**Cross-Sectional Association between Objective Cognitive Performance and Perceived Age-related Gains and Losses in Cognition**

**Supplementary text 1. Study design and participants**

The PROTECT (Platform for Research Online to investigate Genetics and Cognition in Ageing) study aims to provide a detailed long-term picture of multi-level cognitive aging including the exploration of the role of genetic, lifestyle, and medical factors on cognition in the second half of life. PROTECT participants are UK residents, English speakers, aged 50 years or over, have access to the internet, and did not have a clinical diagnosis of dementia at baseline (2015). To recruit participants, the PROTECT study was publicized nationwide and among existing research cohorts of older adults (Exeter 10,000 <https://exetercrfnihr.org/about/exeter-10000/>; Join Dementia Research <https://www.joindementiaresearch.nihr.ac.uk/>; and Brains for Dementia Research <https://bdr.alzheimersresearchuk.org>). At baseline, participants provided informed online consent though the PROTECT platform. The PROTECT study has ethical approval from the London Bridge NHS Research Ethics Committee and Health Research Authority (Ref:13/LO/1578). Ethical approval for the conduct of data analyses was obtained from the ethics committee at the University of Exeter School of Psychology (Ref:eCLESPsy000603 v1.0).

In PROTECT, participants undertake a series of self-administered annual assessments (consisting of self-reported questionnaires and computerized cognitive tests) through the PROTECT platform. PROTECT participants have been able to join the PROTECT study at any point since it launched in November 2015; their annual assessments vary across the cohort based on when they started. For the purpose of the current study in January 2019 additional questionnaires (assessing AARC, ATOA, SA, and SRH) were added to the PROTECT annual assessment. As the intention was to sample from the PROTECT cohort until the desired sample size was achieved, data collection for these additional questionnaires ended on the 31st March 2019 as by that date we obtained a sufficient sample size. Only participants that were sent a reminder about their PROTECT annual assessments between January 2019 and the end of March 2019 could complete the additional measures relevant to the current study. Frequency of cognitive training was based on individual participant registration with PROTECT between 2015 and 2019.

Among PROTECT participants that (N= 14,882) completed the PROTECT annual assessment between January 2019 and March 2019 we excluded from the study analyses those who did not complete the AARC questionnaire (N= 5,472) or did not undertake the cognitive tasks between November 2018 and March 2019 (N= 3,208), and those who scored 1.5 standard deviations (SDs) below the mean study sample score in two or more cognitive tasks (N= 146). We excluded this last group as we deemed it to have pathological cognitive decline (mild cognitive impairment or dementia) and individuals with pathological cognitive decline can be inaccurate when evaluating their cognition (Lehrner *et al.*, 2015). Participants excluded from study analyses (N= 8,826) had comparable demographic variables, mental and perceived health to the study sample but a higher proportion was working (See Table 2).

**Supplementary text 2. Description of tests included in the PROTECT Cognitive Test Battery and brain training games.**

The PROTECT Cognitive Test Battery (Corbett *et al.*, 2015; Hampshire *et al.*, 2012; Huntley *et al.*, 2018) included four tests: (1) Self-Ordered Search (SOS; Owen *et al.*, 1990) assesses spatial working memory by asking participants to recall the position of a hidden object behind a series of panels (range: 0-20); (2) Grammatical Reasoning (GR; Baddeley, 1968) assesses verbal reasoning by asking participants to determine the accuracy of a series of grammatical statements about a presented picture (range: from 0 with no upper limit); (3) Paired Associate Learning (PAL; Owen *et al.*, 1993) assesses visual episodic memory; participants are presented with a series of objects in cells, instructed to remember the locations of the objects, and subsequently asked to select the location where the object was initially presented (range: 0-16); (4) Digit Span (DS; Huntley *et al.*, 2017) assesses verbal working memory by asking participants to repeat sequences of numbers (0-20).

The Brain Training package used in PROTECT consists of 12 computerized brain training games: Balloons, Card Pairs, Tower of London, Slider, Boats, Scanner, Odd-one-out, See-saw, Boxes, Pictures, Loop the Loop, and Crates. In the Balloons game individuals have to make a mathematical calculation before a balloon reaches the top of the screen. In the Card Pairs game individuals are asked to remove matching pairs of cards until they have cleared all the cards presented in the screen. In the Tower of London game individuals are presented with a series of jars filled with sweets and are asked to transfer sweets between the jars until they match the sample answer. In the Boats game individuals are presented with a series of floating boats, each with either a number or a letter attached. Individuals are instructed to click on numbers or letters in the correct sequence on the floating boats. In the Scanner game individuals are shown the picture of an airport security scanner and asked to count the number of bags that do not emerge from the airport security scanner. In the Odd-one-out game participants are asked to spot the odd-flower-out of a group of similar looking flowers. In the See-saw game individuals are asked to work out which object is the heaviest by looking at the arrangement of objects on see-saw. In the Boxes game individuals are asked to match objects that appear in boxes with objects shown on the top of the screen. In the Picture game individuals are shown a picture with some missing pieces and asked to select the missing pieces to add to the picture. In the Loop the Loop game individuals are shown a grid containing boxes and each box has a number assigned. Individuals are asked to draw a loop around the grid to match number of lines alongside each box with numbers inside the box. Lastly, in the Crates game participants are asked to remove crates on the left-hand side of the screen to match pattern on the right-hand side of the screen.

**Supplementary text 3. Information on reliability of study measures.**

The UK validation of the AARC-50 cognitive functioning subscale (Sabatini *et al.*, 2020) and the AARC-10 SF (Sabatini *et al.*, 2020) confirmed their two-factor structure (AARC gains and losses) and adequate subscale reliability (Cronbach’s *αs* of.86 for gains and .88 for losses in the cognitive functioning subscale and of.77 for gains and .80 for losses in the AARC-10 SF). AARC gains and losses in the cognitive functioning subscale, respectively, showed weak and good convergent validity with ATOA, SA, self-reported and objective cognition. The AARC-10 SF showed good convergent validity with measures of self-perceptions of aging (ATOA and SA), mental (depression and anxiety) and physical health (functional ability and SRH). AARC gains and losses, respectively, showed weak and good convergent validity with objective cognitive tasks.

In PROTECT, test-retest reliability for the PROTECT Cognitive Test Battery was obtained by calculating Pearson’s *r* correlation coefficients among participants’ age and scores on the same cognitive tasks completed three times within a week. Test-retest reliability for the DS task was *r*= -.06 at session one, *r*= -.07 at session two, and *r*= -.07 at session three. Test-retest reliability for the PAL task was *r*= -.09 at session one, *r*= -.1 at session two, and *r*= -.11 at session three. Test-retest reliability for the GR task was *r*= -.13 at session one, *r*= -.14 at session two, and *r*= -.17 at session three. Finally, test-retest reliability for the SOS task was *r*= -.06 at session one, *r*= -.11 at session two, and *r*= -.14 at session three. Further information on the cognitive tasks can be found in (Corbett *et al.*, 2015; Ferreira *et al.*, 2015).

Cronbach’ *α* for the IQCODE-Self in this sample is.86. Cronbach’s *α* on the PHQ-9 for this sample is .76. Cronbach’s α on the GAD-7 for this sample is .76.

**Supplementary Table 1. Multiple linear regressions with AARC gains and losses in cognition and AARC gains and losses across life domains as predictors of scores on the cognitive tasks in the overall study sample**

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| --- |
| AARC-50 cognitive functioning subscale |
|  | Self-ordered search | Grammatical reasoning | Paired associate learning | Digit span |
| Predictors | *ß* (95% CI); *p*- value | Partial R2 | *ß* (95% CI); *p*- value | Partial R2 | *ß* (95% CI); *p*- value | Partial R2 | *ß* (95% CI); *p*- value | Partial R2 |
| AARC gains in cognition | -.07 (-.09, -.04); <.001 | .04% | -.10 (-.12, -.07); <.001 | 1% | -.02 (-.05, -.00); .030 | .01% | -.05 (-.07, -.02); <.001 | .02% |
| AARC losses in cognition | -.06 (-.08, -.03); <.001 | .03% | -.12 (-.15, -.10); <.001 | 1% | -.09 (-.11, -.06); <.001 | 1% | -.07 (-.09, -.04); <.001 | .04% |
| AARC-10 SF |
|  | Self-ordered search | Grammatical reasoning | Paired associate learning | Digit span |
| Predictors | *ß* (95% CI); *p*- value | Partial R2 | *ß* (95% CI); *p*- value | Partial R2 | *ß* (95% CI); *p*- value | Partial R2 | *ß* (95% CI); *p*- value | Partial R2 |
| AARC gains across life domains | -.04 (-.07, -.02); <.001 | .02% | -.05 (-.06, -.01); <.001 | .02% | -.02 (-.04, .01); .074 | .01% | -.01 (-.04, .01); .388 | 0% |
| AARC losses across life domains | -.07 (-.10, -.05); <.001 | 1% | -.12 (-.14, -.09); <.001 | 1% | -.08 (-.11, -.06); <.001 | 1% | -.09 (-.11, -.06); <.001 | 1% |

Notes: Sex, education, employment status, depression, anxiety, and frequency of cognitive training are included as covariates in the regression models.

**Supplementary Table 2. Correlations for AARC gains in cognition, AARC losses in cognition, and scores on the objective cognitive tasks**

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| --- | --- | --- | --- |
| Age sub-groups | Variables | AARC gains in cognition | AARC losses in cognition |
| *r* (95% CI); *p-*value | *r* (95% CI); *p-*value |
| Participants aged 51 to 65 | Self-ordered search | -.10 (-.13, -.06); <.001 | -.07 (-.09, -.02); .002 |
| Paired associate learning | -.06 (-.09, -.02); .002 | -.06 (-.15, -.08); .003 |
| Grammatical reasoning | -.09 (-.12, -.05); <.001 | -.12 (-.10, -.03); <.001 |
| Digit span | -.06 (-.09, -.20); .002 | -.06 (-.10, -.03); <.001 |
| AARC losses in cognition |  .06 ( .03, .10); <.001 |  |
| Participants aged 66 to 75 | Self-ordered search | -.07 (-.11, -.03); <.001 | -.03 (-.07, .01); <.001 |
| Paired associate learning | -.01 (-.05, .03); .794 | -.11 (-.15, -.07); <.001 |
| Grammatical reasoning | -.14 (-.18, -.10); <.001 | -.11 (-.15, -.07); <.001 |
| Digit span | -.05 (-.09, -.01); .010 | -.09 (-.13, -.05); <.001 |
| AARC losses in cognition |  .06 ( .02, .10); .003 |  |
| Participants aged 76 and over | Self-ordered search | -.05 (-.14, .05); .328 | -.00 (-.09, .09); .981 |
| Paired associate learning |  .00 (-.09, .10); .926 | -.09 (-.17, .01); .064 |
| Grammatical reasoning | -.10 (-.19, -.01); .031 | -.16 (-.25, -.07); <.001 |
| Digit span | -.06 (-.15, .04); .229 | -.02 (-.11, .07); .699 |
| AARC losses in cognition |  .02 (-.07, .11); .687 |  |

**Supplementary Table 3. Path analysis model exploring AARC gains and losses in cognition as predictors of cognition while controlling for sex, education, employment status**

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| Participants aged 51 to 65 |
|  | Standardized coefficient *ß* (95% CI); *p*- value |
| Predictors | Self-ordered search | Grammatical reasoning | Paired associate learning | Digit span |
| AARC-50 cognitive gains | -.09 (-.12, -.05); <.001 | -.08 (-.12, -.05); <.001 | -.05 (-.09, -.02); .005 | -.05 (-.09, -.02); .005 |
| AARC-50 cognitive losses | -.07 (-.10, -.03); <.001 | -.10 (-.13, -.06); <.001 | -.06 (-.09, -.02); .002 | -.06 (-.09, -.02); .002 |
| RMSEA (90%CI): .07 (.04, .10); CFI: .99; TLI: .61; SRMR: .01; R2: 7% |
| Participants aged 66 to 75 |
|  | Self-ordered search | Grammatical reasoning | Paired associate learning | Digit span |
| AARC-50 cognitive gains | -.05 (-.09, -.01); .008 | -.13 (-.17, -.09); <.001 | -.00 (-.04, .04); .995 | -.04 (-.08, .00); .050 |
| AARC-50 cognitive losses | -.03 (-.07, .01); .105 | -.08 (-.12, -.05); <.001 | -.10 (-.14, -.06); < .001 | -.08 (-.12, -.04); < .001 |
| RMSEA (90%CI): .07 (.04, .11); CFI: .98; TLI: .49; SRMR: .01; R2: 7% |
| Participants aged 76 and over |
|  | Self-ordered search | Grammatical reasoning | Paired associate learning | Digit span |
| AARC-50 cognitive gains | -.05 (-.14, .04); .350 | -.09 (-.18, -.00); .046 |  .00 (-.09, .09); .996 | -.04 (-.13, .05); .261 |
| AARC-50 cognitive losses | -.03 (-.12, .06); .920 | -.15 (-.24, -.06); .001 | -.08 (-.18, .01); .068 | -.01 (-.10, .09); .556 |
| RMSEA (90%CI): .00 (.00, .10); CFI: 1.0; TLI: 1.2; SRMR: .00; R2: 9% |

Notes: RMSEA = Root mean square error of approximation. CFI = Comparative fit index. TLI = Tucker-Lewis index. SRMR = Standard root mean square residual. R2 = R-squared/coefficient of determination.

**Supplementary Table 4. Multiple linear regressions exploring AARC gains and losses in cognition as predictors of cognition while controlling for sex, education, employment status, depression, anxiety and frequency of cognitive training**

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| Participants aged 51 to 65 |
|  | Self-ordered search | Grammatical reasoning | Paired associate learning | Digit span |
| Predictors | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 |
| AARC gains in cognition | -.09 (-.12, -.05); <.001 | .08% | -.09 (-.12, -.05); <.001 | .07% | -.06 (-.09, -.02); .002 | .03% | -.06 (-.09, -.02); .002 | .03% |
| AARC losses in cognition | -.05 (-.09, -.01); .005 | .03% | -.09 (-.13, -.06); <.001 | 1% | -.04 (-.08, -.00); .030 | .02% | -.04 (-.08, -.01); .022 | .02% |
| Participants aged 66 to 75 |
|  | Self-ordered search | Grammatical reasoning | Paired associate learning | Digit span |
| Predictors | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 |
| AARC gains in cognition | -.06 (-.10, -.02); .005 | .03% | -.13 (-.17, -.10); <.001 | 2% | -.01 (-.05, .03); .770 | 0% | -.05 (-.08, -.01); .026 | .02% |
| AARC losses in cognition | -.02 (-.06, .02); .270 | .01% | -.11 (-.15, -.07); <.001 | 1% | -.09 (-.14, -.05); <.001 | .08% | -.07 (-.11, -.03); .001 | .05% |
| Participants aged 76 and over |
|  | Self-ordered search | Grammatical reasoning | Paired associate learning | Digit span |
| Predictors | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 |
| AARC gains in cognition | -.04 (-.13, .05); .356 | .02% | -.09 (-.18, -.00); .047 | 1% | -.01 (-.10, .08); .880 | 0% | -.05 (-.14, .04); .251 | .03% |
| AARC losses in cognition |  .01 (-.09, .11); .797 | 0% | -.20 (-.30, -.11); <.001 | 3% | -.10 (-.20, -.00); .048 | 1% | -.05 (-.15, .05); .337 | 2% |

Notes: *ß* = Standardized regression coefficient. R2 = Partial R-squared/ coefficient of determination.

**Supplementary Table 5. Multiple linear regressions exploring AARC gains and losses in cognition as predictors of cognition while controlling for sex, education, employment status**

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| Participants aged 51 to 65 |
|  | Self-ordered search | Grammatical reasoning | Paired associate learning | Digit span |
| Predictors | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 |
| AARC gains in cognition | -.09 (-.13, -.06); <.001 | 1% | -.09 (-.12, -.05); <.001 | 1% | -.06 (-.09, -.02); .002 | .03% | -.06 (-.09, -.02); .002 | .03% |
| AARC losses in cognition | -.07 (-.11, -.04); <.001 | 1% | -.10 (-.14, -.07); <.001 | 1% | -.06 (-.10, -.02); <.001 | .04% | -.06 (-.10, -.02); <.001 | .04% |
| Participants aged 66 to 75 |
|  | Self-ordered search | Grammatical reasoning | Paired associate learning | Digit span |
| Predictors | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 |
| AARC gains in cognition | -.06 (-.10, -.02); .005 | .03% | -.14 (-.18, -.10); <.001 | 2% | -.01 (-.05, .03); .705 | 0% | -.05 (-.09, -.01); .024 | .02% |
| AARC losses in cognition | -.04 (-.08, .00); .069 | .01% | -.09 (-.13, -.06); <.001 | 1% | -.10 (-.14, -.06); <.001 | 1% | -.09 (-.13, -.05); <.001 | .07% |
| Participants aged 76 and over |
|  | Self-ordered search | Grammatical reasoning | Paired associate learning | Digit span |
| Predictors | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 | *ß* (95% CI); *p*- value | R2 |
| AARC gains in cognition | -.04 (-.13, .05); .348 | .02% | -.09 (-.18, -.01); .038 | 1% | -.00 (-.09, .09); .963 | 0% | -.05 (-.14, .04); .253 | 03% |
| AARC losses in cognition | -.01 (-.10, .09); .899 | 0% | -.16 (-.24, -.07); <.001 | 2% | -.08 (-.18, .01); .066 | 1% | -.03 (-.12, .06); .535 | .01% |

Notes: *ß* = Standardized regression coefficient. R2 = Partial R-squared/coefficient of determination.

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