

The Dutch version of the Oxford Cognitive Screen (OCS-NL): Normative Data and their Association with Age and Socio-economic status

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Abstract

The Oxford Cognitive Screen (OCS) is a screening tool specifically designed for acute stroke patients, assessing 5 domains: attention and executive functions, language, praxis, numeric cognition and memory. Here we present norms for the Dutch version of the OCS (OCS-NL). We evaluated whether age and socio-economic status were linked to OCS-NL performance, since stroke prevalence and recovery are associated to these characteristics. We acquired normative data of the OCS-NL version A in 246 neurologically healthy participants and a subset of 179 participants also completed parallel version B. Socio-economic status was measured using three indicators: education, income and occupation. Data were analyzed in a Bayesian way and we report credible intervals of effect sizes. There were no systematic differences in OCS-NL global performance between low, middle and high income groups, nor between manual and non-manual workers. There were small differences between low and middle and between low and high education groups, and the association of education and OCS-NL performance did not vary across subtests. The association of age and OCS-NL performance varied across subtests. The naming, praxis, verbal memory and executive task had the strongest association with age. These data suggest that normative data for the OCS-NL do not need to be stratified on income and occupation, that age-specific cut-off scores are especially recommended for the naming, praxis, executive function and verbal memory tasks and that education must be considered when interpreting OCS-NL test scores.

Keywords: stroke; cognition; socio-economic status; normative data; screen

The Dutch version of the Oxford Cognitive Screen (OCS-NL)

Stroke is one of the leading causes of burden of disease in high-income countries (Institute for Health Metrics and Evaluation (IHME), 2018) and functional outcome after stroke is negatively affected by cognitive impairments (van Zandvoort, Kessels, Nys, de Haan, & Kappelle, 2005). Prevalence estimates of post-stroke cognitive impairments range broadly across studies (Makin, Turpin, Dennis, & Wardlaw, 2013), with studies reporting that 63 to 91% of acute and subacute stroke patients are impaired in at least one cognitive domain (Hoffmann, 2001; Jaillard, Naegle, Trabucco-Miguel, LeBas, & Hommel, 2009; Leśniak, Bak, Czepiel, Seniów, & Członkowska, 2008; Nys et al., 2007). Post-stroke cognitive impairments typically involve hemispatial neglect, aphasia, apraxia as well as impairments in executive functions, memory, attention and visual perception or visuoconstruction (Hoffmann, 2001; Jaillard et al., 2009; Leśniak et al., 2008; Nys et al., 2007).

Cognitive Screening After Stroke

Many clinical management guidelines recommend the use of screening tools to detect post-stroke cognitive impairment (Eskes et al., 2015; Intercollegiate Stroke Working Party, 2016; National Stroke Foundation, 2010), since there is typically not enough time to perform a full neuropsychological assessment in the acute phase after stroke, and because post-stroke fatigue can prevent lengthy assessments for some patients (van Zandvoort et al., 2005). In clinical practice, post-stroke cognitive impairment is often detected using global screening tools originally developed for dementia such as the Montreal Cognitive Assessment (MoCA) and Mini Mental State Examination (MMSE) (Burton & Tyson, 2015; Kosgallana, Cordato, Chan, & Yong, 2019; Stolwyk, O'Neill, McKay, & Wong, 2014). However, these tools do not assess typical post-stroke impairments such as acalculia, apraxia and hemispatial neglect (Burton &

Tyson, 2015; Stolwyk et al., 2014). Moreover, patients with aphasia, hemianopia and neglect often cannot complete all test items of the MoCA due to test items requiring intact visuospatial and language functions (Demeyere et al., 2016; Horstmann, Rizos, Rauch, Arden, & Veltkamp, 2014). Finally, brief dementia screens do not provide domain-specific test scores, which is especially important in stroke as it has been shown that long-term recovery after stroke can be predicted by impairments in specific cognitive domains (Nys et al., 2005).

For these reasons, the Oxford Cognitive Screen (OCS), consisting of two parallel versions, was developed (Demeyere, Riddoch, Slavkova, Bickerton, & Humphreys, 2015). The OCS is specifically designed for the stroke population and assesses cognitive deficits focusing on five domains: attention and executive functions, language, memory, number processing and praxis (Demeyere et al., 2015). The test was designed to evaluate each domain separately, avoiding confounds caused by typical post-stroke impairments such as hemispatial neglect and aphasia. For instance, stimuli are presented in the intact part of the visual field and responses can be given by using multiple choice options without requiring spoken language. These features make the OCS more inclusive for the stroke population than brief dementia screens (Demeyere et al., 2016) and more sensitive for post-stroke cognitive impairments than the MoCA (Demeyere et al., 2016) and the MMSE (Mancuso et al., 2018). Since the release of the OCS in 2015, several cultural adaptations and translations have been published: the Cantonese (Kong et al., 2016), Chinese Mandarin (Hong et al., 2018), Italian (Mancuso et al., 2016), Brazilian Portuguese (Ramos et al., 2018), Russian (Shendyapina et al., 2018), Spanish (Valera-Gran et al., 2019) and Danish translations (Robotham, Riis, & Demeyere, 2019). The different normative studies show considerable consistency of cut-off scores across languages (Table 1).

The Importance of Socio-economic Status and Age for Stroke and Cognition

Socio-economic status (SES) is a multidimensional construct that refers to an individual's access to socio-economic resources (American Psychological Association, 2007). SES is an important demographic to consider for a post-stroke cognitive screening instrument, as it is associated with stroke incidence and post-stroke recovery (Addo Juliet et al., 2012; Cox, McKevitt, Rudd, & Da Wolfe, 2006; Kerr et al., 2011). A meta-analysis reported that low SES individuals were 1.7 times more likely to have a stroke than high SES individuals (Kerr et al., 2011). Low SES stroke survivors were also 1.7 times more likely to have long-lasting disabilities in daily life than high SES stroke survivors (van den Bos, Smits, Westert, & van Straten, 2002). SES is often operationalized using three inter-related indicators: income, education and occupational status (Duncan & Magnuson, 2012; Grundy & Holt, 2001). Despite being correlated, each indicator represents a unique aspect of SES potentially linked to health through different ways (Duncan & Magnuson, 2012). For instance, higher income results in material benefits, such as better food and housing, which can positively affect health. Higher education is linked to a healthier lifestyle and higher occupational status is coupled to better social integration which can positively affect health (Grundy & Holt, 2001).

Many studies have shown that low-educated individuals perform worse on cognitive tests than high-educated individuals (Lezak et al., 2004; Mitrushina, Boone, Razani, & D'Elia, 2005; Strauss, Strauss, Sherman, Sherman, & Spreen, 2006). The effects of education encompass many cognitive functions, with studies reporting effects on executive functions measured with the Stroop task (Hooren et al., 2007; Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2006) and the letter digit substitution test (Elst, Boxtel, Breukelen, & Jolles, 2006; Hooren et al., 2007), verbal memory (Thielen, Verleysen, Huybrechts, Lafosse, & Gillebert, 2019), visuoconstruction,

verbal fluency, conceptual reasoning and calculation (Ostrosky-Solís, Ardila, & Rosselli, 1999). Illiterates have been shown to perform worse than educated individuals on language comprehension, naming, calculation, praxis and visuospatial attention as measured with cancellation tasks (Rosselli, Ardila, & Rosas, 1990). Moreover, it has been shown that education can differentially impact performance on different test items in the MMSE (Jones & Gallo, 2002). In addition to cognitive test performance being related to education, studies have also reported worse cognitive test performance for individuals with low compared to individuals with high occupation status (Andel, Kåreholt, Parker, Thorslund, & Gatz, 2007; Avolio & Waldman, 1990; Basta, Matthews, Chatfield, & Brayne, 2008; Dartigues et al., 1992; Potter, Helms, & Plassman, 2008; Staff, Murray, Deary, & Whalley, 2004), and worse cognitive test performance for low-income compared to high-income individuals (Lang et al., 2008; Wee et al., 2012, although see Holtsberg, Poon, Noble, & Martin, 1995; Lee, Kawachi, Berkman, & Grodstein, 2003).

Age is another important demographic to consider for norms of post-stroke cognitive screening tools, since stroke occurs more often in older individuals (Bogousslavsky, Van Melle, & Regli, 1988; Jentorp & Berglund, 1992) and because age is associated to worse functional outcome after stroke (Kelly-Hayes et al., 2003; Nakayama, Jørgensen, Raaschou, & Olsen, 1994). Moreover, longitudinal and cross-sectional ageing studies have shown that there are domain-specific cognitive changes throughout the lifespan (Hedden & Gabrieli, 2004; Whalley, Deary, Appleton, & Starr, 2004). Studies have shown that executive functions and language production decline across the adult lifespan, while semantic knowledge, language comprehension and recognition performance remain more stable (Hedden & Gabrieli, 2004; Hooren et al., 2007; Burke & Shafto, 2004; Juncos-Rabadán, Facal, Rodríguez, & Pereiro, 2010).

While cut-off scores of the OCS have been reported for specific education and age groups in the different normative studies (Demeyere et al., 2015; Hong et al., 2018; Kong et al., 2016; Mancuso et al., 2016; Robotham et al., 2019; Shendyapina et al., 2018; Valera-Gran et al., 2019), the association of OCS performance with other socio-economic characteristics, income and occupational status, has not been investigated yet.

The Dutch translation of the Oxford Cognitive Screen

In this study we translated the Oxford Cognitive Screen to Dutch, thereby developing the Dutch Oxford Cognitive Screen (OCS-NL). The first aim of the study was to provide normative data for two parallel versions of the OCS-NL. Second, we aimed to establish the association of socio-economic status and age with OCS-NL performance. This was done to assess whether cut-off scores needed to be stratified on socio-economic status and age. We expected that age would have a stronger negative association with performance on subtests involving naming and executive functions as compared to subtests involving recognition (in contrast to recall) and semantic knowledge (Hedden & Gabrieli, 2004; Hooren et al., 2007; Burke & Shafto, 2004; Juncos-Rabadán, Facal, Rodríguez, & Pereiro, 2010). We expected worse OCS-NL performance for individuals with lower income, lower occupation status and lower education levels.

Method

Participants

Participants were recruited by advertisements in local newspapers and at events for older adults. Participants with a current or history of neurological disease (including previous traumatic brain injury, stroke, brain tumor, etc.) were excluded from the study. Participants were required to be native Dutch speaking or raised bilingual including Dutch. A total of 246 neurologically healthy participants took part in the study and completed version A of the OCS-NL and provided

data about their age and education. Of these 246 participants, 179 participants also completed the parallel version (version B) of the OCS-NL (Subgroup 1) and 147 participants also provided data about their occupation and income (Subgroup 2). The participant characteristics of each group are reported in Table 2. Participants gave written informed consent and all study procedures were in accordance with the Helsinki declaration and approved by the institutional Ethics committee (G2016 12 692). Participants received financial compensation (8 euros per hour) for their participation.

Procedure

Normative data were collected in two study phases. In Phase 1, 179 neurologically healthy participants took part in two sessions. In Session 1, a semi-structured interview about their demographic and health characteristics was conducted and one version of the OCS-NL was administered. In Session 2, a second version of the OCS-NL was administered. For all these participants, the OCS-NL was administered according to a counterbalanced design. A total of 90 participants completed version A and 89 participants completed version B of the OCS-NL in Session 1. The two sessions were 6.4 days apart on average ($SD=2.7$, range: 3-19 days). Questions about income and occupation were added to our demographic questionnaire for the last 63 recruited participants. The first 116 recruited participants received a letter with a questionnaire about their occupation and income sent to them a few months after their study participation ($M=13.6$, $SD=1.9$, Range: 8-18 months). We received 84 correctly filled out questionnaires. In Phase 2 of the study, we recruited and tested an additional 67 participants who completed a short demographic interview (only including information about age and education) and version A of the OCS-NL in a single test session.

Instruments

The Dutch Oxford Cognitive Screen (OCS-NL)

The OCS-NL consists of 11 subtests to assess 5 cognitive domains: language, attention and executive functions, memory, praxis and numeric cognition and a visual confrontation task to assess the presence of visual field deficits. The test items and manual were translated following the approved process, including independent forward and back translation. Dutch versions of the sentences for the reading task were designed to be suitable for the Dutch language area, following the design principles of the original English sentences, including word length, exception words and words with high neighborhood frequencies. The verbal memory test items were adjusted to match the new sentences, and again followed the design principles of the English OCS with recognition multiple choice options consisting of the target word, two related distractors (which could either be a word with a similar or related meaning, or a word related to previous tests), and one unrelated word. All other test items were direct translations of the English OCS. The OCS-NL subtests are described in detail in Supplementary Materials 1. The OCS-NL materials consist of a test book, scoring sheet and a participant work book on A4 sheets of paper. All OCS-NL test materials are licensed at no cost to the user for publicly funded clinical or research use via Oxford University Innovations (<https://innovation.ox.ac.uk/outcome-measures/the-oxford-cognitive-screen-ocs/>). The Dutch manual (see www.ocs-test.org under Dutch translation), instruction video (<https://doi.org/10.6084/m9.figshare.7785614.v1>) and automatic scoring sheet are also available for free (<https://doi.org/10.6084/m9.figshare.8283242>).

Socio-economic status (SES)

Education was measured using the number of years of formal education and the highest achieved degree. Three categories were defined: 1) a degree of primary school (=low), 2) a

degree of secondary school (=mid) and 3) a degree of higher education (=high). Occupation status was measured based on the social class schema of Erikson, Goldthorpe and Portocarero (EGP schema, 1979) which has been shown to be a valid representation of social class (Evans, 1992). We used the 3 class EGP schema, which distinguishes non-manual, manual and farm workers. We merged the farm and manual workers class into one category as we only had three participants in the farm workers class. For individuals who were not active in the workforce during their study participation we used the longest executed occupation as the basis for the EGP coding. Students in higher education were assigned to the “non-manual work” group ($n = 3$). Participants also reported their average monthly net family income using pre-defined categories. Three income categories were defined: ≤ 1500 (low), 1501-2500 (middle), ≥ 2501 EUR (high). In Belgium, a monthly net income of 1139 EUR for a single person is considered the threshold to be at risk of monetary poverty in 2017 (Statbel, 2018b) and the average individual monthly net income in Flanders was 1591 EUR in 2016 (Statbel, 2018a). For students ($n=3$) and individuals who did not respond to the income question ($n=5$), we made a crude income estimate based on Belgian income statistics (Statbel, 2018a). In addition, we evaluated whether our results were affected by including these participants which was not the case.

Data-analysis

Equivalence of parallel versions

We tested whether the two parallel versions of the OCS-NL were equivalent in difficulty on the sample of participants who completed both parallel versions of the OCS-NL ($n = 179$). Percentage correct was modeled as a function of the interaction of the within-subject factors OCS-NL subtest and version. The percentage correct items per subtest was calculated by dividing the number of correct items by the total number of items for each subtest and multiplying this by

100. To this end, a Bayesian logistic hierarchical regression model was estimated on the percentage correct with the brms package v2.7 (Bürkner, 2017) including a maximal random effects structure. The Bayesian method of parameter estimation produces unbiased parameter estimates even for unbalanced designs (i.e. different number of test items per OCS-NL subtest) and can better deal with low numbers of observations than Frequentist methods (Kruschke, 2010). Moreover, the Bayesian method is more conservative than Frequentist methods and allows to compare multiple contrasts without inflation of false positives (Gelman & Tuerlinckx, 2000; Kruschke, 2010). Model fit was checked by visually comparing the observed and predicted data and showed good fit (Gelman, Meng, & Stern, 1996).

Subtest specific effects of age and education

We evaluated whether there was a subtest-specific association between OCS-NL performance, age and education in all participants who completed OCS-NL Version A (N = 246). To this end, a Bayesian logistic hierarchical regression model was estimated on the percentage correct including a random intercept for participants. This percentage correct was modeled as a function of the interaction of age and OCS-NL subtest and the interaction of years of formal education and OCS-NL subtest. The predictor OCS-NL subtest was treated as a within-subject factor.

To illustrate the strength of the association between age and performance, we report the estimated differences in percentage correct between the youngest and oldest adults of the sample, controlling for the influence of education. Similarly, to illustrate the strength of the association between years of formal education and performance, we report the estimated differences in percentage correct between individuals with the lowest and highest level of years of formal education in the sample, controlling for age. Finally, to illustrate the strength of the interaction between the subtests with age and the interaction between the subtests with education, we

respectively report the estimated differences between the subtests in age-related and education-related performance differences. For each of these contrasts, the 95% credible intervals are reported.

The relation of socio-economic status with OCS-NL global performance

We assessed the relation between the three SES indicators (i.e. education, income and occupation) and performance on the OCS-NL. We chose to assess the relation of the SES indicators with an index of OCS-NL performance across all subtests, since we only had complete SES data available of a limited subsample of participants ($n = 147$). Although these analyses cannot reveal potential interactions of SES with OCS-NL subtests, this analysis is still informative regarding the influence of SES on overall OCS-NL performance. OCS-NL performance across the subtests was summarized by counting the number of subtests on which performance was lower than the median score (i.e. *number of low scoring subtests*). This outcome measure can range from 0 (i.e. participant performed above median on all subtests) to 11 (i.e. participant performed below median on all subtests).

The number of low scoring subtests was estimated as a function of the main effect of education level (i.e. low, mid and high education), income (i.e. ≤ 1500 , 1501-2500, ≥ 2501 EUR), occupation (i.e. manual versus non-manual workers) using a Bayesian logistic regression model with the brms package v2.7 (Bürkner, 2017). Age categorized in four groups (i.e. 22-34, 35-54, 55-74, 75-90 year olds) was included as a covariate. Model fit was checked by visually comparing the observed and predicted data and showed a good fit (Gelman et al., 1996).

We considered two correlated summary measures of OCS-NL performance to quantify OCS-NL global performance in healthy volunteers: the number of low scoring subtests and the total number of errors. Although both measures are associated with each other, they differ in their interpretation. The number of low scoring subtests represents a specific profile of errors: making

errors on a small number of subtests versus making errors on a large number of subtests. The total number of errors represents the overall performance level independent of whether errors were made on a small or large number of subtests. Although this second outcome variable is less interesting for clinicians, it has the advantage of being continuous (in contrast to the number of low scoring subtests) and may therefore be more suitable to study the effects of SES and age in neurologically healthy volunteers. The analysis for the total number of errors led to the same conclusions as the analysis for the number of low scoring subtests (Supplementary Materials 2).

Results

Almost all participants (range: 94-100%) achieved the maximum possible score on the subtests semantics, orientation, reading, number writing and episodic memory (Figure 1). Therefore, these subtests could not be included in the statistical analyses.

Equivalence of OCS-NL parallel versions

We first assessed the equivalence of the two parallel versions of the OCS-NL. The model estimates (Table 3) revealed small differences in performance related to the two parallel versions. The percentage correct was on average 6% lower for version A than B on the naming task (95% CI = [4.2, 8.4]). The average percentage correct was 4% higher on the verbal memory task version B than A (95% CI = [2.3, 6.3]) and the percentage correct was 1% higher on version B than version A of the praxis task (95% CI = [0.3, 2.5]). There was no systematic difference in difficulty between version A and B on the executive task (95% CI = [-0.1, 0.3]), on the calculation task (95% CI = [-1.8, 0.0]) and on the hearts cancellation task (95% CI = [-0.5, 0.3]). For all other subtests, average performance was close to ceiling on both parallel versions (Figure 1).

Subtest Specific Effects of Age

We tested the association of age and education with each individual OCS-NL task. Results of this analysis are reported in Table 4. The estimates revealed an age-related decline in performance on each of the OCS-NL subtests included in the regression model (Figure 2). More specifically, there was a difference in percentage correct for a 90- versus a 22-year old of 2% for the calculation task (95% CI = [-6, 0]), 8% for the executive task (95% CI = [-11, -5]), 28% for the naming task (95% CI = [-38, -18]), 17% for the praxis task (95% CI = [-23, -13]), 13% for the verbal memory task (95% CI = [-21, -5]) and 4% for the hearts cancellation task (95% CI = [-6, -2]).

Moreover, the amount of age-related decline in performance differed between the OCS-NL tasks. The difference in performance between a 90- and 22-year old was 25% larger for the naming than calculation task (95% CI = [16, 36]), 20% larger for the naming than executive task (95% CI = [11, 30]), 10% larger for the naming than praxis task (95% CI = [0, 20]), 15% larger for the naming than verbal memory task (95% CI = [3, 27]) and 23% larger for the naming than hearts cancellation task (95% CI = [14, 33]). These results suggest that age-related decline in performance was most pronounced for the naming and praxis task, followed by the verbal memory and executive task and that age-related decline in performance was least pronounced for the calculation and hearts cancellation task (Figure 2). Furthermore, a 90-year old with 14 years of education achieved a percentage correct (on average) of 98% (95% CI = [94, 99]) on the calculation task, 92% on the executive task (95% CI = [88, 94]), 71% on the naming task (95% CI = [62, 79]), 82% on the praxis task (95% CI = [76, 86]), 83% on the verbal memory task (95% CI = [77, 89]) and 94% on the hearts cancellation task (95% CI = [92, 95]).

Subtest Specific Effects of Education

There were education-related differences in performance on the OCS-NL tasks (Figure 3). The model estimates indicated a difference in percentage correct for a person with 6 versus 23 years of formal education of 5% for the calculation task (95% CI = [-13, -1]), 9% for the executive task (95% CI = [-13, -5]), 6% for the naming task (95% CI = [-14, 1]), 7% for the praxis task (95% CI = [-11, -3]), 10% for the verbal memory task (95% CI = [-19, -5]) and 2% for the hearts cancellation task (95% CI = [-4, 0]).

There were no systematic differences between the OCS-NL tasks in the effect of education (Figure 3). That is, the difference in performance between a person with 6 versus 23 years of education did not differ between the naming and calculation task (95% CI = [-9, 9]), between the naming and hearts cancellation task (95% CI = [-12, 3]), between naming and praxis (95% CI = [-7, 9]), between naming and verbal memory (95% CI = [-8, 15]) and between naming and the executive task (95% CI = [-5, 10]). Moreover, 60 year old participants with 6 years of education performed accurately on the tasks. That is, a person with 6 years of education of this age achieved a percentage correct of 95% (95% CI = [88, 98]) on the calculation task, 90% on the executive task (95% CI = [87, 94]), 89% on the naming task (95% CI = [83, 94]), 90% on the praxis task (95% CI = [87, 94]), 86% on the verbal memory task (95% CI = [78, 91]) and 95% on the hearts cancellation task (95% CI = [94, 96]).

The Relation of Socio-economic Status with OCS-NL Global Performance

The association of the number of low scoring subtests with income, occupation, education and age was evaluated. Model estimates are reported in Table 5. There was no evidence for systematic differences in performance between the three income groups when controlling for age, education and occupation, as the estimated intervals consist of negative and positive values

(Figure 4a). More specifically, the middle income group scored below the median on 0.2 fewer to 0.4 more subtests than the low income group. The high income group scored below the median on 0.6 fewer to 0.4 more subtests than the low income group. There were also no systematic differences in performance between non-manual and manual workers when controlling for age, education and income, as the estimated interval contained negative and positive values (95% CI = [-0.2, 0.6]) (Figure 4b). There were small differences in the number of low scoring subtests for the different education levels when controlling for age, income and occupation. That is, the low educated group scored below the median on 0.3 (95% CI = [0.0, 0.8]) and 0.4 (95% CI = [0.1, 0.9]) more subtests compared to the mid and high educated group (Figure 4c). The intervals suggest that differences between education levels in the number of low scoring subtests were smaller than a single subtest.

There were systematic differences between age groups in the total number of low scoring subtests when controlling for education, income and occupation (Figure 4d). The number of low scoring subtests increased by 0.3 subtests for the 35-54 year old group compared to the 22-34 year old individuals. The interval of estimates revealed that the difference between these two age groups was unclear, as the interval contained negative and positive values (95% CI = [-0.4, 1.0]). The number of low scoring subtests increased by 1.6 subtests (95% CI = [0.9, 2.3]) for the 55-74 year olds and by 2.8 subtests (95% CI = [1.9, 3.8]) for the 75-90 year olds as compared to the 22-34 year olds.

Normative data

Age-specific normative data and cut-off scores of OCS-NL version A of 246 participants are presented in Table 6. In addition, percentile ranks for OCS-NL version A per age group are reported in Supplementary Table S1, and education-specific norms for OCS-NL version A in

Supplementary Table S2. For the subtests of OCS-NL version B that differed in difficulty from OCS-NL version A, cut-off scores specific to OCS-NL version B are reported (Supplementary Table S3). Details about these analyses are reported in Supplementary Materials 2. All normative data were pooled across test sessions as there were no systematic performance differences between the two test sessions, except for a 2% performance difference on the praxis task (Supplementary Materials 3).

Discussion

We developed the Dutch translation of the Oxford Cognitive Screen (OCS-NL) and present age-, education- and version-specific cut-off scores as well as percentile ranks of the OCS-NL. We formally assessed the equivalence of the two parallel versions of the OCS-NL. In addition, given that age and socio-economic status are linked to a higher stroke risk, we assessed whether there was an association between performance on the individual OCS-NL subtests with age and education, and whether there was a relation between global OCS-NL performance and the broader construct of socio-economic status.

Equivalence of Parallel Versions and OCS Translations

Parallel versions of neuropsychological tests can be valuable for clinicians as they can be used to re-assess patients over time reducing item-specific practice effects (Goldstein & McNeil, 2004). However, parallel versions are often not equivalent in difficulty (Gross et al., 2012). For this reason, we explicitly collected normative data for the two parallel versions of the OCS-NL in the same cohort of participants. These data revealed that performance was highly similar between parallel versions, except for small differences in performance on the naming, verbal memory and praxis tasks. Thus, for these three subtests it is recommended to use version-specific cut-off scores. Moreover, overall the cut-off scores of the OCS-NL showed good correspondence to cut-

off scores of the other OCS translations (Table 1 and Table 6). This suggests that it could be interesting to develop cut-off scores across all OCS translations in the future. Combining data across the OCS translations produces a much larger normative dataset, resulting in more reliable and robust estimates of percentile cut-off scores. Cross-translation norms are likely more appropriate for the non-language OCS subtests than the language subtests, but future studies should investigate whether there are significant differences in OCS performance between different language areas. Moreover, future studies should investigate whether the specificity and sensitivity of the OCS is affected by using cross-translation as compared to translation-specific norms.

Age-associated Decline in OCS-NL Performance Varies across Subtests

While the effect of education did not vary across the different subtests, our results indicated that certain OCS-NL subtests were more strongly associated to age than other subtests. More specifically, the age-related decline in performance was most pronounced for the naming and praxis task, followed by the verbal memory and the executive task and the age-related decline in performance was less pronounced on the calculation and hearts cancellation task. Performance remained at ceiling across all ages for the semantics, reading and orientation tasks and there may have been minimal age-related decline in performance on the episodic memory and number writing tasks. Our results correspond to previous findings on domain-specific ageing, where it has been shown that executive functions and language production declined more across the adult lifespan than semantic knowledge, recognition performance and language comprehension (Burke & Shafto, 2004; Hedden & Gabrieli, 2004; Juncos-Rabadán, Facal, Rodríguez, & Pereiro, 2010). However, the generalizability of these findings is limited. Since there were a low number of test items for the majority of the OCS-NL subtests, our findings

cannot be generalized to more elaborate neuropsychological tests in which performance may vary more in the healthy population. These results do imply that the use of age-adjusted cut-off scores is particularly recommended for the naming, praxis, verbal memory and executive task of the OCS-NL.

Income and Occupation do not Affect OCS-NL Performance in Healthy Participants

In addition, we evaluated whether the three most frequently used SES indicators - occupation, income and education - contributed to the prediction of OCS-NL performance across all subtests in a subset of our participants. Normative data of neuropsychological tests are often reported for participants of a certain age group, education level and sex (Strauss et al., 2006). However, numerous studies have shown links between SES, health and cognition in childhood and older adults (Brito & Noble, 2014; Jang, Choi, & Kim, 2009; Knesebeck, Lüschen, Cockerham, & Siegrist, 2003; Schöllgen, Huxhold, & Tesch-Römer, 2010). SES is especially important to consider for norms of a post-stroke screening instrument, as low SES is associated with higher stroke incidence and worse long-term outcome after stroke (Addo Juliet et al., 2012; Cox, McKevitt, Rudd, & Da Wolfe, 2006).

Our results revealed no support for a contribution of occupation status and income to the prediction of OCS-NL performance when controlling for age and education. Noteworthy, in this study we assessed the association of SES with OCS-NL performance in the neurologically healthy population. These results imply that we expect no impact of income and occupation in addition to age and education on the premorbid OCS-NL test profiles of stroke survivors. However, the generalizability of these results to the stroke population is limited. That is, our results leave the possibility open that income and occupation are associated to OCS-NL

performance post-stroke, as these two SES indicators could interact with the effects of stroke on cognition.

Clinical Recommendations

We found evidence for small education-related and considerable age-related differences in OCS-NL performance. These data clarify that age is the most important characteristic of individuals to consider when comparing OCS-NL test scores of stroke patients to healthy controls. For this reason, we recommend the use of age-specific cut-off scores to interpret test scores of stroke patients on the OCS-NL. This is especially useful for the subtests naming, praxis, verbal memory and the executive task. Additionally, when using parallel version B of the OCS-NL, we recommend the use of version-specific cut-off scores for the subtests naming, praxis and verbal memory. For all other subtests, the cut-off scores based on OCS-NL version A can be used to interpret the scores on parallel version B.

Moreover, effects of education – although small - also need to be considered when interpreting OCS-NL test scores of stroke patients. Our results show that individuals with neurologically healthy individuals with 6 years of formal education perform highly accurately on the different OCS-NL subtests. It is therefore very unlikely that low test scores would result from low education levels. The current normative sample for the OCS-NL is not large enough to obtain reliable cut-off scores for the different combinations of age and education categories. In the future, when a larger normative dataset is available, norms stratified on age and education will be made available. For now, age-adjusted norms are recommended as age was more strongly associated with OCS-NL performance than education.

Additionally, when retesting stroke patients, we recommend to use the same normative data to interpret test scores of stroke patients on a second assessment, as we did not observe

systematic test-retest performance differences in our healthy volunteers, except for a 2% performance difference on the praxis task (Supplementary Materials 3). In addition, there was no systematic relation between the delay between the two test sessions and test-retest performance differences in our healthy volunteers possibly due to performance being at ceiling on both test sessions (Supplementary Materials 3). For this reason, we cannot formulate a recommendation regarding the delay of testing in patients, and envisage that further research with our target clinical population can help inform this.

Conclusions

We provide normative data of the Dutch Oxford Cognitive Screen, a neuropsychological tool designed to screen for post-stroke cognitive impairments. We showed that performance was highly similar between the two OCS-NL parallel versions and across different OCS translations. Moreover, our results show that normative data of the OCS-NL do not need to be stratified on income and occupation. In contrast, we did find considerable age-related decline in OCS-NL performance that varied across subtests and small effects of education on OCS-NL performance that did not vary across subtests. To conclude, we can make the following recommendations for the clinical use of the OCS-NL: 1) use version-specific cut-off scores for the naming, verbal memory and praxis task, 2) use age-specific cut-off scores for the naming, praxis, verbal memory and executive task and 3) consider that education can have small effects on OCS-NL performance.

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Declaration of interest statement

The researchers declare no conflicts of interest.

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Table 1.
Norms of different OCS translations.

			Translations: ^a	English	Italian ^b	Hong-Kong ^b	Danish	Russian	Spanish
			Sample size (N):	140	498	70	89-91	60	54
			Age in years:	<i>M</i> = 65 <i>SD</i> = 12 R: 36 - 88	< 50: n=196 50–70: n=188 >70: n=114	<50: n=22 50–59: n=26 >59: n=22	<65: n=34 65-75: n=38 >75: n=19	<i>M</i> = 61 <i>SD</i> = 19 R: 20 - 91	Mdn = 63 IQR: 58 - 71
			Education: ^c	<i>M</i> = 14 <i>SD</i> = 4	≤ 8: 134 9-13: 201 >14: 163	Low: n=12 Mid: n=39 High: n=19	<12: n=25 12 - 16: n=43 >16: n=23	<i>M</i> = 15 <i>SD</i> = 2.7 R: 7 - 21	Low: n=28 High: n=26
Domain	Subtest	Score range	Cut-off scores ^d						
Language	Naming	0 - 4	3	2.9 - 3.7	4	3	3	2	
	Semantics	0 – 3	3	3	3	3	3	2	
	Reading	0 – 15	14	14.1 - 15	22/22 ^e	15	15	14	
Numeric cognition	Number writing	0 – 3	3	2.8 - 3	3	3	3	2	
	Calculation	0 – 4	3	3.3 - 3.8	4	3	3	3	
Praxis	Imitation	0 – 12	8	9	12	8	8	8	
Memory	Orientation	0 – 4	4	3.9 - 4	4	4	4	3	
	Verbal memory	0 – 4	3	2.4 - 3.4	2-4	3	3	3	
	Episodic memory	0 - 4	3	3.4 - 3.8	4	3.5	3	3	
Attention	Executive score	-13 – 12	>4	>3	> 0 – 3.7	> 1	> 6	> 0	
	Total hearts cancelled	0 – 50	42	43.4 - 47.4	49 - 50	39.5	40	43	
	Object Asymmetry	-50 – 50	< 0 and > 0	< -2 and > 2	> 0 – 1	< 0 and > 1	Not reported	< -1 and > 1	
	Space Asymmetry	-20 - 20	< -2 and > 3	< -3 and > 3	> 0 - 3	< -2 and > 2	< -3 and > 3	< -4 and > 2	

Table Note. IQR = interquartile range, R = range

^a The Mandarin OCS and the Brazilian Portuguese OCS studies do not report cut-off scores for each subtest.

^b The Italian and Hong-Kong OCS reported cut-off scores adjusted by age, education or gender. The range of cut-off scores is reported here.

^c The English and Russian OCS reported years of education. The Italian and Danish OCS reported the sample size of three education levels separated on years of education. The Hong-Kong OCS reported the sample size of three education levels: primary (low), secondary (mid) and higher education (high). The Spanish OCS reported the sample size of two education levels: uneducated or primary education (low) and secondary or higher education (high).

^d The Spanish OCS reported cut-off scores based on an area under the curve analysis, the Italian OCS reported cut-off scores based on 95% confidence intervals using linear regression. The other OCS translations reported the 5th and 95th percentiles.

^e The maximum score on the sentence reading was 22 for the Hong-Kong OCS.

Table 2.

Demographic characteristics.

Variable		Total group	Subgroup 1	Subgroup 2
Sample size		246	179	147
Age in years (<i>M, SD, Min-Max</i>)		60, 17, 22-90	59, 19, 22-90	62, 17, 22-89
Years of formal education (<i>M, SD, Min-Max</i>)		14, 3, 6-23	13, 4, 6-23	13, 4, 6-23
Sex (% female)		56	56	56
Handedness (% right)		85	88	86
Age groups in years	% 22-34	13	17	12
	% 35-54	24	22	20
	% 55-74	45	39	44
	% 75-90	19	22	25
Education groups	% low	21	26	29
	% mid	30	27	29
	% high	49	47	42
Income groups	% low			46
	% mid			43
	% high			12
Occupation (% non-manual workers)				58
Available data	OCS-NL version A	Yes	Yes	Yes
	OCS-NL version B	No	Yes	Yes
	All 3 SES indicators	No	No	Yes

Table 3.

Estimates of the probability of a correct item as a function of OCS-NL subtest and OCS-NL version.

Predictor	Estimate ^a	95% CI
Intercept	2.22	[1.96, 2.51]
Executive task	2.76	[2.07, 3.56]
Calculation	2.26	[1.53, 3.23]
Praxis	0.61	[0.26, 0.95]
Total hearts cancelled	1.05	[0.74, 1.36]
Verbal memory	0.18	[-0.18, 0.56]
Version B	1.08	[0.66, 1.52]
Executive task * version B	-0.92	[-1.45, -0.39]
Calculation * version B	-1.62	[-2.45, -0.82]
Praxis * version B	-1.31	[-1.81, -0.83]
Total hearts cancelled * version B	-1.11	[-1.58, -0.65]
Verbal memory * version B	-0.31	[-0.90, 0.29]

Table note. CI = Bayesian credible interval.

^a Estimates are based on a Bayesian mixed effects logistic regression model. Coefficients are in log odds units. Odds = probability of completing a test item accurately divided by the probability of completing a test item inaccurately.

Table 4.

Estimates of the probability of a correct item as a function of age, education and OCS-NL subtest.

Predictor	Estimate ^a	95% CI
Intercept	3.38	[0.29, 6.71]
Executive task	0.19	[-3.25, 3.53]
Naming	1.63	[-2.02, 5.09]
Praxis	1.24	[-2.15, 4.52]
Total hearts cancelled	0.35	[-2.95, 3.44]
Verbal memory	-0.65	[-4.15, 2.69]
Age	-0.03	[-0.07, 0.00]
Years of education	0.22	[0.07, 0.39]
Executive task * Age	-0.01	[-0.04, 0.03]
Naming * Age	-0.02	[-0.06, 0.02]
Praxis * Age	-0.02	[-0.05, 0.02]
Total hearts cancelled * Age	0.01	[-0.02, 0.05]
Verbal memory * Age	0.01	[-0.03, 0.05]
Executive task * Years of education	-0.06	[-0.24, 0.09]
Naming * Years of education	-0.17	[-0.34, -0.01]
Praxis * Years of education	-0.14	[-0.31, 0.01]
Total hearts cancelled * Years of education	-0.20	[-0.36, -0.05]
Verbal memory * Years of education	-0.15	[-0.33, 0.01]

Table note. CI = Bayesian credible interval.

^a Estimates are based on a Bayesian mixed effects logistic regression model. Coefficients are in log odds units. Odds = probability of completing a test item accurately divided by the probability of completing a test item inaccurately.

Table 5.

Model estimates of association of the number of low scoring subtests, SES and age.

	<u>Estimate</u> ^a	<u>95% CI</u>
Intercept ^b	-2.25	[-2.94, -1.59]
Age group 35-54	0.30	[-0.31, 0.94]
Age group 55-74	1.09	[0.54, 1.68]
Age group 75-90	1.64	[1.06, 2.23]
Education level (mid)	-0.40	[-0.78, -0.02]
Education level (high)	-0.47	[-0.86, -0.08]
Income 1501-2500	0.09	[-0.18, 0.37]
Income \geq 2501	-0.12	[-0.62, 0.33]
Manual worker	0.18	[-0.15, 0.54]

Table note. CI = Bayesian credible interval.

^a The estimates are based on a Bayesian logistic regression model. Coefficients are in log odds units.^b The intercept represents the age group of 22-34, the low education level, the income \leq 1500 and the non-manual workers.

Table 6.

OCS-NL subtest descriptive statistics of OCS-NL version A per age group.

	<u>Age: 22-34 (n = 31)</u>						<u>Age: 35-54 (n = 58)</u>					
	Education (years): M = 14, SD = 2, Range: 7 - 18						Education (years): M = 14, SD = 3, Range: 9 - 22					
	Mdn	Mod	Min	Max	pc5	pc95	Mdn	Mod	Min	Max	pc5	pc95
Naming	4	4	3	4	3	4	4	4	3	4	3	4
Semantics	3	3	3	3	3	3	3	3	3	3	3	3
Orientation	4	4	4	4	4	4	4	4	4	4	4	4
Reading	15	15	15	15	15	15	15	15	15	15	15	15
Number writing	3	3	3	3	3	3	3	3	2	3	3	3
Calculation	4	4	4	4	4	4	4	4	3	4	3	4
Praxis	12	12	10	12	11	12	12	12	8	12	10	12
Verbal memory	4	4	3	4	3	4	4	4	2	4	2	4
Episodic memory	4	4	4	4	4	4	4	4	3	4	4	4
Executive score	-1	-1	-2	0	-1	-1	-1	-1	-1	5	-1	3
Total hearts cancelled	49	50	43	50	45	50	48.5	49	39	50	43	50
Object Asymmetry	0	0	-1	1	0	1	0	0	-1	0	0	0
Space Asymmetry	0	0	-4	2	-2	2	0	0	-3	4	-2	2

Table Note. Mod = modus, Min = minimum observed value, Max = maximum observed value, pc 5 = 5th percentile, pc95 = 95th percentile.

Table 6 continued.

OCS-NL subtest descriptive statistics of OCS-NL version A per age group.

	<u>Age: 55-74 (n = 111)</u>						<u>Age: 75-90 (n = 46)</u>					
	Education in years: M = 14, SD = 4, Range: 6 - 23						Education in years: M = 13, SD = 4, Range: 8 - 22					
	Mdn	Mod	Min	Max	pc5	pc95	Mdn	Mod	Min	Max	pc5	pc95
Naming	4	4	2	4	2	4	3	3	1	4	2	4
Semantics	3	3	3	3	3	3	3	3	3	3	3	3
Orientation	4	4	4	4	4	4	4	4	2	4	4	4
Reading	15	15	12	15	14	15	15	15	14	15	14	15
Number writing	3	3	2	3	3	3	3	3	2	3	2	3
Calculation	4	4	3	4	3	4	4	4	2	4	3	4
Praxis	12	12	4	12	8	12	11	12	6	12	7	12
Verbal memory	4	4	2	4	3	4	3	4	1	4	2	4
Episodic memory	4	4	3	4	3	4	4	4	3	4	3	4
Executive score	-1	-1	-8	12	-2	3	-1	-1	-7	9	-2	4
Total hearts cancelled	48	50	39	50	43	50	48	48	33	50	37	50
Object Asymmetry	0	0	-2	1	-1	0	0	0	-1	2	-1	0
Space Asymmetry	0	0	-5	6	-2	3	0	0	-11	5	-3	3

Table Note. Mod = modus, Min = minimum observed value, Max = maximum observed value, pc 5 = 5th percentile, pc95 = 95th percentile.

Figure 1. Equivalence of the two OCS-NL parallel versions. Percentage correct items is shown per OCS-NL subtest and per OCS-NL version (version A and B). The distribution represents the observed percentages correct for all 179 participants. The error bar represents the estimated credible interval for the percentage correct per version. For subtests semantics, reading, orientation, episodic memory and number writing the dot represents the mean percentage correct.

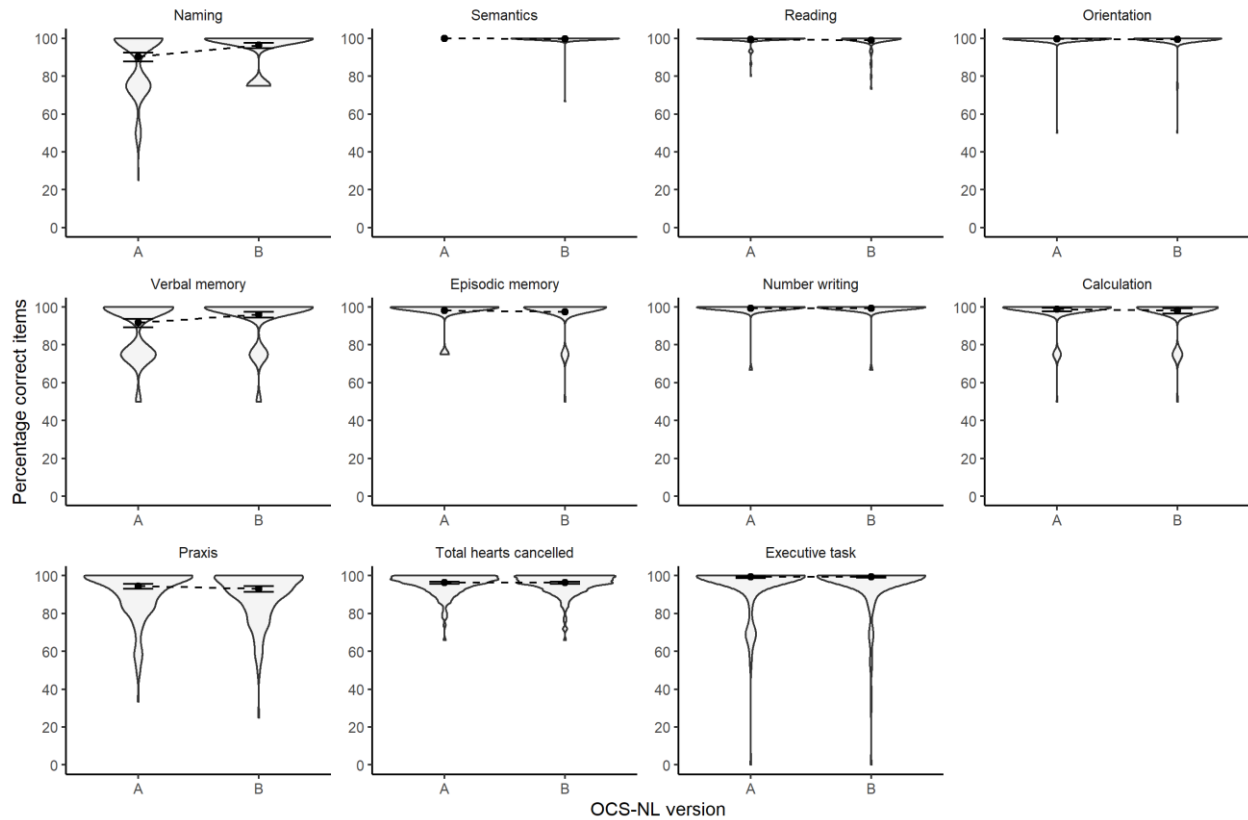


Figure 2. Association between age and the percentage correct per OCS-NL subtest. The line represents the predicted percentage correct for different ages when years of formal education is kept at a constant value of 13.8 years. The dots represent the average percentage correct of all participants of a certain age in years. Note that as individuals with different ages are not matched on years of education, the average percentage correct for a certain age can reflect a mixed effect of age and education. The regression line represents the pure effect of age, keeping education constant. The size of the dot represents the number of participants in each age group. The colors represent the cognitive domain of the subtest: language (green, panels 1-3), memory (purple, panels 4-6), numeric cognition (pink, panels 7-8), praxis (blue, panel 9), attention (kaki, panels 10-11).

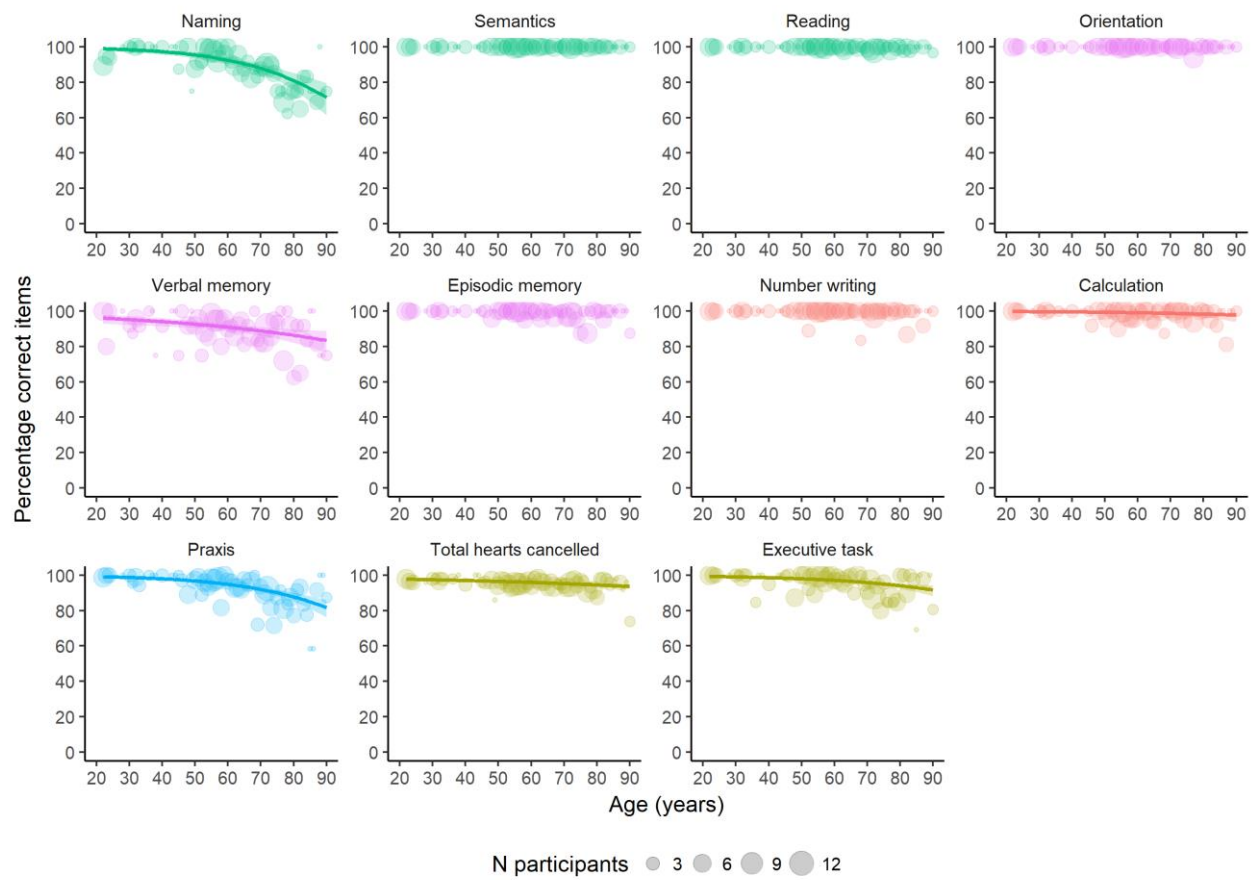


Figure 3. Association between years of formal education and the percentage correct items per OCS-NL subtest. The line represents the predicted percentage correct for different years of formal education when age is kept at a constant value of 59.7 years. The dots represent the average percentage correct of all participants of a certain number of years of education. Note that as individuals with different number of years of education are not matched on age, the average percentage correct can reflect a mix of effects of age and education. The regression line represents the pure effect of education, keeping age constant. The size of the dot represents the number of participants for each number of years of education. The colors represent the cognitive domain of the subtest: language (green, panels 1-3), memory (purple, panels 4-6), numeric cognition (pink, panels 7-8), praxis (blue, panel 9), attention (kaki, panels 10-11).

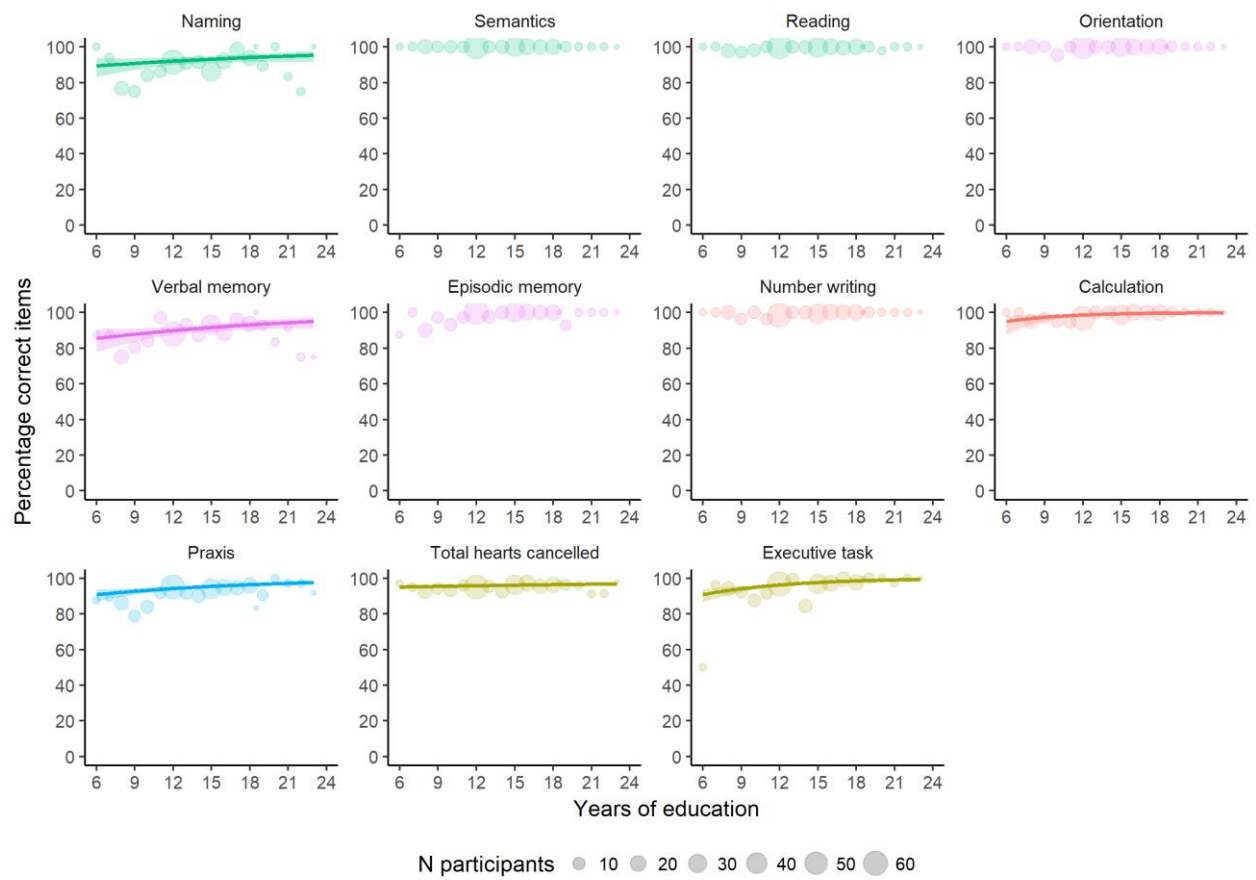


Figure 4. The number of low scoring subtests for different income, occupation, education and age groups. The grey area represents the distribution of the number of low scoring subtests for all participants split up either according to income, occupation, education and age. Note that groups split up on a single participant characteristic (i.e. age, education, income or occupation) are not necessarily matched on all other characteristics. Thus, these distributions can represent a mix of effects of multiple participant characteristics. The black dots represent the estimated number of low scoring subtests either as a function of age, education, income or occupation keeping the other characteristics constant and equal to the reference group. These estimates represent the unique effect of each single characteristic. The age group 22-34, low education level, income group ≤ 1500 and non-manual worker group were used as reference group. The black error bar represents the 95% credible interval of the model estimates.

