on PA (H2a). The adverse effect of the lack of access to services on PA was more pronounced in individuals with lower levels of verbal fluency or delayed recall, whereas the adverse effect of neighborhood nuisances was higher only for individuals with lower verbal fluency. Specifically, the adverse effects of these poor neighborhood conditions were observed in individuals with low or moderate, but not high, levels of cognitive resources. In other

Table 2
Associations of neighborhood conditions with the odds of engagement in moderate physical activity across aging, as well as the moderating role of cognitive resources.

Variables	Model 1a		Model 2a Delayed recall		Model 2a Verbal fluency	
	RR (95% CI)	*p* value	RR (95% CI)	*p* value	RR (95% CI)	*p* value
Level						
Intercept (at age 73 years)	0.61 (0.59–0.63)	< 0.001	0.62 (0.60–0.63)	< 0.001	0.63 (0.61–0.64)	< 0.001
Neighborhood conditions						
Neighborhood nuisances (ref. absence of nuisances)						
Nuisances	0.98 (0.96–0.99)	< 0.001	0.98 (0.96–0.99)	< 0.001	0.98 (0.97–0.99)	0.002
Neighborhood access (ref. access)						
Lack of access	0.98 (0.97–0.99)	0.002	0.98 (0.97–0.99)	0.002	0.98 (0.96–0.99)	< 0.001
Cognitive resources						
Delayed recall			1.03 (1.02–1.04)	< 0.001		
Verbal fluency					1.08 (1.07–1.09)	< 0.001
Moderating effect of cognitive resources						
Delayed recall × neighborhood nuisances (ref. absence of nuisances)						
Delayed recall × nuisances						
Delayed recall × neighborhood access (ref. access)						
Delayed recall × lack of access						
Verbal fluency × neighborhood nuisances (ref. absence of nuisances)						
Verbal fluency × nuisances						
Verbal fluency × neighborhood access (ref. access)						
Verbal fluency × lack of access						

Variables	Model 1b		Model 2b Delayed recall		Model 2b Verbal fluency	
	RR (95% CI)	*p* value	RR (95% CI)	*p* value	RR (95% CI)	*p* value
Rate of change						
Age (10 year follow-up)	0.81 (0.80–0.83)	< 0.001	0.83 (0.81–0.84)	< 0.001	0.85 (0.83–0.86)	< 0.001
Age (10 year follow-up) squared	0.93 (0.92–0.94)	< 0.001	0.94 (0.93–0.95)	< 0.001	0.95 (0.94–0.96)	< 0.001
Neighborhood conditions						
Neighborhood nuisances (ref. absence of nuisances)						
Age × nuisances	0.99 (0.97–1.02)	0.547	1.00 (0.97–1.03)	0.974	1.01 (0.98–1.03)	0.702
Age squared × nuisances	1.00 (0.99–1.02)	0.557	1.01 (0.99–1.02)	0.473	1.01 (0.99–1.02)	0.372
Neighborhood access (ref. access)						
Age × lack of access	0.95 (0.92–0.97)	< 0.001	0.96 (0.93–0.98)	0.001	0.96 (0.94–0.99)	0.005
Age squared × lack of access	0.98 (0.97–1.00)	0.029	0.99 (0.97–1.00)	0.053	0.99 (0.97–1.00)	0.120
Cognitive resources						
Age × delayed recall			1.04 (1.02–1.05)	< 0.001		
Age squared × delayed recall			1.01 (1.00–1.02)	0.067		
Age × verbal fluency					1.06 (1.05–1.08)	< 0.001
Age squared × verbal fluency					1.01 (1.01–1.02)	0.001
Moderating effect of cognitive resources						
Delayed recall × neighborhood nuisances (ref. absence of nuisances)						
Age × delayed recall × nuisances						
Age squared × delayed recall × nuisances						
Delayed recall × neighborhood access (ref. access)						
Age × delayed recall × lack of access						
Age squared × delayed recall × lack of access						
Verbal fluency × neighborhood nuisances (ref. absence of nuisances)						
Age × verbal fluency × nuisances						
Age squared × verbal fluency × nuisances						
Verbal fluency × neighborhood access (ref. access)						
Age × verbal fluency × lack of access						
Age squared × verbal fluency × lack of access						

Notes. All models were adjusted for gender, education, household's ability to make ends meet, measurement occasion, birth cohort, chronic conditions, and participants' attrition. All models included a random intercept and linear slopes for the repeated measurements at the level of participants. “Age (10-year follow-up)” and “Age (10-year follow-up) squared” estimated the linear and quadratic changes in the odds of engagement in physical activity over a 10-year period.

words, results suggested that higher levels of verbal fluency buffered the adverse effects of both service inaccessibility and neighborhood nuisance, whereas higher levels of delayed recall buffered the negative influence of poor accessibility to services only.

When considering cognitive resources, a decrease of 1 SD in delayed recall was associated with a 3% decrease in the odds of engagement in PA, whereas a decrease of 1 SD in verbal fluency was associated with an 8% decrease. Moreover, the moderating effect of verbal fluency increased as adults aged (H2b), suggesting that this cognitive resource explained differences in the decline of engagement in PA. Although both verbal fluency and delayed recall tasks are used to assess fluid cognitive abilities (i.e., the ability to processes and integrate information and solve new problems), verbal fluency is thought to be particularly related to executive functioning, such as executive control, selective attention, or selective inhibition. Delayed recall is more particularly related to early cognitive impairment (Lezak et al., 2004; Zhao et al., 2012). These findings suggesting that poor executive functioning is particularly detrimental to PA are consistent with previous evidence demonstrating that cortical activity associated with inhibition and conflict monitoring (Cheval et al., 2018d) is critical for the

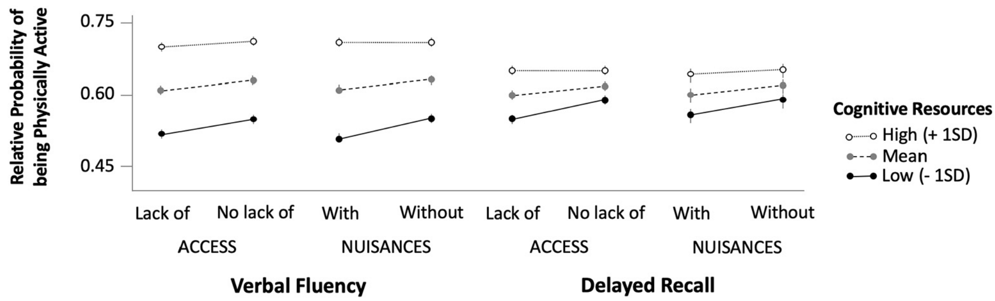

Fig. 2. Relative probability of being physically active as a function of cognitive resources (verbal fluency; delayed recall) and neighborhood conditions (lack of access to local services; nuisances).
Notes. Error bars = 95% confidence interval; SD = standard deviation.

successful regulation of PA. These results support a recent theory (Cheval et al., 2018b) contending that cognitive resources are required to counteract an automatic attraction to effort minimization, especially in modern societies, where opportunities to minimize energy expenditure are ubiquitous. The interaction between individual and environmental factors is also consistent with socio-ecological models of PA arguing that multiple levels (i.e., from individual to environment and social policy) may work together to influence behaviors (Rhodes et al., 2018; Sallis et al., 2006).

4.3. Public health implications

Socio-ecological models put forth that effective health promotion efforts must account for both individual and environmental factors. This study provides evidence that the individual factor of cognitive resources may be worth targeting in PA interventions for people who face perceived barriers within their neighborhoods. Cognitive resources may be important to overcome such barriers. Moreover, as PA has shown to improve cognitive function (Erickson et al., 2011), engaging in regular PA may trigger a “virtuous circle” in which PA strengthens cognitive resources, which in turn increase the level of PA. Therefore, policy makers should promote safe and well-maintained infrastructures and provide ubiquitous, attractive, and easily-accessible spaces to facilitate the engagement in PA.

4.4. Strengths and weaknesses

The strengths of this study include the large sample size, a follow-up of 12 years with repeated measurement, the use of two different indicators of cognitive resources, the use of multiple sensitivity analyses, and the control of multiple sociodemographic and health-related covariates. However, several limitations should also be noted. First, PA was measured using a self-report questionnaire, which may reduce the validity of the estimated levels of PA (Prince et al., 2008). Moreover, this measure focused on low-to-moderate PA and did not assess vigorous PA. The item used to measure PA was not initially designed to assess PA in the neighborhood, such as walking to the shops. Nevertheless, focusing on PA that is specifically related to active movement in the neighborhood would most likely strengthen rather than weaken the effect of neighborhood conditions on PA. Second, this study assessed perceived neighborhood but not objective conditions, which are related but distinct constructs (Orstad et al., 2016). As such, the current design cannot exclude reverse causality as age, cognitive resources, or usual PA is also likely to influence these perceptions. To more comprehensively test socio-ecological models, it is important to investigate perceived and objective assessments of contexts (and their interactions). Neighborhood conditions were only assessed once, thereby preventing drawing conclusions on the dynamic associations between changes in neighborhood and changes in PA. Third, we argue that the level of cognitive resources predicts PA, whereas previous studies also reported a protective effect of PA on cognitive function (Loprinzi et al., 2017; Sofi et al., 2011), thereby suggesting a bidirectional relationship between cognitive resources and PA. Future studies such as the one of (Cheval et al. 2018a) should formally test for this potential reciprocal association. Finally, residential self-selection bias, defined as the influence of attitudinal predispositions to choose to live in a specific neighborhood, may confound the observed association between neighborhood conditions and PA (Boone-Heinonen et al., 2011; Cao et al., 2009).

5. Conclusion

Socio-ecological models emphasize the need to optimize both individual and environmental factors in PA promotion efforts (Sallis et al., 2015; Sniehotta et al., 2017). This study supports that claim: poor neighborhood conditions are associated with lower engagement in PA and with a steeper decline of this engagement across aging. Additionally, cognitive resources temper the adverse impact of these environmental conditions. Therefore, cognitive resources may be a particularly relevant target for interventions in older adults with poor neighborhood conditions. On a larger scale, this study highlights the necessity for policy-makers to promote safe and well-maintained infrastructures and provide ubiquitous, attractive, and easily accessible spaces facilitating PA such as walkways, stairs, and cycle paths. This general, multi-level, and multi-dimensional approach to promote an activity-friendly environment would participate to curing the pandemic of physical inactivity (Kohl et al., 2012).

Contributors

B.C. and M.P.B. designed the analyses. B.C. and M.P.B. analyzed the data. B.C. and M.P.B. drafted the manuscript. All authors critically appraised and approved the final version of the manuscript.

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Ethical approval

This study was part of the SHARE study, approved by the relevant research ethics committees in the participating countries, and all participants provided written informed consent.

Data sharing

This SHARE dataset is available at http://www.share-project.org/data-access.html.

Declaration of Competing Interest

The authors declare no conflict of interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2019.05.029.

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