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# The Relationship of Obesity Predicting Decline in Executive Functioning is Attenuated with Greater Leisure Activities in Old Age

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## Conflict of interest

We declare that there is no conflict of interest.

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**Abstract**

*Objectives*: We investigated the longitudinal relationship between obesity and subsequent decline in executive functioning over six years as measured through performance changes in the Trail Making Test (TMT). We also examined whether this longitudinal relationship differed by key markers of cognitive reserve (education, occupation, and leisure activities), taking into account age, sex, and chronic diseases as covariates.

*Method*: We used latent change score modeling based on longitudinal data from 897 older adults tested on TMT parts A and B in two waves six years apart. Mean age in the first wave was 74.33 years. Participants reported their weight and height (to calculate BMI), education, occupation, leisure activities, and chronic diseases.

*Results*: There was a significant interaction of obesity in the first wave of data collection with leisure activities in the first wave on subsequent latent change. Specifically, obesity in the first wave significantly predicted a steeper subsequent decline in executive functioning over six years in individuals with a low frequency of leisure activities in the first wave. In contrast, in individuals with a high frequency of leisure activities in the first wave, this longitudinal relationship between obesity and subsequent decline in executive functioning was not significant.

*Conclusion*: The longitudinal relationship between obesity and subsequent decline in executive functioning may be attenuated in individuals who have accumulated greater cognitive reserve through an engaged lifestyle in old age. Implications for current cognitive reserve and gerontological research are discussed.

*Keywords*: decline in executive functioning; cognitive reserve; obesity; longitudinal study

Word counts: Abstract = 236, text = 4118

## Introduction

Due to the demographic changes, with more and more adults attaining older ages, but, at the same time, also an increase of people suffering from cognitive impairments, the preservation of cognitive health in old age constitutes one of the major challenges in this century (Gouveia et al., 2017; Suzman, Beard, Boerma, & Chatterji, 2015). In this regard, the cognitive reserve concept postulates that lifelong experiences, including educational and occupational attainment, and leisure activities, provide cognitive stimulation building up a buffer that is instrumental for preserving cognitive functioning in aging (Stern, 2009, 2012). Empirically corroborating the predictions of the cognitive reserve concept, both cross-sectional and longitudinal evidence for example showed that multiple frequently-used markers of cognitive reserve such as longer education in early life, more cognitively demanding jobs in midlife, and a greater engagement in leisure activities in old age contribute to the accumulation of cognitive reserve and are related to better executive functioning in old age (Hertzog, Kramer, Wilson, & Lindenberger, 2008; Opdebeeck, Martyr, & Clare, 2016; Schneeweis, Skirbekk, & Winter-Ebmer, 2014; Wang et al., 2013). The latter findings on late-life activity engagement dovetail with the concept of "use it or lose it" (Hultsch, Hertzog, Small, & Dixon, 1999; Orrell & Sahakian, 1995), which postulated that a cognitively engaged lifestyle during adulthood preserves and possibly even increases cognitive functioning while not using one's intellectual resources would decrease the buffer against cognitive impairment.

Previous research has demonstrated that cognitive reserve may help to overcome cognitive impairments that are related to health risk factors such as obesity (Galioto, Alosco, Spitznagel, Stanek, & Gunstad, 2013). In general, obesity (Body Mass Index [BMI] of 30 or higher, as defined by the World Health Organization; WHO, 1995) is a major health risk, particularly in older adults. For instance, obesity is related to cardiovascular diseases and metabolic disorders such as diabetes (Bell, Kivimaki, & Hamer, 2014; Fan, Song, Chen, Hui, & Zhang, 2013), which are risk factors for cognitive impairments in midlife and old age

(Carmichael, 2014; Reijmer et al., 2012; Schneider et al., 2015). Accordingly, several studies found that obesity is associated with impaired cognitive abilities such as executive functioning and memory in midlife and old age (Dahl et al., 2010; Ravona-Springer, Schnaider-Beeri, & Goldbourt, 2013; Stanek et al., 2013). Yet, the relationship between obesity and cognitive functioning is not always negative and may depend on the particular life phase studied. For example, while obesity at midlife and young-old age is a risk factor for late life cognitive impairment, in contrast, obesity in late life seems somehow protective for cognitive abilities such as executive functioning (for discussions see e.g. Benito-León, Mitchell, Hernández-Gallego, & Bermejo-Pareja, 2013; Fitzpatrick, Gilbert, & Serpell, 2013; Gunstad, Lhotsky, Wendell, Ferrucci, & Zonderman, 2010; Smith, Hay, Campbell, & Troller, 2011). Furthermore, the relationship between obesity and executive functioning in old age may be modulated by individual-difference characteristics such as an individual's cognitive reserve.

In this regard, recent empirical cross-sectional evidence suggests that in individuals with greater cognitive reserve (e.g., higher education and greater engagement in leisure activities) the detrimental relations of obesity to poorer performance status in executive functioning were markedly reduced (e.g., Ihle et al., 2016; see also Galioto et al., 2013; Kirton & Dotson, 2016). Yet, to the best of our knowledge, there is no longitudinal investigation to date regarding the role of cognitive reserve in modifying the longitudinal relationship between obesity and subsequent decline in executive functioning. This gap in the literature is particularly troubling, as longitudinal research is needed to evaluate whether cognitive reserve not only modifies the cross-sectional association between obesity and executive functioning at a given point in time, but also the longitudinal relationship between obesity and the rate of subsequent decline in executive functioning. To address this major gap in the literature, we investigated the longitudinal relationship between obesity and subsequent decline in executive functioning over six years as measured through performance changes in the Trail Making Test

(TMT). We also examined whether this longitudinal relationship differed by key frequently-used markers of cognitive reserve (i.e., education, occupation, and leisure activities), taking into account age, sex, and chronic diseases as covariates.

## Methods

### Participants

We analyzed data from 897 community-dwelling individuals who participated in the two waves of the Vivre-Leben-Vivere (VLV) survey (Ihle, Ghisletta et al., 2018; Ihle et al., 2015; Oris et al., 2016). VLV is a large interdisciplinary survey targeting the life and health conditions of individuals aged 65 and older living in Switzerland. VLV assessed multiple spheres of individuals' life such as mental and physical health, and activity participation. For further details regarding the rationale, design, recruitment, materials, and data collection procedures of the VLV survey see e.g. Ihle, Ghisletta et al. (2018), Ihle et al. (2016), Ludwig et al. (2014), and Oris et al. (2016). Respondents were first interviewed during 2011 (Wave 1; W1) and again in 2017 (Wave 2; W2) using face-to-face computer-assisted personal interviewing (CAPI) and paper-pencil questionnaires. Mean age of these respondents in W1 was 74.33 years (*SD* = 6.50, range 65-96).

All participants were volunteers and gave their written informed consent for inclusion in the study before participating. The present study was conducted in accordance with the Declaration of Helsinki, and the study protocol had been approved by the ethics commission of the Faculty of Psychology and Social Sciences of the University of Geneva (project identification codes: CE_FPSE_14.10.2010 and CE_FPSE_05.04.2017).

### Materials

*Trail Making Test Completion Time*

In both waves, we administered the Trail Making Test part A (TMT A; Reitan, 1958) involving processing speed and visuoperceptual abilities. After one exercise trail (connecting the numbers from 1 to 8), participants had to connect the numbers from 1 to 25 as fast as possible and without error in ascending order. The TMT A completion time was the time in seconds needed to correctly connect the 25 numbers.

In addition, we administered in both waves the Trail Making Test part B (TMT B; Reitan, 1958) involving cognitive flexibility / set-shifting / task-switching and working memory. After one exercise trail (connecting 1-A-2-B-3-C-4-D), participants had to connect the numbers 1 to 13 in ascending order and the letters A to L in alphabetic order while alternating between numbers and letters (i.e., 1-A-2-B-3-C ... 12-L-13) as fast as possible and without error. The TMT B completion time was the time in seconds needed to correctly connect the 25 numbers / letters.

*Obesity*

We asked participants in W1 to indicate their weight and height. We calculated BMI as the weight in kg divided by the squared height in m. We classified participants as being obese using conventional criteria for Western countries, based on having a BMI of at least 30 (WHO, 1995).

*Markers of Cognitive Reserve*

*Education*. We asked participants to indicate the total time in years they had spent for formal education (comprising primary school, secondary school, and university).

*Cognitive demand of jobs*. We asked participants to indicate their past professions and how many years they had each been practiced during adulthood. Following Nucci, Mapelli, and Mondini (2012), we recorded these professions in different job categories based on a five-point Likert-type scale reflecting the degree of intellectual involvement and personal responsibility at work: (1) unskilled manual / non-manual work (e.g., farmer, car driver, call center operator); (2) skilled manual work (e.g., craftsman, clerk, hairdresser); (3) skilled non-manual or technical work (e.g., trader, kindergarten teacher, real estate agent); (4) specialized work (e.g., psychologist, physician, head of a small enterprise); or (5) highly intellectual work with large responsibilities (e.g., director of a large company, judge, top manager). Following

Nucci et al. (2012), we calculated the overall score of cognitive demand of jobs by multiplying the years of professions by the respective cognitive demand (1 to 5, as illustrated above) and summing up across the different job categories.

*Leisure activities*. We asked participants in W1 about their engagement in the following 18 leisure activities: (1) go for a walk; (2) gardening; (3) gymnastics or other physical exercises; (4) other sports; (5) go into a café, restaurant, etc.; (6) go to the cinema, theater, etc.; (7) excursions of 1 or 2 days; (8) journeys of at least 3 days; (9) play a musical instrument; (10) other artistic activities; (11) take courses, go to conferences, etc.; (12) party games (cards, scrabble, etc.); (13) crossword puzzles, sudoku, etc.; (14) needlework (knit, dressmaking, etc.); (15) handicrafts, repair, carpentry, pottery, etc.; (16) participation in political or labor union activities; (17) participation in municipality or district activities; and (18) participation in sporting events (e.g., visit a football match, etc.). These activities had been a priori selected with respect to different life domains such as cognitive activities, physical activities, and social activities comprising a large variety of leisure activities (e.g., Karp et al., 2006). For each of the 18 activities, participants reported in W1 current frequency of engagement at that time, using a five-point Likert-type scale with values of 0 ('never'), 1 ('at least once a year'), 2 ('at least once a month'), 3 ('at least once a week'), or 4 ('every day or almost every day'). To derive an overall measure of frequency of leisure activities in W1, we averaged frequency scores across all 18 leisure activities in W1 (possible range 0-4; for a validation see e.g. Jopp & Hertzog, 2010; see Paggi, Jopp, & Hertzog, 2016, for the same approach).

*Chronic Diseases*

We interviewed participants in W1 regarding the chronic diseases they suffered from, such as heart diseases of ischemic or organic pathogenesis, primary arrhythmias, pulmonary heart diseases, hypertension, and peripheral vascular diseases. For analyses, we summed up the overall number of chronic diseases participants suffered from in W1 as a global indicator of individuals' multimorbidity (Ihle, Oris et al., 2018; Rozzini et al., 2002).

**Statistical Analyses**

We conducted latent change score modeling (McArdle, 2009) using the R package lavaan (Rosseel, 2012). The specification of our latent change score model is illustrated in Figure 1. Specifically, we modeled latent executive functioning factors of TMT completion time in W1 (constructed from scores in TMT parts A and B in W1) and W2 (constructed from scores in TMT parts A and B in W2) as well as a latent change in executive functioning variable regarding change in TMT completion time from W1 to W2. We enforced strong factorial invariance on the factor loadings, with intercepts of all indicators being fixed to zero to assure that the same executive functioning factor was assessed at both waves (Meredith & Teresi, 2006). We included several covariates that predicted latent change and were correlated to the latent executive functioning factor in W1: obesity in W1, the markers of cognitive reserve (education, cognitive demand of jobs, and frequency of leisure activities in W1), the number of chronic diseases in W1, age in W1, sex, and the interactions of obesity in W1 with the markers of cognitive reserve. We also included interrelations of all covariates to take the dependencies among them into account.

For model estimation, we used full information maximum likelihood. We calculated bootstrapped standard errors (based on 1000 bootstrap draws). We additionally inspected the bootstrapped 95% confidence intervals (*CI*s). We evaluated model fit as follows: Given that with large study samples the $\chi^2$ test often indicates a significant deviation of the model matrix from the covariance matrix despite good model fit (Hu & Bentler, 1999), we inspected several additional fit indices. Specifically, we used the following criteria: Comparative Fit Index (good models: $CFI > .95$), Incremental Fit Index (good models: $IFI > .95$), Root Mean Square Error of Approximation (good models: $RMSEA < .06$), and Standardized Root Mean Square Residual (good models: $SRMR < .08$; Hu & Bentler, 1999). We analyzed education, cognitive demand of jobs, frequency of leisure activities, the number of chronic diseases, and age as continuous variables. We standardized these covariates so that the reported raw estimates (*b*) can be interpreted in terms of *SD*s. We did not standardize completion time in TMT A or TMT B so that the reported raw estimates can be interpreted in seconds.

## Results

### Descriptive Statistics

Table 1 shows descriptive statistics of all analyzed measures in terms of means and standard deviations as well as sample proportions. Comparing both waves, there were no statistically significant differences in the average completion time in neither TMT A nor TMT B ($p$s > .145).

### Latent Change Score Modeling

The latent change score model provided a good statistical account of the data ($\chi^2$ = 43.69, $df$ = 19, $p$ = .001, *CFI* = .98, *IFI* = .99, *RMSEA* = .04, *SRMR* = .02).

*Longitudinal Predictions of Subsequent Change in TMT Completion Time*

Longer TMT completion time in W1 (i.e., lower performance status in executive functioning) and a higher frequency of leisure activities in W1 significantly predicted a smaller subsequent increase in TMT completion time from W1 to W2 (i.e., a smaller decline in executive functioning; see upper panel of Table 2). A larger number of chronic diseases in W1 and older age in W1 significantly predicted a larger subsequent increase in TMT completion time from W1 to W2 (i.e., steeper decline in executive functioning). Obesity in W1, education, cognitive demand of jobs, and sex did not predict changes in TMT completion time. Notably, there was a significant interaction of obesity in W1 with the frequency of leisure activities in W1. Specifically, at a low frequency of leisure activities in W1 (-1 *SD*), obesity in W1 significantly predicted a larger subsequent increase in TMT completion time from W1 to W2 (i.e., steeper decline in executive functioning, raw estimate $b$ = 6.57, $p$ = .046, 95% *CI*: 0.27 to 13.47, corresponding standardized estimate $\beta$ = .12). In contrast, at a high frequency of leisure activities in W1 (+1 *SD*), this longitudinal relationship between obesity and subsequent decline in executive functioning was not significant ($b$ = -2.71, $p$ = .358, 95% *CI*: -8.43 to 3.00, corresponding $\beta$ = -.05; cf. Figure 2). Besides that, no other interactions of obesity in W1 with the markers of cognitive reserve on latent change in TMT completion time were observed.

*Cross-Sectional Correlations with TMT Completion Time in W1*

Longer education, higher cognitive demand of jobs, and a higher frequency of leisure activities in W1 significantly correlated with shorter TMT completion time in W1 (i.e., better performance status in executive functioning; see lower panel of Table 2). A larger number of chronic diseases in W1 and older age in W1 significantly correlated with longer TMT completion time in W1 (i.e., lower performance status in executive functioning). Obesity in W1 and sex were not related to TMT completion time in W1.

## Discussion

The present study investigated the longitudinal relationship between obesity and subsequent decline in executive functioning over six years as measured through performance changes in the TMT. We also examined whether this longitudinal relationship differed by key markers of cognitive reserve. We found that higher values in several markers of cognitive reserve (in terms of education, cognitive demand of jobs, and leisure activities) were related to a better performance status in executive functioning (i.e., indicated by shorter TMT completion time). This finding confirms the conceptual view that cognitive stimulation may be associated with cognitive reserve, thereby being related to better executive functioning in old age (Hertzog et al., 2008; Opdebeeck et al., 2016; Stern, 2012).

However, regarding decline in executive functioning across six years, we observed only few longitudinal associations with markers of cognitive reserve. Neither education nor cognitive demand of jobs did significantly predict changes in TMT completion time. Yet, we observed that a higher frequency of leisure activities pursued in the first wave of data collection longitudinally predicted a smaller subsequent decline in executive functioning (i.e., indicated by a smaller increase in TMT completion time). Thus, our findings are also consistent with studies that observed a longitudinal relationship between greater activity engagement in old age and reduced decline in executive functioning (Wang et al., 2013).

Notably, and most importantly, with respect to the longitudinal relationship between obesity and subsequent decline in executive functioning, we found a significant interaction of obesity in the first wave of data collection with leisure activities in the first wave on subsequent latent change. Specifically, obesity in the first wave significantly predicted a steeper subsequent decline in executive functioning (i.e., indicated by increases in TMT completion time) only in individuals with a low frequency of leisure activities in the first wave. In contrast, in individuals with a high frequency of leisure activities in the first wave, this longitudinal relationship between obesity and subsequent decline in executive functioning was not significant. Thus, the longitudinal relationship between obesity and subsequent decline in executive functioning may be attenuated in individuals who have accumulated greater cognitive reserve through an engaged lifestyle in old age. This finding confirms our prediction regarding the key role of cognitive reserve in attenuating obesity-related executive functioning changes in old age. In this regard, present longitudinal findings confirm recent empirical cross-sectional studies reporting that cognitive reserve (e.g., greater engagement in leisure activities in old age) is associated with a reduced negative cross-sectional relationship between obesity (as well as other metabolic disorders such as unfavorable blood fat level and hypertension) and poorer executive functioning (as well as short-term, long-term, and working memory) in old age (Ihle et al., 2016; see also Galioto et al., 2013; Ihle, Gouveia et al., 2018a; Ihle et al., 2017a; Kirton & Dotson, 2016). Importantly, our study extends those cross-sectional studies with longitudinal data regarding obesity-related decline in executive functioning over six years. Specifically, the longitudinal latent change score modeling approach in the present paper implies a highly important advancement since we were now able to investigate the proposed obesity-cognitive-reserve compensation mechanism on subsequent decline in executive functioning over time.

In terms of possible underlying mechanisms, structural and functional compensation effects related to cognitive reserve (Stern, 2009, 2012) may buffer the detrimental influences of obesity-related increased health risk on cognitive performance. Specifically, obesity is related to cardiovascular diseases and metabolic disorders such as diabetes (Bell et al., 2014; Fan et al., 2013), which are risk factors for cognitive impairments in midlife and old age (Carmichael, 2014; Reijmer et al., 2012; Schneider et al., 2015). Thus, one angle of mechanisms may concern potential compensation effects related to cognitive reserve attenuating an increased health risk in terms of chronic diseases and metabolic disorders such as unfavorable blood fat level and hypertension as possible detrimental side- and aftereffects of obesity (for discussions see Ihle, Ghisletta et al., 2018; Ihle, Gouveia et al., 2018a, 2018b; Ihle et al., 2017a, 2017b). Another, possibly complementary angle of mechanisms may concern health-related physiological mechanisms mediating between the build-up of cognitive reserve on the one hand and cognitive performance on the other (Arenaza-Urquijo, Wirth, & Chetelat, 2015; Ihle, Oris et al., 2018; Robertson, 2013). Such physiological pathways may concern a decreased risk for developing metabolic-syndrome related cardiovascular and cerebrovascular diseases such as arteriosclerosis (Ihle, Oris et al., 2018). Future research will have to further pin down the detailed underlying mechanisms of the attenuated relation between obesity and executive functioning in individuals with greater activity engagement observed in the present study.

Given the ongoing trends of growing obesity and demographic aging, the present results also have policy implications. Our findings seem to suggest that not only physical activities are important targets for prevention in obesity related programs. In the light of our results, also intellectual activities across the lifespan should be enhanced, especially in this population, to help building up cognitive reserve and subsequently reduce the cognitive aftereffects of obesity.

In the context of the latter notions, we acknowledge that the present correlative study does not allow drawing causal inferences. Thus, we cannot fully disentangle a potentially protective effect of activity engagement on subsequent decline in executive functioning from alternative explanations related to the potential self-selection of older adults with better executive functioning to maintain an active lifestyle. Yet, importantly, given that our analyses are based on longitudinal change scores in executive functioning and took into account executive functioning level in the first wave of data collection (when activity engagement was assessed), it is less probable that the observed relationship between activity engagement and a smaller subsequent decline in executive functioning is due to individuals who reduced activity engagement because of decline in executive functioning. Moreover, we acknowledge the limitation that present results are based on self-reported weight and height to calculate individuals' BMI. Notably, although in old age the prevalence of obesity may be slightly underestimated when been calculated from self-reported values, there is evidence that BMI values derived from self-reported weight and height and those derived from objective measures are highly correlated (*r*s up to .97; Kuczmarski, Kuczmarski, & Najjar, 2001) and may can be used as a marker for overweight (see e.g. Castro, 2015, for a discussion). Nevertheless, present findings await replication with objective measures of individuals' weight and height. One may argue that income and socioeconomic status are associated with access to many of the activities investigated in the present study. Yet, importantly, controlling for socioeconomic status (in terms of income) in additional analyses revealed the same pattern of results. Given the finding that obesity in late life being somehow protective for cognitive abilities such as executive functioning (for discussions see e.g. Benito-León et al., 2013; Fitzpatrick et al., 2013; Gunstad et al., 2010; Smith et al., 2011), one may argue that weight loss in older adults may reflect reduced functional abilities in a prodromal stage of cognitive impairments and that (in contrast to young-old age) obesity may be protective in late life for those who are at increased risk of frailty (i.e., with extra weight they may be more able to engage in leisure activities). We explored such differential age effects in additional analyses. There was no three-way interaction with age, i.e. the interaction of obesity with leisure activities on change in TMT completion time did not further differ by age. Future longitudinal research will have to investigate the interplay of obesity, leisure activity engagement, and age group / life phase on cognitive aging in more detail. We assessed the TMT as a sensitive measure of inter-individual differences in intra-individual cognitive change (e.g., Chen et al., 2001; Ihle, Ghisletta et al., 2018). Yet, we acknowledge that the current study is limited by a relatively short assessment of executive functioning. Thus, future studies will have to examine whether the present pattern of results holds also for a broader range of executive functions. Moreover, we acknowledge that our assessment of cognitive reserve markers is limited to education, cognitive demand of jobs, and W1 frequency of leisure activities. Future studies have to take a more fine-grained life course perspective, for example, using detailed life-interview operationalizations, including a broader focus on lifelong stimulating activities, to disentangle the differential contributions of different domains of cognitive reserve accumulation (e.g., formal and lifelong education, non-formal intellectual activities, physical activities, and social activities) from the different life phases (e.g., childhood, early, mid-, and late adulthood) in which these contributions to cognitive reserve happen.

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Table 1

*Descriptive statistics of analyzed measures*

| Variable | *M* (*SD*) / sample proportions |
|---|---|
| TMT A completion time (W1) {seconds} | 55.23 (24.40) |
| TMT A completion time (W2) {seconds} | 56.03 (24.37) |
| TMT B completion time (W1) {seconds} | 115.13 (44.80) |
| TMT B completion time (W2) {seconds} | 108.90 (45.40) |
| Obesity (W1) | obese: 10.5%<br>non-obese: 89.5% |
| Education {years} | 13.46 (3.96) |
| Cognitive demand of jobs {overall score} | 114.95 (62.94) |
| Frequency of leisure activities (W1) {rating} | 1.28 (0.38) |
| Number of chronic diseases (W1) {number} | 1.90 (1.56) |
| Age (W1) {years} | 74.33 (6.50) |
| Sex | men: 51.4%<br>women: 48.6% |

*Note*: Descriptive statistics for completion time in Trail Making Test (TMT) parts A and B in Wave 1 (W1) and Wave 2 (W2), obesity in W1, education, cognitive demand of jobs, frequency of leisure activities in W1, the number of chronic diseases in W1, age in W1, and sex in terms of means (standard deviations are given in parentheses) as well as sample proportions.

Table 2

*Latent change score modeling results*

| | *Raw estimate* | *Standardized estimate* |
|---|---|---|
| **Longitudinal predictions of subsequent change in TMT completion time** | | |
| TMT completion time (W1) {latent factor} | -0.43*** [-0.56 – -0.25] | -.45 |
| Obesity (W1) {0 = non-obese; 1 = obese} | 2.09 ns [-1.88 – 6.05] | .04 |
| Education | -0.01 ns [-1.26 – 1.42] | .00 |
| Cognitive demand of jobs | 1.03 ns [-0.69 – 2.85] | .06 |
| Frequency of leisure activities (W1) | -1.58* [-3.05 – -0.11] | -.10 |
| Number of chronic diseases (W1) | 1.76* [0.25 – 3.39] | .11 |
| Age (W1) | 4.86*** [3.22 – 6.52] | .30 |
| Sex {0 = men; 1 = women] | -0.81 ns [-3.96 – 2.43] | -.02 |
| Interaction of obesity (W1) with frequency of leisure activities (W1) | -5.76* [-10.32 – -1.40] | -.11 |
| **Cross-sectional correlations with TMT completion time in W1** | | |
| Obesity (W1) {0 = non-obese; 1 = obese} | -0.31 ns [-0.65 – 0.10] | -.06 |
| Education | -3.51*** [-4.83 – -2.16] | -.20 |
| Cognitive demand of jobs | -2.03** [-3.31 – -0.73] | -.12 |
| Frequency of leisure activities (W1) | -3.33*** [-4.77 – -1.89] | -.19 |
| Number of chronic diseases (W1) | 1.57* [0.13 – 2.95] | .09 |
| Age (W1) | 5.50*** [4.03 – 6.98] | .32 |
| Sex {0 = men; 1 = women} | 0.03 ns [-0.71 – 0.75] | .00 |

*Note*: Parameter estimates of latent change score modeling. Upper panel: Longitudinal predictions of subsequent change in Trail Making Test (TMT) completion time from Wave 1 (W1) to Wave 2 (W2). Raw estimates *b* [with the corresponding bootstrapped 95% confidence interval in square brackets] and standardized estimates β are given. Lower panel: Cross-sectional correlations with TMT completion time in W1. Raw estimates *b* [with the corresponding bootstrapped 95% confidence interval in square brackets] and standardized estimates *r* are given. *** $p < .001$; ** $p < .01$; * $p < .05$; ns = non-significant, $p > .05$.

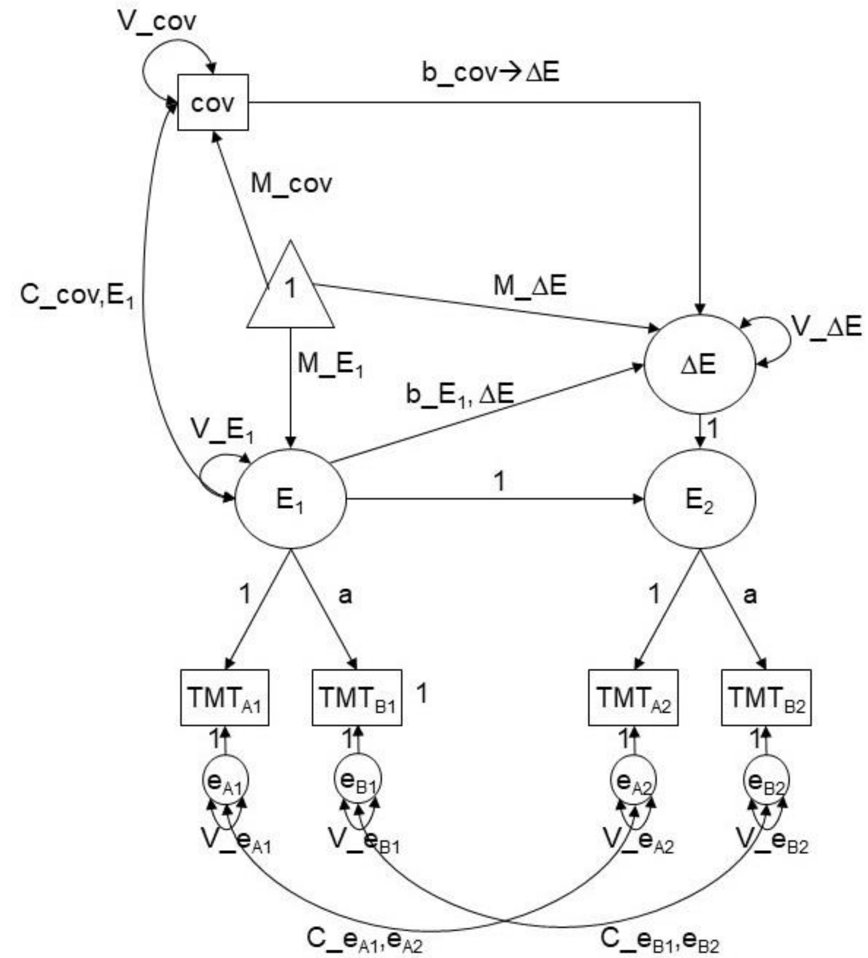


*Figure 1*. Specification of the tested latent change score model. $E_1$ and $E_2$ represent the latent executive functioning factors of Trail Making Test (TMT) completion time in Wave 1 (W1; constructed from scores in TMT parts A and B in W1) and Wave 2 (W2; constructed from scores in TMT parts A and B in W2), respectively. ΔE represents the latent change in executive functioning variable regarding change in TMT completion time from W1 to W2. Note that for clarity purposes the illustration is simplified. We enforced strong factorial invariance on the factor loadings, with intercepts of all indicators being fixed to zero to assure that the same executive functioning factor was assessed at both waves. For simplification purposes, arrows from the triangle to the observed indicator variables (TMT A and B) that would indicate that intercepts of all indicators being fixed to zero are not displayed. cov represents all covariates that predicted latent change and were correlated to the latent executive functioning factor in W1: obesity in W1, the markers of cognitive reserve (education, cognitive demand of jobs, and frequency of leisure activities in W1), the number of chronic diseases in W1, age in W1, sex, and the interactions of obesity in W1 with the markers of cognitive reserve (including interrelations of all covariates, which are not displayed here for a better overview).

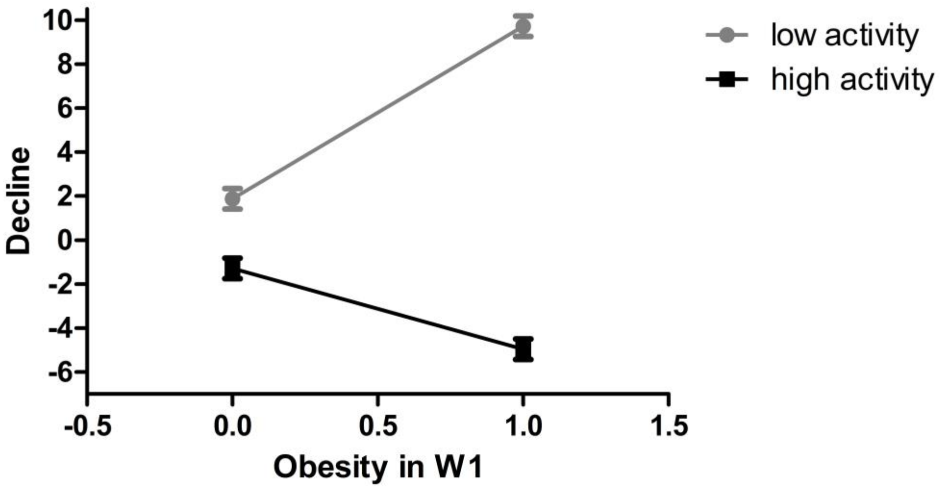


*Figure 2*. Illustration of the interaction of obesity in Wave 1 (W1) with frequency of leisure activities in W1 on latent change. Estimated mean increase in Trail Making Test (TMT) completion time from W1 to Wave 2 (W2) in seconds (i.e., decline in executive functioning) for non-obese (0) and obese (1) individuals as a function of leisure activities in W1 (at a low and a high frequency, i.e. -1 and +1 *SD*, respectively). Bars represent standard errors.