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The Longitudinal Relationship of Perceived Stress Predicting Subsequent Decline in Executive Functioning in Old Age is Attenuated in Individuals with Greater Cognitive Reserve

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Abstract

Background: Cognitively stimulating activities contribute to the accumulation of cognitive reserve that is proposed to be instrumental for maintaining cognitive functioning in aging. Adopting a novel, more general conceptual perspective including models of vulnerability, we argue that cognitive reserve may modify the longitudinal association between perceived stress and the rate of subsequent decline in executive functioning.

Objective: The present study set out to investigate the longitudinal relationship between perceived stress and subsequent decline in executive functioning over six years as measured through performance changes in the Trail Making Test (TMT) and 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.

Methods: 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 information on perceived stress, education, occupation, leisure activities, and chronic diseases.

Results: The longitudinal relationship between greater perceived stress in the first wave of data collection and steeper subsequent decline in executive functioning over six years was significantly reduced in individuals who had pursued a higher frequency of leisure activities in the first wave.

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

Keywords: decline in executive functioning; cognitive reserve; perceived stress; longitudinal study

Word count: 3,791

A major goal of current gerontological research is to better understand how inter-individual differences in maintenance of cognitive functioning in old age emerge [1]. 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 [2, 3]. Empirically corroborating the predictions of the cognitive reserve concept, both cross-sectional and longitudinal evidence for example showed that multiple markers of cognitive reserve that have been frequently used in the literature such as longer education, more cognitively demanding jobs, and a greater engagement in leisure activities contribute to the accumulation of cognitive reserve and are related to better executive functioning in old age [1, 4-6].

Cognitive reserve may be particularly important when faced with stressors that affect executive functioning. In particular, both perceived and physiological stress have been found to impair executive functioning [7, 8]. Yet, the relationship between stress and executive functioning is not always negative since it was also documented to depend on the type and duration of stressor exposure and the investigated correlates of stress [8]. Furthermore, the relationship between stress and executive functioning may be modulated by individual-difference characteristics such as an individual’s cognitive reserve.

Adopting a more general conceptual perspective employing models of vulnerability [9] and cognitive reserve [2], we argue that individuals who accumulated less cognitive reserve are more vulnerable to stress-related impairments in executive functioning [10, 11]. Therefore, we predict that cognitive reserve may modify the cross-sectional association between perceived stress and executive functioning at a given point in time and possibly also the longitudinal relationship between perceived stress and the rate of subsequent decline in executive functioning. Consistent with this conceptual view, recent empirical cross-sectional evidence suggests that in individuals with greater cognitive reserve (in terms of e.g. higher education, higher cognitive demand of jobs, and greater engagement in leisure activities) the negative cross-sectional association between greater perceived stress and poorer executive functioning in old age was markedly reduced [11, 12].

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 stress 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 stress and executive functioning at a given point in time, but also the longitudinal relationship between stress and the rate of subsequent decline in executive functioning. To address this major gap in the literature, we investigated the longitudinal relationship between perceived stress and subsequent decline in executive functioning over six years as measured through performance changes in the Trail Making Test (TMT). We also assessed whether this longitudinal relationship differed by key markers of cognitive reserve that have been frequently used in the literature (i.e., education, occupation, and leisure activities), taking into account age, sex, and chronic diseases as covariates.

Methods

Participants

The data of this study come from two waves of the Vivre-Leben-Vivere (VLV) survey [13, 14], which is part of the research program LIVES on vulnerability processes across the life course. Respondents were first interviewed during 2011 (Wave 1; W1) using face-to-face computer-assisted personal interviewing (CAPI) and paper-pencil questionnaires. VLV drew a stratified random sample of 3,080 participants in W1 based on administrative records from five Swiss cantons with stratification by age (65-69, 70-74, 75-79, 80-84, 85-89, and 90+), sex, and canton (Basel, Bern, Geneva, Ticino, and Valais). A subsample of 1,059 participants from four cantons (Basel, Bern, Geneva, and Valais) was interviewed again during 2017 (Wave 2; W2). Present analyses were based on 897 participants with data on TMT parts A and B, the outcome variables in the present study. Mean age of these respondents in W1 was 74.33 years (SD = 6.50, range 65-96).

Reflecting the longitudinal study design, our sample only contained survivors.[1] Compared to all participants initially tested in W1, the participants retained in the present study were younger (M = 74.33 years in W1, SD = 6.50) than the individuals who were lost at follow-up in W2 (M = 80.00 years in W1, SD = 8.60; $p < .001$). Importantly though, our sample still contained a considerable proportion of respondents aged 85 years and older in W2 (24.5% in W2 among the participants who were analyzed in the present study; in comparison, 25.7% in W1 among the participants initially tested in W1). The fraction of male vs. female participants did not differ significantly between our analytical sample and individuals who were lost at follow-up in W2 (51.4% vs 51.9% men, $p = .811$). With respect to perceived stress, the participants retained in the present study reported a slightly lower overall perceived stress level in W1 (M = 3.14, SD = 2.30) than the individuals who were lost at follow-up in W2 (M = 3.59 in W1, SD = 2.62; $p < .001$). Yet, our sample still contained a considerable proportion of respondents with overall perceived stress scores of 4 or higher (42.8% among the participants who were analyzed in the present study; in comparison, 44.7% among the participants initially tested in W1). Moreover, with respect to years of education the participants retained in the present study (*M* = 13.46, *SD* = 3.96) had spent more time for education than the individuals who were lost at follow-up in W2 (*M* = 12.58, *SD* = 3.97; *p* = .018). However, our sample still contained a considerable proportion of respondents with lower educational levels (43.2% individuals with primary and inferior secondary school levels as well as apprenticeship graduation among the participants who were analyzed in the present study; in comparison, 53.6% among the participants initially tested in W1). With respect to cognitive demand of jobs the participants retained in the present study (*M* = 114.95, *SD* = 62.94) did not differ significantly from the individuals who were lost at follow-up in W2 (*M* = 110.81, *SD* = 68.72; *p* = .491). The participants retained in the present study also had pursued leisure activities in W1 with higher frequency (*M* = 1.28, *SD* = 0.38) than the individuals who were lost at follow-up in W2 (*M* = 0.97 in W1, *SD* = 0.45; $p < .001$). However, our sample still contained a considerable proportion of respondents in the lower range of leisure activity participation (23.6% individuals with seven or fewer activities among the participants who were analyzed in the present study; in comparison, 42.6% among the participants initially tested in W1). Moreover, the participants retained in the present study had suffered from slightly fewer chronic diseases in W1 (*M* = 1.90, *SD* = 1.56) than the individuals who were lost at follow-up in W2 (*M* = 2.49 in W1, *SD* = 2.10; $p < .001$). However, we still had a considerable proportion of respondents with four or more chronic diseases (29.7% among the participants who were analyzed in the present study; in comparison, 21.1% among the participants initially tested in W1), suggesting sufficient variance in multimorbidity in the study sample. Thus, systematic attrition did not eliminate entire population groups of interest (see [15], for comparable retention patterns over six years in the Longitudinal Aging Study Amsterdam; see [16], for a similar follow-up of participants over six years in the Victoria Longitudinal Study; see [17], for a similar follow-up of participants over four years in the Survey of Health, Ageing and Retirement in Europe).

All participants 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 [18]). 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.[2]

In addition, we administered in both waves the Trail Making Test part B (TMT B [18]). 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.

Perceived Stress

We assessed perceived stress in W1 using the four-item Perceived Stress Scale (PSS-4 [19]) that evaluates how unpredictable, uncontrollable, and overloaded participants find their lives, using a five-point Likert-type scale ranging from 0 ('never') to 4 ('very often'). The four items showed an internal consistency of Cronbach's $\alpha = .60$. The four item scores were summed up to derive an overall score of perceived stress in W1 (possible range 0-16) [19].

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 et al. [20], 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., 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 [20].

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, or social activities comprising a large variety of leisure activities [21]. 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. [22]; see [23], 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 [24, 25].

Statistical Analyses

We conducted latent change score modeling [26] using the R package lavaan [27]. The specification of our latent change score model is illustrated in Fig. 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 [28]. We included several covariates that predicted latent change and were correlated to the latent executive functioning factor in W1: perceived stress 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 perceived stress in W1 with the markers of cognitive reserve. We also included interrelations of all covariates to take the dependencies among them into account.

We evaluated model fit as follows: Given that with large study samples the χ^2 test often indicates a significant deviation of the model matrix from the covariance matrix despite good model fit [29], 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: $SRMR < .08$ [29]). We analyzed perceived stress, 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 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).

With respect to first-order correlations, greater perceived stress in W1 was significantly related to longer completion time in both TMT A and TMT B in W2 (but not in W1). Longer education was significantly related to shorter completion time in TMT A in W1 (but not in W2) as well as in TMT B in both waves. Higher cognitive demand of jobs was significantly related to shorter completion time in TMT B in W1 (but not in W2) and unrelated to TMT A in both waves. A higher frequency of leisure activities in W1 was significantly related to shorter completion time in both TMT A and TMT B in both waves. A larger number of chronic diseases in W1 was significantly related to longer completion time in TMT A in W2 (but not in W1) as well as TMT B in both waves. Older age in W1 was significantly related to longer completion time in both TMT A and TMT B in both waves. Women had a significantly shorter completion time in TMT A in W2 than men. Otherwise, TMT completion time did not differ significantly by sex (see Table 2 for the full correlation matrix).

Latent Change Score Modeling

The latent change score model provided a very good statistical account of the data (χ^2 = 30.14, *df* = 19, *p* = .050, *CFI* > .99, *IFI* > .99, *RMSEA* = .03, *SRMR* = .02).

Longitudinal Predictions of Subsequent Change in TMT Completion Time

Greater perceived stress in W1, 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; see upper panel of Table 3). 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). Education, cognitive demand of jobs, and sex did not predict changes in TMT completion time. There was a significant interaction of perceived stress in W1 with the frequency of leisure activities in W1. Specifically, the longitudinal relationship between greater perceived stress in W1 and larger subsequent increases in TMT completion time from W1 to W2 (i.e., decline in executive functioning) was significantly attenuated in individuals with a higher frequency of leisure activities in W1 (cf. Fig. 2). Besides that, no other interactions of perceived stress in W1 with the markers of cognitive reserve on latent changes in TMT completion time were observed.

Cross-Sectional Correlations with TMT Completion Time in W1

Greater perceived stress in W1, 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; see lower panel of Table 3). 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). Sex was not related to TMT completion time in W1.

Discussion

The present study assessed the longitudinal relationship between perceived stress and subsequent decline in executive functioning over six years as measured through performance changes in the TMT. We also assessed whether this longitudinal relationship differed by key markers of cognitive reserve.

Our longitudinal analyses using latent change score modeling showed that greater perceived stress in the first wave of data collection predicted a steeper subsequent decline in executive functioning (i.e., indicated by a larger increase in TMT completion time). Moreover, 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 [1, 2, 4].

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 [6].

Notably, and most importantly, we found that the detrimental longitudinal relationship between greater perceived stress in the first wave of data collection and subsequent decline in executive functioning (i.e., indicated by increases in TMT completion time) was attenuated in individuals with greater engagement in leisure activities in the first wave. This finding confirmed our prediction regarding the key role of cognitive reserve in attenuating stress-related executive functioning changes in old age. In this regard, present findings confirm recent empirical cross-sectional studies reporting that cognitive reserve (in terms of e.g. higher education, higher cognitive demand of jobs, and greater engagement in leisure activities) is associated with a reduced negative cross-sectional relationship between perceived stress and poorer executive functioning in old age [11, 12]. Importantly, our study extends those cross-sectional studies with longitudinal data regarding stress-related decline in executive functioning over six years.

We acknowledge that the present correlative study does not allow drawing causal inferences. Moreover, we acknowledge that the present two-wave longitudinal design is somehow limited to investigate longitudinal change since a larger number of longitudinal assessments is generally more preferable. Yet, latent change score models can be appropriately used already with two waves of data assessment to model latent variables of inter-individual differences in intra-individual change over time [26]. Likewise, we acknowledge that we can only draw conclusions regarding the time period and time scale captured in the present study since inter-individual differences in executive functioning at any given point in time are the result of previous changes. Thus, we cannot draw conclusions regarding a point in time or time scale that was not captured in the present study. We acknowledge that therefore future longitudinal studies encompassing much broader phases of individuals' aging trajectories with assessments at multiple timepoints will have to investigate whether present observations hold over a broader time frame.

One could also argue that comparing both waves, there was no difference in completion time in TMT A nor TMT B on average. Yet, note that the present study focused on explaining inter-individual differences regarding intra-individual change (not average change). Importantly, despite non-significant average change, however, in ageing there are in general large inter-individual differences in intra-individual change over time [30-33]. Present results showed that there was a sufficient amount of inter-individual differences in intra-individual change in TMT completion time to be able to detect differential relationship patterns with respect to perceived stress and activity engagement. Furthermore, we acknowledge that the current study is limited by a relatively short assessment of executive functioning. Thus, future longitudinal studies will have to examine whether the present pattern of results holds also for a larger set of cognitive abilities such as episodic memory and working memory (besides a broader range of executive functions) and thereby apply to cognitive decline in general. In addition, we acknowledge that due to the restrictive criteria for the TMT (see Footnote 2), there was a certain selection of the remaining sample. It may be possible that participants who properly did the test had better executive functioning than those who did an error. Thus, future research might investigate whether the present pattern of results holds also for tasks that allow error exclusion on a trial basis. Moreover, we acknowledge that our assessment of cognitive reserve markers is limited to education, cognitive demand of jobs, and 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 social 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.

Footnotes

[1] The major part of the selection occurred through the fact that over six years individuals had died, refused to continue, or moved away and thus could not be re-contacted (N = 1,415). In addition, a subsample of participants in the canton Ticino that had participated in W1 could not be included in W2 due to funding restrictions (N = 606).

[2] We terminated the TMT parts A / B (without any score) when the individual made any error in connecting the 25 numbers/letters in the respective test. We applied these restrictive criteria to be able to directly compare the completion times across individuals (i.e., completion times would be confounded when including participants who made errors and took additional time to correct them).

Conflict of Interest

None.

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Table 1

Descriptive statistics of analyzed measures

Variable	*M* (*SD*) / sample proportions
1. TMT A completion time (W1) [seconds]	55.23 (24.40)
2. TMT A completion time (W2) [seconds]	56.03 (24.37)
3. TMT B completion time (W1) [seconds]	115.13 (44.80)
4. TMT B completion time (W2) [seconds]	108.90 (45.40)
5. Perceived stress (W1) [overall score]	3.14 (2.30)
6. Education [years]	13.46 (3.96)
7. Cognitive demand of jobs [overall score]	114.95 (62.94)
8. Frequency of leisure activities (W1) [rating]	1.28 (0.38)
9. Number of chronic diseases (W1) [number]	1.90 (1.56)
10. Age (W1) [years]	74.33 (6.50)
11. Sex	men: 51.4% 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), perceived stress 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

Full correlation matrix of measures

Variable	1	2	3	4	5	6	7	8	9	10
1. TMT A completion time (W1)	---									
2. TMT A completion time (W2)	.38***	---								
3. TMT B completion time (W1)	.55***	.38***	---							
4. TMT B completion time (W2)	.35***	.63***	.49***	---						
5. Perceived stress (W1)	.08	.09**	.06	.12*	---					
6. Education	-.10**	-.05	-.18***	-.12*	.03	---				
7. Cognitive demand of jobs	-.05	.03	-.11**	-.04	-.11***	.39***	---			
8. Frequency of leisure activities (W1)	-.17***	-.25***	-.16***	-.21***	.00	.01	.07*	---		
9. Number of chronic diseases (W1)	.04	.15***	.08*	.15**	.20***	.01	-.01	-.13***	---	
10. Age (W1)	.19***	.34***	.27***	.40***	-.01	-.08*	.04	-.27***	.15***	---
11. Sex (0 = men; 1 = women)	.00	-.07*	-.01	.03	.13***	-.25***	-.57***	.03	.06	-.06

Note: First-order correlations between completion time in Trail Making Test (TMT) parts A and B in Wave 1 (W1) and Wave 2 (W2), perceived stress 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.
*** $p < .001$; ** $p < .01$; * $p < .05$.

Table 3

Latent change score modeling results

	Raw estimate	*Standardized estimate*
Longitudinal predictions of subsequent change in TMT completion time		
TMT completion time (W1)	-0.43*** (0.06)	-.46
Perceived stress (W1)	1.54* (0.68)	.09
Education	-0.18 (0.74)	-.01
Cognitive demand of jobs	1.21 (0.86)	.07
Frequency of leisure activities (W1)	-2.15** (0.71)	-.13
Number of chronic diseases (W1)	1.54* (0.67)	.09
Age (W1)	4.84*** (0.75)	.30
Sex (0 = men; 1 = women)	-1.19 (1.61)	-.04
Interaction of perceived stress (W1) with frequency of leisure activities (W1)	-1.24* (0.63)	-.08
Cross-sectional correlations with TMT completion time in W1		
Perceived stress (W1)	1.48* (0.74)	.08
Education	-3.52*** (0.75)	-.20
Cognitive demand of jobs	-2.05** (0.74)	-.12
Frequency of leisure activities (W1)	-3.80*** (0.74)	-.22
Number of chronic diseases (W1)	1.65* (0.73)	.09
Age (W1)	5.52*** (0.76)	.32
Sex (0 = men; 1 = women)	0.00 (0.37)	.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 their respective standard errors in parentheses) and standardized estimates β are given. Lower panel: Cross-sectional correlations with TMT completion time in W1. Raw estimates *b* (with their respective standard errors in parentheses) and standardized estimates *r* are given.
*** $p < .001$; ** $p < .01$; * $p < .05$.

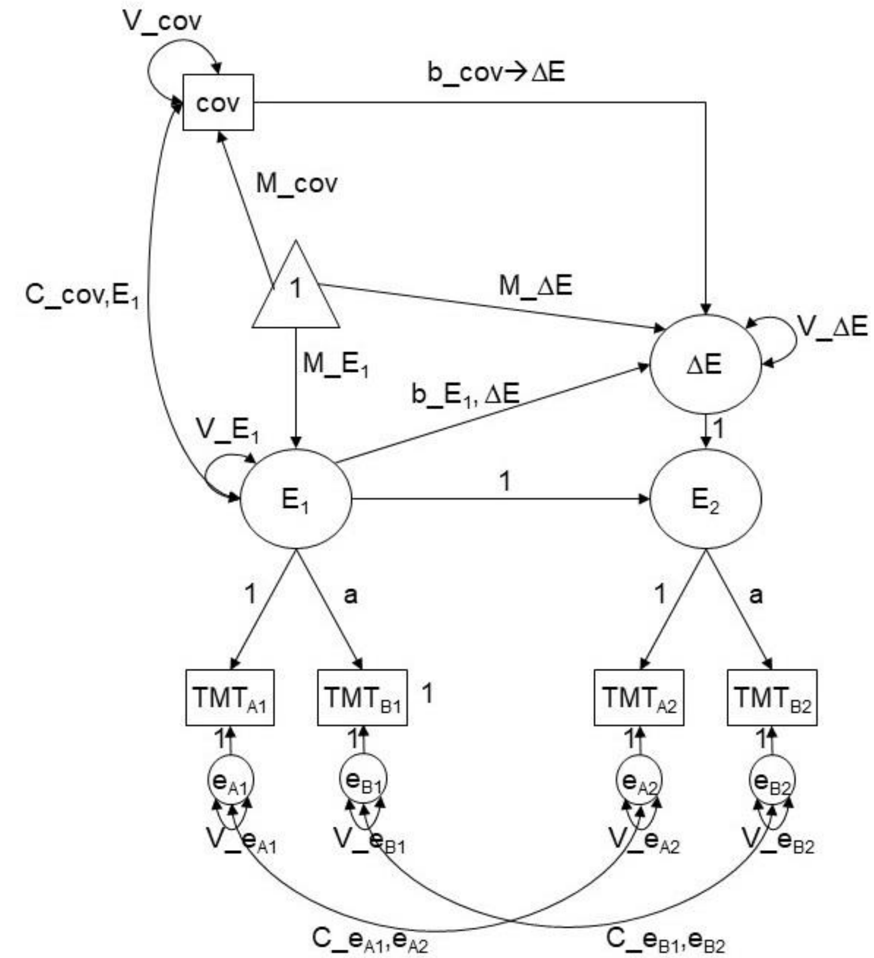

Fig. 1. Specification of the tested latent change score model. E_1 and E_2 represent the latent executive functioning factors of Trail Making Test (TMT) completion time in Wave 1 (W1; constructed from scores in TMT parts A and B in W1) and Wave 2 (W2; constructed from scores in TMT parts A and B in W2), 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: perceived stress 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 perceived stress in W1 with the markers of cognitive reserve (including interrelations of all covariates, which are not displayed here for a better overview).

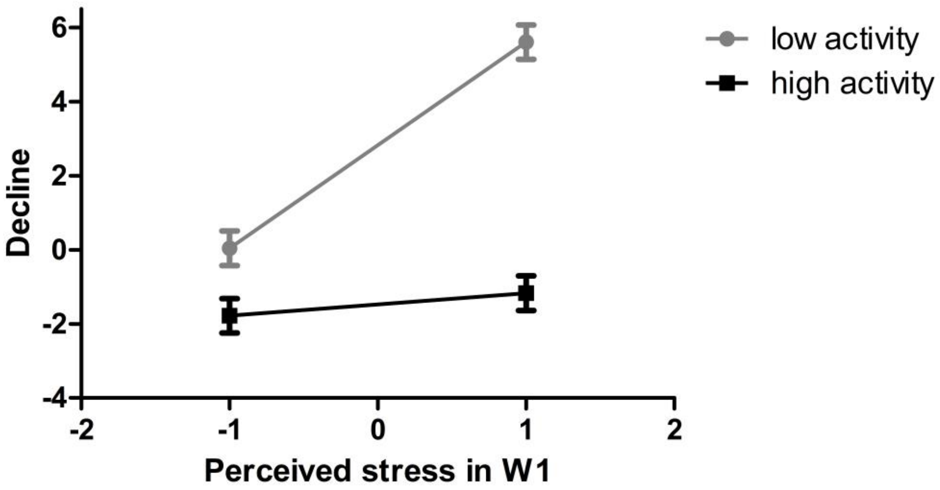

Fig. 2. Illustration of the interaction of perceived stress in W1 with frequency of leisure activities in W1 on latent change. Estimated mean increase in Trail Making Test (TMT) completion time in seconds (i.e., decline in executive functioning) at a low and a high perceived stress level in W1 (i.e., -1 and +1 *SD*, respectively) 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.