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RESEARCH ARTICLE

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Active lifestyle as a reflection of cognitive reserve: The Modified Cognitive Reserve Scale

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Abstract

Cognitive reserve (CR) refers to individual differences in cognitive processing that can protect from and compensate for functional decline related to ageing or brain pathology. The CR theory postulates that attaining an active and cognitively stimulating lifestyle can accumulate CR. The Cognitive Reserve Scale (CRS) is a questionnaire that measures lifelong attainment in leisure activities. This cross-sectional study aimed to examine the usefulness, validity and reliability of a modified Finnish translation of the CRS, the Modified Cognitive Reserve Scale (mCRS). The mCRS consists of 20 questions concerning studying and information seeking, hobbies and social relationships during three age phases: young adulthood (18–35 years), adulthood (36–64 years) and late adulthood ($\geq$65 years). A group of 69 neurologically healthy adults aged 26–78 filled the mCRS and completed a neuropsychological test battery. We examined the internal consistency of the mCRS and associations between the mCRS, demographical variables and cognitive performance. The mCRS was normally distributed and showed satisfactory internal consistency (Cronbach's alpha 0.81). It was significantly associated with occupation ($\varepsilon^2 = 0.14$) and education (rho = 0.51) but not with age or gender. There were significant associations between the mCRS and verbal reasoning (rho = .306), visual reasoning (r = .319), learning (r = .293) and inhibition (rho = -.368). Our study suggests that the mCRS is a reliable and valid method to assess lifelong leisure activity. The mCRS is related to other factors that enhance CR, occupation and education, and associated with cognitive performance of healthy adults. It provides an easily administrable means to assess lifelong attainment in stimulating leisure activities.

Keywords: cognitive reserve, leisure time, questionnaires, neuropsychological assessment

Introduction

Cognitive reserve (CR) refers to efficiency of cognitive task processing that provides protection against functional manifestations of brain diseases, injury or ageing. The concept of CR aims to explain why ageing or brain pathology can be associated with a varying degree of clinical symptoms (Stern, 2002). Higher CR has been associated with less cognitive decline

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relative to brain pathology in, e.g. Alzheimer's disease (Stern, 2012), cerebral small vessel disease (Jokinen et al., 2016) and multiple sclerosis (Sandroff et al., 2016). Recently, diverse terminology and concepts underlying CR and its neural background have been under debate (Cabeza et al., 2018; Nilsson & Lövdén, 2018; Stern et al., 2018). Both genetic factors and enriching experiences can enhance the individual's capacity to perform particularly demanding tasks, and, most importantly, to cope with cognitive changes related to age or pathology (Cabeza et al., 2018; Stern, 2017; Stern et al., 2018).

Various enriching experiences, such as education, occupational demands and leisure activities associate with better cognitive performance relative to age or level of pathology (Chapko et al., 2018; Opdebeeck et al., 2016). Although widely used as proxies for CR, the aforementioned enriching experiences should, however, not be regarded as direct measures of CR. Instead, they represent factors that may increase CR (Jones et al., 2011; Nilsson & Lövdén, 2018; Stern et al., 2018). Concerning lifelong accumulation of CR, leisure activity is of particular interest. Primary cognitive abilities and early life socioeconomic factors, such as given historical and societal situation and available family support, may have a great influence on educational possibilities and occupational choices. Moreover, long-lasting educational and occupational choices are largely made in early adulthood. While genetic, socioeconomic, educational and occupational variables may also influence free time activities, changes towards more stimulating leisure life can also be made in advanced age in order to buffer against cognitive deterioration and to gain more active years towards later life. Hence, promoting awareness on cognitively stimulating free time choices may have beneficial effects on CR throughout life.

Several assessment methods have been developed to assess engagement in cognitively stimulating leisure activities, such as studying, hobbies and social activity. The majority of these instruments are cross-sectional questionnaires (Lara et al., 2017; Lojo-Seoane et al., 2014; Scarmeas et al., 2001; Wilson et al., 2002). However, engagement in leisure activities may vary across different stages of life, for instance because of the variability of the associated social and occupational demands. Moreover, individuals prone to dementing illness may gradually withdraw from cognitively stimulating and social activities already before overt clinical symptoms appear and become diagnostic, which may bias cross-sectional assessment of leisure activity and its connections with cognitive status in late adulthood. Thus, cross-sectional measures on leisure activity may not capture the full picture of lifelong cognitive stimulation and its association with cognitive functioning.

Some assessment methods have also been introduced to examine leisure activity across different phases of life. The Cognitive Reserve Index questionnaire (CRIq) is a half-structured interview that measures total years spent in education, occupational attainment and leisure activities (Nucci et al., 2012). Due to the rather demanding assessment method, the CRIq cannot be completed without an interviewer. The Lifetime of experiences questionnaire (LEQ) assesses educational, occupational and leisure activity with different age-related questions during three age phases, and is only administrable for people over 65 years of age (Valenzuela & Sachdev, 2007). The Cognitive Reserve Scale (CRS) (León et al., 2014) overcomes the aforementioned disadvantages. The questionnaire covers a broad range of leisure activities during three different age phases: early adulthood, adulthood and late adulthood. The participants can fill the CRS independently, and it can be applied at any age. The CRS was originally developed and validated in Spanish (Leon et al., 2011, 2014;

Leon-Estrada et al., 2017; Roldán-Tapia et al., 2017) and has later been applied in Italy (Altieri et al., 2018) and Chile (Cancino et al., 2018). In the present study, some items of the original scale were excluded and modified in order to increase construct validity of the questionnaire.

Leisure activity is important to be assessed and promoted in order to accumulate CR through the life span. However, available methods to measure lifelong enriching free time activity are scarce. This study aimed to examine the usefulness, validity and reliability of a modified Finnish translation of the CRS, the Modified Cognitive Reserve Scale (mCRS) in healthy Finnish people. We examined the associations between the mCRS, other reserve-inducing variables and cognitive functioning.

Materials and methods

Participants

We recruited 70 independent, neurologically healthy, native Finnish speaking participants to this cross-sectional study as part of control population of two clinical studies. The studies were approved by the ethical committee of the Helsinki University Hospital, Finland (approval numbers 86/13/03/01/2014 and 105/13/03/01/2014) and performed in accordance with the ethical standards of the Declaration of Helsinki. The participants were recruited between 1 June 2016 and 28 February 2019 in the Neurocenter of Helsinki University Hospital, Finland, and gave written informed consent for participation in the study. One participant was excluded from the study due to extreme CRS values resulting from obvious misunderstanding of instructions. The final study population consisted of 69 participants (26 women) aged 26–78 (median age 62 years). The participants were stratified into three age groups (young adulthood, ages 18–35, 9 participants; adulthood, ages 36–64, 30 participants; late adulthood, $\geq$65 years, 30 participants).

The Modified Cognitive Reserve scale

The Modified Cognitive Reserve Scale (mCRS) consists of 20 questions concerning studying and information seeking (4 items), hobbies (13 items) and social relationships (3 items). Examples of items in each category are shown in Table 1. Compared with the original Cognitive Reserve Scale (León et al., 2014), we decided to exclude four items on activities of daily living (controlling one's own life such as choosing clothes, controlling financial matters at home, doing housework and using basic information technology, such as the television) because they reflect basic independence in daily life instead of cognitively stimulating leisure activities like the other items. In addition, we modified some items in order to capture a richer picture of leisure activities. Namely, we added more examples of activities and replaced "active shopping" with "active spectator sports, animal or nature hobby (e.g. going to sports events, hunting, mushrooming, bird-watching or taking care of a pet)."

The items were responded on a Likert scale 0–4 (0 = never, 1 = once or several times per year, 2 = once or several times per month, 3 = 1–2 times per week, 4 = almost every day). The participants were asked to fill the mCRS according to how much they remember attaining to each activity during young adulthood (18–35 years) and, if applicable, adulthood (36–64 years) and late adulthood ($\geq$65 years). Thus, the participants filled the mCRS 1–3

Table 1. Examples of translated items of the Modified Cognitive Reserve Scale.

Category	Example of item
Studying and information seeking	Studying during free time (e.g. language or computer courses)
	Using information technology (e.g. information seeking from the internet, email, social media)
Hobbies	Reading during free time (e.g. magazines, newspapers, books)
	Playing an instrument
	Spectator sports, animals or nature (e.g. going to sports events, hunting, mushrooming, bird-watching, taking care of a pet)
Social relationships	Meeting friends, relatives or neighbours (e.g. parties, family dinners, meetings at a café)
	Spending time with people of different age (e.g. baby sitting or visiting elderly people)

times depending on their age. Each item was averaged across the 1–3 age groups. The total mCRS score comprised of the sum of the averaged item scores, maximum score, thus, being 80. Missing values (in total four single values, each in different participants) were imputed with individual age-specific median scores.

Educational and occupational attainment

Educational attainment was measured as completed educational level and converted into education years according to standard completion times in the Finnish education system based on UNESCO's International Standard Classification of Education 2011 (UNESCO Institute for Statistics, 2012). Occupational attainment was scored into four classes based on the International Standard Classification of Occupations (ISCO-08) occupational skill levels: 1 = simple physical or manual routine tasks, 2 = tasks that require good literacy and numeracy, interpersonal communication skills or manual dexterity, 3 = complex tasks requiring an extensive body of factual, technical and procedural knowledge in a specialized field, 4 = tasks that require complex problem solving and decision making based on extensive theoretical knowledge in a specialized field (International Labour Organization, 2012). Because only one participant fell in occupational class 1, classes 1 and 2 were combined in analyses.

Neuropsychological assessment

The neuropsychological test battery consisted of verbal reasoning (WAIS-IV Similarities), visual reasoning (WAIS-IV Block Design), learning (WMS-III Word list, sum score of trials 1–3), processing speed (Stroop Color condition, time to complete), inhibition (Stroop Word condition subtracted by Color condition, times to complete), phonemic fluency and semantic fluency.

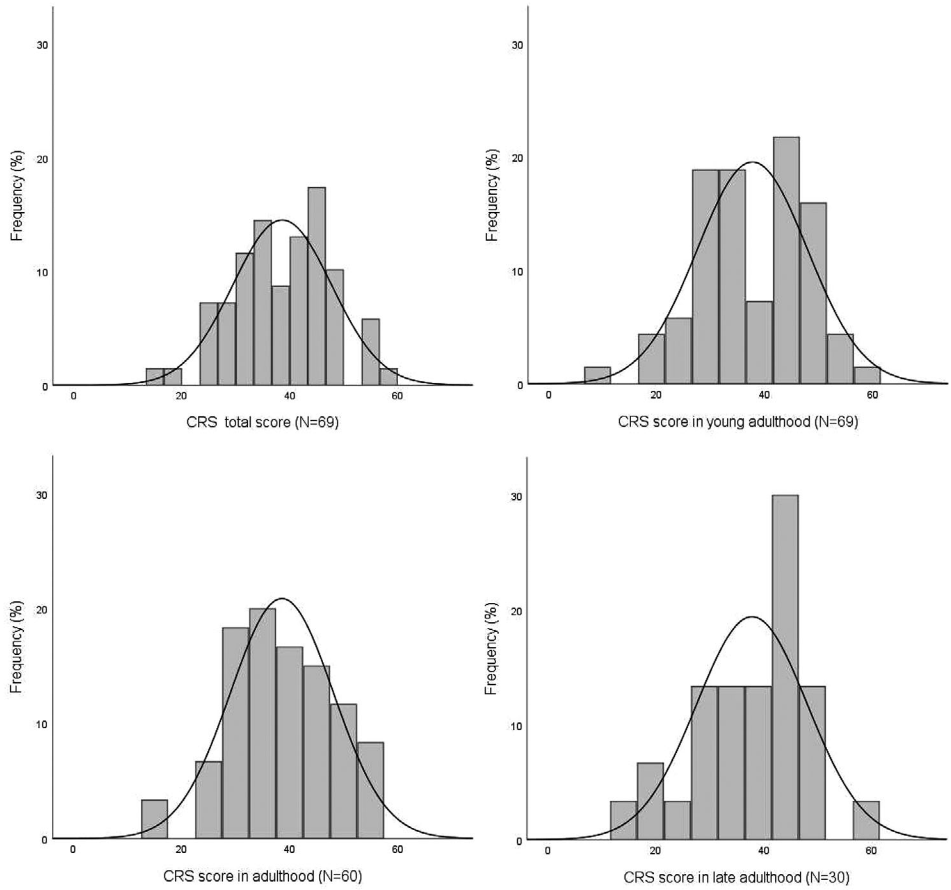

Figure 1. Distribution of the mCRS (Modified Cognitive Reserve Scale) scores: total score and score in young adulthood (18–35 years), adulthood (36–64 years) and late adulthood (≥65 years).

Statistical analyses

Statistical analyses were performed with IBM SPSS 25 (IBM Corp., 2017). P-values below .05 were considered significant. Normality of the mCRS score and other variables was measured with Kolmogorov-Smirnov test. Internal consistency of the mCRS was computed with Cronbach's alpha, item-item correlations and corrected item-total correlations. Effects of gender and occupational attainment on the mCRS were calculated with independent samples *t*-test and Kruskal-Wallis test, respectively. ε^2 was used as a measure of effect size for Kruskal-Wallis test. Differences in the young adulthood mCRS score between age groups were assessed with Kruskal-Wallis test. Differences in the mCRS score between different age phases were assessed with repeated *t*-test within the 36–64 years group and with repeated analysis of variance within the ≥65 years group. Greenhouse-Geisser test was used to adjust for nonsphericity in repeated measures analysis of variance and *p*-values of *post hoc* tests were Bonferroni corrected for multiple comparisons. Associations between the mCRS and education, age in years and cognitive performance were assessed with Pearson's and Spearman's correlations. In order to adjust for years of age, we also calculated partial correlations.

Table 2. Characteristics of the study population.

Age, years	62 (19)
Age group	
18–35	9 (13%)
36–64	30 (44%)
≥65	30 (44%)
Gender, female	26 (38%)
Education, years	14 (5)
Occupational skill level	
1	1 (1%)
2	19 (28%)
3	15 (22%)
4	34 (49%)
mCRS	
total score	38.6 ± 9.1
young adulthood	37.7 ± 10.2
adulthood	38.6 ± 9.5
late adulthood	37.8 ± 10.3
WAIS-IV Similarities	28 (6)
WAIS-IV Block design	42.67 ± 12.25
WMS-III Word list	22.13 ± 5.01
Stroop Color condition	36 (6.5)
Stroop Inhibition	22 (11.5)
Phonemic fluency	18.33 ± 6.46
Semantic fluency	22.55 ± 5.45

Data are presented as mean ± *SD*, median (interquartile range) or *N* (%).

Results

Distribution of the mCRS is shown in Figure 1. The total mCRS score ranged between 14 and 58 and was normally distributed (skewness = -.17, kurtosis = -.21, Kolmogorov–Smirnov = .09, $p > .05$). The mCRS showed satisfactory to good internal consistency: Cronbach's alpha was 0.81 (95% CI 0.74–0.87) for the total mCRS score and 0.78 (95% CI 0.70–0.85), 0.78 (95% CI 0.70–0.86) and 0.79 (95% CI 0.67–0.89) for young adulthood, adulthood and late adulthood, respectively. Corrected item-total correlations varied between 0.22 and 0.63. Inter-item correlations of the total score ranged between -0.20 and 0.61 (mean 0.18).

Characteristics of the study population are presented in Table 2. The mCRS was associated with occupation ($\chi^2(2)=9.66$, $p = .008$, $\varepsilon^2 = 0.14$) and education (rho = 0.51, $p < .001$) but not with years of age or gender. Looking at the results within age groups, the young adulthood mCRS score was 45.2 in the 18–35 years group, 37.7 in the 36–64 years group and

Table 3. Correlations and age-adjusted partial correlations between the mCRS and cognitive performance.

Test	*r*	*p*	*r* (adjusted)	*p*
WAIS-IV Similarities	.306[b]	.011*	.339[b]	.005**
WAIS-IV Block design	.319	.008**	.262[b]	.031*
WMS-III Word list	.293	.014*	.175[b]	NS
Stroop Color condition[a]	.081 [b]	NS	.120[b]	NS
Stroop Inhibition[a]	-.368[b]	.002**	-.323 [b]	.007**
Phonemic fluency	.199	NS	.239[b]	.0495*
Semantic fluency	.040	NS	.013[b]	NS

[a]Lower scores reflect better performance.
[b]Nonparametric Spearman's correlation.
*$p < .05$.
**$p < .01$.
NS: not significant.

35.4 in the ≥65 years group. The difference between age groups did not reach significance ($\chi^2(2)=5.96$, $p = .051$). Within the 36–64 years group, the mCRS score did not differ significantly between young adulthood (mCRS score mean 37.7) and adulthood (mean 37.4). Within the ≥65 years group, the mCRS score differed significantly between young adulthood (mean 35.4), adulthood (mean 40.0) and late adulthood (mean 37.8) ($F(1,38)=6.12$, $p = .011$). Bonferroni corrected *post hoc* tests revealed that the difference in mCRS score was significant between adulthood and young adulthood ($p < .001$) but not between other contrasts.

Associations between the mCRS and cognitive performance are shown in Table 3. In sum, there were significant correlations between the mCRS and verbal reasoning (rho = .306, $p = .011$), visual reasoning ($r = .319$, $p = .008$), learning ($r = .293$, $p = .014$) and inhibition (rho = -.368, $p = .002$). When adjusted for age, also phonemic fluency (rho = .239, $p = .0495$), but no longer learning correlated with the mCRS. Processing speed and semantic fluency were not associated with the mCRS.

Discussion

The present study suggests that the Modified Cognitive Reserve Scale (mCRS), a modified translation of Cognitive Reserve Scale (CRS) (León et al., 2014) is a reliable and valid method to assess CR associated with leisure activity. The mCRS is related to occupation and education, but not to age or gender. Most importantly, leisure activity assessed with the mCRS is associated with a wide range of complex cognitive abilities. It provides a useful and easily administrable means to assess lifelong attainment in cognitive stimulating leisure activities.

Our findings are concurrent with previous findings on CR and its assessment. The mCRS was significantly associated with other factors that enhance CR, education (in line with Altieri et al., 2018; León et al., 2014) and occupation (in line with Altieri et al., 2018), but not with age or gender. Most importantly, the mCRS score was associated with performance in several cognitive functions. Associations between leisure activity and cognition were roughly similar to those found with the original CRS (León et al., 2014), with significant relationships between leisure activity and learning, verbal reasoning/execution and visual reasoning, but not with processing speed or verbal fluency. Associations between the CRS, memory and visuospatial abilities (Altieri et al., 2018), as well as memory and inhibition (Roldán-Tapia et al., 2017), have also been found in other subsequent studies. Indeed, it is postulated that CR is based on allocating strategic or compensational resources (Stern, 2002). It has also been suggested that CR is related to strategic abilities that are less prone to age-related decline, thus, enabling compensation of age-related decreases in other mental abilities (Nilsson & Lövdén, 2018). Thus, it is reasonable that reserve is associated with complex cognitive functions that require high-level strategic competence, such as executive functioning, learning and reasoning, rather than mechanical processing speed, which is particularly prone to deteriorating effects of ageing (Ebaid et al., 2017; Salthouse, 1996). In conclusion, the present findings on the interconnections between leisure activity, measured with the mCRS and cognitive functioning are in accordance with current understanding of CR.

Compared with the original CRS (León et al., 2014), we chose to make some modifications to the scale. First, we excluded items measuring daily functioning, such as choosing one's own clothes or doing housework, which we considered less cognitively stimulating than the other items. Secondly, we modified some items of the scale to capture a more comprehensive picture of leisure activity. Internal consistency of the mCRS was acceptable (Cronbach's alpha 0.81 for the total score and 0.78 to 0.79 for different life stages) and even higher than that of the original scale (0.77, total score) (León et al., 2014) and of a direct translation of it (0.73 total score, 0.74 to 0.75 for different life stages) (Altieri et al., 2018). These results indicate that the chosen modifications were justified. As expected (Kartschmit et al., 2019) and in accord with Altieri et al. (2018), the inter-item correlations of the scale in the present study were variable, reflecting the broad range of leisure activities included with an aim to reach diverse cognitively stimulating leisure activities that different people prefer. Thus, we suggest that the mCRS reflects cognitively stimulating free time activity comprehensively and reliably.

The mCRS has several advantages compared to other proxies of CR. First, while educational and occupational decisions are subject to primary cognitive abilities as well as early life socioeconomical factors and often made rather early in adulthood, changes towards more stimulating leisure life can also be made in advanced age in order to buffer against cognitive deterioration and to gain more active years towards later life. Thus, assessing leisure activities may provide a richer picture of cognitively stimulating experiences that contribute to CR. The mCRS covers a wide range of both educational, cultural and social activities, including physical exercise. Second, because CR can be gained throughout life, it is important to be assessed separately for different phases of life (Kartschmit et al., 2019). The mCRS provides a means to assess lifelong attainment to leisure activity as opposed to cross-sectional assessment methods, which are prone to bias because of varying leisure possibilities in different life stages. On the one hand, some age phases are often filled with educational, occupational and/or parental demands and on the other hand, physical limitations as well as changes in cognitive abilities may limit possibilities to take part in cognitively stimulating activities in advanced age. Moreover, leisure possibilities may also vary according to sociohistorical circumstances. The mCRS score of the oldest age group indeed differed between age phases in the present study, whereas there were no such differences in the 36–64 years group, supporting the view that leisure activity should be assessed separately in different stages of life especially within older adults. Third, despite the comprehensive nature of the mCRS, the participants can fill it independently in a relatively short time without an interviewer. Thus, in addition to clinical contexts such as neuropsychological assessments, the mCRS is usable also in large epidemiological studies (Kartschmit et al., 2019).

Limitations of the present study include a rather small sample with somewhat skewed distribution of occupational class and a restricted range of neuropsychological tests. In addition, we did not use a formal translation process, such as forward and backward translation. Instead of a direct translation, we intended to make a modified version of the CRS by means of excluding less stimulating items and modifying some items in order to capture a more comprehensive picture of leisure activity. These modifications resulted in increased internal consistency compared to the original scale (León et al., 2014) and increased its construct validity. Even in the presence of these methodological restrictions, we were able to demonstrate the validity and reliability of the mCRS in estimating leisure activity and its connections with CR in healthy Finnish adults. The usefulness of the mCRS in clinical groups and longitudinal settings remain to be investigated.

While the effects of cognitive decline cannot be fully overcome, an active lifestyle may build cognitive reserve against changes related to age or disease. The present study suggests that the Modified Cognitive Reserve Scale is a valid, reliable and easily administrable method to assess lifelong engagement in cognitively stimulating leisure activities.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Data availability statement

Requests for sharing of data will be given individual consideration after additional approval for sharing by the local Ethics committee.

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