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Cognitive Functioning Mediates the Association of Cognitive Reserve with Health-Related Quality of Life

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Abstract: We investigated whether the relations of the cognitive reserve markers education and cognitive level of work to the physical and the mental component of health-related quality of life (HRQoL) were mediated via cognitive functioning in a large sample of 701 older adults (mean age = 70.36 years, SD = 6.87). HRQoL was measured with the 12-item Short-Form Health Survey. To measure cognitive functioning, we used the COGTEL, which is a cognitive test battery assessing prospective memory, verbal short-term memory, verbal long-term memory, working memory, verbal fluency, and inductive reasoning, combined into a composite score. Individuals reported information on their education and their main profession during their working life. Mediation analyses showed that better cognitive functioning mediated the association of higher values in the cognitive reserve markers (longer education and a high cognitive level of work) with higher HRQoL. In conclusion, the present study suggests that the sustainability of cognitive functioning in old age with the help of cognitive reserve is fundamental for the sustainability of quality of life, presumably particularly for the mental HRQoL component.

Keywords: health-related quality of life; well-being; mental health; cognitive health; cognitive functioning; cognitive abilities; cognitive reserve; education; profession; old age

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1. Introduction

Sustainability of quality of life in old age represents a major aim for public health policies in our aging societies [1,2]. Prior research has been adopting this health focus to examine health-related quality of life (HRQoL) as an overall measure [3,4]. In this respect,

HRQoL comprises physical and mental aspects and can therefore be characterized by a physical component (that includes, for example, physical functioning, pain, and general health) and a mental component (that covers, for example, vitality, social and emotional functioning, and mental health) [5].

The sustainability of quality of life and well-being in old age is strongly related to the sustainability of cognitive functioning during this life phase [6,7]. With regard to the sustainability of cognitive functioning in old age, the cognitive reserve concept [8] proposes that education in early life and cognitively demanding work in midlife build up a buffer that helps to compensate for neurological loss and pathological decline such as dementia [9]. In individuals with healthy cognitive development in old age, these supportive mechanisms sustain and promote the adaptation of brain activity when the difficulty of a cognitive task is increased and, as a result, improve cognitive performance [9]. Empirical evidence confirming these propositions of the cognitive reserve concept indicated that education and cognitively demanding work contribute to the build-up of cognitive reserve and are associated with better cognitive functioning in old age [10–16].

Cognitive reserve has also been found to play an important role in the sustainability of quality of life and well-being in old age. For instance, evidence shows that cognitive reserve markers such as education and cognitively demanding work are associated with a higher quality of life and well-being in midlife and old age [17,18]. Notably, the association of cognitive reserve markers with quality of life and well-being may be explained by the role of cognitive reserve for sustaining cognitive functioning. For example, evidence suggests that the association of low cognitive functioning with low quality of life and well-being in old age is mitigated in individuals with greater cognitive reserve built up over the life course, such as through cognitively demanding work in midlife [19].

Concerning the novel contribution of the present study by combining the interplay of the aforementioned relationships in one overarching framework, we developed the hypothesis that sustained cognitive functioning mediates the association of cognitive reserve on the one hand with sustained quality of life and well-being in old age on the other hand. That means, cognitive reserve helps to sustain cognitive functioning, which in turn helps to sustain quality of life and well-being in old age. However, to the best of our knowledge, one gap in prior research is that this mediation framework has not been empirically tested so far in detail based on a large-scale examination of cognitive functioning using a broad battery of cognitive tests. Moreover, a further gap in prior research is that it remains an open question whether this mediation framework holds for different aspects, such as the physical and the mental HRQoL component, or whether it is unique for one of those aspects. Therefore, to close these important gaps and to advance the conceptual perspective on the role of cognitive reserve for sustaining cognitive functioning and its aftereffects on sustained quality of life in old age, the present study set out to investigate whether the relations of the cognitive reserve markers education and cognitive level of work to the physical and the mental HRQoL component were mediated via cognitive functioning based on a broad cognitive assessment in a large sample of older adults.

2. Materials and Methods

2.1. Sample and Study Design

This cross-sectional study included 701 older adults from the regions Fonte Boa, Apuí, and Manaus in Amazonas, Brazil. All of them participated in the project entitled "Health, Lifestyle, and Functional Fitness in the Older People from Amazonas, Brazil" (SEVAAI) that was directed by the Amazonas State University, Manaus, Brazil, and the University of Madeira, Funchal, Portugal. Of the 701 individuals, 268 were men, and 433 were women. The mean age of these participants was 70.36 years (SD = 6.87). All participants were community-dwelling volunteers that had been recruited by the use of advertisements that were distributed through senior centers, churches, local radio, and newspapers. The inclusion criteria of the present study were as follows: (1) residing in one of the three

selected geographic regions of Brazil and (2) age of 60 years old or older. The data collection took place from July to December 2016. All individuals provided their informed consent before participation. This study included adherence to the declaration of Helsinki and was approved by the local ethics commission before the start of the assessments (ethics committee name: The Research Ethics Committee—Human Beings; approval code: CAAE: 56519616.6.0000.5016, Number: 1.599.258, Brazil Platform; approval date: 20 June 2016).

2.2. Instruments

2.2.1. Health-Related Quality of Life

HRQoL was measured with the Portuguese version [20] of the 12-item Short-Form Health Survey (SF-12 [5]). The SF-12 questionnaire includes eight dimensions, namely physical functioning (PF), role physical (RP), bodily pain (BP), general health (GH), vitality (VT), social functioning (SF), role emotional (RE), and mental health (MH). With this questionnaire, two main HRQoL components can be derived: the physical component (weighted sum score of PF, RP, BP, and GH) and the mental component (weighted sum score of VT, SF, RE, and MH). See [5,20] for further details on the specific weighting procedure. Each of these HRQoL component scores can range from 0 to 100.

2.2.2. Cognitive Functioning

We used the COGTEL [21] to measure cognitive functioning. The COGTEL is a cognitive test battery composed of six subtests. In the prospective memory subtest, participants have to remember to say aloud their year of birth as soon as the experimenter states a cue phrase later during the assessments ("Please try to name as many professions as possible"), which occurs during the verbal fluency subtest (0 or 1 point). The verbal short-term memory subtest requires the immediate cued recall of eight word-pairs (i.e., participants have to learn the word pairs and for the recall of the second word they are cued with the first word of the respective pair; 0 to 8 points). Similarly, the verbal long-term memory subtest consists of the delayed cued recall of these eight word-pairs (0 to 8 points). In the working memory subtest, participants hear 12 progressively longer sequences of single-digit numbers. They have to immediately reproduce each sequence by saying aloud the respective digits in the reverse order as initially presented (0 to 12 points). In the verbal fluency subtest, participants have to name as many words as possible within one minute, beginning with the letter A (letter fluency), and as many professions as possible (category fluency) within one further minute (0 points to unlimited—as many words as the participant produces during the two assessments). In the inductive reasoning subtest, participants hear eight sequences of five numbers that are constructed following a specific mathematical rule and they have to complete each of these sequences by adding a sixth number by detecting the respective rule on their own (0 to 8 points). For a more detailed description of the six COGTEL subtests, see [21]. To derive an overall measure of cognitive functioning, the scores of the six COGTEL subtests are combined into a weighted composite score (possible range: 0 points to unlimited; for further details regarding the reliability and validity of the COGTEL scoring procedure, see [21,22]).

2.2.3. Markers of Cognitive Reserve

Education. Participants reported the number of years that they had spent on their education (including primary school education, secondary school education, apprenticeship education, and university education; see, e.g., [10,23] for studies that examined years of education as a cognitive reserve marker).

Cognitive Level of Work. Participants reported the main profession during their working life that they had pursued. We classified this profession into two levels of cognitive demands: 1 = high cognitive level of work (i.e., white-collar work, such as teaching, trading, medical practice, clerical work) versus 0 = low cognitive level of work (i.e., blue-collar work, such as farming, factory work, carpentry, plumbing; see, e.g., [10,24] for studies

that applied a similar classification to examine the cognitive level of work as a cognitive reserve marker).

2.3. Statistical Analyses

First, we calculated descriptive statistics for the sample in terms of means, standard deviations (SD), and sample proportions. Then, we inspected bivariate associations between the study variables in terms of Pearson's correlation coefficients, *r*, except for associations with the cognitive level of work and sex for which we calculated point biserial correlation coefficients, r_{pb}. Regarding our main study goal, we conducted mediation analyses to investigate whether the relations of the cognitive reserve markers education and cognitive level of work to the physical and the mental HRQoL component were mediated via cognitive functioning (see Figure 1 for a general illustration). Importantly, for examining these mediation pathways, with the applied analytical approach we simultaneously estimated the residual direct (i.e., non-mediated) association between the cognitive reserve markers and the HRQoL components (i.e., the coefficient of the path c) and the indirect (i.e., mediated) relation via cognitive functioning (i.e., the product of the coefficients for the paths a and b), and also calculated their significance. The data presented in this study are available online as Supplemental Material (Table S1).

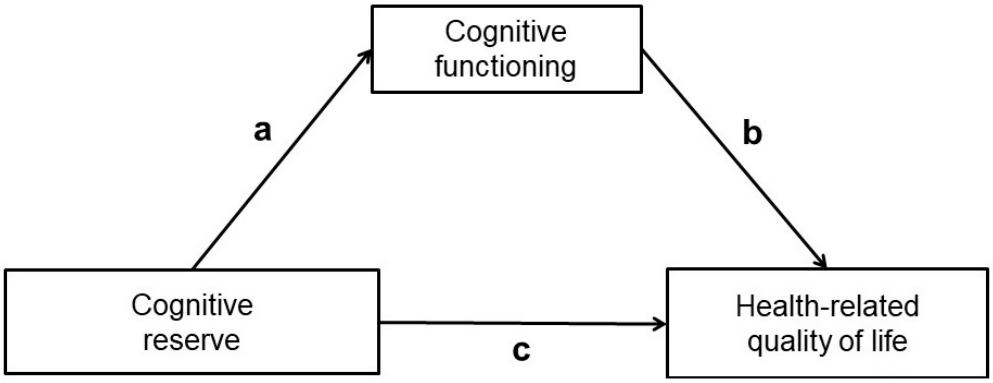

Figure 1. Illustration of the general structure of the mediation models applied to investigate whether the relations of the cognitive reserve markers education and cognitive level of work to the physical and the mental HRQoL component were mediated via cognitive functioning.

3. Results

3.1. Descriptive Statistics

Mean HRQoL scores were 65.94 (SD = 23.86) for the physical component and 81.18 (SD = 18.95) for the mental component. The mean score in cognitive functioning was 18.96 (SD = 9.46). Mean years of education was 5.36 (SD = 5.54). Regarding participants' main professions during working life, 56.6% of individuals had pursued work with a low cognitive level and 43.4% work with a high cognitive level.

With regard to associations between the investigated variables, longer education was weakly related to higher scores in the physical HRQoL component ($r = 0.29$), weakly to the mental HRQoL component ($r = 0.19$), and strongly to cognitive functioning ($r = 0.68$; see Table 1 for an overview). Likewise, a high cognitive level of work was weakly related to higher scores in the physical HRQoL component ($r = 0.23$), weakly to the mental HRQoL component ($r = 0.18$), and strongly to cognitive functioning ($r = 0.55$). Higher scores in cognitive functioning were weakly associated with higher scores in the physical HRQoL component ($r = 0.24$) and weakly with the mental HRQoL component ($r = 0.21$). Given the unbalanced study design regarding sex distribution, we additionally inspected the associations of sex with the study variables. Sex was not related to the physical HRQoL component. Being a woman was weakly related to having lower scores in the mental HRQoL component ($r = -0.10$), weakly to having better cognitive functioning ($r = 0.09$), weakly to longer education ($r = 0.15$), and weakly to a high cognitive level of work ($r = 0.28$).

Table 1. Associations between analyzed variables.

	Physical HRQoL Component	Mental HRQoL Component	Cognitive Functioning	Sex
Education	0.29 ***	0.19 ***	0.68 ***	0.15 ***
Work (0 = low; 1 = high)	0.23 ***	0.18 ***	0.55 ***	0.28 ***
Cognitive functioning	0.24 ***	0.21 ***	—	—
Sex (1 = men; 2 = women)	−0.04 ns	−0.10 **	0.09 *	—

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ns = non-significant, $p > 0.05$.

3.2. Mediation Analyses

The relation of a high cognitive level of work to a higher score in the physical HRQoL component was partly mediated (by 36.1%) via better cognitive functioning (see Table 2 for an overview). Moreover, the relations of longer education and a high cognitive level of work to a higher score in the mental HRQoL component were partly mediated (by 48.0% and 44.2%, respectively) via better cognitive functioning. There was no significant mediation of the association between education and the physical HRQoL component via cognitive functioning.

Table 2. Results of mediation analyses.

	Physical HRQoL Component		Mental HRQoL Component	
	Indirect Relation	Residual Direct Relation	Indirect Relation	Residual Direct Relation
Education	0.05 ns (17.8%)	0.24 ***	0.09 ** (48.0%)	0.10 *
Work	0.08 *** (36.1%)	0.15 ***	0.08 *** (44.2%)	0.10 *

Results of mediation analyses to investigate whether the relations of the cognitive reserve markers education and cognitive level of work to the physical and the mental HRQoL component were mediated via cognitive functioning. Left panel: Values represent indirect (mediated) relation sizes, β. In parentheses, the portion of the relation of education/cognitive level of work to the physical/the mental HRQoL component that was exerted indirectly via cognitive functioning is presented. Right panel: Values represent residual direct (non-mediated) relation sizes, β. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ns = non-significant, $p > 0.05$.

3.3. Mediation Analyses Controlling for Sex

Given the unbalanced study design regarding sex distribution as well as the weak associations of sex with the study variables, we additionally repeated mediation analyses controlling for sex differences. These control analyses showed the same pattern of results. Specifically, the relation of a high cognitive level of work to a higher score in the physical HRQoL component was partly mediated (by 30.9%) via better cognitive functioning (see Table 3 for an overview). Moreover, the relations of longer education and a high cognitive level of work to a higher score in the mental HRQoL component were partly mediated (by 42.7% and 33.4%, respectively) via better cognitive functioning. There was no significant mediation of the association between education and the physical HRQoL component via cognitive functioning.

Table 3. Results of mediation analyses controlling for sex.

	Physical HRQoL Component		Mental HRQoL Component	
	Indirect Relation	Residual Direct Relation	Indirect Relation	Residual Direct Relation
Education	0.05 ns (16.6%)	0.25 ***	0.09 ** (42.7%)	0.12 *
Work	0.08 *** (30.9%)	0.18 ***	0.08 ** (33.4%)	0.15 ***

Results of mediation analyses controlling for sex differences to investigate whether the relations of the cognitive reserve markers education and cognitive level of work to the physical and the mental HRQoL component were mediated via cognitive functioning. Left panel: Values represent indirect (mediated) relation sizes, β. In parentheses, the portion of the relation of education/cognitive level of work to the physical/the mental HRQoL component that was exerted indirectly via cognitive functioning is presented. Right panel: Values represent residual direct (non-mediated) relation sizes, β. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ns = non-significant, $p > 0.05$.

4. Discussion

The present study investigated whether the relations of the cognitive reserve markers education and cognitive level of work to the physical and the mental HRQoL component were mediated via cognitive functioning. Bivariate associations between the analyzed variables are in line with prior research. Specifically, our observations that better cognitive functioning was associated with higher scores in the physical and mental HRQoL components corroborate prior evidence for the association between cognitive functioning with quality of life and well-being in old age [6,7]. Second, our observed associations of longer education and a high cognitive level of work with better cognitive functioning are consistent with the cognitive reserve concept [8] and empirical research showing that these cognitive reserve markers are key predictors of cognitive functioning in old age [10–13]. Third, the associations of longer education and a high cognitive level of work with higher scores in the physical and the mental HRQoL component found in our study are in line with evidence documenting that these cognitive reserve markers relate to a higher quality of life and well-being [17,18].

Most importantly, concerning the novel contribution of merging all these associations in one overarching mediation framework, we found that better cognitive functioning mediated the association of higher values in the cognitive reserve markers (longer education and a high cognitive level of work) with higher HRQoL. Thereby, advancing the conceptual perspective on the role of cognitive reserve for sustaining cognitive functioning and its aftereffects on sustained quality of life in old age, present findings suggest that cognitive reserve helps to sustain cognitive functioning, which in turn helps to sustain quality of life in old age. Interestingly, there seem to be differences between the physical and the mental HRQoL component regarding this mediation framework. Specifically, the mediations seemed less evident for the physical HRQoL component: there was no mediation of the association between education and physical HRQoL. Regarding the relation of cognitive level of work to physical HRQoL, only a third was explained by cognitive functioning. In contrast, the mediations seemed more substantial for the mental HRQoL component. Here, almost half of the association with the cognitive reserve markers education and cognitive level of work was mediated via cognitive functioning. These differences could be explained by the fact that mental aspects of HRQoL strongly depend on good cognitive functioning in old age [25]. In this regard, our study suggests that the sustainability of cognitive functioning in old age with the help of cognitive reserve is essential for the sustainability of quality of life, presumably particularly for the mental HRQoL component.

Concerning the limitations of the present study, we acknowledge that the cross-sectional study design did not allow for concluding changes over time, which needs to be addressed in future longitudinal research. Furthermore, our data were based on retrospective evaluations and self-reports. However, as documented in a large body of empirical evidence, retrospective data on education and cognitive level of work are valid markers of cognitive reserve [9–13,23,24]. Moreover, to minimize bias in the assessment of the cognitive reserve markers and HRQoL, we conducted face-to-face interviews. Further strengths of our study include the broad cognitive assessment in a large sample of older adults. We acknowledge that we only included education and cognitive level of work as cognitive reserve markers. In addition, the latter was only classified into two levels of low versus high cognitive demands (see, e.g., [10,24] for studies that applied a similar classification to examine the cognitive level of work as a cognitive reserve marker). A more fine-grained assessment was unfortunately not possible due to time constraints in the study procedure. Therefore, the present study may encourage future research efforts targeting a more detailed assessment of cognitive reserve markers, including education, work, and leisure activity engagement throughout the life course, such as, for example, using the Cognitive Reserve Index questionnaire [26].

5. Conclusions

In our study, we concluded that sustained cognitive functioning mediates the association of cognitive reserve on the one hand with sustained quality of life in old age on the other. Thereby, advancing the conceptual perspective on the role of cognitive reserve for sustaining cognitive functioning and its aftereffects on sustained quality of life in old age, present findings suggest that cognitive reserve helps to sustain cognitive functioning, which in turn helps to sustain quality of life in old age. In this respect, the present study proposed that the sustainability of cognitive functioning in old age with the help of cognitive reserve is fundamental for the sustainability of quality of life, presumably particularly for the mental HRQoL component.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14020826/s1, Table S1: Dataset of analyzed variables.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study before participation.

Data Availability Statement: The data presented in this study are available online as Supplemental Material (Table S1).

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