Cognitive Reserve Index questionnaire (CRIq): a new instrument for measuring cognitive reserve

Massimo Nucci[1], Daniela Mapelli[1,2] and Sara Mondini[1,3]

[1]Department of General Psychology, University of Padova, [2]Centro Interdipartimentale CIRMANMEC, University of Padova, [3]Casa di Cura Figlie di San Camillo, Cremona, Italy

ABSTRACT. ***Background and aims:*** *The concept of "reserve" has been used to explain the difference between individuals in their capacity to cope with or compensate for pathology. Brain reserve refers to structural aspects of the brain, such as brain size and synapse count. Cognitive reserve is the ability to optimize and maximize performance through two mechanisms: recruitment of brain networks, and/or compensation by alternative cognitive strategies. The aim of the present research was to devise an instrument for comprehensive assessment and measurement of the quantity of cognitive reserve accumulated by individuals throughout their lifespan.* ***Methods:*** *A new approach using the Cognitive Reserve Index questionnaire (CRIq) was developed and tested in a sample of 588 healthy individuals, from 18 to 102 years old, stratified by age (Young, Adults, Elderly) and gender. The CRIq includes demographic data and items grouped into three sections: education, working activity and leisure time, each of which returns a subscore. The WAIS Vocabulary test and TIB were also administered.* ***Results:*** *The main descriptive features and some inferential results are described. Intelligence was only moderately correlated with cognitive reserve, stressing the distinction between these two concepts. Age and gender significantly affected CRIq scores, whereas no effect emerged from their interaction. Adults showed a higher score than Young and Elderly.* ***Conclusions:*** *This study provides a new instrument for a standardized measure of the cognitive reserve accumulated by individuals through their lifespan. The potential use of the CRIq in both experimental research and clinical practice is discussed.*
(Aging Clin Exp Res 2012; 24: 218-226)

©2012, Editrice Kurtis

INTRODUCTION

The concept of "reserve" was proposed in the late 1980s to explain the differences among individuals in their ability to cope with physiological or pathological cognitive decline. There is not always a direct relationship between the severity of brain pathologies or brain damage and the degree of deficit in performance. For many years, *Brain Reserve* (BR) was the prevalent construct of the potential ability of the brain to cope with neuronal damage. Katzman et al. (1) examined the brains of ten subjects who had documented post-mortem neuropathology of Alzheimer's dementia (AD), even though they had not expressed any sign of cognitive decline when alive. The authors attributed the absence of clinical signs of dementia to the higher-than-average weight of their brains. Later, BR was defined as the brain's resilience: that is, the possibility of the brain itself coping with increasing brain damage (2). The *Brain Reserve hypothesis* is primarily a passive-quantitative model related to individual differences (e.g., brain size and synapse count); a greater BR is considered as a protective factor, and a lower one indicates vulnerability.

The debate on BR and aging introduced and developed the concept of *Cognitive Reserve* (CR), a fascinating concept at the basis of brain plasticity. The *Cognitive Reserve hypothesis* suggests that the brain actively attempts to cope with damage by using pre-existing cognitive processes or enlisting compensatory strategies. Thus, people with a high CR can withstand more age-related changes and disease-related pathologies by effectively and flexibly using cognitive paradigms or compensatory brain networks (2-7). However, there is no a clear-cut distinction between BR and CR. As Stern (2) explicitly suggested, there is neural implementation of CR in terms of efficiency, capacity and flexibility of synaptic reorganization, and in terms of the relative utilization of specific brain regions. Similarly, intensive cognitive stimulation may be associated with increased brain volume in childhood (e.g., 8).

So far, CR has been estimated by extremely heterogeneous methods and more than a few proxies, as shown

Key words: Brain reserve, cognitive reserve, cognitive reserve questionnaire, dementia.

Correspondence: Massimo Nucci, Department of General Psychology, University of Padova, Via Venezia 8, 35131 Padova, Italy.
E-mail: massimo.nucci@unipd.it

Received February 18, 2011; accepted in revised form May 24, 2011.
First published ahead of print June 20, 2011 as DOI: 10.3275/7800

© 2012 Editrice Kurtis FOR PERSONAL USE ONLY

Table 1 - *Cognitive reserve proxies identified in 24 studies explicitly evaluating CR.*

Study	Education	Occupation	Intelligence	Leisure activity
Alexander et al. (9)	numerical scale (years of education)	no	demographics-based IQ estimation; WRAT (reading subtest)	no
Bialystok et al. (10)	numerical scale (years of education)	5-point scale (Human Resources and Skills Development, Canada, 2001)	no	no
Christensen et al. (11)	3-point scale (less than 10, 10-12, over 12 years of education)	no	Spot-the-Word Test	Self-directed Search Test
Daffner et al. (12)	numerical scale (years of education)	no	AMNART; Raven's Progressive Matrices Test	no
Garibotto et al. (13)	numerical scale (years of education)	6-point scale (NEST-DD project protocol)	no	no
Garrett et al. (14)	numerical scale (years of education)	no	NART	no
Le Carret et al. (15)	4-point scale (less than 5, 6-9, 10-12, over 12 years of education)	no	no	no
Martino et al. (16)	numerical scale (years of education)	no	WAIS-R (Vocabulary subtest)	no
McDowell et al. (17)	numerical scale (years of education) and 4-point scale (qualification)	6-point scale (Statistics Canada's standard occupational codes, 1981)	no	no
Ngandu et al. (18)	3-point scale (less than 5, 6-8, over 8 years of education)	no	no	no
Perneczky et al. (19)	numerical scale (years of education)	no	no	no
Ropacki et al. (20)	no	7-point scale (US Census categories, 1994)	OPIE	no
Roselli et al. (21)	dichotomous scale (less or more than 8 years of education)	no	no	no
Scarmeas et al. (22)	numerical scale (years of education)	no	NART	customized questionnaire
Solé-Padullés et al. (23)	4-point scale (qualification)	customized 4-point scale	WAIS-R (Vocabulary subtest)	customized questionnaire
Spitznagel et al. (24)	no	no	WRAT	no
Staff et al. (25)	numerical scale (years of education)	9-point scale (GB: Office of Population Censuses and Surveys, 1990)	no	no
Stern et al. (26)	numerical scale (years of education)	no	WAIS-R (Vocabulary subtest); NART	no
Tucker-Drob et al. (27)	dichotomous scale (less or more than 12 years of education)	no	Kit of factor-referenced cognitive tests	no
Valenzuela & Sachdev (28)	numerical scale (years of education) plus courses	9-point ordinal scale (Australian Standard Classification of Occupations, 1997)	no	customized questionnaire

© 2012, Editrice Kurtis
FOR PERSONAL USE ONLY

from a systematic literature revision of CR indicators (some examples are given in Table 1).

Education is one of the first and most commonly used proxies in studies on CR (17-19, 29, 30). Education plays a role in the cognitive decline in normal aging, as well as in degenerative disease or traumatic brain injury. Nevertheless, it is frequently recognized that higher (or lower) education levels have an influence on adult lifestyles. The effect is rather difficult to isolate from other protective factors such as a successful job, the awareness of health risks, and the quality of the social environment, amongst others. The proxy is usually indicated by the number of years of education (or, alternatively, the degree of literacy), in some cases on an ordinal scale and in others a numerical one.

Several studies have shown that occupation may provide an additive and independent source of CR throughout a person's lifetime (13, 25, 31). The last (or the longest) job is usually taken into account. Occupation has a different value according to the cognitive load involved. Perceived prestige and/or salary are also common indices.

Over and above education level and occupation, epidemiological evidence has shown that premorbid engagement in leisure activities may also provide a separate or synergic increase in CR (22, 23, 32, 33). Intellectual, social and physical activities are usually considered. Several activities have been recorded by means of instruments applying various types and numbers of items, target periods and frequencies (23, 28, 34, 35). The rationale behind these studies is that experiences acquired during adulthood and later can affect reserve.

Intelligence is another frequently used index of CR (9, 22, 23, 36), in which I.Q. or pre-morbid I.Q. are the most common proxies used to estimate CR. Also in this case, the instruments used to evaluate I.Q. are quite heterogeneous. Some of the most common tests are the Vocabulary Subtest of the Wechsler Adult Intelligence Scale (WAIS, 37) and the National Adult Reading Test (NART, 38).

Therefore, even when the same proxies are used, the procedures and measurement scales are difficult to compare and the various studies are, so far, not always easily comparable. For the same reasons, use of the CR in clinical settings is rather difficult.

Our research aimed at standardizing a new procedure to quantify the amount of CR accumulated by individuals throughout their lifetimes by introducing a new questionnaire, the Cognitive Reserve Index questionnaire (CRIq), and a new index, the Cognitive Reserve Index (CRI). The relevance and potential use of the CRIq in both experimental research and clinical practice is discussed.

METHOD

Participants and data collection

A total of 588 participants, randomly selected from the general Italian population (323 women, 55%), were enrolled in this study. Their age ranged from 18 to 102 years old (50.21±19.62, women 51.91±20.99 and men 48.13±17.65) and was arbitrarily divided into the following three groups: Young, from 18 to 44 years old (n=246; 31.52±7.89), Adults, from 45 to 69 (n=212; 54±6.70) and Elderly, from 70 to 102 (n=120; 78.87±6.28). Participants were healthy and without evident neurological or psychiatric illness; no other specific exclusion criteria were used. The participants did not receive any compensation for taking part in the study.

Trained psychologists (all studying for a Master's degree) administered the CRIq in single individual sessions lasting about 15 minutes. The CRIq is not anonymous; however, if participants objected to registering their names, a fictitious name was generated. All data were collected from September 2009 to June 2010.

Intelligence assessment

As the existence of a correlation between CR and intelligence is undoubted, in order to quantify this relationship, two tests highly correlated with intelligence were administered: 1) the Vocabulary Test from the WAIS (Italian version, 39); 2) the TIB (Test di Intelligenza Breve, 40, English translation: Short test of Intelligence, a reading test very similar to the NART, 38).

CRIq scale construction

The CRIq includes some demographic data (date and place of birth, gender, place of residence, nationality, marital status), and 20 items grouped into three sections, education, working activity, and leisure time, each of which returns a subscore.

CRI-Education: years of education plus possible training courses (lasting at least six months); the raw score of this section is the sum of these two values.

CRI-WorkingActivity: adulthood professions. Five different levels of working activities are available, dealing with the degree of intellectual involvement and personal responsibility: unskilled, manual work (e.g., farmer, car driver, call centre operator); skilled manual work (e.g., craftsman, clerk, hairdresser); skilled non-manual or technical work (e.g., trader, kindergarten teacher, real estate agent); professional occupation (e.g., lawyer, psychologist, physician); highly intellectual occupation (e.g., university professor, judge, top manager). Working activity was recorded as the number of years in each profession over the lifespan. The raw score of this section was the result of years of working activity multiplied by the cognitive level of job (from one to five), as detailed above.

CRI-LeisureTime: cognitively stimulating occupations carried out during leisure time (out of working time or school schedule). Sixteen items were related to various intellectual activities (e.g., reading newspapers or books, playing music), social activities (participation in charitable activities, going to a museum, travel) and physical activities (sports, dancing). The frequency (i.e., *never/rare, often/always*) and the number of years (how long each activity had been carried out) were recorded. The raw score of this section was the total number of years of activity for which frequency was *often/always*. A score related to the number of children was also included.

The CRIq questionnaire (Italian, French and English versions), instructions, and the Excel file for automatic calculation of scores, are available at http://cri.psy.unipd.it.

Computation of CRI

The raw scores of the three sections of the CRIq were correlated with age by the number of years an activity had been carried out (correlation r=-0.56 for education; r=0.48 for working activity, r=0.66 for leisure time activity). In order to rule out this "age effect", three linear models were used: the raw scores of the three sections were set as dependent variables, and age as the independent (or predictor) variable (see Fig. 1).

The three CRIq subscores (CRI-*Education*, CRI-*WorkingActivity*, CRI-*LeisureTime*) were the residuals of the relative linear models, standardized and transposed to

© 2012, Editrice Kurtis
FOR PERSONAL USE ONLY

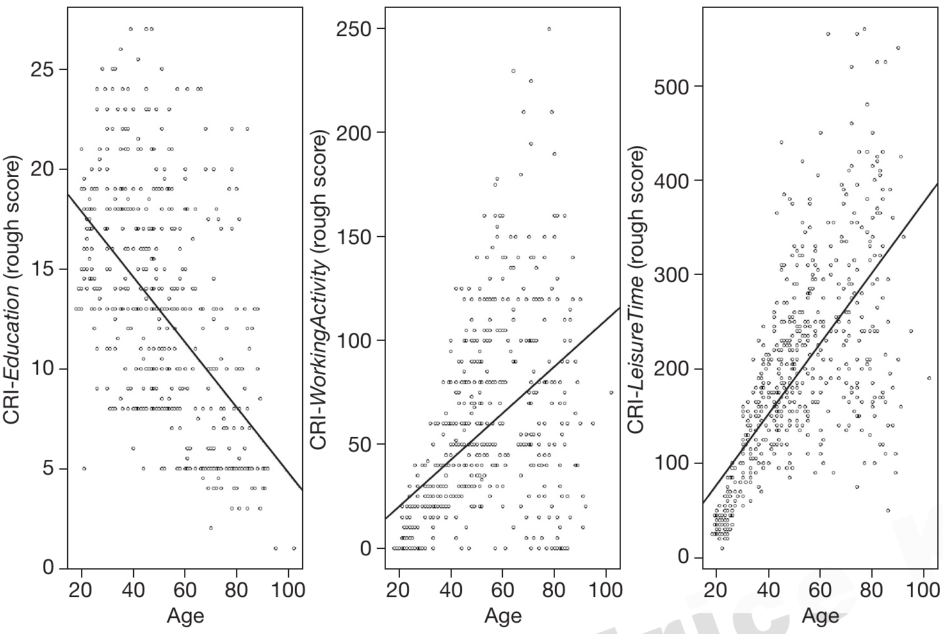

Fig. 1 - *Scatter-plots of raw scores of three sections of CRIq according to age. Lines: estimators of linear regression model, with age as predictable variable and raw scores of sections as dependent variables.*

©2012 Editrice Kurtis FOR PERSONAL USE ONLY

a scale with M=100 and SD=15. This allowed all participants to be systematically compared with their corresponding age class. Lastly, CRI (total CRIq score) was the average of the three subscores, again standardized and transposed to a scale with M=100 and SD=15. The higher the CRI, the higher the estimated CR. CRI could be classified into five ordered levels: Low (less than 70), Medium-low (70-84), Medium (85-114), Medium-high (115-130) and High (more than 130).

Toward a validation of the CRIq

The CRI-*LeisureTime* section was progressively simplified and improved by means of the Item Response Theory (41, 42), by either excluding redundant, non-discriminative items or by joining some of them. The actual sixteen items used showed good reliability (α=0.73, 95% CI [0.70, 0.76]).

The majority of elderly Italians did not have more than five years of education, for social and/or historical reasons. Therefore, in our database it is not surprising that elderly people had low CRI-*Education* but high CRI-*WorkingActivity* or high CRI-*LeisureTime* scores. Instead, at present, young subjects with Master's degrees (high CRI-*Education*) may have unskilled jobs (low CRI-*WorkingActivity*), due to the current crisis of the job market. Therefore, all three sections of the questionnaire equally co-occurred to the CRI (reliability of CRIq α=0.62, 95% CI [0.56, 0.97]). The prediction was that, although the three subscores were all proxies of the same construct (i.e., CR), the correlation between them would not be very high.

Because of the lack of standardized questionnaires for estimating the CR, a concurrent validation of the CRIq could not easily be obtained. "Intelligence" is the construct which is most closely related to the CR (and was thus used as a predictive proxy in some studies). However, the CRI and IQ are not equivalent to each other. Thus, a perfect correlation between them is neither expected, nor desirable. In our sample, the correlation between CRI and two tests considered as being highly correlated with intelligence (Vocabulary tests from WAIS and TIB) was around 0.45.

RESULTS

Statistical analyses are organized into three sections: Frequencies, Correlations, ANOVAs.

Frequencies

Some main descriptive features from the data collected (588 participants) are reported, in order to shape the whole database. The raw CRI-*Education* score (12.28±5.34) showed frequency peaks around 5, 8, 13 and 18 years of school, easily linked to Italian levels of education. As predicted, Elderly showed a lower level of education than Adults and Young (7.33±4.17, 11.98±4.93 and 15.15±4.11, respectively). Women also showed a lower level of education than men (11.58±5.30 and 13.13±5.28, respectively).

In CRI-*WorkingActivity*, low skilled manual work was the most frequently recorded activity (33%), followed by skilled manual work, professional occupation and skilled non-manual work (20%, 18% and 15%, respectively). On-

Table 2 - *Percentages of types of working activity according to cognitive resources involved.*

	Total n=588	Females n=323	Males n=265	Young n=246	Adults n=212	Elderly n=130
Never employed	13%	16%	9%	24%	1%	11%
Low skilled manual work: agricultural worker, waiter, driver, mechanic, plumber, call centre operator, etc.	33%	37%	28%	26%	35%	45%
Skilled manual work: craftsman, clerk, cook, shop assistant, tailor, nurse, professional soldier, barber/haidresser, ect.	20%	15%	27%	18%	23%	21%
Skilled non manual work: shopkeeper, white-collar worker, priest or monk-nun, sales representative, estate agent, musician, etc.	15%	15%	15%	15%	17%	12%
Professional occupation: CEO of a small company, lawyer, physician, psychologist, engineer, teacher, etc.	18%	16%	20%	17%	23%	10%
Highly responsible or intellectual occupation: CEO of large company, politician, university professor, judge, surgeon, etc.	1%	0%	2%	0%	1%	1%

ly 1% of the sample had a highly responsible or intellectual occupation; 13% had been never employed. The frequencies of various working activities across gender and age are listed in Table 2.

CRI-*LeisureTime* showed Housework and Driving as the most frequently recorded activities (12%). The least were Going to the cinema/theatre, and Charitable or artistic activities (about 2%). Table 3 lists the frequencies across gender and age.

Correlations

Results for Pearson's correlations and the Fisher test are reported here, in order to show the degree of dependence between the main variables involved in CRIq.

The CRI showed a satisfactory correlation with the three subscores, CRI-*Education*, CRI-*WorkingActivity* and CRI-*LeisureTime*: r=0.77, r=0.78 and r=0.72, respectively[1] (see Fig. 2). As predicted, the correlation between the subscores was not high: CRI-*Education* and CRI-*WorkingActivity* were r=0.44; CRI-*Education* and CRI-*LeisureTime* were r=0.30; CRI-*WorkingActivity* and CRI-*LeisureTime* were r=0.32. The first was significantly higher than the other two (z=2.78, $p<0.01$ and z=2.40, $p<0.01$, respectively, with the formula recommended by Cohen et al., 43).

Differences across Gender were minimal, except for the

© 2012, Editrice Kurtis
FOR PERSONAL USE ONLY

Table 3 - *Percentages of types of activities carried out during leisure time.*

	Total n=588	Women n=323	Men n=265	Young n=246	Adults n=212	Elderly n=130
Reading newspapers and magazines	11%	10%	11%	7%	10%	14%
Housework (cooking, washing, ironing, etc.)	12%	18%	5%	9%	11%	16%
Driving (not biking)	12%	9%	16%	13%	14%	8%
Leisure activities (sports, hunting, dancing, cards, bowling, etc.)	4%	4%	6%	4%	4%	5%
Using new technologies (digital camera, computer, internet, etc.)	5%	4%	6%	1%	4%	1%
Social activities (parties/going out with friends, local community events, etc.)	8%	7%	9%	11%	8%	6%
Cinema or theatre	2%	3%	2%	3%	2%	2%
Gardening, handicraft, knitting, etc.	9%	10%	7%	3%	8%	13%
Taking care of children or elderly	3%	4%	2%	2%	3%	4%
Volunteering	2%	2%	1%	2%	1%	1%
Artistic activities (playing an instrument, painting, writing, etc.)	2%	2%	2%	3%	2%	2%
Exhibitions, concerts, conferences	4%	3%	4%	4%	4%	2%
Holidays	3%	2%	4%	5%	3%	2%
Reading books	7%	8%	6%	8%	8%	7%
Pet care	5%	6%	5%	5%	5%	5%
Managing one's bank account(s)	12%	10%	14%	11%	12%	12%

[1]Following Fisher transformation, in a sample of 588 individuals, all Pearson's correlations greater than 0.107 were significantly different from 0, $p<0.01$.

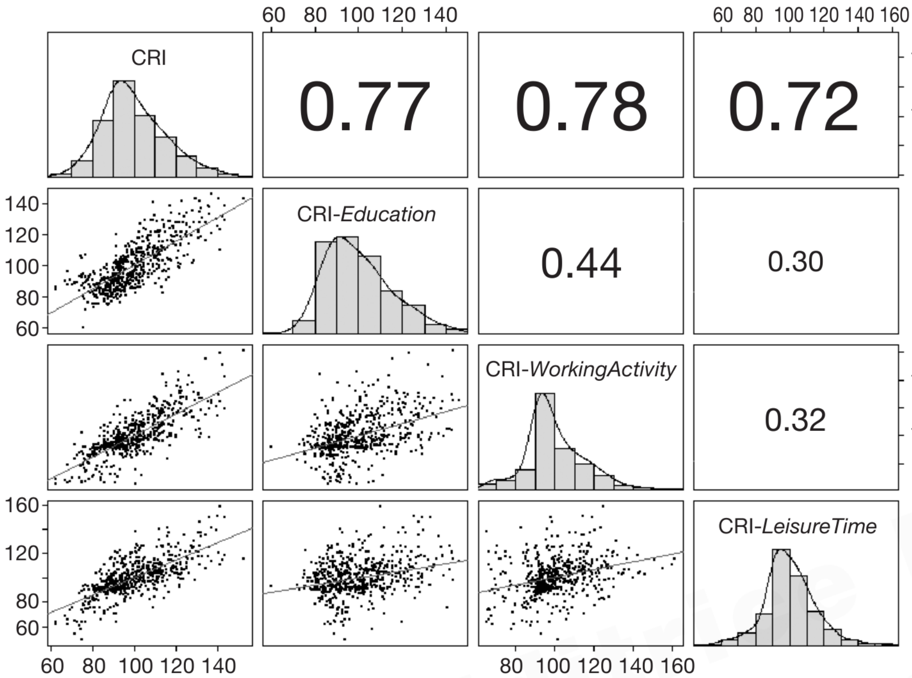

Fig. 2 - Upper right triangle*: correlations between CRI, CRI-*Education, *CRI-*WorkingActivity *and CRI-*LeisureTime. Bottom left triangle*: relative scatter plots. Histograms with estimated density of each variable on diagonal.*

© 2012, Editrice Kurtis
FOR PERSONAL USE ONLY

correlation between CRI and CRI-*LeisureTime*: women showed a higher correlation than men (r_{women}=0.76; r_{men}=0.68; z=2.85, *p*<0.01). As expected, the correlation between CRI and CRI-*Education* was significantly lower for the Elderly ($r_{elderly}$=0.76) with respect to the Young and Adults (r_{young}=0.81, r_{adults}=0.83; z=2.23, *p*<0.05 and z=3.28, *p*<0.01, respectively). The correlation between CRI and CRI-*WorkingActivity* was significantly the lowest for Young (r_{young}=0.67, r_{adult}=0.80, $r_{elderly}$=0.74; z=4.92, *p*<0.01 and z=2.38, *p*<0.01, respectively). Adults also showed the significantly lowest correlation between CRI and CRI-*LeisureTime* (r_{adults}=0.62, r_{young}=0.75, $r_{elderly}$=0.75; z=4.24, *p*<0.01 for both).

The two intelligence tests used in this study (Vocabulary tests of WAIS and TIB, number of errors) were only moderately correlated with the CRI (r=0.42 and r=-0.45, respectively). Among the three sections of the CRIq, as expected, the highest correlation with the two intelligence tests was with CRI-*Education* (r=0.44 and r=-0.43, respectively); CRI-*WorkingActivity* (r=0.29 and r=-0.28) and CRI-*LeisureTime* (r=0.22 and r=-0.32) were slightly less correlated.

ANOVAs

Four ANOVA tests were performed, in order to verify the effects of Age and Gender on the CRI and CRI subscores (Fig. 3, Table 4). A few *post-hoc* analyses were performed with the *t*-test. Type I error control was not provided, owing to the small number of tests.

Gender and Age significantly affected the CRI. Men had a higher CRI than women (101.53 *vs* 98.75, $F_{(1,582)}$=5.56, *p*=0.02) and age also turned out to be a significant factor (Young 97.57, Adults 106.22, Elderly 94.45, $F_{(2,582)}$=32.08, *p*<0.01). *Post-hoc* analyses revealed the highest CRI in Adult (Young *vs* Adults $t_{(456)}$=-7.27, *p*<0.01; Young *vs* Elderly $t_{(374)}$=2.13, *p*=0.03 and Adults *vs* Elderly $t_{(340)}$=6.32, *p*<0.01). No effect emerged from the Age-Gender interaction ($F_{(2,582)}$=0.98, *p*=0.37).

For the CRI-*Education* subscore, Gender was the only significant factor, men exceeding women (101.42 *vs* 98.82, $F_{(1,582)}$=4.40, *p*=0.03) whereas Age groups and Age-Gender interactions did not reach significance (Young 99.41, Adults 101.74 and Elderly 98.26, $F_{(2,582)}$=2.02, *p*=0.13 and $F_{(2,582)}$=0.22, *p*=0.79 respectively).

ANOVA on the subscore CRI-*WorkingActivity* showed Gender and Age as significant factors. Men exceeded women (103.09 *vs* 97.46, $F_{(1,582)}$=24.65, *p*<0.01) and the three Age groups were also significant (Young 97.24, Adults 107.00, Elderly 93.79, $F_{(2,582)}$=41.54, *p*<0.01). A *post-hoc* analysis revealed a significant difference in CRI-*WorkingActivity* across the three Age groups, CRI-*WorkingActivity* in the Adult group being highest (Young *vs* Adults: $t_{(456)}$=-8.82; *p*<0.01; Young *vs* Elderly: $t_{(374)}$=2.41, *p*=0.02; Adults *vs* Elderly: $t_{(340)}$=6.85; *p*<0.01). Age and Gender showed a significant interaction ($F_{(2,582)}$=7.84, *p*<0.01).

Lastly, Age was the only significant main effect on CRI-

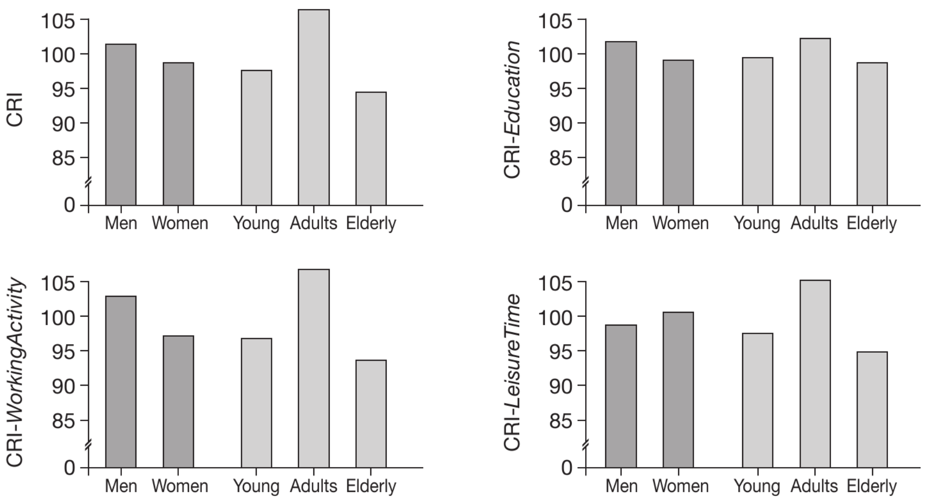

Fig. 3 - *Barplots of CRI and subscores in Gender and Age groups.*

©2012, Editrice Kurtis
FOR PERSONAL USE ONLY

LeisureTime (Young 97.84, Adults 105.34, Elderly 95.36, $F_{(2,582)}$=25.85, $p<0.01$). *Post-hoc* analyses showed Adults had the highest CRI-*LeisureTime* with respect to Young and Elderly groups, which did not differ (Young *vs* Adults: $t_{(456)}$=7.04, $p<0.01$; Adults *vs* Elderly: $t_{(340)}$=5.06; $p<0.01$, Young *vs* Elderly: $t_{(374)}$=1.57, p=0.11). No significant difference was found in Gender (men 98.93 *vs* women 100.87, $F_{(2,582)}$=2.66, p=0.10).

DISCUSSION

This study proposes a new questionnaire, the CRIq, to collect and quantify the amount of CR acquired during a person's lifetime. In a single index, the CRIq conveys three main sources of CR: education, working activity and leisure time activities. Each of these aspects of an individual's lifetime is recorded as a subscore. The CRIq calculates each activity according to the number of years and frequency of practice. Thus, the raw score increases throughout an entire lifespan, as Stern stated "CR is not fixed; at any point in one's lifetime it results from a combination of exposures" (2, p. 2017). However, by means of a linear model, the three subscores and the final CRIq score discards age, allowing comparisons across groups.

The data collected for 588 Italian participants indicated that all three sections of the CRIq gathered distinct and non-redundant information on individual lifestyles (correlations between subscores were not high and ranged between r=0.30 and r=0.44). The Italian population divided by age and gender showed several interpretable features. The lowest correlation, between CRI and CRI-*Education*, was found in the Elderly group. As already reported, elderly Italians generally only attended a few years of school (particularly women) for historical and social reasons. Instead, the lowest correlation between CRI and CRI-*WorkingActivity* was found in the Young group probably because most young people were not yet work-

Table 4 - *Means and standard deviations of CRI and sub-indices across gender and age.*

	Age	n	CRI	CRI-*Education*	CRI-*WorkingActivity*	CRI-*LeisureTime*
TOTAL	**18-102**	**588**	**100 (15)**	**100 (15)**	**100 (15)**	**100 (15)**
Men	Young (18-44)	118	98.63 (10.53)	101.09 (14.87)	97.88 (7.73)	97.92 (7.63)
	Adults (45-69)	107	106.19 (14.92)	102.71 (16.25)	108.81 (15.36)	102.48 (13.00)
	Elderly (70-102)	40	97.60 (16.81)	98.99 (13.17)	103.15 (19.82)	92.42 (19.75)
Total Men	20-90	265	101.52 (13.97)	101.43 (15.20)	103.09 (14.30)	98.093 (12.78)
Women	Young (18-44)	128	96.60 (8.95)	97.88 (12.59)	96.65 (6.93)	97.77 (8.34)
	Adults (45-69)	105	106.25 (15.96)	100.75 (16.81)	105.15 (15.38)	108.25 (15.00)
	Elderly (70-102)	90	93.05 (19.36)	97.94 (14.98)	89.64 (18.64)	96.67 (23.12)
Total Women	18-102	323	98.75 (15.71)	98.83 (14.75)	97.46 (15.10)	100.87 (16.57)

ing or had not reached top positions. Interestingly, the only correlation in which women overtook men was in CRI-*LeisureTime*, in which several items (e.g., housework, caring for grandchildren or elderly people) pertained specifically to women. This balanced the fact that CRI-*WorkingActivity* did not include housewife as a profession. Men had a higher CRI than women, because of differential involvement in work, low for women in the Elderly group. Instead Adults had the highest CRI, both CRI-*WorkingActivity* and CRI-*LeisureTime*.

CR and intelligence are undoubtedly related, and their measures are therefore correlated. Nevertheless, CR and intelligence are distinct. Wechsler (44) defined intelligence as "the aggregate or global capacity of the individual to act purposefully, to think rationally, and to deal effectively with his environment". Sternberg (45) stated that intelligence is a "goal-directed adaptive behavior". Thus, the focus of intelligence is on acting and behaviour, in other words, on intellectual performance. Instead, CR is a construct based on the idea of the storage of resources: the potential cognitive capabilities acquired throughout life. This clear-cut difference is reflected in their measurement. Whereas I.Q. is a measure of performance, CRI is not. For this reason, we chose to exclude I.Q. as a CR proxy, despite its undisputed correlation. We postulated that CR and intelligence are two distinct constructs and our results (correlation r=0.44) sustain our assumption. Obviously, as expected, the highest correlation between I.Q. and the CRI subscores of our sample was found with CRI-*Education*.

The specific results obtained from our sample indicate that CRIq is an efficient and reliable tool for measuring CR. In particular, it is short and easy to administer, and thus can easily be included in standard assessments without too much effort for the subject in terms of both time and cognitive resources. It also overcomes the major limitations found in studies estimating CR. The three proxies of the CRIq have already been used in other studies (23, 28), but they were usually combined in couples or used with premorbid I.Q. (see Table 1). In a recent paper from a broad systematic review of CR indicators, Jones et al. (46) confirmed education, occupation and leisure activities as the most frequently used proxies of CR. The CRIq considers activities carried out throughout adulthood (from the age of 18) (32, 28), whereas others gathered information exclusively from current lifestyles or the past six months (22, 47). The CRIq also takes into account not only the number of years during which the activities were carried out, but also their frequency. Unlike other instruments which only measure activities late in life (28, 34), the CRIq can be administered at any age. Lastly, since the measurement of CR is not one of performance, a significant and interesting feature of CRIq is that it can also be administered to relatives or close friends, if an individual cannot be interviewed for any reason (e.g., brain impairment, aphasia, coma, dementia, etc.). Above all, the CRIq provides a standardized and psychometrically controlled measure of cognitive reserve, allowing its extensive employment in both experimental research and clinical practice.

In fundamental research, the CRIq represents a single index to compare data and results from different studies. All investigations evaluating cognitive abilities could benefit from it in place of education only, in order to assess individual performance better. The CRIq may also be used to validate new psychometric tests (only age and education are usually considered).

In clinical settings, the CRIq could be used to diagnose senile dementia, comparing CRI and cognitive performance. In subjects with high CRI scores, the richness of neuronal synaptic tissue and its plasticity acts as a reserve, compensating for the atrophy of grey matter and covering clinical pathological signs (2). Thus, poor performance on cognitive tests, but still within the normal range, must be considered suspect in cases of a high CRI. Conversely, poor performance combined with a low CRI is expected. The CRIq could also enable psychologists to gain a more complete image of their patients and their lifestyles, including information from standard assessments which usually depend on the clinician's experience.

The *Cognitive Reserve hypothesis* assumes that the fuller the life a person has had in terms of intellect, abilities and experiences, the more that person will be able to cope with difficult cognitive tasks and social events in life. The CRIq is the tool to quantify this cognitive, social, cultural and human capital.

REFERENCES

1. Katzman R, Terry R, Deteresa R et al. Clinical, pathological, and neurochemical changes in dementia: a subgroup with preserved mental status and numerous neocortical plaques. Ann Neurol 1988; 23: 138-44.
2. Stern Y. Cognitive reserve. Neuropsychologia 2009; 47: 2015-28.
3. Keller JN. Age-related neuropathology, cognitive decline, and Alzheimer's disease. Ageing Res Rev 2006; 5: 1-13.
4. Kramer AF, Bherer L, Colcombe SJ, Dong W, Greenough, WT. Cognitive decline is related to education and occupation in a Spanish elderly cohort. Aging Clin Exp Res 2002; 14: 132-42.
5. Stern Y. Cognitive reserve and Alzheimer disease. Alzheimer Dis Assoc Disord 2006; 20: 69-74.
6. Valenzuela MJ, Sachdev P. Brain reserve and dementia: a systematic review. Psychol Med 2005; 35: 1-14.
7. Whalley LJ, Deary IJ, Appleton CL, Starr JM. Cognitive reserve and the neurobiology of cognitive aging. Ageing Res Rev 2004; 3: 369-82.
8. Kesler SR, Adams HF, Blasey CM, Bigler ED. Premorbid intellectual functioning, education, and brain size in traumatic brain injury: an investigation of the cognitive reserve hypothesis. Appl Neuropsychol 2003; 10: 153-62.
9. Alexander GE, Furey ML, Grady CL, Pietrini P, Mentis MJ,

©2012, Editrice Kurtis
FOR PERSONAL USE ONLY

Shapiro MB. Association of premorbid function with cerebral metabolism in Alzheimer's disease: implications for the reserve hypothesis. Am J Psychiatry 1997; 154: 165-72.

10. Bialystok E, Craik FI, Freedman M. Bilingualism as a protection against the onset of symptoms of dementia. Neuropsychologia 2007; 45: 459-64.
11. Christensen H, Anstey KJ, Parslow R, Mackinnon A, Sachdev P. The brain reserve hypothesis. Brain Atrophy and aging. Gerontology 2006; 53: 82-95.
12. Daffner KR, Ryan KK, Williams DM et al. Age-related differences in novelty and target processing among cognitively high performing adults. Neurobiol Aging 2005; 26: 1283-95.
13. Garibotto V, Borroni B, Kalbe E et al. Education and occupation as proxies for reserve in aMCI converters and AD: FDG-PET evidence. Neurology 2008; 71: 1342-9.
14. Garrett DD, Grady CL, Hasher L. Everyday memory compensation: the impact of cognitive reserve, subjective memory, and stress. Psychol Aging 2010; 25: 74-83.
15. Le Carret N, Auriacombe S, Letenneur L, Bergua LV, Dartigues JF, Fabrigoule C. Influence of education on the pattern of cognitive deterioration in AD patients: the cognitive reserve hypothesis. Brain Cogn 2005; 57: 120-6.
16. Martino DJ, Strejilevich SA, Scàpola M et al. Heterogeneity in cognitive functioning among patients with bipolar disorder. J Affect Disord 2008; 109: 149-56.
17. McDowell I, Xi G, Lindsay J, Tierney M. Mapping the connections between education and dementia. J Clin Exp Neuropsychol 2007; 29: 127-41.
18. Ngandu T, Von Strauss E, Helkala EL et al. Education and dementia: what lies behind the association? Neurology 2007; 69: 1442-50.
19. Perneczky R, Drzezga A, Diehl-Schmid J et al. Schooling mediates brain reserve in Alzheimer's disease: findings of fluoro-deoxy-glucose-positron emission tomography. J Neurol Neurosurg Psychiatry 2006; 77: 1060-3.
20. Ropacki SA, Bert AA, Ropacki MT, Rogers BL, Stern RA. The influence of cognitive reserve on neuropsychological functioning following coronary artery bypass grafting (CABG). Arch Clin Neuropsychol 2007; 22: 73-85.
21. Roselli F, Tartaglione B, Federico F, Lepore V, Defazio G, Livrea P. Rate of MMSE score change in Alzheimer's disease: influence of education and vascular risk factors. Clin Neurol Neurosurg 2009; 111: 327-30.
22. Scarmeas N, Zarahn E, Anderson KE et al. Association of life activities with cerebral blood flow in Alzheimer Disease. Implications for the cognitive reserve hypothesis. Arch Neurol 2003; 60: 359-65.
23. Solé-Padullés C, Bartrés-Faz D, Junqué C et al. Brain structure and function related to cognitive reserve variables in normal aging, mild cognitive impairment and Alzheimer's disease. Neurobiol Aging 2009; 30: 1114-24.
24. Spitznagel MB, Tremont G. Cognitive reserve and anosognosia in questionable and mild dementia. Arch Clin Neuropsychol 2005; 20: 505-15.
25. Staff RT, Murray AD, Deary IJ, Whalley LJ. What provides cerebral reserve? Brain 2004; 127: 1191-9.
26. Stern Y, Habeck C, Moeller J et al. Brain networks associated with cognitive reserve in healtly young and old adults. Cerebr Cortex 2005; 15: 394-402.
27. Tucker-Drob EM, Johnson KE, Jones RN. The cognitive reserve hypothesis: a longitudinal examination of age-associated declines in reasoning and processing speed. Dev Psychol 2009; 45: 431-46.
28. Valenzuela MJ, Sachdev P. Assessment of complex mental activity across the life span: development of the Lifetime of experiences Questionnaire (LEQ). Psychol Med 2007; 37: 1015-25.
29. Gatz M, Svedberg P, Pedersen NL, Mortimer JA, Berg S, Johansson B. Education and the risk of Alzheimer's disease: findings from the study of dementia in Swedish twins. J Gerontol B Psychol Sci Soc Sci 2001; 56: 292-300.
30. Stern Y, Alexander GE, Prohovnik I, Mayeux R. Inverse relationship between education and parietotemporal perfusion deficit in Alzheimer's disease. Ann Neurol 1992; 32: 371-5.
31. Stern Y, Alexander GE, Prohovnik I et al. Relationship between lifetime occupation and parietal flow: implications for a reserve against Alzheimer's disease pathology. Neurology 1995; 45: 55-60.
32. Crowe M, Andel R, Pedersen NL, Johansson B, Gatz M. Does participation in leisure activities lead to reduced risk of Alzheimer's disease? A prospective study of Swedish twins. J Gerontol B Psychol Sci Soc Sci 2003; 58: 249-55.
33. Wilson RS, Bennett DA, Bienias JL et al. Cognitive activity and incident AD in a population-based sample of older persons. Neurology 2002; 59: 1910-4.
34. Schinka JA, McBride A, Vanderploeg RD et al. Florida Cognitive Activities Scale: intial development and validation. J Int Neuropsychol Soc 2005; 11: 108-16.
35. Wilson, RS, Barnes, LL, Krueger, KR et al. Early and late life cognitive activity and cognitive systems in old age. J Int Neuropsychol Soc 2005; 11: 400-7.
36. Scarmeas N, Zarahn E, Anderson KE et al. Cognitive reserve modulates functional brain responses during memory tasks: a PET study in healthy young and elderly subjects. Neuroimage 2003; 19: 1215-27.
37. Wechsler D. Wechsler Adult Intelligence Scale-Revised. New York: Psychological Corp, 1981.
38. Nelson HE. National Adult Reading Test: Test Manual. Windsor, Berks: NFER-Nelson, 1982.
39. Orsini A, Laicardi C. Wechsler Adult Intellingence Scale-Revised-WAIS-R, Contributo alla taratura italiana. Firenze: Organizzazioni Speciali, Giunti, 1997.
40. Colombo L, Sartori G, Brivio C. Stima del quoziente intellettivo tramite l'applicazione del TIB (test breve di Intelligenza). Giornale Italiano di Psicologia 2002; 3: 613-37.
41. Rizopoulos D. ltm: An R package for latent variable modeling and item response theory analyses. J Stat Software 2006; 17: 1-25.
42. Van Der Linden WJ, Hambleton RK. Handbook of modern item response theory. New York: Springer-Verlag, 1997.
43. Cohen J, Cohen P, West SG, Aiken LS. Applied multiple regression/correlation analysis for the behavioural sciences, 3rd ed. Mahwah, NJ: Lawrence Erlbaum, 2003.
44. Wechsler D. The Measurement of Adult Intelligence. Baltimore: Williams & Wilkins, 1944.
45. Sternberg RJ. Handbook of Human Intelligence. New York: Cambridge University Press, 1982.
46. Jones RN, Fong TG, Metzger E et al. Aging, brain disease, and reserve: implications for delirium. Am J Geriatr Psychiatry 2010; 18: 117-27.
47. Hall CB, Lipton RB, Sliwinski M. Cognitive activities delay onset of memory decline in persons who develop dementia. Neurology 2009; 73: 356-61.

©2012, Editrice Kurtis
FOR PERSONAL USE ONLY