The Mini-Oxford Cognitive Screen (Mini-OCS): a very brief cognitive screen for use in chronic stroke

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Declarations

Nele Demeyere is a developer of the “Oxford Cognitive Screen” and “Oxford Cognitive Screen-Plus” but does not receive any remuneration from its use.

Guarantor: ND

Contributorship: SSW, LS, EYHT, and ND researched literature and conceived the study. SSW and ND developed the protocol, gained ethical approval, and coordinated patient recruitment. SSW curated the data and conducted all data analyses, with data analysis supervision from LS. SSW wrote the first draft of the manuscript. ND supervised the overall project. All authors reviewed and edited the manuscript and approved the final version of the manuscript

Abstract

Introduction

There is currently no dedicated cognitive screen for chronic stroke survivors, with primary care and community settings currently using dementia tools which often do not take into account post-stroke impairments. We aimed to standardise, norm, and psychometrically validate the Mini-Oxford Cognitive Screen (Mini-OCS), a very brief (<8 minute) cognitive screen for use in chronic stroke.

Methods

Data for 464 chronic stroke survivors on the OCS were analysed to determine the possibility of a short form. Theoretical and statistical choices were made to adapt the short form. The newly 'Mini-OCS' was then completed by 164 neurologically healthy controls (*M*age = 68.66(*SD*=12.18), *M*yrs of education 15.40(*SD*=3.64), & 61% Female), and 89 chronic stroke survivors (*M*age = 69.86(*SD*=14.83), *M*yrs education = 14.29(*SD*=4.01), 45% Female,, *M*days since stroke = 597.02(*SD*=881.12), 79% ischaemic, 49% R hemisphere, & Median NIHSS = 6.50(*IQR*=4-11)) . Additionally, we administered an extended neuropsychological battery and cognitive screening, as well as the Nottingham Extended Activities of Daily Living scale. We evaluated reliability and construct validity.

Results

Normative data for the Mini-OCS is provided and known-group discrimination demonstrates increased sensitivity in the memory and executive function domains compared to the OCS. The Mini-OCS further met all appropriate benchmarks for evidence of reliability and validity for each of the subtasks.

Discussion and Conclusion

The Mini-OCS was developed as a standardised, stroke-specific cognitive screening tool with good psychometric properties for use in a chronic stroke population. The Mini-OCS is quick to administer and highlights cognitive strengths and weaknesses.

The Mini-Oxford Cognitive Screen (Mini-OCS): a very brief cognitive screen for use in chronic stroke

Stroke is a leading cause of disability and mortality globally (1,2), leading to high rates of cognitive impairment (>85% of stroke survivors acutely after stroke, ~65% longer-term), though these estimates vary depending on the sample and measurements taken (2–6). Global guidelines state that cognitive impairments should be sensitively screened for as soon as possible following stroke, including cognitive domain-specific impairments (7–9). Little attention has been paid to advise on routine cognitive screening long-term post-stroke (greater than 6-months post-stroke), despite the high rates of objective and subjectively reported cognitive impairment (3,4,6) , and a recent systematic review demonstrating that the most frequent unmet care need in chronic stroke is managing cognition (10).

However, consultations in primary care are time limited and existing tools may not always pick up or take into account post-stroke sequelae. This can lead to both under or overreporting of suspected cases of both dementia and cognitive impairment. Whilst the most frequently used cognitive screening tool is the Montreal Cognitive Assessment (11), this screen was designed for dementia screening, with a focus on assessing impaired verbal memory as a key feature of Alzheimer's disease. This makes it less suitable for post-stroke cognitive impairment, which is often characterized by complex multi-domain cognitive impairments, resulting from a focal injury with a backdrop of

degenerating brain health (see overview by (12)). The Oxford Cognitive Screen (OCS) (13) was designed as a first-line multi-domain screening tool to determine the extent of focal cognitive deficits incurred by stroke. Whilst the OCS has seen a wide take up in acute stroke-specific settings, its length (approx.. 20 min) and focus on acute deficits such as hemispatial neglect, apraxia, reading/writing impairments, as well as its inclusive nature (no penalties for using multiple choice responses in order to not unfairly penalise patients with aphasia), means it works well as a first line screening tool, but it is less sensitive at detecting domain-general deficits in memory and executive function (14).

The OCS-Plus (15) was designed as a highly sensitive test for these domain general impairments in memory and executive functioning; its longer duration and focus on milder deficits makes it a follow-up screening tool, mostly used in those with mild deficits. If sufficient time were available, a protocol of first-line cognitive screening with OCS, followed by screening for milder domain-general deficits with OCS-Plus might be a sensible suggestion, though practical and time constraints led us to conceive of the Mini-OCS.

We created a brief (less than 10 minutes) cognitive screening tool for chronic stroke survivors, which was developed following practical, theoretical, and statistical considerations, to reduce key barriers for uptake in primary care settings (16). The Mini-OCS is largely based upon the OCS (13) with complex subtest elements taken from the OCS-Plus (15). The intention of the Mini-OCS is to quickly screen for cognitive

impairments which are common post-stroke, and to be sensitive enough to detect mild cognitive impairments, in line with the complex cognitive picture encompassing domain-specific focal deficits due to the focal injury alongside potentially declining brain health resulting in domain-general cognitive difficulties. The Mini-OCS was designed to be inclusive for all stroke survivors, with tasks developed with consideration of visual acuity, hemi-spatial neglect, motor impairment, and dysphasia.

The current study presents the development of the Mini-OCS and psychometric validation using a cohort of stroke survivors and neurologically healthy ageing adults for normative reference. We examined the psychometric properties of test-retest reliability, construct validity, and known-group discrimination based upon newly generated normative data.

Development: Methods

Our manuscript adheres to the COSMIN guideline for studies on measurement properties (17) and the STROBE cohort checklist (18). Ethical approval for the study was granted by the Medical Sciences Interdivisional Research Ethics Committee at the University of Oxford (REF: R86339/RE001).

Development of the Mini-OCS

Data for 464 participants who completed the full OCS at least 6 months post stroke were analysed to determine the possibility of a short form. The data were part of the OCS-Recovery (Milosevich et al 2023) and OCS-Care (Demeyere et al 2019) studies. This dataset was chosen as it

fits the demographic of chronic stroke survivors and was available for use immediately.

We started with a core set of essential OCS subtasks which covered the main cognitive domains of the OCS. At the most minimal level, we aimed to include subtasks that adhered to international guidelines for cognitive screening in stroke.

In addition, we further theoretically organised several alternative minimal datasets with further subtasks. We selected the best model which fit statistical, theoretical, and practical criteria. Confirmatory Factor Analysis was used to assess unidimensionality of the OCS for subsequent analyses. Item response theory methods were chosen to establish discrimination and difficulty of each OCS subtask, to enable better selection of informative items. We then used an iterative approach to piloting the Mini-OCS, refining it, editing the Mini-OCS, and continuing to pilot it, before psychometric validation. We extensively detail the process in the supplementary materials.

CFA and IRT modelling

Twelve binary variables, indicating the impairment in the OCS subtasks, were included in a unidimensional confirmatory factor analysis model. We used a factor loading cut off of >.39 for inclusion in a factor (19,20). Subsequently, a 2PL IRT model (discrimination and difficulty) was fit. Two theta values (measurement of the underlying construct of the OCS tasks) were estimated for each participant: one based on the full form with all 12 subtasks, and one based on the proposed short form with the pre-selected tasks covering the different cognitive domains.

Development: Results

CFA and IRT modelling

The unidimensional CFA model showed a good model fit (CFI: 0.981, RMSEA: 0.024). All factor loadings were significant and salient (above 0.40). No signs of local dependency were found. All subtasks of the OCS had discriminations above 1, and all subtasks had relatively high difficulty on average (mean difficulty= 1.95; *SD*= .44; range= 1.19 to 2.73). Using different numbers of subtests with the highest discriminations (the discrimination parameter indicates the overall information one can obtain from each subtest), one can observe a decreasing correlation between the estimated theta and the full-scale theta. With three subtests, the correlation is .72. With six subtests, the correlation is .85. Assuming this unidimensional structure, the results suggest that we could shorten the test by half without losing much precision.

Several models were found with sufficient correlations between the thetas, we report data from model 1 (r=.93) consisting of: orientation, number calculation, verbal memory, praxis , broken hearts, trails, sentence reading. See underlying code for additional information for each other model. Some tasks were replaced with more sensitive versions from OCS-Plus and the eventual Mini-OCS is composed of the following 9 subtasks; 1) orientation, 2) calculation, 3) word encoding and 4) recall (OCS-Plus), 5) meaningless gesture imitation, 6) shortened broken hearts test, 7) mixed trails (OCS-Plus), 8) delayed word recall

(OCS-Plus), and 9) sentence reading. The broken hearts task has three metrics; a) total accuracy, b) object asymmetry (calculated as the number of right-gap hearts taken from the number of left-gap hearts), and c) space asymmetry (calculated as the number of correct hearts on the left four divisions of the stimuli sheet from the rightmost four divisions of the sheet.

Theoretical and practical factors

To reduce time, multiple-choice options were only to be used if language and communication difficulties were present. To reduce materials, the instructions for the cancellation and trail making tasks moved onto the test sheet for reference. We further generated a short version of the broken hearts test which was developed with 30 hearts, rather than 50 target hearts. The shortened hearts task involved similar crowding of the remaining 90 hearts (30 targets, 60 distractors) on a vertically centred subsection of the page to keep the cognitive load whilst shortening administration. We also changed the shortened broken hearts test to have thicker lined hearts outlines, with an approximate visual acuity of 1.0 LogMAR equivalent at 30cm distance, to aid those with poorer visual acuity or lack of availability of their reading glasses. This lower visual acuity adaptation of the OCS broken hearts task was developed with orthoptic input as part of a separate project (21). Four pages per patient are required for the Mini-OCS: 1) examiner form, 2) mixed trails practice sheet, 3) the mixed trails test sheet, and 4) shortened broken hearts cancellation. In addition, a reusable test booklet contains a mixed trails demonstration page, large print sentence reading task page along with

multiple-choice questions and answers for those with limited to no expressive speech. All materials are available through Oxford University Innovations, who hold the copyright. Licences are provided free of charge for publicly funded research and clinical use.

Psychometric study: Methods

Participants

We recruited chronic stroke survivors (approximately at least 6 months post stroke) from our research volunteer database including people who had previously taken part in the Oxford Cognitive Screening studies (OCS-RECOVERY [REC reference 18/SC/05501, IRAS project ID: 241571] and OX-CHRONIC [REC reference 19/SC/0530, IRAS project ID: 259478]). All stroke survivors were based in the community at time of recruitment. Self-reported neurologically healthy controls were recruited either from our healthy ageing research volunteer database or were family/friends/partners of the stroke survivors in the study. Details of recruitment adverts are reported in supplementary materials. Neurologically healthy adults were included to generate normative data for the Mini-OCS.

Stroke survivors were included if they met the following inclusion criteria: 1) confirmed clinical stroke diagnosis from medical notes, 2) able to concentrate for at least 20 minutes (judged by the participant), and 3) able to give informed consent (mental capacity assessed as part of consent process following approved protocol). Neurologically healthy controls were included if they met the following inclusion criteria: 1) no

self-reported neurological or psychiatric complaints or diagnoses; and 2) a Montreal Cognitive Assessment (MoCA) score > 22 (11) on the day of participation. Note, this reduced cut off was used in line with the recommended adjusted cut-off for stroke (22), and the inclusion of older adults where the original cut off may be too strict (e.g., (23))

Exclusion criteria for both groups included sensory/perceptual/motor impairments that would prevent the ability to complete the tasks beyond reasonable adjustment (not inclusive of wheelchair/assistance use, which still allowed participants to complete the tasks). A priori power calculations indicated a minimum of 182 participants for the convergent/discriminant validity correlation analyses (alpha = .05/24 (where 24 = 12 Mini-OCS tasks analysed at least twice – Bonferroni correction), power = 90%, one sided, correlation >.30).

Measures

We administered the Montreal Cognitive Assessment (MoCA) and a brief battery of neuropsychological assessments chosen for their format- and construct-relevance to Mini-OCS subtasks to determine evidence of validity. Tasks were: the Oxford Cognitive Screen (13); the Comprehensive Aphasia Test battery number multiple-choice number calculations (range 0-6) (24) with a cut off of <4 (25); the Boston Diagnostic Aphasia Examination pretended objects and (range 0-24; 8 items ranked 0-3 on accuracy gesturing picking them up and using them) with a cut off of <19, and 10 sentence reading subtasks (range 0-10, cut off <2) (26,27); The Cognitive Linguistic Quick Test symbol trails (a cut

off of <8) (28); and the Behavioral Inattention Test star cancellation (range 0-54 on accuracy, with a cut off of 44, and egocentric neglect cut off of less than -.43 referring to left-neglect and a score greater than .56 referring to right neglect (29)) (30).

Data analysis

We assessed several aspects of the new test's reliability and validity before generating normative data. We present participant demographics, new normative data, summarised reliability and test-retest reliability, and validity, as well as known-group differences for Mini-OCS performance, with supplemental materials presenting detailed analyses. Benchmark for convergent/discriminant validity is r >(or< for discriminant validity).30 (22,31,32).

The total score for the Mini-OCS was generated via the 'lavPredict' function from the 'lavaan' package (33) which used regression to calculate factor scores on the basis of a confirmatory factor analysis (maximum likelihood estimator) using all raw subtask scores. We examined modification indices and included the covariances between specific items from the same subtask to allow for better model fit; these are as follows.

Statistical analysis software

All statistical analysis and data wrangling was computed in R Studio version 4.0.4 (34). We used the following additional packages for the

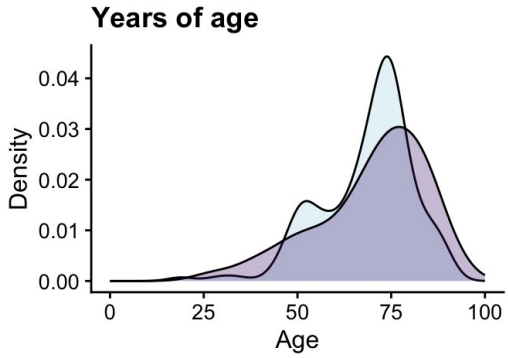
production of the RMarkdown manuscript and analysis: readxl version 1.3.1 (35); cowplot version 1.1.1 (36); ggplot2 version 3.3.5 (37); kableExtra version 1.3.4 (38); ggpubr version 0.6.0 (39); and tidyr 1.2.0 (40). For statistical analyses, lavaan version 0.6.12 (33), psych version 2.4.3 (41), and catR version 3.17 (42,43) were used. Data and analysis scripts to recreate the manuscript are openly available in CC-BY 4.0 license (https://doi.org/10.17605/OSF.IO/CE3ZS).

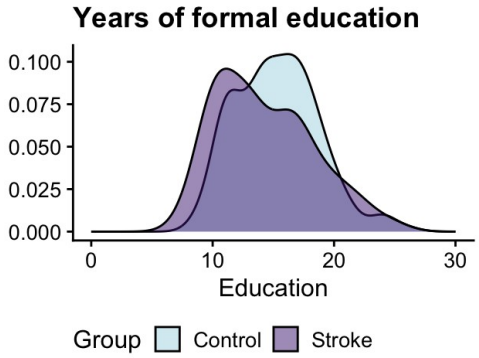
Psychometric study: Results

Participants

In total, 164 neurologically healthy adults and 89 stroke survivors completed the Mini-OCS. All demographics are reported in Table 1 and Figure 1. Sample groups were statistically different in years of education $t(166.45)=2.18, p=.03$, d=-0.3, 95% CI for Cohen's d = -.55 to -0.04, but not in age $t(153.12)=-0.65, p=.52$, d=0.09, 95% CI for Cohen's d = -0.17 to 0.35.

Figure 1. Density distribution of key sample characteristics (for both the normative and stroke cohort sample) of age, education, and stroke severity (for the stroke sample only) via the National Institute of Health Stroke Scale (NIHSS).


Years of age
Density
0.04
0.03
0.02
0.01
0.00
0
25
50
75
100
Age


Years of formal education
0.100
0.075
0.050
0.025
0.000
0
10
20
30
Education
Group
Control
Stroke

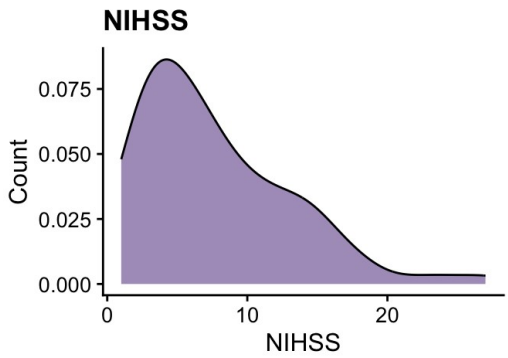

NIHSS
Count
0.075
0.050
0.025
0.000
0
10
20
NIHSS

Table 1. Summary of sample characteristics for all participants

Demographic	Controls		Stroke	
	N (Missing %)	Value	N (Missing %)	Value
Age (*M*(*SD*))	164 (0%)	68.66 (12.18)	89 (0%)	69.86 (14.83)
Education (*M*(*SD*))	164 (0%)	15.4 (3.64)	89 (0%)	14.29 (4.01)
Handedness	164 (0%)	R= 89.02% L= 10.37% B= 0.61%	89 (0%)	R= 85.39% L= 12.36% A= 1.12% B= 1.12%
Sex	164 (0%)	F= 64.63% M= 35.37%;	89 (0%)	M= 55.06% F= 44.94%
Ethnicity	164 (0%)	White: English, Welsh, Scottish, Northern Irish or British= 85.98% White: Any other white background= 9.15% White: Irish= 1.22% Asian or Asian British: Chinese= 0.61% Asian or Asian British: Indian= 0.61% Black, Black British, Caribbean, or African: Caribbean= 0.61% Mixed or multiple ethnic groups: Any other Mixed or multiple ethnic group background= 0.61% Mixed or multiple ethnic	89 (0%)	White: English, Welsh, Scottish, Northern Irish or British= 91.01% Other ethnic group: Any other ethnic group= 2.25% Asian or Asian British: Any other Asian background= 1.12% Asian or Asian British: Indian= 1.12% Black, Black British, Caribbean, or African: Any other Black, Black British, Caribbean, or African background= 1.12% Black, Black British, Caribbean, or African: Caribbean= 1.12%

Demographic	Controls		Stroke	
	N (Missing %)	Value	N (Missing %)	Value
		groups: White and Asian= 0.61% White: Roma= 0.61%;		White-British= 1.12% White: Any other white background= 1.12%;
Days since stroke (*M*(*SD*))	-	-	84 (6%)	597.02 (881.12, 167-4472)
Stroke Type	-	-	84 (8.38%)	ischaemic= 78.57% intracerebral haemorrhage= 15.47% multiple= 2.38% subarachnoid haemorrhage= 1.19%
Stroke Side	-	-	84 (6%)	R= 48.81% L= 40.48% B= 5.95%
Stroke Severity (Median(IQR))	-	-	84 (6%)	6.50(4-11)
Modified Rankin Scale (mRS)	158 (4%)	0= 94.94% 1= 3.16% 2= 1.9%	80 (10%)	0= 13.75% 1= 18.75% 2= 18.75% 3= 36.25% 4= 6.25% 5= 6.25%

Note. Missing data is presented in parentheses as a percentage next to N per demographic. Stroke severity is established via the National Institute of Health Stroke Scale. We used ethnic categories devised by the UK government census data 2021.

Psychometric evidence

Extensive psychometric evidence for the Mini-OCS is presented in supplementary materials; including reliability over time, by comparing a mixed sample (neurologically healthy ageing and stroke) on their first and retested Mini-OCS scores; convergent and discriminant validity against the MoCA as a reference standard for chronic stroke cognitive screening and against the construct and format matched neuropsychological battery, using correlational analyses in the full mixed sample. For test-retest reliability, we used ANCOVA analyses covarying for change in MoCA score as a reference standard for cognition across time and found no differences in Mini-OCS performance. When we examined the percentage of scores between test and retest that were identical, the percentages varied between tasks, but ranged from 39.13% for broken hearts total score to 91.30% for orientation scores (M=65.61%, SD=19.19% - excluding time taken in seconds). For convergent validity, all Mini-OCS scores correlated with at least one comparison task per comparison (e.g., some metrics used more than one comparison task) above a pre-defined benchmark of r=.30, except broken hearts ego- and allo-centric neglect. For discriminant validity, none exceeded the benchmark of r=.30.

The model fit of the Mini-OCS total score was acceptable; $x^2(41)=44.93$, p=.31, CRI = .92, TLI = .89, RMSEA = .02, SRMR = .056, suggesting a unidimensional model fits the current data. The predicted factor scores are referred to as ‘Mini-OCS total score’ henceforth.

Normative data for Mini-OCS

We present normative data for the Mini-OCS taken from all neurologically healthy aging adults. The Mini-OCS took on average 7.33 minutes to complete (*SD*=1.63, range = 4-13minutes) by controls. We used 5th centile cut offs for accuracy scores and 95th centile cut offs for error scores in general, with the exception of executive function trails, cancellation accuracy, and time to complete, which use a 1.65 *SD* cut off, similar to previously used in the OCS-Plus (15). The normative data cutoffs are presented in Table 2 and further stratified by age classification for further information. Age brackets were chosen by selecting the most equal segregation of age groups using the 'split' function in r. Finally, to aid interpretation of impairment on the Mini-OCS, we examined sample differences in Mini-OCS performance; the results are presented in Table 3.

Table 2. Normative data for the Mini-OCS including 5th and 95th centile cut offs, and for wider range tasks, 1.65*SD* based cut offs for classifying possible cognitive impairment per task, further stratified by age classification grouping.

	All neurologically healthy aging adults							<68yrs			68-76yrs			>76yrs		
Measure	N	Mean (*SD*)	Min	Max	5th	95th	1.65 *SD*	5th	95th	1.65 *SD*	5th	95th	1.65 *SD*	5th	95th	1.65 *SD*
Orientation	164	3.99 (0.11)	3	4	<4			<4			<4			<4		
Number calculations	123	3.76 (0.45)	2	4	<3			<3			<3			<3		
Immediate recall 1	164	4.41 (0.85)	0	5	<3			**<2**			**<4**			<3		
Immediate recall 2	164	4.90 (0.38)	2	5	<4			**<5**			<4			<4		
Meaningless gesture imitation (praxis)	164	1.87 (0.4)	0	2	<1			<1			<1			<1		
Broken hearts total	164	28.6 (2.25)	10	30	<25		<25	**<24**		**<24**	**<27**		**<27**	<25		<25
Broken hearts allocentric neglect	164	0.02 (0.22)	-1	1	<0	>0		**<-2**	**>3**		**<-1**	**>2**		<0	>2	
Broken hearts egocentric neglect	164	0.29 (1.19)	-6	4	<-1	>2		**<0**	**>0**		**<0**	**>0**		**<0**	**>0**	
Executive function	123	11.56 (4.03)	0	14			<5			<5			**<7**			**<2**
Delayed recall	164	3.85 (1.35)	0	5	<1			**<2**			**<1**			**<0**		
Sentence reading	164	14.68 (0.61)	12	15	<13			**<14**			<13			**>14**		
Time (seconds)	164	439.88 (97.33)	240	780		>600	>293.88		>600	**>284.00**		**>540**	**>275.86**		**>678**	**>317.42**
Mini-OCS total score	164	0 (0.27)	-1.91	0.17	-0.28		-0.45	-0.24		-0.35	-0.34		-0.6	-0.28		-0.25

Note. The cut off for executive function used the 1.65SD based cut, the rest of the tasks used 5th centile in general or both 5th and 95th centile for allo- or ego-centric neglect. Normative data for the trails and number

calculation tasks were taken only from Mini-OCS version 1.4.1 onwards - see supplementary data for details. Differences in age group cut offs from the overall control sample are noted with bold cut offs. All values are rounded to nearest whole number except for time.

Table 3. Descriptive statistics (M(SD)for neurologically healthy ageing controls and stroke survivors on Mini-OCS metrics, with ANCOVA sample differences analyses (covarying for education differences).

Measure	Control *M*(*SD*)	Stroke *M*(*SD*)	ANCOVA	% Stroke survivors impaired
Orientation	3.99 (0.11)	3.78 (0.56)	F(1,250)=20.68, p<.001**, partial eta squared=0.08	6.72%
Number calculations	3.76 (0.45)	3.37 (0.95)	F(1,250)=18.64, p<.001**, partial eta squared=0.07	2.77%
Immediate recall 1	4.41 (0.85)	3.81 (1.24)	F(1,250)=18.25, p<.001**, partial eta squared=0.07	8.30%
Immediate recall 2	4.9 (0.38)	4.31 (0.95)	F(1,250)=44, p<.001**, partial eta squared=0.15	6.32%
Meaningless gesture	1.87 (0.40)	1.64 (0.69)	F(1,250)=9.77, p=0.002**, partial eta	5.93%

Measure	Control *M*(*SD*)	Stroke *M*(*SD*)	ANCOVA	% Stroke survivors impaired
imitation (praxis)			squared=0.04	
Broken hearts total	28.6 (2.25)	26.62 (6.03)	F(1,250)=14.44, p<.001**, partial eta squared=0.06	11.07%
Broken hearts allocentric neglect	0.02 (0.22)	0.11 (1.05)	F(1,250)=0.56, p=.453, partial eta squared=0	7.91%
Broken hearts egocentric neglect	0.29 (1.19)	0.13 (1.63)	F(1,250)=0.89, p=0.347, partial eta squared=0	10.67%
Executive function	11.56 (4.03)	8.99 (5.11)	F(1,250)=11.91, p=0.001**, partial eta squared=0.04	10.28%
Delayed recall	3.85 (1.35)	3.08 (1.63)	F(1,250)=13.97, p<.001**, partial eta squared=0.05	5.53%
Sentence reading	14.68 (0.61)	13.99 (2.09)	F(1,249)=16.26, p<.001**, partial eta squared=0.06	3.57%
Overall duration	439.88 (97.33)	522 (157.85)	F(1,239)=24.18, p<.001**, partial eta squared=0.09	98.76%
Mini-OCS total score	0 (0.27)	-0.02 (0.27)	F(1,250)=0.36, p=.551, partial eta squared=0	5.93%

Note. ‘**’ refers to significance below an alpha corrected level of .05/13 = .003.

Discussion

We developed and presented psychometric reliability and validity evidence as well as normative data for a stroke specific brief form cognitive screening tool for use in chronic stroke: the Mini-Oxford Cognitive Screen (Mini-OCS). The Mini-OCS is a reliable and valid rapid screen taking less than eight minutes to complete on average with new, age stratified, normative data. Allo- and ego-centric neglect measure were not validated, which may be explained by lack of variance in scores due to low levels of neglect subtypes found. Mini-OCS performance scores were able to differentiate stroke survivors from neurologically healthy controls even when accounting for education effects, with overall 7.9% of chronic stroke survivors showing an impairment. Time taken to complete the Mini-OCS was consistently slower than the controls, confirming an overall slowing of responses and processing speed typically found (44,45).

Normative data

There were ceiling effects found in the allocentric neglect, orientation, meaningless gesture imitation, and the second immediate recall, where the range was small, and most controls performed with no errors. These lower range tasks may be useful in the wider context of Mini-OCS to differentiate those with more severe cognitive impairment or large changes in cognition over time.

Age adjusted cut offs differentially affected Mini-OCS subtasks. Orientation and number calculation were unaffected by age, with all cut offs being identical. Immediate recall 1 and 2 had different cut offs, suggesting some sensitivity to age related cognition. Interesting effects were found in the broken hearts total, where participants in the middle age group performed worse than those in the oldest age group, resulting in a higher 5th centile cut off of 27. Education and age cut offs were not possible due to very small numbers in combination. Education based cut offs were not generated as there were very minimal education effects except for immediate recall, as seen in the supplementary materials Table S3.

No age/education differences on Mini-OCS subtasks with a restricted range of outcome scores (e.g., orientation, number calculations, allo- and ego-centric neglect) reflect the qualitative rather than quantitative nature of interpretation of performance, with neurologically healthy adults performing at ceiling. Future studies are invited to continuously extend the norm data which will enable us to divide participants in more narrow age and education groups and define their cut-off values in a dynamically evolving normative base.

Psychometrics

For test-retest reliability we found great consistency between time points on Mini-OCS subtasks with no group differences found in performance. We acknowledge that other methodologies of assessing test-retest reliability are superior such as intraclass correlation coefficients

accounting for practice effects. However, the range of Mini-OCS tasks precluded the use of continuous variable analyses, thus ANCOVA was used to indicate test-retest stability.

We found evidence of convergent and discriminant validity, allowing us to conclude that the Mini-OCS is most likely to measure what it is intended to measure in each subtask. Though the correlations were not exceptionally high, it is not necessarily common practice for them to be in neuropsychological psychometrics (15,22,46), and large correlations found in general psychology tend to be around r=.40 (47). There were some differences between associations of OCS and neuropsychological subtests. For instance, whilst the Mini-OCS orientation subtest was significantly associated with both MoCA orientation and OCS orientation subtests, Mini-OCS orientation was only associated with OCS orientation over the pre-defined benchmark of r=.30, which we suggest is down to the exact questions used being identical between tasks. Note here, even with identical questions asked on different tasks, the correlation between subtasks was only r=.45, which could be due to practice effects of realizing one makes a mistake and correcting for it in subsequent task – which subtask this affected was controlled for in counterbalancing, but it does not remove the effect.

Study limitations

Our neurologically healthy control sample was more highly educated than our patient sample and this may restrict the interpretation of an individual's performance where they have low levels of education. Test–

retest reliability was assessed based on a relatively small subsample of mostly controls, as such, potential variance in scores is lost where stroke survivors may change over time. Whilst the present data provide first insights into the reliability of the Mini-OCS over time, future studies are needed to assess test–retest reliability in standardized and clinically relevant intervals, in addition to internal consistency.

Conclusions and future directions

The Mini-OCS was developed based on item response theory modeling of the full OCS in combination with executive functioning and memory tasks from the OCS-Plus. The Mini-OCS was normed in 164 neurologically healthy adults and validated in a cohort of 89 stroke survivors and controls. The psychometric properties of the Mini-OCS confirm it as a reliable and valid assessment of cognition for use in chronic stroke. Further research should examine test-retest reliability and the feasibility and practical implementation of using the Mini-OCS in primary care and community settings.

References

1. Feigin VL, Stark BA, Johnson CO, Roth GA, Bisignano C, Abady GG, et al. Global, regional, and national burden of stroke and its risk factors, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. The Lancet Neurology. 2021 Oct 1;20(10):795–820.

2. Johnson CO, Nguyen M, Roth GA, Nichols E, Alam T, Abate D, et al. Global, regional, and national burden of stroke, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. The Lancet Neurology. 2019 May 1;18(5):439–58.

3. Kusec A, Milosevich E, Williams OA, Chiu EG, Watson P, Carrick C, et al. Long-term psychological outcomes following stroke: The OX-CHRONIC study. BMC Neurology. 2023;(23):426.

4. Milosevich ET, Moore MJ, Pendlebury ST, Demeyere N. Domain-specific cognitive impairment 6 months after stroke: the value of early cognitive screening. medRxiv. 2023;2023–06.

5. Nys GMS, van Zandvoort MJE, de Kort PLM, Jansen BPW, de Haan EHF, Kappelle LJ. Cognitive Disorders in Acute Stroke: Prevalence and Clinical Determinants. Cerebrovasc Dis. 2007;23(5–6):408–16.

6. Stroke Association. Lived Experience of Stroke Report [Internet]. 2018 [cited 2020 Nov 11]. Available from: http://www.stroke.org.uk/sites/default/files/conferences/nisc/documents/lived_experience_of_stroke_chapter_1.pdf

7. Intercollegiate Stroke Working Party. National Clinical Guideline for Stroke for the UK and Ireland [Internet]. Intercollegiate Stroke Working Party; 2023. Available from: www.strokeguideline.org

8. Rudd AG, Bowen A, Young G, James MA. National clinical guideline for stroke: 2016. Clinical Medicine. 2017;

9. Quinn TJ, Richard E, Teuschl Y, Gattringer T, Hafdi M, O'Brien JT, et al. European Stroke Organisation and European Academy of Neurology joint guidelines on post-stroke cognitive impairment. European Stroke Journal. 2021 Oct 8;23969873211042192.

10. Lin B lei, Mei Y xia, Wang W na, Wang S shan, Li Y shuang, Xu M ya, et al. Unmet care needs of community-dwelling stroke survivors: a systematic review of quantitative studies. BMJ open. 2021;11(4):e045560.

11. Nasreddine ZS, Phillips NA, Bédirian V, Charbonneau S, Whitehead V, Collin I, et al. The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. Journal of the American Geriatrics Society. 2005;53(4):695–9.

12. Rost NS, Brodtmann A, Pase MP, van Veluw SJ, Biffi A, Duering M, et al. Post-Stroke Cognitive Impairment and Dementia. Circulation Research. 2022 Apr 15;130(8):1252–71.

13. Demeyere N, Riddoch MJ, Slavkova ED, Bickerton WL, Humphreys GW. The Oxford Cognitive Screen (OCS): Validation of a stroke-specific short cognitive screening tool. Psychological assessment. 2015;27(3):883.

14. Murphy D, Cornford E, Higginson A, Norman A, Long R, Noad R. Oxford cognitive screen: A critical review and independent psychometric evaluation. Journal of Neuropsychology. 2023;17(3):491–504.

15. Demeyere N, Haupt M, Webb SS, Strobel L, Milosevich E, Moore MJ, et al. Introducing the tablet-based Oxford Cognitive Screen-Plus (OCS-Plus) as an assessment tool for subtle cognitive impairments. Sci Rep [Internet]. 2021 [cited 2020 Oct 12];11(8000). Available from: https://psyarxiv.com/b2vgc/

16. Gong N, Yang D, Zou J, He Q, Hu L, Chen W, et al. Exploring barriers to dementia screening and management services by general practitioners in China: a qualitative study using the COM-B model. BMC Geriatrics. 2023 Jan 31;23(1):55.

17. Gagnier JJ, Lai J, Mokkink LB, Terwee CB. COSMIN reporting guideline for studies on measurement properties of patient-reported outcome measures. Qual Life Res. 2021 Aug;30(8):2197–218.

18. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. The Lancet. 2007 Oct 20;370(9596):1453–7.

19. Lyden P, Claesson L, Havstad S, Ashwood T, Lu M. Factor Analysis of the National Institutes of Health Stroke Scale in Patients With Large Strokes. Archives of Neurology. 2004 Nov 1;61(11):1677–80.

20. Li J, Li Y, Li P, Ye M. Early Symptom Measurement of Post-Stroke Depression: Development and validation of a new short version. Journal of Advanced Nursing. 2019;75(2):482–93.

21. Hepworth LR, Helliwell B, Wright L, Demeyere N. Adaptation of the Oxford Cognitive Screen to increase accessibility for reduced visual acuity. In preparation. 2024;

22. Webb SS, Demeyere N. Comparing the Oxford Digital Multiple Errands Test (OxMET) to a real-life version: convergence, feasibility, and acceptability. 2023 Dec 23;

23. Malek-Ahmadi M, Powell JJ, Belden CM, O'Connor K, Evans L, Coon DW, et al. Age- and education-adjusted normative data for the Montreal Cognitive Assessment (MoCA) in older adults age 70-99. Neuropsychol Dev Cogn B Aging Neuropsychol Cogn. 2015;22(6):755–61.

24. Swinburn K, Porter G, Howard D. Comprehensive aphasia test. 2004 [cited 2024 Apr 8]; Available from: https://psycnet.apa.org/doiLanding?doi=10.1037/t13733-000

25. Jensen BU, Norvik MI, Simonsen HG. Statistics and psychometrics for the CAT-N: Documenting the Comprehensive Aphasia Test for Norwegian. Aphasiology. 2024 Mar 3;38(3):412–39.

26. Borod JC, Goodglass H, Kaplan E. Normative data on the boston diagnostic aphasia examination, parietal lobe battery, and the boston naming Test. Journal of Clinical Neuropsychology. 1980 Nov;2(3):209–15.

27. Fong MWM, Van Patten R, Fucetola RP. The Factor Structure of the Boston Diagnostic Aphasia Examination, Third Edition. J Int Neuropsychol Soc. 2019 Aug;25(7):772–6.

28. Helm-Estabrooks N. Cognitive linguistic quick test: CLQT. Psychological Corporation; 2001.

29. Halligan P, Robertson I, Pizzamiglio L, Homberg V, Weber E, Bergego C. The laterality of visual neglect after right hemisphere damage. Neuropsychological Rehabilitation. 1991 Oct;1(4):281–301.

30. Wilson B, Cockburn J, Halligan P. Development of a behavioral test of visuospatial neglect. Archives of physical medicine and rehabilitation. 1987;68(2):98–102.

31. Webb SS, Hobden G, Roberts R, Chiu EG, King S, Demeyere N. Validation of the UK English Oxford cognitive screen-plus in sub-acute and chronic stroke survivors. European Stroke Journal. 2022 Aug 19;23969873221119940.

32. Rotenberg S, Ruthralingam M, Hnatiw B, Neufeld K, Yuzwa KE, Arbel I, et al. Measurement Properties of the Multiple Errands Test: A Systematic Review. Archives of Physical Medicine and Rehabilitation. 2020;101(9):1628–842.

33. Rosseel Y. lavaan: An R package for structural equation modeling. Journal of Statistical Software. 2012;48(2):1–36.

34. R Core Team. R: A language and environment for statistical computing [Internet]. Vienna, Austria: R Foundation for Statistical Computing; 2022. Available from: https://www.R-project.org/

35. Wickham H, Bryan J. readxl: Read excel files [Internet]. 2019. Available from: https://CRAN.R-project.org/package=readxl

36. Wilke CO. cowplot: Streamlined Plot Theme and Plot Annotations for 'ggplot2' [Internet]. 2020. Available from: https://CRAN.R-project.org/package=cowplot

37. Wickham H. ggplot2. 2nd ed. 2016. Cham: Springer International Publishing; 2016.

38. Zhu H. kableExtra: Construct complex table with 'kable' and pipe syntax [Internet]. 2021. Available from: https://CRAN.R-project.org/package=kableExtra

39. Kassambara A. ggpubr: 'ggplot2' based publication ready plots [Internet]. 2023. Available from: https://CRAN.R-project.org/package=ggpubr

40. Wickham H. tidyr: Tidy messy data [Internet]. 2021. Available from: https://CRAN.R-project.org/package=tidyr

41. Revelle W. psych: procedures for personality and psychological research. Northwestern University, Evanston. 2018.

42. Magis D, Barrada JR. Computerized adaptive testing with R: Recent updates of the package catR. Journal of Statistical Software, Code Snippets. 2017;76(1):1–19.

43. Magis D, Raîche G. Random generation of response patterns under computerized adaptive testing with the R package catR. Journal of Statistical Software. 2012;48(8):1–31.

44. Low E, Crewther SG, Ong B, Perre D, Wijeratne T. Compromised motor dexterity confounds processing speed task outcomes in stroke patients. Frontiers in neurology. 2017;8:484.

45. Forstmann BU, Tittgemeyer M, Wagenmakers EJ, Derrfuss J, Imperati D, Brown S. The speed-accuracy tradeoff in the elderly brain: a structural model-based approach. Journal of Neuroscience. 2011;31(47):17242–9.

46. Webb SS, Anders J, Chiu EG, Payne F, Basting R, Duta MD, et al. The Oxford Digital Multiple Errands Test (OxMET): Validation of a Simplified Computer Tablet Based Multiple Errands Test. Neuropsychological Rehabilitation. 2021;

47. Funder DC, Ozer DJ. Evaluating effect size in psychological research: Sense and nonsense. Advances in Methods and Practices in Psychological Science. 2019;2(2):156–68.