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Psychological Evaluation

Instruments for measuring cognitive reserve: A systematic review

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Abstract

The Cognitive Reserve (CR) construct seeks to explain the brain's ability of compensate for degeneration caused by age or neuropathology. However, standardized measures of CR are incipient. Through a systematic review, this study aimed to investigate the instruments in the form of scales and questionnaires used as objective measures of CR, through the measurement of multiple variables related to activities conducted throughout the lifetime. The search for articles was conducted in the PubMed, Scopus, Science Direct, PsycINFO, VHL and Cochrane databases. Seven studies were selected after applying the inclusion and exclusion criteria. The existence of five scales/questionnaires that measure CR was verified. The instruments present a short duration, however, they vary in the items/variables measured, there being a lack of in-depth studies with large and diversified samples. Further studies are needed to improve the validity evidence and to conduct cross-cultural adaptations of the CR scale/questionnaires.

Keywords: cognitive reserve; measurement instruments; evaluation; scales/questionnaires; cognition.

Instrumentos de medida de reserva cognitiva – uma revisão sistemática

Resumo

O construto reserva cognitiva (RC) busca explicar a capacidade de o cérebro compensar a degeneração causada pela idade ou neuropatologia. Contudo, medidas padronizadas de RC são incipientes. Por meio de uma revisão sistemática, este estudo objetivou investigar os instrumentos em formato de escalas e questionários utilizados como medida objetiva de RC, a partir da mensuração de múltiplas variáveis relacionadas a atividades realizadas ao longo da vida. A busca por artigos foi realizada nas bases de dados PubMed, Scopus, ScienceDirect, PsychINFO, BVS e Cochrane. Sete estudos foram selecionados após a aplicação dos critérios de inclusão e exclusão. Constatou-se a existência de cinco escalas/questionários que mensuram RC. Os instrumentos são de curta duração, porém variam quanto aos itens/às variáveis mensuradas e carecem de estudos aprofundados, com amostras amplas e diversificadas. São necessários mais estudos que busquem aprimorar as evidências de validade e realizar adaptações transculturais das escalas/dos questionários de RC.

Palavras-chave: reserva cognitiva; instrumentos de medida; avaliação; escala/questionários; cognição.

Instrumentos de medida de reserva cognitiva – una revisión sistemática

Resumen

La Reserva cognitiva (RC) busca explicar la capacidad del cerebro para compensar el declive causado por la edad y neuropatologías. Además, las escalas estandarizadas de RC son aún incipientes. La presente revisión sistemática, tuvo como objetivo investigar los instrumentos utilizados para medir objetivamente la RC, a partir de la evaluación de diversas variables asociadas con actividades realizadas durante el ciclo vital. La búsqueda se realizó en las bases de datos PubMed, Scopus, Science Direct, PsycInfo, Bvs y Cochrane. Después de aplicar los criterios de inclusión y exclusión siete artículos fueron seleccionados. Se identificó cinco instrumentos que miden RC. Dichos instrumentos son de corta duración, pero varían en cuanto a los ítems evaluados y carecen de estudios con muestras más amplias y diversas. Es necesaria la elaboración de estudios que busquen mejorar la validez, así como realizar adaptaciones transculturales de las escalas de RC.

Palabras clave: reserva cognitiva; instrumentos psicométricos; evaluación; escalas/cuestionarios; cognición.

1. Introduction

Cognitive reserve (CR) is a concept proposed to explain the observed discrepancy between the degree of brain injury or pathology, and its clinical manifestations (Stern, 2009). Individual differences in cognitive processes or neural networks underlying the performance of tasks are assumed to exist, which allow some people to better compensate for age-related degeneration or neurological disease (Stern, 2009, 2017).

These differences in the brain's ability to cope with neurological damage are considered from two models of reserve, the passive and the active. In the passive model, the reserve would be mediated through anatomical substrate characteristics such as brain size and number of neurons or synapses – cerebral reserve (Katzman, 1993). This is related to the amount of damage that the brain is able to withstand before it exceeds the threshold for symptoms and allows the diagnosis (Stern, 2009, 2017).

This model, however, became insufficient when it was realized that, even when individuals had similar brain volumes, similar neurological damage had different effects on them. According to the active model, this difference would occur

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through the active and efficient effort of the brain to compensate for the injury using pre-existing cognitive processes or compensatory processes (Stern, 2009, 2017). Thus, although two individuals have the same brain reserve capacity, the one with more CR would be better able to tolerate an injury, delaying the clinical onset of the disability (Stern, 2009).

Although CR is predominantly discussed in the context of aging and dementia, several studies have demonstrated its neuroprotective effect, verifying the attenuation of cognitive symptoms in different pathological conditions. These include multiple sclerosis (Silva et al., 2015), chemical dependence (Pedrero-Pérez et al., 2014), bipolar disorder (Forcada et al., 2014), traumatic brain injury (Mathias & Wheaton, 2015), HIV (Shapiro, Mahoney, Peyser, Zigman, & Verghese, 2014), Hepatitis C (Sakamoto et al., 2013) and obesity (Galioto, Alosco, Spitznagel, Stanek, & Guntad, 2013), among others.

Cognitive reserve is not fixed, but continues to evolve from experiences throughout all stages of life (Stern, 2012; 2017). Epidemiological studies have highlighted different lifestyle-related variables that could be associated with higher CR indices, such as education, occupational activity and cognitively stimulating activities (Opdebeeck, Martyr, & Clare, 2015; Stern, 2017).

However, the methods used to measure CR are varied, which makes it difficult to compare studies (Opdebeeck et al., 2015). In addition, although it is a dynamic construct, a result of the combination of lifelong experiences, many consider a single variable to estimate CR, such as the IQ or pre-morbid IQ of the individual (Grotz, Seron, Van Wissen, & Adam, 2017). Recent studies, however, considering the multiplicity of CR variables, highlight the need for evaluation methods that integrate the different dimensions (Grotz et al., 2017; Stern, 2017).

The importance of sensitive and validated instruments for CR evaluation is based on the relevance of this construct in the clinical practice, both in the evaluation context and for cognitive interventions. In the evaluation, for example, early signs of cognitive decline may be more difficult to detect among individuals with higher CR, since, despite cognitive complaints, it is possible that no impairment of results in formal cognitive tests can be detected in these individuals (Elkana et al., 2016). Thus, clinical and neuropsychological evaluation instruments may lose the sensitivity of detecting cognitive impairment when used in individuals with a high

CR, as well as in individuals with very low educational levels, where the disease may be underdiagnosed or false negatives may be promoted (Piovezan, 2012).

In view of this, the aim of this review was to investigate the instruments in the form of scales and questionnaires, used as an objective measure of CR, by measuring multiple variables related to activities performed throughout life. It was also sought to ascertain 1. the origin and characteristics of the public evaluated in each study; 2. the CR theoretical framework, the variables and the stages of life in which these variables were evaluated in each instrument; 3. characteristics related to the application of the scales/questionnaires, such as: number of items, time of application, respondents and; 4. the psychometric properties studied.

2. Method

The present study followed the systematic review model according to the PRISMA guidelines (Moher, Liberati, Tetzlaff, & Altman, 2010). The searches were conducted in May 2018, by two independent judges, in the PubMed, Scopus, Science Direct, PsycINFO, VHL and Cochrane electronic databases. The descriptors used for the search were "cognitive reserve" OR "brain reserve" AND questionnaire OR scale OR index OR psychometric OR assessment. The descriptors were selected based on the MeSH (PubMed) and Thesaurus (PsycINFO) dictionaries. Advanced searches were performed with the mentioned terms present in the title, abstract or keywords, without any other filter.

The inclusion criteria were: 1. studies that used scales or questionnaires to evaluate CR; 2. articles that address the validation process of the instrument. No restrictions were applied regarding the age and clinical characteristics of the population, nor were the year of publication or the language of the manuscript restricted, aiming for a more comprehensive scan of the literature. Review studies, repeated articles and articles of cross-cultural adaptation of the instruments were excluded.

The first search, conducted by the two judges, generated an initial number of abstracts, which were analyzed independently and selected according to the inclusion and exclusion criteria previously established. Repeated abstracts were excluded so that they were not counted twice. A second search was performed manually in the references of the selected studies. All included articles were reviewed in their entirety to answer the research questions of this study.

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3. Results

The present systematic review identified a total of 1,248 studies. After detailed screening of the titles and abstracts, 21 articles were selected for reading in full. There was divergence among the judges in relation to the inclusion of some of these studies (n = 06), with a third judge that is an expert on the subject being consulted. There was complete agreement between the three judges regarding the final inclusion of five articles and two additional manuscripts from the manual search in the references of the selected articles. Figure 1 presents the steps from the identification to the final selection of the studies.

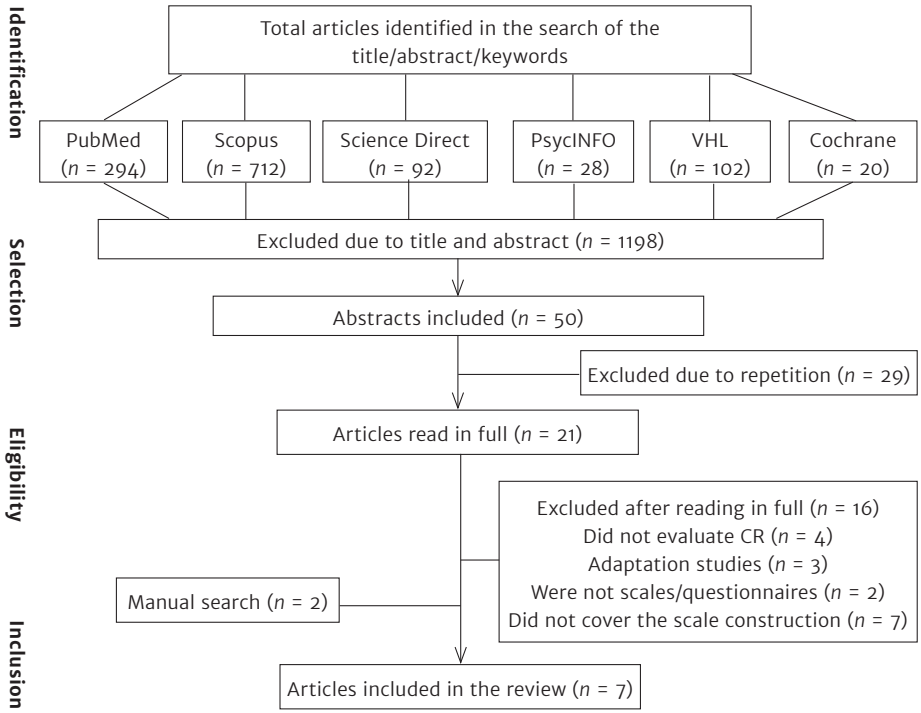

Figure 3.1. Flowchart of the selection process of the articles.

3.1 Instruments for measuring cognitive reserve

Five instruments to measure CR through an objective measure, based on multiple variables related to activities performed throughout life, were identified. In the English language, predominantly in science, they are identified as: Cognitive

Reserve Scale (CRS), Cognitive Reserve Index Questionnaire (CRIq), Cognitive Reserve Questionnaire (CRQ), Lifetime of Experiences Questionnaire (LEQ) and Lifetime Cognitive Activity Scale (LCAS).

One of the scales, the CRS, appeared repeatedly in three studies, all organized by the original authors (León-Estrada, García-García, & Roldán-Tapia, 2017; León-Estrada, García, & Roldán-Tapia, 2011; Leon, García-García, & Roldán-Tapia, 2016; León, García-García, & Roldán-Tapia, 2014). The studies were included in this review, since they deal with adjustments made in the instrument, theoretical adaptation and updating of normative data. Information synthesized from the seven studies, i.e. authors, year of publication, instrument used and characteristics of the population, are described in Table 3.1.1.

Table 3.1.1. Summary of the studies included in the review.

Study	Country	Instrument	Sample	Age group	Female gender	Clinical Population
León-Estrada et al. (2017)	Spain	CRS	110 adults 62 older adults	36-64 65-88	60.0% 64.5%	No
León et al. (2014)	Spain	CRS	87 adults 30 older adults	36-64 72-74*	62.1% 73.3%	No
León-Estrada et al. (2011)	Spain	CRS	75 youths 20 older adults	21-26* 60-71*	74.6% 55.0%	No
Rami, et al. (2011)	Spain	CRQ	55 healthy older adults 53 older adults with AD	68-80* 73-82*	51.0% 58.0%	Both
Nucci, Mapelli and Mondini (2011)	Italy	CRIq	458 adults 120 older adults	18-69 70-102	55.0%	No
Valenzuela e Sachdev (2006)	Australia	LEQ	79 healthy adults	58-93	43.2%	No
Wilson, Barnes, and Bennett (2003)	USA	LCAS	141 older adults	78-89*	73.8%	No

Note: *Estimated age range based on standard deviation; AD – Alzheimer's disease.

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3.2 Origin of the studies and characteristics of the public evaluated

The studies found come from different countries, with three scales originating in Europe (two in Spain and one in Italy), one in Australia and the other one in North America. Regarding the participants, a prevalence of the adult and older adult public was observed, with two studies involving youth participants (León-Estrada et al., 2011; Nucci, Mapelli, & Mondini, 2011). In general, participants with a minimum of 18 and a maximum of 102 years of age were considered. Regarding gender, with the exception of the study by Valenzuela and Sachdev (2006), a prevalence of the female gender was observed among the samples. Only one of the studies used a clinical sample of participants (Rami et al., 2011), which included older adults diagnosed with AD.

3.3 Theoretical framework, variables and stages of life evaluated

The theoretical framework from which the scales and questionnaires were constructed is predominantly based on Stern's CR concept (2009, 2012, 2017) and the variables evaluated in each instrument vary according to evidence suggested in the literature. In general, as described in Table 3.2.1, variables such as education, occupation, cognitively stimulating activities (e.g., reading, language proficiency, use of technologies, musical training, intellectual games) and social life are included. The CRS (León-Estrada et al., 2011), and LCAS (Wilson et al., 2003) instruments do not include educational level and professional variables. León-Estrada et al. (2011) considered that these variables are not part of the operational definition of CR.

The participation in each variable is measured considering the different stages of life. The CRS (León-Estrada et al., 2011), and LEQ (Valenzuela & Sachdev, 2006) scales evaluate three stages, contemplating the young adult, adult and older adult. The LCAS (Wilson et al., 2003) proposes five stages, being the only instrument that contemplates childhood (≥ 6 years). The CRIq (Nucci et al., 2011) has 18 years of age as the starting age. The CRQ (Rami et al., 2011) does not contemplate a specific period, thus considering experiences throughout life. In its original version, the CRS assessed six different stages of life. Later, this was reduced to three stages aiming at reducing the fatigue effect on the participants (León-Estrada et al., 2011).

Regarding the form of measurement, in general, the instruments seek to assess the frequency with which each activity is performed throughout the different stages of life, and they use different methods to obtain these data. The CRS, LEQ and LCAS use a Likert-type response scale (0-5), while the CRIq measures the years of participation in each activity and the CRQ defines a specific score for different levels of education, work activity and frequency of each activity evaluated. In all cases, the data become a final total score, considered the total CR score.

Table 3.3.1. CR measurement instruments, the factors and stages of life evaluated and the main characteristics related to their structure and application.

Instrument	Theoretical framework	Factors evaluated	Stages of life evaluated	Type of measure	No. of items	Application time	Respondent
*CRS** (León-Estrada et al., 2017)	Cognitive Reserve (Stern)	1. Activities of daily living; 2. training information; 3. hobbies and pastimes; 4. social life.	In three stages: Young adult (18-35); adult (36-64); older adult (over 65)	Frequency (Likert Scale)	24	20-30min	Self-report
CRIq (Nucci et al., 2011)	Cognitive Reserve (Stern)	1. Education; 2. work activity and 3. free time activity (intellectual, social and physical)	From 18 years of age	Years of involvement	20	15 min	Self-report
CRQ (Rami, et al., 2011)	Cognitive Reserve (Stern)	1. Education; 2. parents' education; 3. training courses; 4. work occupation; 5. musical training; 6. language proficiency; 7. reading and intellectual games	Throughout life	Defined score for level reached or frequency in the different activities	08	2 min	Self-report In the case of mild AD, under the supervision of a relative.

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Instrument	Theoretical framework	Factors evaluated	Stages of life evaluated	Type of measure	No. of items	Application time	Respondent
LEQ (Valenzuela & Sachdev, 2006)	Cerebral Reserve (Stern)	Participation in cognitive activities specific (education, work occupation) and non-specific for the stage of life (playing instrument, arts, reading, social life, sports, languages, travel and hobbies)	In three stages: Young adult (13-30); adult (30-65) and older adult (from 65)	Frequency/ intensity (Likert Scale)	42	30 min	Self-report
LCAS (Wilson, et al., 2003)	Cognitive Reserve (Stern)	Participation in cognitive activities (reading, visiting bookstores and games)	In five stages: at 6, 12, 18, and 40 years of age and at the current age	Frequency (Likert Scale)	25	-	Self-report

Note: *Latest published version of the scale

3.4 Characteristics of the application of the instruments

The scales are short and vary in length of application, taking from 2 to 30 minutes. This time is associated with the number of items and how many life stages are evaluated, since each stage will require the participant to respond to the items again. Thus, the CRQ is the shortest scale, with only 8 items, while the LEQ is the longest, composed of 42 items and 3 life stages. The majority are self-report scales, however, in some cases they can be answered by a family member or someone close to the subject.

3.5 Psychometric properties

Table 3.4.1 summarizes the strategies for obtaining the psychometric properties of the instruments. In relation to the validity evidence, the majority of the studies sought to verify characteristics of the internal structure of the cognitive reserve scales, except in the CRQ scale (Rami et al., 2011). There was greater use of the analysis of the internal consistency of the items (LEQ, CRS, CRIq and LCAS), and the Item Response Theory was used to verify latent constructs in two studies (LEQ and CRIq). In general, the scales were found to investigate a single factor corresponding to the cognitive reserve. The Cronbach's alpha values of the general scores varied from 0.62 to 0.88, indicating that the LEQ and CRIq scales presented very low reliability indexes, while in the CRQ scale the Cronbach's alpha value was not obtained.

When considering relationships with external variables, only the CRS scale study did not use this strategy. The main variables used were age (CRIq and CRO), education (CRO and LCAS), gender (CRIq), clinical and control groups (CRO) and performance in other cognitive tasks (CRIq, CRO and LCAS). The cognitive functions that presented significant associations with the scores of the cognitive reserve scales were intelligence (León-Estrada et al. 2014), processing speed (Rami et al., 2011), cognitive flexibility (Rami et al., 2011), working memory (Remi et al., 2011), visuospatial abilities and semantic memory (Wilson et al., 2003).

Only the CRS scale study presented normative reference data for the general cognitive reserve index.

4. Discussion

Through this review, it was sought to identify the existing cognitive reserve evaluation instruments, which consider the multiplicity of variables associated with this construct. It was also sought to explore the structure, form of application and psychometric validity data of each instrument. A total of five different scales/questionnaires were identified, with a description of their construction process and satisfactory psychometric evidence.

Many studies consider a single variable to estimate CR, such as the individual's IQ or level of education (Grotz et al., 2017). In a meta-analysis, it was identified that only six of 135 studies combined more than one variable for the evaluation of CR (Opdebeeck et al., 2015). In addition, the CR construct is considered

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recent in the literature, which may explain the reduced number of existing scale/questionnaire type instruments, with the format, the variables and their form of measurement not yet presenting a consensus (Opdebeeck et al., 2015; Stern, 2017).

Table 3.4.1. Indicators of evidence of validity and internal consistency index of the CR valuation measures

Instrument	Evidence of validity	Cronbach's alpha
LEQ (Valenzuela & Sachdev, 2006)	Based on the internal structure. Based on relations with external variables.	Young adult subscale = 0.43; adult of intermediate age subscale = 0.78; older adult subscale = 0.84. Total = 0.66
CRS* (Leòn-Estrada et al., 2017)	Based on the internal structure. Normative performance data.	Total = 0.80
CRIq (Nucci et al., 2011)	Based on the internal structure. Based on relations with external variables.	Total = 0.62
CRO (Rami et al., 2011)	Based on relations with external variables	-
LCAS (Wilson et al., 2003)	Based on the internal structure and relations with external variables	Total = 0.88

Note: * Latest published version of the scaleSource?

Regarding the variables evaluated by the instruments found, it was observed that there is still no consensus regarding what activities related to life experiences actually contribute to the development of CR. However, in general, all of them are based on variables already elucidated in the literature, such as education, occupation and cognitively stimulating activities (Opdebeeck et al., 2015; Stern, 2017).

The CRS and LCAS instruments do not include the educational level and professional variables. According to León-Estrada et al. (2011), these variables are not part of the operational definition of RC. A study on the impact of education and years of schooling on the diagnosis of dementia, however, showed that the impact of the level of education on the diagnosis is greater than that of years of schooling

(Contador et al., 2016). Thus, even a few years of formal education contribute to the CR and are capable of modifying the relationship of neuropathological indexes with dementia (Farfel et al., 2013). Similarly, studies also highlight that all types of occupational activity (professional and non-professional) clearly have a protective effect on cognitive aging (Adam, Bonsang, Grotz, & Perelman, 2013).

The variable "cognitively stimulating activities" stands out, being present in all the instruments. According to Opdebeeck et al. (2015), this is indicated as the second indirect form of CR measurement most used in the literature, behind only education. There is evidence that engagement in these activities may reduce the risk of dementia, delaying the onset of disease manifestations (Scarmeas, 2001; Then et al., 2016; Kühn, Gleich, Lorenz, Lindenberger, & Gallinat, 2013). However, the scales differ in their items, combining different types of activities, such as reading habits, visiting bookstores, intellectual games, language proficiency and playing a musical instrument, among others. There is, therefore, no consensus or even a classification of types of activities considered cognitively stimulating.

Although less consensual among the instruments, other experiences are still being evaluated, according to the literature (Stern, 2017), such as the practice of physical activity and participation and engagement in social activities. In addition, it is important to consider that there is a variety of studies indicating the effects of cognitive training with electronic games on cognition and this is an expanding area providing new opportunities considering the technological advances (Cardoso, Landenberger, & Argimon, 2017; Gleich, Lorenz, Gallinat, & Kühn, 2017; Stern, 2012).

This is an innovative study as no previous reviews have been identified that aimed to investigate the existing CR instruments. The results presented here can contribute to researchers having access to the materials available up to now in the scientific environment and, from this, to deepen psychometric validation studies, to expand data from cross-cultural adaptations of existing instruments, and/or to improve areas that are still without consensus, in order to achieve a "gold standard" instrument. A valid and reliable evaluation instrument for CR evaluation would have an important contribution for the early diagnosis of neurodegenerative disease, thus offering greater possibilities of efficiency and optimization of preventive and treatment measures, improving the quality of life of individuals affected by cerebral pathology (Stern, 2012; Piovezan, 2012).

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One of the main limitations of this study is related to not including the studies that used the scales mentioned in this review, carried out after the original validation process of the instrument. It is understood that these data could contribute to a better understanding of the psychometric characteristics of the same instrument in different age groups or in other cultures.

Finally, five scales/questionnaires that measure CR originating from different contexts were identified. All the instruments are of short duration, however, they vary in the items/variables measured and they need in-depth studies, with larger and diversified samples. Throughout the search, few studies involving adaptation of these scales were found (Choi et al., 2016; Maiovis, Ioannidis, Nucci, Gotzamani-Psarrakou, & Karacostas, 2016). Thus, studies that improve the validity evidence and carry out cross-cultural adaptations of the CR scales/questionnaires are suggested, in order to arrive at an instrument with quality power that is scientifically and internationally recognized.

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