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BRIEF COMMUNICATION

The Influence of Cognitive Reserve on Strategy Selection in Normal Aging

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Abstract

Cognitive reserve (CR) has been proposed as a latent variable that can account for the frequent discrepancy between an individual's underlying level of brain pathology and their observed clinical outcome. A possible behavioral manifestation of CR is best strategy choice. Older adults have been shown to choose sub-optimal strategies for performing various tasks. The present study attempted to investigate whether greater levels of CR could predict greater strategy selection, particularly in older adults. A computational estimation task was administered to 20 healthy young adults (mean age = 24.7 ± 3.6; 20–31 years) and 18 healthy older adults (68.2 ± 4.5; 62–77 years) wherein participants needed to estimate the product of two two-digit numbers by using one of two strategies. The results revealed an effect of age group on strategy choice and supported the hypothesis that CR is associated with increased strategy selection abilities. (*JINS*, 2013, *19*, 841–844)

Keywords: Aging, Cognitive reserve, Compensation, Strategy selection, Strategy adaptivity, Computational estimation

INTRODUCTION

In healthy adults cognitive reserve (CR) is hypothesized to mitigate cognitive decline associated with age-related brain changes (Stern, 2009). One aspect of CR that has received little previous research is its possible role in an individual's adapting their explicit cognitive strategy to the demands of a particular task. A "strategy" can be viewed as a means to achieve some target (Lemaire, 2010), for example, using a semantic or phonological strategy to memorize a pair. Given any two strategies, young adults are generally more accurate when choosing the best strategy than older adults (Lemaire, Arnaud, & Lecacheur, 2004). This difference in group performance suggests that strategy choice is impaired in older adults similarly to other more basic abilities such as memory or processing speed, and, therefore, we might expect that a property such as CR which has been shown to preserve the latter abilities would also help to maintain strategy selection.

To investigate age-related differences in strategy selection, Lemaire et al. (2004) used a computational estimation task wherein younger and older participants would need to estimate the product of two two-digit numbers by either rounding both numbers down to their nearest decade or by rounding both numbers up to the next highest decade and then multiplying. This task had the advantage of allowing the researchers to determine which strategy is best (i.e., the one whose product is closer to the actual product). Using this task, an age-related difference in strategy selection was found, with older adults being less capable than young adults of adapting their strategy use as measured by diminished accuracy and increased reaction time.

The present study seeks to extend this research on age-related differences in strategy selection by asking a related question: is higher CR associated with better strategy selection. To this end, we used a modified version of the computational estimation task (Lemaire et al., 2004). In addition, we collected two CR proxy measures (years of education and National Adult Reading Test [NART] IQ), which are often used in research on CR to approximate it. If high levels of estimated CR can be used to predict superior strategy selection, we may be able to better understand cognitive manifestations of CR. Following Lemaire et al. (2004), we predicted that we would detect an effect of age-group on strategy selection. We also predicted that individuals with higher estimated levels of CR would demonstrate better

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Table 1. Participant characteristics

Variable	Young adults	Older adults
N	20	18
Age range	20–31	62–77
Age	24.7 ± 3.6	68.2 ± 4.5
% Female	60	55.56
Years of education	16.2 ± 1.8	16.4 ± 2.6
DRS	142.45 ± 1.2	141.44 ± 2.1
NART IQ	118.32 ± 6.9	115.95 ± 9.8

Note. Values for age, years of education, Mattis Dementia Rating Scale (DRS), and National Adult Reading Test (NART) are the mean ± 1 standard deviation. Education is measured in years.

performance on the estimation task, thus supporting the idea that strategy selection is associated with CR.

METHOD

Participants

Twenty healthy young adults and eighteen healthy older adults participated in the experiment (see Table 1). Participants were volunteers selected from existing subject pools. All spoke English as a first language and had normal or corrected-to-normal vision, had no current psychiatric disorders, were not on any psychoactive medications, and were screened for the absence of dementia using the Mattis Dementia Rating Scale (Mattis, 1988) with a minimum inclusion score of 133. All procedures were reviewed by the Columbia University Medical Center (CUMC) Institutional Review Board. All participants provided informed consent and were compensated for their time.

Stimuli

The stimuli were adapted from Lemaire et al. (2004) and included 100 two-digit multiplication problems presented in standard format, that is, (a × b), where both a and b are two-digit numbers. Each problem had the property that one of its two-digit operands had a unit-digit greater than five and the other had the unit-digit less than five. Fifty matched problems were included in the set of stimuli, wherein for 50 problems the best strategy for estimating the product of the two numbers was to round down, whereas for the other 50 the best strategy was to round up (Table 2). The problems were designed such that, when performing rounding-down trials, estimating the product of the two operands by rounding both operands down to the closest smaller decade (e.g., 33 to 30) would result in greater accuracy; and conversely for rounding-up trials.

For 50 of the problems, the larger of the two operands was on the left, while for the other 50, it was presented on the right. Likewise, for 50 of the problems the smaller of the unit-digits was on the left, while for the other fifty it was on the right. In addition, none of the operands had 0 or 5 as its unit-digit, no digits were repeated in the 10's or unit's place across problems and none of the operands' closest decades were equal to 0, 10, or 100. Across problems, no problem was repeated in reverse (e.g., if "58 × 32" was presented, "32 × 58" was not). Rounding-down and rounding-up trials were matched for the mean correct products and the mean percent deviations of the estimated product using the best strategy from the actual product for each respective strategy type.

Participants completed the experiment on a Sony VAIO notebook computer with a 13.3-inch LCD monitor. Testing happened in a well-lit room, with all participants approximately 25 inches from the screen. The total width of the stimulus on the screen was 1.75 in. The task was programmed using E-prime (2004). Participants made verbal responses that were recorded by researchers.

Procedure

Participants completed the study in a single session. After giving informed consent to participate, they completed the task as well as a short neuropsychological battery (described below). The entire protocol lasted approximately 1 hr and 15 min.

Participants first completed a short training session and were instructed to solve each problem by rounding both numbers in the same direction and calculating their product out loud. Participants were given two sets of eight problems each, the first set preceded by instructions to use the rounding-down strategy exclusively and the second set preceded by instructions to only use the rounding-up strategy. These problems matched the format of the actual task. Any deviations from the instructions were here noted and corrected by the researcher, as were errors in calculation.

Table 2. Mean percent use of best strategy by problem type and age group; mean reaction times (in milliseconds) by strategy used, problem type, and age group

	Problem type: Rounding down best		Problem type: Rounding up best	
	Young	Old	Young	Old
Mean percent use	69.5 ± 4.0	57.2 ± 4.6	76.2 ± 3.7	60.8 ± 5.0
Reaction Time				
Strategy Used: Down	7542.6 ± 712.9	10957.1 ± 1211.6	7988.5 ± 1829.2	12593.6 ± 1457.9
Strategy Used: Up	9520.3 ± 1042.7	13637.3 ± 1460.2	9487.8 ± 741.2	13058.3 ± 1727.4

Note. Values are condition means ± one standard error of the mean.

Participants were next administered the actual task. Each session began with a written reminder of the instructions displayed on screen, which told participants to now *choose* the strategy that would get them closest to the actual product. A 500-ms inter-trial interval followed and preceded each problem. The two-by-two digit multiplication problems were then presented horizontally, with the multiplication symbol and numbers being separated by a single space character.

Participants estimated the product of the two numbers out loud by using one of two strategies. When they gave their final answer, the researcher immediately pressed the enter key to record their reaction times (RTs). The next screen was displayed immediately and prompted the participant to explicitly declare which strategy they had used. The researcher recorded both the answer given and the strategy that the participant claimed they used. The participants performed 50 trials before being allowed a 5- to 10-min break, then they were given the second set of 50 trials.

No feedback was given on any of the products estimated or on any of the strategies used, with the exception that after every consecutive five trials wherein the participant used the same strategy, the researcher reminded the participant that they should be using the strategy that they think will result in the estimate closest to the actual product.

Following the estimation task, participants were administered the Mattis Dementia Rating Scale (DRS; Mattis, 1988) for neuropsychological screening. All participants were also administered the NART (Grober & Sliwinsky, 1991) and a brief questionnaire (developed in-house) on their level of education as proxy measures of cognitive reserve.

Statistical analysis

Accuracy was calculated using a variable defined by Lemaire et al. (2004) as the mean percent use of the best strategy (henceforth MPUBS). This is defined for each participant as the percentage of trials in which the subject used the best strategy. To ensure the non-normal distribution of the percentages would not impact the analyses, we also computed the arcsin transform of the MPUBS variable and replicated each analysis using both variables (we report only results of the MPUBS models, since these were identical to the arcsin models). The RT models used mean RT for each of the following trial types for each subject: down-used/down-correct, down-used/up-correct, up-used/up-correct, up-used/down-correct.

To analyze the effects of CR covariates on MPUBS and RT, we constructed two separate general linear models (GLM) that were analyzed in stages (heterogeneous slopes) (Kumar, Rakitin, Nambisan, Habeck, & Stern, 2008; Siegel, 1956). In each, we introduced various proxies for CR into our model, including score on the NART IQ and years of education (EDU). Participants' scores on the DRS were also included as a measure of general cognitive function. The initial, heterogeneous-slopes model (Kumar et al., 2008; Siegel, 1956) used a repeated measures analysis of variance (ANOVA) design with problem type as a within-subjects factor (MPUBS_down and MPUBS_up), and added the main effects of the three covariates in addition to their respective interactions with age group. The latter effects tested the assumption of the analysis of covariance that the effects of the covariates are equivalent at each level of the model's fixed effects, and only these effects were inspected.

In the first stage, we constructed a full model with the following predictors: age group, years of education, NART IQ, and DRS. We also added interaction terms by multiplying the group predictor by each of the covariates. Including such interactions allowed us to test for the presence of group differences in slopes describing relation between the CR variables and MPUBS and RT, respectively. After performing this full model, retaining problem-type as a within-subjects factor, we constructed a reduced model which retained only the covariate main effects, as well as any interaction terms which were statistically significant in the full model ($p = .05$). The simple models, in contrast, used a 2×2 repeated-measures ANOVA, with one within-subjects factor (problem type) and one between-subjects factor (age group); this contained only the fixed effect and would be relevant only if none of the covariates in the reduced model retained statistical significance.

RESULTS

Results of the simple analysis replicated the work of Lemaire et al. (2004): we found an age group effect on the MPUBS variable: older participants were significantly worse at using the appropriate strategy than younger participants, $F(1,36) = 5.699$, MSE = 2586.321, $p = .022$.

Results of the full CR-covariate model revealed a strategy type × age group × NART IQ interaction, $F(1,36) = 6.736$; MSE = 1287.176; $p = .014$. None of the other interactions were significant.

The next, reduced model retained all covariate main effects but only the age group × NART IQ interaction as this was the only significant interaction in the full model. Results of this reduced model revealed an effect on MPUBS of age group, $F(1,36) = 5.373$; MSE = 1112.735; $p = .027$; DRS, $F(1,36) = 6.299$; MSE = 1304.576; $p = .017$; EDU, $F(1,36) = 4.395$; MSE = 910.227; $p = .044$; and age group × NART IQ, $F(1,36) = 5.521$; MSE = 1143.438; $p = .025$. These results indicate associations between CR and task performance and suggest a role for CR in the moderation of age-related differences in task performance. By "moderation," we refer here only to a group effect on the outcome variable; for each group, CR is correlated to different degrees with strategy selection.

Results of our simple RT model replicated those of Lemaire et al. (2004). Younger participants demonstrated significantly reduced RTs compared to older participants, $F(1,35) = 6.686$, MSE = 1287.176, $p = .014$.

In the full RT model, age group was the only significant predictor of RT, $F(1,35) = 4.254$, MSE = 21606972.5. Results of the reduced RT model were the same as in the full model: none of the main effects were significant.

DISCUSSION

In this study, younger and older adults were asked to complete a computational estimation task using only one of two strategies. Our first hypothesis was that this experiment would replicate prior work in finding an age difference in performance on a strategy selection task: older adults, we speculated, would show diminished accuracy relative to younger adults, and would execute this strategy more slowly. Results demonstrated that, regardless of trial type, older adults were less accurate in choosing the best strategy than younger adults.

Our second hypothesis was that older adults with higher estimated CR would demonstrate best strategy selection more often than those with lower estimated CR and be able to implement this strategy more quickly. Our results indicate that this was at least partially the case. In particular, the significant age by NART IQ effect on MPUBS indicates that verbal IQ is moderating the relationship between age-related cognitive decline and strategy selection. Those with higher verbal IQ chose the best strategy more often than those with lower verbal IQ in the olds, but youngs showed almost no association. As verbal IQ is a strong proxy for CR, this provides evidence for an association between CR and strategy selection. We did not find this interaction for education. This may be because education may not be an effective proxy for CR in younger participants who are still in the process of acquiring it. There were no significant interactions between age and the CR proxies on RT, possibly because RT may reflect strategy implementation and not strategy selection and, therefore, may be mediated by other factors beyond CR such as executive functions (EFs).

Some studies have begun to investigate the moderating role that certain cognitive abilities such as EFs may play in buffering against diminished strategy adaptivity (Duverne & Lemaire, 2004). One such study (Hodzik & Lemaire, 2011) investigated how much variance in performance on tasks of strategy selection can be accounted for by differential levels of inhibition and task-switching ability. The authors found that much of the age-related variance in strategy selection could be accounted for by declines in EFs. The present study derives originality from its testing of CR as a moderator of performance. While EFs may be mediating age-related decline in strategy selection, CR may be moderating this relationship between age and task performance. However, another possibility is that IQ is itself related to the executive functions used by these authors, and the present study reflects very similar findings to those reported previously using an alternative measure (verbal IQ) that differs significantly from those used before (EFs), and may be indicative of a more general moderating variable (such as general intelligence) than are EFs. Further research is needed to test these possibilities, as well as the possibility that CR additionally moderates the relationship between discrete cognitive variables like EF and task performance. Explicating the nature of the association between CR and strategy selection, for example, if strategy selection underlies CR, or if CR supports better strategy selection, etc., requires consideration of all these possibilities.

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