Title: Motivation as a mediator of the relation between cognitive reserve and cognitive performance

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Abstract

Objectives. Interindividual differences in cognitive aging may be explained by differences in cognitive reserve (CR) that are built-up across the lifespan. A plausible but under-researched mechanism for these differences is that CR helps compensating cognitive decline by enhancing motivation to cope with challenging cognitive situations. Theories of motivation on cognition suggest that perceived capacity and intrinsic motivation may be key mediators in this respect.

Method. In 506 older adults, we assessed CR proxies (education, occupation, leisure activities), motivation (perceived capacity, intrinsic motivation), and a global measure of cognitive functioning.

Results. Perceived capacity, but not intrinsic motivation, significantly mediated the relation between CR and cognitive performance.

Discussion. Complementary with neurobiological and cognitive processes, our results suggest a more comprehensive view of the role of motivational aspects built-up across the lifespan in determining differences in cognitive performance in old age.

Keywords: Cognitive reserve, motivation, perceived capacity, cognitive performance

Introduction

Although aging is traditionally associated with cognitive decline, the rate and extent of this decline differs greatly between individuals. These differences have been linked to cognitive reserve (CR): "the ability to optimize or maximize performance through differential recruitment of brain networks, which perhaps reflect the use of alternate cognitive strategies" (Stern, 2002, p.451). CR is built-up across the lifespan through education, occupation, and leisure activities. For example, intellectually engaging activities (Hultsch, Hertzog, Small, & Dixon, 1999) and a variety of social and physical activities (Hertzog, Kramer, Wilson, & Lindenberger, 2009) are known to be protective factors against cognitive decline. More broadly, positive associations have been found between numerous types of cognitive performance and markers of CR, such as activities, early education, and type of occupation (Opdebeeck, Martyr, & Clare, 2016). In addition, higher levels of CR are associated with a lower risk of dementia (Valenzuela & Sachdev, 2005). Different mechanisms are proposed to explain the CR-performance link, such as neural or cognitive compensation processes (Stern, 2002, 2009). Higher CR is hypothesized to involve an efficient use of brain networks and the shift to alternative brain networks when individuals encounter difficulties.

A more recent and complementary explanation focuses on motivational reserve: "the driving forces or processes that lead to this more efficient or flexible use of brain networks" (Maercker & Forstmeier, 2011, p.175). Being confronted with cognitively demanding situations during the lifespan, especially through occupations involving goal orientation and action planning, may give people higher motivational abilities (i.e., perseverance, decision regulation, activation regulation), associated with a more efficient compensation of age-related decline. First empirical studies have shown that motivational abilities, derived from the type of occupation, have an impact on older adults' cognitive status and on the risk of developing Mild Cognitive Impairment (Forstmeier & Maercker, 2008). Moreover, from a socio-cognitive perspective, regardless of the intellectual abilities built-up across the lifespan, individual differences in the motivation towards cognitive activities, have been shown to play a role in compensating for cognitive decline (Hess, 2005). However, the specific motivational constructs that are shaped across the lifespan and that may mediate the CR–performance relationship have not yet been clearly identified. The present study set out to address this gap.

Most socio-cognitive models of motivation posit that task performance, regardless of cognitive abilities, is influenced by two main motivational constructs, performance expectation and subjective value (see Eccles & Wigfield, 2002 for a review). These two constructs capture more specific variables that have been introduced under varying names across theories (e.g., self-efficacy in social cognitive model Bandura 1977; intrinsic motivation in the self-determination theory Deci & Ryan, 2008). Performance expectation relates to the perception individuals have about how they will perform an activity, including perceived capacity; while the subjective value of the activity refers to the reasons for doing an activity, including intrinsic motivation. Thus, these constructs (i.e., perceived capacity and intrinsic motivation) capture a broad base of a person's motivation about cognition, and are particularly relevant in the context of CR, as they both have been shown to vary depending on people's lifestyle, and to influence cognitive performance.

First, perceived capacity construct is predicted by an active lifestyle, as people with more active lifestyles and larger social networks believe they have better memory capacities (Stevens, Kaplan, Ponds, & Jolles, 2001). In turn, perceived capacity has been shown to influence cognitive performance (Beaudoin & Desrichard, 2011, 2017; Valentijn, et al., 2006) and to mediate the link between the frequency with which people engage in different activities and cognitive performance (Jopp & Hertzog, 2007).

Second, intrinsic motivation (i.e., doing an activity for itself) is an important predictor of performance in a wide variety of domains (Cerasoli, Nicklin, & Ford, 2014). In the context of cognitive aging, older adults' engagement in cognitive tasks has been shown to be particularly sensitive to their interest in a task (Adams, Smith, Pasupathi, & Vitolo, 2002). This self-determined motivation also impacts older adults' cognitive performance (Clement, Vivicorsi, Altintas, & Guerrien, 2014). Importantly, CR may contribute to intrinsic motivation for cognition in older adults. Because higher education and intellectually stimulating occupations impose frequent challenging cognitive situations, they may enhance feelings of competency and autonomy, which are key factors in maintaining one's intrinsic motivation to undertake cognitively demanding tasks (Deci & Ryan, 2008). Moreover, engagement in leisure activities involves repeated self-determined motivation, which may foster the development of intrinsic motivation in general (Guay, Mageau, & Vallerand, 2003). In this sense, Baer et al. (2013) showed that higher number of cognitive activities and a higher level of education both correlate with a higher need for cognition, which was predictive of less decline in cognitive performance at older age.

Taken together, the literature on motivation suggests that the effect of CR proxies on older adults' differences in cognitive performance may be mediated by two important motivational constructs in the light of the expectancy-value model: perceived capacity and intrinsic motivation. However, the role of CR proxies constructed during the lifespan to impact motivation later in life has not been tested directly. We examined the effects of these two motivational constructs, predicting that regular exposure to cognitively demanding situations during the lifespan may result in older adults building stronger perceived capacity and intrinsic motivation for cognitive activities, independently of current exposure to cognitive situations. Furthermore, because perceived capacity and intrinsic motivation are expected to influence cognitive performance, we hypothesized that both motivational constructs mediate the CR-cognitive performance association.

Methods

Procedure

Data analyzed in the present paper come from the second wave of the Vivre/Leben/Vivere (VLV) study conducted in 2017-2018. The VLV2 study comprises both a large battery of self-administered questionnaires and a face-to-face interview including a cognitive performance test session. In terms of domains assessed it contains a large variety of measures (e.g., socio-demographics, autonomy, physical and mental health, personality, cognition; see Ihle et al., 2015; Oris et al., 2016).

Participants

From the initial sample of 1059 valid participants, we excluded participants with no data on MMSE or with MMSE < 21 (*n*=31), those who had no cognitive measures due to a random rotation procedure (*n*=345), and those missing one or more measures (measures with less of 50% of items or sub-dimensions completed were considered as missing). Our final sample consisted in 506 participants (see Table 1).

Measures

Cognitive reserve

We used the Cognitive Reserve Index Questionnaire (CRIq) to assess proxies of accumulated cognitive reserve (CR) across the lifespan (Nucci, Mapelli, & Mondini, 2012). The CRIq comprises three sub-scores: CRI-education (number of years spent in education and on training courses lasting at least six months), CRI-working activity (number of years and type of work carried out, divided into five cognitive levels and weighted accordingly), and CRI-leisure time (number of years' experience for activities carried out "often/always" from a list of 16 types of activity). We assessed accumulated exposure to cognitively demanding situations via a total CR score obtained by standardizing and transforming the three sub-scores as *M*=100 and *SD*=15, and then computing the mean of these scores (Nucci et al., 2012).

Motivation for cognitive activities

Motivation was assessed using the Motivation for Cognitive Activities Questionnaire (Schlemmer, Desrichard, Vallet, & Beaudoin, 2018), which allows different motivational constructs to be measured on a single scale. We assessed perceived capacity, frequency of performing cognitive activities and three types of motivation (intrinsic, identified, external) to do eight types of cognitive activity (e.g., analyze and solve problems, memorize things).

Perceived capacity was evaluated via the question: "For each activity presented below, rate your abilities in these kinds of situations", using a Likert scale from 1 (very poor), to 7 (very good). We then assessed frequency of the eight cognitive activities on a Likert scale from 0 (never), to 4 (every day). Finally, we assessed the type of motivation for each cognitive activity performed–excluding activities with a reported frequency of "never"–via the question: "Most of the time, for what reason(s) do you engage in activities that involve [name of the cognitive domain]". We obtained our measure of intrinsic motivation by asking participants to rate the following item: "I like it, I enjoy it (satisfaction)", on a scale ranging from 1 (not at all) to 7 (totally), for each cognitive domain. Internal consistency was good for frequency of performing cognitive activities (α= .795), perceived capacity (α= .884), and intrinsic motivation (α= .871). Frequency of performing cognitive activities correlated with perceived capacity (*r*= .399, *p*< .001) and intrinsic motivation (*r*= .417, *p*< .001). Perceived capacity and intrinsic motivation were also correlated (*r*= .600, *p*< .001).

Cognitive performance

We used a measure adopted from the Cognitive Telephone Screening Instrument comprising different cognitive functions in adulthood (Kliegel, Martin, & Jäger, 2007):

Verbal short-term memory: Participants had to learn four pairs of unrelated words[1] and then recall for each pair the related word within 5s after being cued with the first word of the respective pair (scores ranged from 0 to 4).

Working memory: Participants had to recall a sequence of digits in reverse order, with sequences progressively increasing in length after every second sequence. The test was stopped if participants failed both trials at a given sequence length. Scores (from 0 to 12) were the number of sequences correctly recalled.

Verbal fluency: Participants were asked to name as many words beginning with the letter A as possible (letter-fluency) within a minute and to name as many professions as possible (category-fluency) within a minute. The two scores were summed up to derive a total verbal-fluency score.

Inductive reasoning: Participants had to complete a sequence of five numbers following specific rules. The test was stopped if participants failed two consecutive trials. Scores (from 0 to 8) were the number of correctly completed sequences out of the eight trials presented.

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[1] To maintain comparability between the different language versions, we selected four semantically non-related pairs from the eight pairs presented in this test.

To compute a global score, we followed a weighting procedure validated by Kliegel et al. (2007) to allocate a similar contribution to each subtest previously mentioned (see also Breitling et al., 2010; Ihle, Gouveia, Gouveia, & Kliegel, 2017). From this formula we doubled the weight of the verbal short-term memory in order to take account of this score possible range from 0 to 4 instead of 0 to 8 in the original version. Therefore, we used the following weightings: 2*verbal short-term memory + 0.8*working memory + 0.2*verbal fluency + 1.7*inductive reasoning.

Depressive mood

Ten items adopted by the Wang Brief Self-Assessing Depression Scale (Wang, Treul, & Alverno, 1975) were used to evaluate depressive mood. This tool had been chosen in order to ensure cross cohort comparisons with previous Swiss samples collected by the CIGEV in 1979 (Ludwig, Cavalli, & Oris, 2014). Participants indicated how frequently they experienced different states, giving their answers on 4-point scales ranging from 0 (never) to 3 (always). We reversed items when required and then calculated the mean of the responses (α= .734).

Data analyses

We tested the relation between CR and performance for the two motivational constructs via two mediation models. Following Preacher and Hayes' (2008) strategy, we used Model 4 of Process 3 SPSS macro (5000 bootstrap samples for percentile bootstrap confidence intervals) to test total, direct, and indirect effects, while controlling for age, sex, language, depressive mood, and current frequency of performing cognitive activities.

Results

The indirect effect of CR on performance by perceived capacity was significant (b= .0030, 95% CI [0.0007; 0.0062], β= .0187)–confirmed by Sobel test (Z= 2.02, p<.05) -

indicating that a part of the CR–cognitive performance relation (9.4% of the total effect) was mediated by perceived capacity. This was not the case for intrinsic motivation (b= .0000, 95% CI [-0.0008; 0.0007], β= -.0001). The other links tested are presented in the Figure 1.

Discussion

Our study's main goal was to test whether motivation for cognition mediates the CR-cognitive performance relationship. Results supported our hypothesis in the case of perceived capacity, which partially mediated the link between CR and cognitive performance, but, unexpectedly, not with intrinsic motivation.

The association between CR and perceived capacity is consistent with the idea that perceived capacity is built-up across the lifespan by exposure to cognitively demanding activities. This exposure may provide more mastery experiences of cognitive activities, which are an important determinant of self-efficacy (Bandura, 1977). Moreover, because we used a CR measure that covers the full lifespan and controlled for the current frequency with which activities are performed, our results suggest that older adults with greater confidence in their cognitive abilities may owe this confidence to accumulative exposure to cognitively demanding situations throughout life, rather than to just an active lifestyle later in life. However, due to the cross-sectional nature of our study, alternative explanations are also possible. For example, higher perceived capacity for cognitive activities may encourage people to engage in intellectually stimulating occupations and activities, and/or to undertake higher education, all of which are proxies for CR. Nevertheless, several arguments support the mediation model we proposed. First, CR is a life-course retrospective measure of past cognitive activities and the relation between CR and perceived capacity remains significant even when controlling for the current frequency of cognitive activities. This suggests that the CR-perceived capacity relationship is not fully explained by impact of perceived capacity on a higher engagement in cognitive activities but that CR also influences perceived capacity. Second, the part of our model regarding the positive relationship between perceived capacity and cognitive performance is in line with previous studies using longitudinal designs (e.g., Valentijn et al., 2006) and experimental designs (e.g., Beaudoin, 2018), which suggest that higher perceived capacity increases the ability of older adults to cope with cognitively challenging situations. As the analyzed sample was quite positively selected, our results can be only generalized to older adults who are relatively motivated and in quite good health.

Contrary to our expectations, we did not observe a significant relation between CR and intrinsic motivation for cognition. We expected to find such an effect because some CR proxies (e.g., leisure activities) are associated with intrinsic motivation, especially through higher levels of autonomy. Therefore, the influence of regular, lifelong exposure to cognitively challenging situations may not be captured by intrinsic motivation at older age. This could be due to laboratory cognitive tasks failing to arouse participants' interest.

Perceived capacity explains partially the association between CR and cognitive performance at older age and has to be considered in complement with other motivational (e.g., motivational reserve) and neural or cognitive processes (e.g., use of alternate networks, adapting cognitive to task demand) previously proposed to explain the role of CR on cognitive performance. Further studies will have to assess factors potentially explaining the CR-performance relation in order to determine their respective links and their independent contributions to the CR-performance mediation in a comprehensive way. It would be also particularly interesting to test whether CR and perceived capacity explain cognitive change in addition to cognitive performance. Moreover, the mechanisms underlying the link between CR indicators and perceived capacity (e.g., mastery experiences, social valuation, positive feedback) and between perceived capacity and cognitive performance (e.g., persistence, strategy use) also require further research.

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Conflict of interest

We declare that there is no conflict of interest.

Ethics

All participants gave their written informed consent for inclusion before they participated in the study. The present study was conducted in accordance with the Declaration of Helsinki, and the protocol had been approved by the ethics commission of the Faculty of Psychology and Social Sciences of the University of Geneva (project identification code: CE_FPSE_05.04.2017).

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Table

Table 1. Description of the sample included in the analyses and of the measures used

	Participants included in the analyses (N= 506)	Participants not included in the analyses because of the presence of missing data (N= 177)		Sample differences
Variables	**Mean (SD) or %**	**N**	**Mean (SD) or %**	**T test or χ^2**
Age [a]	M= 79.96 (SD= 6.13)	177	M= 81.88 (SD= 6.94)	$t(277.862)^c$= -3.257, p=.001
Sex	Women = 47.2%, Men= 52.8%	177	Women = 58.2%, Men= 41.8%	χ^2= 6.299, p= .012
Language of region	French = 43.5%, Swiss German = 56.5%	177	French = 50.8%, Swiss German = 49.2%	χ^2= 2.873, p= .09
Depressive mood	M= 0.75 (SD= 0.36)	135	M= 0.74 (SD= 0.34)	$t(639)$= 0.033, p= .974
CR-education [b]	M= 15.04 (SD= 5.69)	175	M= 13.79 (SD= 4.90)	$t(348.263)^c$= -2.797, p=.005
CR-occupation [b]	M= 119.65 (SD= 64.59)	173	M= 100.22 (SD= 60.26)	$t(668)$= 3.466 , p=.001
CR-leisure [b]	M= 455.68 (SD= 127.85)	175	M= 407.73 (SD= 132.69)	$t(678)$= 4.234, p<.001
Frequency of performing cognitive activities	M= 2.75 (SD= 0.71)	94	M= 2.10 (SD= 1.15)	$t(106.795)^c$= 5.279, p<.001

Perceived capacity	*M*= 5.11 (*SD*= 0.88)	101	*M*= 4.79 (*SD*= 1.00)	*t*(605)= 3.221, *p*<.001
Intrinsic motivation	*M*= 5.03 (*SD*= 1.14)	43	*M*= 4.85 (*SD*= 1.17)	*t*(547)= 0.967, *p*=.334
Verbal short-term memory	*M*= 0.96 (*SD*= 1.00)	136	*M*= 0.64 (*SD*= 0.86)	*t*(640)= 3.464, *p*=.001
Working memory	*M*= 5.43 (*SD*= 1.77)	169	*M*= 4.79 (*SD*= 1.83)	*t*(673)= 4.041, *p*<.001
Verbal fluency	*M*= 25.66 (*SD*= 8.15)	177	*M*= 21.34 (*SD*= 8.38)	*t*(681)= 6.028, *p*<.001
Inductive reasoning	*M*= 3.17 (*SD*= 1.82)	169	*M*= 2.47 (*SD*= 1.74)	*t*(673)= 4.423, *p*<.001

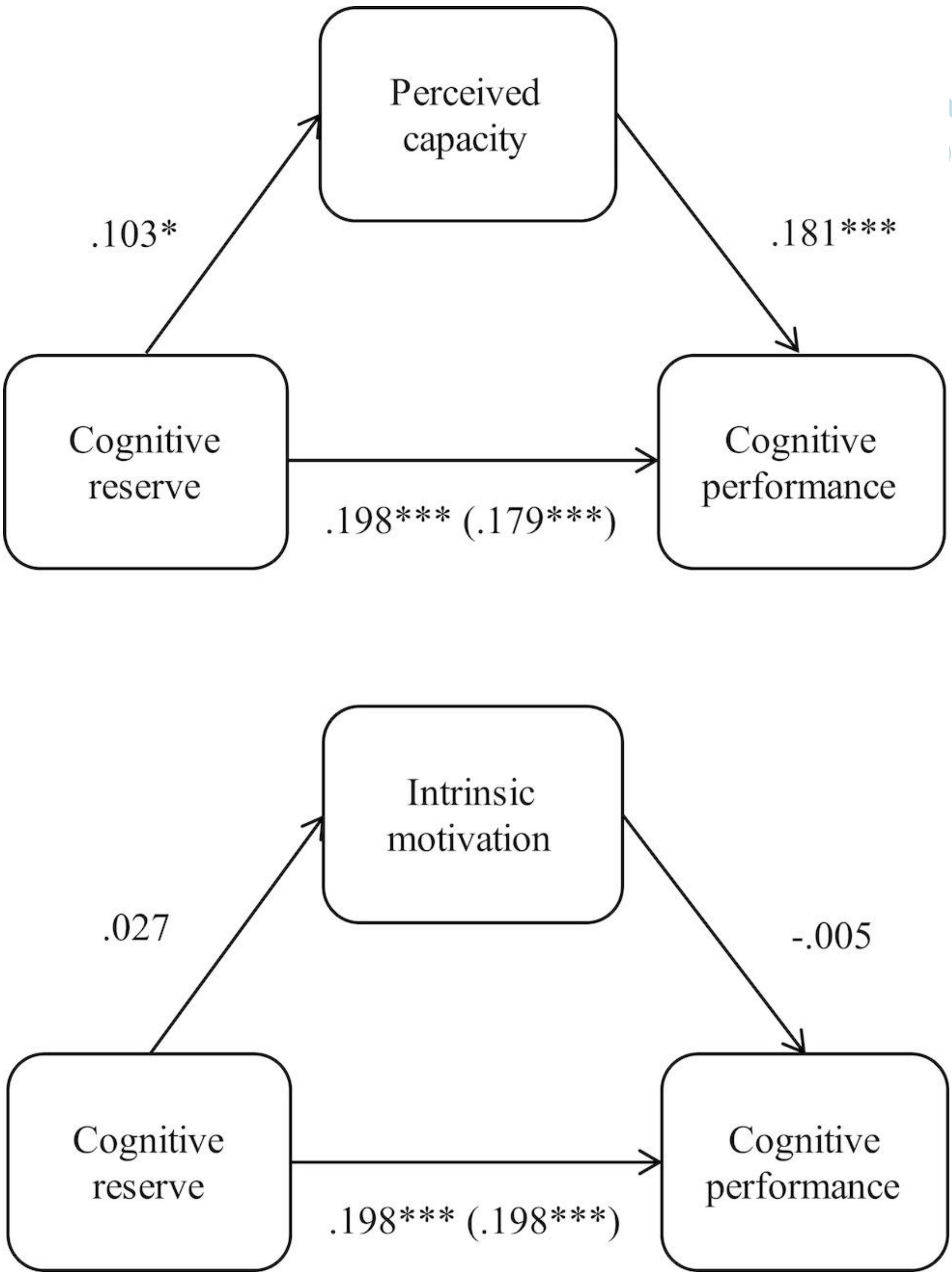
Note. CR= Cognitive Reserve

[a] The age ranged between 70 and 99 years old.

[b] The means and standard deviations are given before the score transformation. Regarding the CR sub-dimensions, the sample size was slightly lower for the CR-occupation (*N*= 497) and the CR-leisure (*N*= 505).

[c] Degrees of freedom were adjusted when Levene test was significant.

Figure 1



Perceived capacity
.103*
.181***
Cognitive reserve
Cognitive performance
.198*** (.179***)
Intrinsic motivation
.027
-.005
Cognitive reserve
Cognitive performance
.198*** (.198***)