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## Validation of French upper-limb Erasmus modified Nottingham Sensory Assessment in stroke

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### Abstract

**Background.** Somatosensory impairment of the upper limb (UL) occurs in approximately 50% of adults post-stroke, associated with loss of hand motor function, activity and participation. Measurement of UL sensory impairment is a component of rehabilitation

contributing to the selection of sensorimotor techniques optimising recovery and providing a prognostic estimate of UL function. To date, no standardized official French version of a measure of somatosensory impairment has been established.

**Objective.** To develop and validate a French version of the Erasmus modified Nottingham Sensory Assessment somatosensory (EmNSA-SS) and stereognosis (EmNSA-ST) component for evaluating the UL among adults with stroke.

**Methods.** This study is a single-center observational cross-sectional study. A French version of the EmNSA for UL was developed by forward-backward translation and cross-cultural adaptation. Fifty stroke patients were recruited to establish concurrent criterion-related validity, internal consistency, intra- and inter-rater reproducibility with intraclass correlation coefficients (ICCs) for reliability and the minimal detectable change with 95% confidence interval (MDC95) for agreement, as well as ceiling and floor effects. Criterion validity was assessed against the Fugl-Meyer Assessment-Sensory (FMA-S) for the UL.

**Results.** The median (range) EmNSA-SS score was 41.5 (1-44). The Spearman rank correlation coefficient between EmNSA-SS and FMA-S total scores was moderate ( $\rho=0.74$ ,  $P<0.001$ ). The EmNSA-SS/ST internal consistency was adequate across subscales; with Cronbach  $\alpha$  ranging from 0.82-0.96. For the EmNSA-SS total score, intra- and inter-rater reliability was excellent (ICC=0.92 in both cases), with MDC95 of 12.3 and 14.6, respectively. EmNSA-SS/ST total scores demonstrated no ceiling or floor effects.

**Conclusions.** The French EmNSA is a valid and reproducible scale that can be used for comprehensive and accurate assessment of somatosensory modalities in adults post-stroke. Taking less than 30 min to administer, the instrument has clinical utility for use in patients with cognitive comorbidities and at various stages of recovery in multidisciplinary clinical practice and research settings.

**Keywords:** Stroke, Upper Extremity, Outcome Assessment, Somatosensory Disorders, Reproducibility of Results.

## Introduction

Somatosensory impairment occurs in 60% to 89% of adults with stroke [1,2]. Impaired tactile capacity of the paretic hand, due to cerebral lesions altering somatosensory processing, is common in half of the patients with stroke [1–5]. Sensory processing is a component of normal movement because input is processed via somatosensory modalities producing sensorimotor output necessary for hand motor function and control [3,6,7]. Somatosensory feedback allows manipulation, coordination and strength skills to be adapted to tasks and the environment [2,3,8,9]. Sensory damage after stroke affects performance due to loss of arm movement impacting activity, participation and consequently quality of life in individuals post-stroke [2,10–12].

Integration of sensory modalities in clinical sensorimotor rehabilitation should be based on quantitative evaluation to optimize selection and implementation of appropriate techniques contributing to improved outcomes [1,2,13]. Measures with established psychometric properties contribute to prognostic estimates of loss of movement and function [4,5]. Somatosensory impairment is associated with longer hospital stays, which illustrates the prognostic utility of assessment for recovery post-stroke [2,4,14]. Clinical practice should include relevant measures to assess sensory impairment; however, measures of sensory impairment warrant further development to contribute to evidence-based practice and facilitate professional communication throughout the rehabilitation process [2,15,16].

The current literature reveals few standardized sensory assessments for stroke with established validity and reliability [16]. The development of sensory assessments evaluating exteroceptive, proprioceptive and cortical sensory functions is recommended for stroke,

warranting attention from research and clinical practice [16,17]. Exteroceptive sensation, also termed superficial sensation, refers to tactile or touch, pain, temperature sensations and sensory perversions [17]. Limitations arise from issues including lack of generalizability, subjectivity of assessment, and lack of standardized protocols [18,19]. Evaluations may not consider the impact of neurological comorbidities on results (such as cognitive deficits and aphasia) due to strict inclusion and exclusion criteria, so the measures are best suited for use with musculoskeletal, rheumatic and/or peripheral nerve disorders [19–21].

The Nottingham Sensory Assessment (NSA), Fugl-Meyer Assessment-Sensory Section (FMA-S) and the Rivermead Assessment of Sensory Processing are standardized tools showing clinical relevance for the stroke population [21–23]. The FMA-S does not provide a comprehensive assessment of somatosensory capacity post-stroke but does provide a standardized assessment of tactile and proprioception in French. The tactile light-touch subscale demonstrates poor to moderate reliability (weighted kappa from 0.3-0.55) and low to moderate validity (rho from 0.29-0.53) with the Barthel Index, as well as a significant ceiling effect, which explains its decreased use in clinical trials [18,19,24]. Lack of published protocols contribute to low reliability and weak face validity, thus indicating a need for further testing of psychometric qualities [16,18,24]. The Rivermead Assessment of Sensory Processing demonstrates good intra- and inter-reliability; however, its restricted heterogeneity, with cognitive impairment and comprehension difficulties excluded, and non-probability sampling limit generalizability of its use among the general stroke population [21].

The original NSA is a standardized measure created specifically for adults with stroke, demonstrating good intra-rater reliability but poor inter-rater reliability [15,19,23]. The tool, now known as the Revised NSA, was shortened, and a hierarchized protocol established reducing testing time [15]. This version demonstrates good intra-rater reliability and

acceptable inter-rater reliability in English [15,19]. The standardized tool is time- and cost-effective, demonstrating clinical utility among adults post-stroke [9,15].

The Revised NSA was modified as the Erasmus modification of the NSA (EmNSA), demonstrating good to excellent ( $k > 0.75$ ) intra- and inter-reliability kappa coefficients among 18 adults with intracranial disorders [7]. Modifications included removal of the temperature test due to poor psychometric qualities, the addition of sharp-blunt discrimination, modification of two-point discrimination testing, standardization and cartography of defined points of testing, as well as standardization of a uniform scoring system [7]. The stereognosis component of the NSA can be used as an accompanying scale to the EmNSA. The 10-item scale is an established measure demonstrating reliability between assessors; however, the small sample size ( $n = 20$ ), strict exclusion criteria and non-probability sampling techniques limit its generalizability [6].

At present, there are no standardized tools in the French language for somatosensory assessment of UL specific to adults with stroke. Furthermore, validity and reliability testing of such a measure is needed before it can be adopted in clinical practice and research.

The objectives of this study were to translate and cross-culturally adapt the EmNSA in French and to examine and report criterion-related validity, internal consistency, floor and ceiling effects, intra/inter-rater reliability and minimal detectable change for UL in adults with stroke.

## **Methods**

The study consisted of 2 phases, defined as instrument translation and validation, to examine the psychometric properties of the EmNSA.

### **Instrument translation and cross-cultural adaptation**

Only the UL component of the EmNSA was translated, cross-culturally adapted and validated in accordance with study objectives and identified gaps in the literature. Translation was conducted in accordance with guidelines, with outcome measures objectively assessed to ensure culturally specific clinical tools contributing to evidence-based practice [25]. An eight-step translation procedure for self-reported outcome measures, modified for objective-outcome measures, ensured appropriate professional vocabulary of administration procedures relevant for clinical use in a foreign language and face validity [25].

Forward-backwards translation and cross-cultural adaptation were ensured by involving native-speaking professionals and was reviewed by a multi-disciplinary group of medical professionals to check for comprehensiveness and linguistic issues [25,26]. The final version was approved by the original authors. Consensus meetings were carried out to review testing equipment, clarify procedures and scoring to ensure validity [25].

Health professionals with clinical experience in neurological rehabilitation studied whether the EmNSA-SS was representative of somatosensory evaluation for patients with stroke. Procedures and scoring were critiqued by focus groups influencing the inclusion of a stereognosis component (EmNSA-ST) ensuring a comprehensive assessment of somatosensation of the UL in patients with stroke [17]. Lawshe's method describing inter-rater agreement for scale items reflecting the construct of scale measurement as a content validity ratio supported the inclusion of EmNSA items for the development of the instrument [27]. A panel of 9 subject-matter experts rated item relevance as "not necessary; useful but not essential; and essential" to the construct of the measurement of somatosensory capacity. Items included were found to be above the threshold of content-validity ratio critical values congruent with number of matter experts ( $>0.78$ ) [27].

### **Validation phase**

An observational cross-sectional design study was implemented to determine the psychometric properties of the French EmNSA-SS and EmNSA-ST. The single-center study took place in the Neurological Rehabilitation Department of the University Hospital of Toulouse from May 2015 to September 2016. The hospital's ethical committee approved the study (no. 02-0415 on May 18, 2015) and all participants provided informed consent before data collection.

### *Participants*

Participants were recruited by occupational therapy staff from a convenience sample of inpatients with stroke. Eligibility criteria were 1) age > 18 years with principle diagnosis of first-time ischemic or hemorrhagic stroke at least 1 month since onset and confirmed by MRI or CT; (2) subscale of aphasia severity from the Boston Diagnostic Aphasia Examination  $\geq 2$  indicating sufficient comprehension and expression for testing [28]; and 3) motivation to participate and informed written consent. Individuals were excluded if they presented peripheral neuropathy disease, additional central neurological disease or diabetes mellitus. Sample size was determined in accordance with recommendations for reliability studies design [29].

### *Testing procedure*

EmNSA was administered on 3 separate occasions by 2 assessors. The principal assessor administered the Fugl Meyer Assessment–Motor scale (FMA-M), EmNSA and FMA-S for concurrent criterion validity. The same principal assessor conducted a second EmNSA within 7 to 14 days of the first evaluation to establish test–retest intra-rater reliability. Other assessors administered the EmNSA within 3 days for test–retest inter-rater reliability.

Random allocation to testing of the second assessor was ensured. Assessors were 3 certified occupational therapists having undergone training for tool use, further contributing to the study's internal validity.

Blinding of participants and assessors was not possible due to the rehabilitation context, but assessors were blinded to previous results and specifically instructed not to discuss results throughout the study [30]. Pilot testing was conducted by all assessors, and data collection commenced when all assessors established good inter-rater reliability (intraclass correlation coefficient [ICC] > 0.75) to reduce measurement bias [31].

#### *Measurement tools*

The EmNSA was the main outcome measure for UL sensory capacity [7,15,23]. The UL components of the French-Canadian version of the FMA-S and FMA-M subscales were other outcome measures administered to establish criterion validity and illustrate demographic characteristics of participants, respectively [32]. Two-point discrimination was included on the scoring sheet regardless of low reproducibility contributing to a comprehensive assessment of somatosensation [7,17]. Inclusion of stereognosis and its items was also agreed upon in consensus meetings for cross-cultural adaptation and supported by the literature [14,17,23,33].

The EmNSA-SS comprises 22 items of somatosensory functions across 3 subscales including 1) tactile sensation, 2) two-point discrimination, and 3) proprioception. Tactile sensation includes 4 components corresponding to light touch, pressure, pinprick and sharp-blunt discrimination. A maximal score of 44 points on a three-point scale (0 = absent, 1 = impaired, 2 = normal) demonstrates somatosensory capacity [6,7]. The EmNSA-ST comprises 10 items on stereognosis function, with a maximal score of 20 indicating normal function. The complete version of the French EmNSA testing guidelines is in Appendix A,

and its score sheet is in supplementary material. Testing is conducted at the shoulder, elbow, wrist and hand, standardized by instructions and a visual chart presented in Appendix A.

The FMA-S subscale was used to collect data regarding light touch and proprioceptive data for patients with stroke [22,24]. Assessment is conducted by bilateral light touch of anterior and posterior regions, and proprioception [22,24,32]. Scoring is conducted with an ordinal three-point scale (0 = absent, 1 = impaired, 2 = normal).

The FMA-M domain of UL was used to collect UL motor scores. A maximal score of 66 points indicates minimal motor impairment severity correlated with functional ability [9,22].

#### *Data analysis*

Normal distribution of data was assessed by examining graphical interpretations and the Shapiro-Wilk statistic. Quantitative measures for normally distributed variables were described with mean (SD) and skewed variables were described with median (minimum and maximum). Statistical analyses involved using SPSS v22.0 (IBM SPSS Statistics for Windows) and Matlab (Release 2012a, The MathWorks, Inc., Natick).

#### *Verification of hierarchical aspect of the scale*

Hierarchized testing procedures were developed for EmNSA, with the aim to reduce the length of administration if some items could be predictable from the score of other items [7,20]. EmNSA hierarchized testing procedures state that (1) when a score of 2 is assigned for each item (total score is 8 for the whole UL) of light touch modality of the tactile sensation subscale, a score of 2 can be assigned for each pressure and pinprick item (scores of 8 for the whole UL); 2) when a score of 0 or 1 is assigned to an item of at least one of light touch, pressure and pinprick, a score of 0 can be assigned for the same sharp-blunt item; and 3) two-

point discrimination is only tested if a maximal score of 24 was obtained with the additional score of light touch, pressure and pinprick [7]. Verification of the hierarchical aspect of the scale was carried out on data collected by the principal assessor from the first assessment. This was done by recording the number of discrepancies between the scores obtained from hierarchized testing procedures and comparing them to the testing of all items. The number of errors was expressed in percentages of all EmNSA scoring, and the average loss of points was computed.

#### *Concurrent-criterion validity*

Concurrent-criterion validity was examined by comparing the association between the light touch component, proprioception and total scores of EmNSA-SS with the FMA-S collected by the principal assessor. Spearman coefficient ( $\rho$ ) was used because of skewed data in conjunction with visual interpretation of scatterplots. Correlation was classified as poor ( $<0.5$ ), moderate ( $0.5-0.75$ ) and good ( $>0.75$ ) [31].

#### *Internal consistency*

Cronbach  $\alpha$  coefficient was used to analyze the internal consistency of the EmNSA. Values 0.7 to 0.9 were interpreted as excellent ( $>0.8$ ), acceptable ( $0.7-0.8$ ) or low ( $<0.7$ ) [34,35]. Internal consistency was calculated for the total number of items of each subscale measuring the same type of sensation for the EmNSA-SS and EmNSA-ST, as well as the total number of items of 3 subscales representing the total score of the EmNSA-SS UL. Floor and ceiling effects, assessed by frequency analyses were defined as significant if more than 20% of the participants had the lowest or highest possible score, respectively [35].

### *Reproducibility*

Reproducibility concerns the degree to which intra- and inter-rater test–retest measurements provide similar results [37]. ICCs with 95% confidence intervals (CIs) were used to assess the intra- and inter-rater test–retest reliability of the EmNSA subscale and total scores (i.e., the measurement error related to the variability between subjects) [37]. Intra-rater reliability using the ICC<sub>2,1</sub> (two-way random model with absolute agreement) was determined from scores collected by the principal assessor on 2 testing sessions. Inter-rater reliability using the ICC<sub>1,1</sub> (one-way random model with absolute agreement) was determined from scores of the principal assessor in comparison to 2 other assessors [36]. ICC estimates were ranked according to values and interpreted as excellent (>0.75), moderate to good (0.5>0.75), fair (0.25-0.5) or low (0.2) [9,31].

The minimal detectable change with 95% level of confidence (MDC95) was used to assess the intra- and inter-rater test–retest agreement of the EmNSA subscale and total scores (i.e., the measurement error in repeated measurements expressed in the actual scale of the measurement) [37]. MDC95 reflects the smallest detectable change between 2 repeated measures for a given individual, ensuring that this minimum amount of change is not the result of measurement error [31,37]. MDC95 was calculated from the standard error of measurement taking into account systematic differences between the test and retest, suitable for use in clinical evaluation at different times (SEM

agreement):  $SEM = \sqrt{\sigma_{intra}^2 + \sigma_{residual}^2}$ , where  $\sigma_{intra}^2$  is the variance of the individual differences between the test–retest measurements, and  $\sigma_{residual}^2$  is the residual variance of the interaction between intra and inter-individual differences obtained from a repeated-measures ANOVA [37]; and  $MDC95 = 1.96 \times SEM \times \sqrt{2}$  [31].

Bland-Altman plot analysis was used to plot differences in test–retest scores against the mean of the 2 test scores for each participant for visual examination of distribution [38]. When zero

was included within the 95% CI for the test–retest mean differences, no systematic bias was assumed [38].

## **Results**

### **Participants**

The flow of participants in the study is shown in Figure 1. Data were collected from 50 participants who gave informed consent. Characteristics and clinical scores of participants are in Table 1. Score distribution for EmNSA and FMA-S are illustrated in Figure 2. The mean delay for the test–retest intra-rater was 7.1 days (range 4 to 14) and inter-rater delay 2.1 days (range 1 to 7).

### **Protocol and hierarchical aspect of the scale**

Administration time was influenced by hierarchized testing procedures, ranging from 15 to 30 min. No errors were found from testing the hierarchical scoring aspect of tactile sensation associated with the shortened testing method. In other words, a score of 8 for light touch indicates a score of 8 for pressure and pinprick subscales. Hierarchical scoring of the sharp-blunt items was incorrect in 24%, 24%, 16% and 12% of cases for fingers, hand, forearm and arm, respectively. In other words, when a score of 0 or 1 is assigned to an item of at least one of light touch, pressure and pinprick, a score of  $> 0$  was found for the corresponding sharp-blunt item, which resulted an average loss of 3.5 points (range 1 to 8). Hierarchical scoring aspect of two-point discrimination subscale score was incorrect in 20% of cases. In other words, a score of  $> 0$  on two-point discrimination subscale was found for scores less than 24 in light touch, pressure and pinprick, which resulted in an average loss of 2.6 points (range 1 to 4). A score  $< 11$  for light touch, pressure and pinprick was associated in all cases with a two-point discrimination score of 0.

**Concurrent-criterion validity**

Significant and moderate to good positive correlations were observed between the EmNSA-SS and FMA-S UL for total, tactile and proprioception subscales. The scores ranged from 0.74 to 0.77, as demonstrated in Table 2.

**Internal consistency**

As stated in Table 3, the Cronbach's alpha coefficients suggested acceptable to excellent consistency for EmNSA-SS and EmNSA-ST total scale, and individual EmNSA-SS subscales, with scores ranging from 0.82 to 0.96. A significant floor effect was found for the two-point discrimination subscale. Significant ceiling effects were found for tactile sensation, two-point discrimination and proprioception subscales of the EmNSA-SS UL. The FMA-S demonstrated significant ceiling effects for its total score, tactile sensation and proprioception subscales (Table 3).

**Reproducibility**

Reproducibility scores are reported in Table 4, with data distribution illustrated in supplemental Figure S1. Intra-rater reliability of the EmNSA subscales and total score demonstrated excellent values, with ICC<sub>2,1</sub> values ranging from 0.86 to 0.92. Inter-rater reliability was also excellent with the exception of proprioception and discrimination of two-point subscales, which were both found to be moderate, with ICC<sub>1,1</sub> values of 0.71. Intra- and inter-rater MDC<sub>95</sub> values for the total score of EmNSA-SS were 12.3 and 14.6, respectively. The EmNSA-ST showed a systematic increase of scores, which suggests systematic bias, likely due to a learning effect between the test–retest measurements (see supplemental material, Fig. S1B and S1D).

## Discussion

This study supports the use of the French EmNSA for comprehensive UL somatosensory assessment in adults with stroke. Validation of the tool for adults with stroke demonstrated acceptable psychometric properties in terms of validity and reproducibility of EmNSA-SS, thereby suggesting its use in evidence-based clinical practice and research trials. Meanwhile, findings identify limitations of the EmNSA-ST in comparison to the EmNSA-SS, which suggests that the stereognosis component is more suited for screening purposes [6,15,19].

### Validity, ceiling and floor effects

The good concurrent-criterion validity of the EmNSA-SS is consistent with previous studies describing moderate to excellent validity of the Brazilian NSA and English Revised NSA in adults post-stroke appropriate for clinician professionals across populations [9,11,14]. Our results indicate advantages of the use of the EmNSA-SS over the FMA-S in terms of better floor and ceiling effects. The FMA-S demonstrated a significant ceiling effect of 34% for the total score, as compared with 14% for the EmNSA-SS. Similar results for adults with stroke demonstrated ceiling effects ranging from 44% to 72% for the FMA-S associated with time since stroke onset, which indicates limited discrimination of the measure for somatosensory recovery in adults with stroke [24]. Ceiling effects for the EmNSA-SS were significant for tactile sensation, two-point discrimination and proprioception but remained less than the FMA-S, demonstrating effects for tactile sensation and proprioception, as shown in previous studies on similar populations [11]. Our study indicates less ceiling and floor effects for the EmNSA-SS as compared with the Brazilian-NSA, which demonstrated ceiling effects for tactile sensation (66%) and stereognosis (38%) as well as two-point discrimination floor effects (42%) identified as limitations of this version. However, the small sample size (n=21)

and chronic phase of stroke among participants (onset > 6 months) associated with lower recovery should be noted as potential factors of floor and ceiling effects [11]. Our study identified floor effects of 30% of two-point discrimination; however, no other significant floor effects were found for other EmNSA subscales, congruent with findings of the FMA-S.

### **Internal consistency and hierarchical scoring**

The EmNSA demonstrates efficient internal consistency for total and subscale scores.

EmNSA-SS total score, tactile sensation and stereognosis components revealed values > 0.9, thereby indicating redundancy of content across items [39], which could be influenced by the number of items [20]. Analysis of the hierarchical testing procedure supports its use for light touch pressure and pinprick scores, which is consistent with previous studies regarding the redundancy of similar-site testing to reduce testing time [7,20]. However, errors associated with sharp-blunt items should be considered to minimize loss of points. The two-point discrimination procedure tested for scores of >24 in light touch, pressure, pinprick indicates discrepancies and loss of points of total score. Comprehensive testing of all items is recommended for evaluation in recovery clinical practice and/or testing when a score of >11 is detected for light touch, pressure and pinprick items for screening purposes.

### **Reproducibility**

The EmNSA-SS presents excellent intra- and inter-reliability properties with the exception of proprioception and two-point discrimination that demonstrates moderate to good reliability in a population of adults post-stroke. Findings are consistent with previous studies that reported high inter- and intra-rater reliability coefficients of the measure and limited discriminative touch reliability, not present in our study with a larger stroke population [13,24]. The MDC95

results address a gap in the current literature because it could be used to interpret modifications of an individual's score over time in relation to the measurement error.

Our results support previous findings from smaller samples ( $n=20$ ) that identified the stereognosis component as moderately appropriate for somatosensory evaluation of recovery among assessors [6,11]. The MDC95 for EmNSA-ST was associated with a systematic increase in score between test–retest, thus indicating that the EmNSA-ST is not suitable for monitoring stereognosis impairment over time because learning and recall might have influenced the score [33]. Our findings illustrate the limitations of the psychometric properties of the EmNSA-ST in contrast to the EmNSA-SS, thereby suggesting inclusion of the stereognosis in the final measure because exclusion would not provide a comprehensive somatosensory assessment [6,7,19,33]. The influence of learning and memory associated with cortical sensory function on stereognosis scores supports its use for screening purposes and/or modification of the testing procedure to 2 sets of 5 paired items [7,14,33].

### **Limitations, strengths and future research**

Although the use of standardized validated assessments for data collection limited information bias, the associated subjectivity of responses of sensory evaluation should not be ignored [23]. Blinding of assessors was impossible, but training, pre-pilot design and blinding of previous scores minimized the influence of information bias. Generalization of results to national and/or international populations is limited because of the single-center design and sample size, thus indicating the potential perspective of testing with a larger sample size. Responsiveness of the French version of EmNSA was not studied; however, this is a potential perspective of research to establish the ability of this scale to identify changes that are clinically meaningful [35]. Participants were representative of stroke characteristics, such as experiencing communication and cognitive deficits, which were previously overlooked in

other studies [6,7,11,15]. This study also demonstrates application to a wider stroke population including various times since stroke onset with regard to recovery phases. A Rasch analysis regarding the separate use of two sets of items to minimize associated learning effects may reduce systematic bias of the subscale [16]. Additional Guttman scale analysis would contribute to improve the hierarchical procedure of tactile sensation and the related two-point discrimination subscale enhancing its use in clinical practice [7].

### **Conclusion**

The French version of the EmNSA demonstrates good concurrent validity and reproducibility for UL evaluation of somatosensory impairment in adults post-stroke, thus providing a comprehensive measure of somatosensory function with inclusion of the stereognosis component. The tool, which takes between 15 and 30 min to administer, demonstrates clinical utility for use across the general stroke population with cognitive comorbidities, at various stages of recovery, in clinical practice and research. The EmNSA-SS can be used for screening purposes and monitoring of recovery, whereas the EmNSA-ST has application for screening purposes. This study highlights the potential use of the French EmNSA in evidence-based practice and research trials.

### **Authors' contributions**

Concept, idea and research design: CV, DG, HC

Instrument development: CV, CL, DG, EC, EC-L, MM, SH, ST

Providing participants and facilities/equipment: SH, ST, EC, MM, CL, EC-L, XdB

Data collection: CV, EC, MM, CL

Project management, data analysis, writing manuscript and final review of manuscript: CV, DG, HC

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**Conflict of interest.** None declared.

## **Data statement**

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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## **Figure legends**

**Fig. 1.** Flow of participants in the study.

**Fig. 2.** Score frequencies for **(A)** Erasmus modified Nottingham Sensory Assessment–somatosensory component (EmNSA-SS) and sensory subscale of the Fugl-Meyer Assessment (FMA-S) for upper limb, **(B)** EmNSA-SS tactile sensation and FMA-S light touch subscales, **(C)** EmNSA-SS proprioception and FMA-S proprioception subscales, **(D)** EmNSA-SS two-point discrimination subscale, and **(E)** EmNSA–stereognosis component (EmNSA-ST).

## Supplementary material

Score sheet for the EmNSA-SS and EmNSA-ST components in Excel format.

**Figure S1.** Bland-Altman graph illustrating the mean difference (mDiff; continuous black line) of the test–retest with its 95% confidence interval (95% CI), and the upper and lower limits of agreement (dashed lines corresponding to the mean  $\pm 1.96 \times$  SD) for the intra (A and B) and inter-rater (C and D) test–retest of the EmNSA somatosensory (EmNSA-SS UL; A and C) and stereognosis (EmNSA-ST UL; B and D) components for upper-limb. Systematic bias was present when the 95% CI of the mDiff did not include the zero (dotted line).

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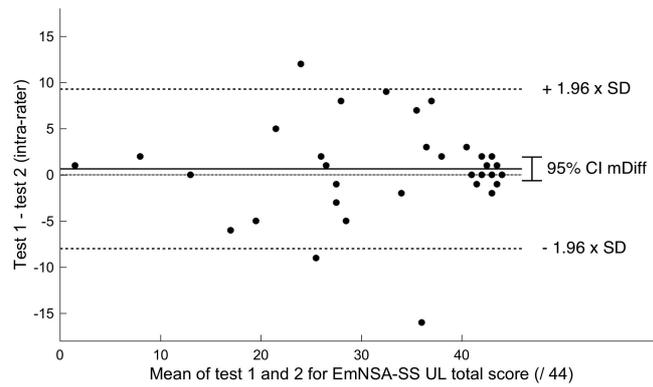
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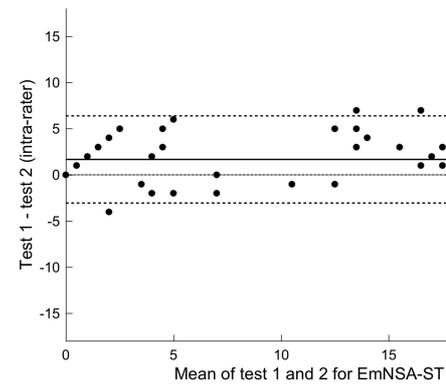
### Highlights

- The French EmNSA is a measure of somatosensory function in adults after stroke.
- It includes both somatosensory and stereognosis components.
- The somatosensory component is appropriate for screening and monitoring recovery.
- The stereognosis component is applicable for screening purposes.
- The hierarchical testing procedure was revised to reduce loss of total points.

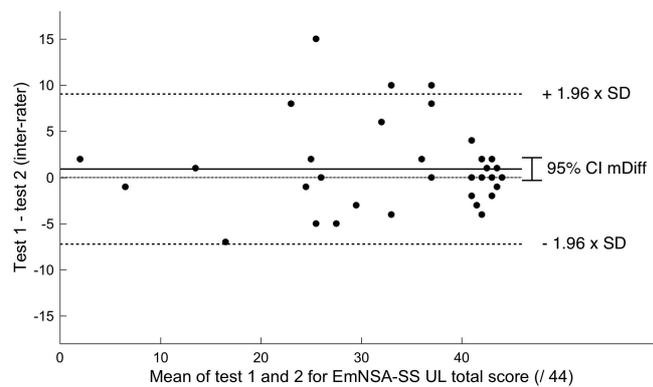
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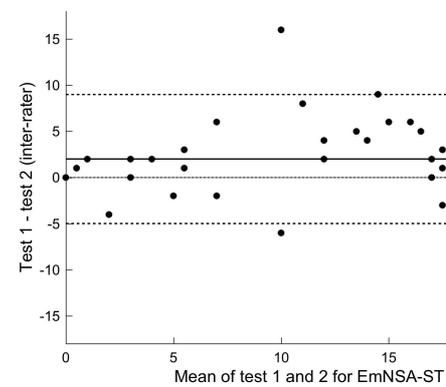
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C



D



## Appendix A. French version of the guidelines of the Erasmus Modified Nottingham Sensory Assessment with somatosensory (EmNSA-SS) and stereognosis (EmNSA-ST) components.

### Guide de passation de l'échelle Erasmus Modified Nottingham Sensory Assessment traduite, adaptée et validée en français avec les scores somesthésie et stéréognosie.

#### Instructions générales

Le patient est en sous-vêtements, en position assise (sans accouder si son équilibre du tronc le permet), les avant-bras en supination. On demande au patient de fermer les yeux ou un bandeau est positionné sur les yeux pendant l'évaluation.

Chaque item doit être expliqué au patient, et si nécessaire montré sur le membre considéré comme sain.

L'évaluation doit débiter en distalité (i.e. au niveau des doigts). Dans le cadre d'une évaluation de dépistage, seul le côté atteint est testé. Pour une évaluation plus complète les deux côtés peuvent être testés.

Chaque segment est testé en une seule fois au niveau des trois points de contact indiqués sur la cartographie (annexe 1 à la fin du document). L'ordre de test des points de contact est aléatoire. Pour chaque item, ne pas laisser plus de 2 à 5 secondes entre chaque application des 3 stimuli. Un aide-mémoire des points de contact prédéfinis est disponible sur la feuille de cotation.

### 1. Sensibilité Superficielle (toucher léger, pression, piquer)

#### Hiérarchisation de la passation

Si un score de 8 est obtenu pour le *toucher léger* de l'ensemble d'un membre supérieur (score de 2 pour chacun des 4 points), un score de 2 est automatiquement attribué chaque item de la *pression* et du *piquer* (soit un score total de 8 pour la pression et le piquer).

#### Modalités de passation

Pour chaque segment, la peau est stimulée 3 fois sur chaque point de contact, dans un ordre aléatoire. Le patient indique de façon verbale ou non-verbale<sup>1</sup> son ressenti du stimulus. En cas de négligence, l'attention du patient peut être attirée sur la partie du corps concernée avant le test.

#### Stimulation pour chaque modalité

*Toucher léger* : Toucher légèrement la peau, aux points de contacts prédéfinis, avec du coton.

*Pression* : Appliquer une pression avec l'index, aux points de contacts prédéfinis, juste suffisante pour déformer la peau.

*Piquer* : Piquer la peau en utilisant un cure dent, aux points de contacts prédéfinis, avec une intensité juste suffisante pour déformer la peau.

L'examineur donne la consigne suivante : « Dites-moi quand je vous touche la peau ? ». Il n'y a pas de prise en compte de la localisation du stimulus par le patient.

#### Critères de cotation pour le toucher léger, la pression et le piquer

Cotation	Sensation	Précisions
0	Absente	Le patient ne réussit pas à identifier la sensation lors des 3 applications du stimulus.
1	Altérée	Le patient identifie la sensation sur une ou deux applications du stimulus.
2	Normale	Le patient identifie la sensation lors de chacune des 3 applications du

<sup>1</sup> Le patient et le thérapeute s'accordent avant de débiter l'évaluation sur la manière la plus adaptée d'indiquer la sensation ressentie, par exemple avec un mouvement de la main lorsque le stimulus est ressenti.

		stimulus.
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## 2. Discrimination du piquer / toucher

### Modalités de passation

Stimuler la peau 6 fois aux points de contacts prédéfinis dans un ordre aléatoire, 3 fois avec un cure dent et 3 fois avec l'index.

Le patient doit décrire verbalement, ou indiquer de façon non-verbale, s'il perçoit un contact avec un objet pointu ou émoussé.

L'examineur donne la consigne suivante : « Dites-moi si vous ressentez une sensation de piquer ou de toucher ? ».

### Critères de cotation pour le piquer / toucher

Cotation	Sensation	Précisions
<b>0</b>	Absente	Le patient est incapable de discriminer les 2 stimuli lors des 6 essais.
<b>1</b>	Altérée	Le patient fait entre 1 et 5 erreurs de discrimination de stimuli.
<b>2</b>	Normale	Le patient discrimine correctement les 2 stimuli lors des 6 essais.

## 3. Discrimination de deux points

### Hiérarchisation de la passation

A effectuer systématiquement. En cas de score total du toucher léger, de la pression et du piquer inférieur à 11, il est possible de ne pas effectuer la discrimination de 2 points et d'attribuer un score de 0.

### Modalités de passation

Le seuil de discrimination est évalué de manière décroissante. Appliquer les 2 points de contact simultanément sur la pulpe de l'index et ensuite sur l'éminence thénar durant environ 0,5 seconde. Demander au patient d'indiquer s'il a perçu 1 ou 2 points de contact. Noter le dernier seuil pour lequel les 2 points ont été discriminés.

Il est recommandé de commencer avec un intervalle entre les deux pointes de 10 mm pour la pulpe de l'index et de 20 mm pour l'éminence thénar. Augmenter ou diminuer millimètre par millimètre.

*Pour plus de précision, possibilité de relever l'écart minimal discriminé.*

### Critères de cotation pour la discrimination de deux points

Cotation	Sensation	Précisions
<b>0</b>	Absente	Le patient est incapable de percevoir les 2 points.
<b>1</b>	Altérée	Le patient perçoit les 2 points avec un écart de 10 mm sur la pulpe de l'index et de 20 mm sur l'éminence thénar.
<b>2</b>	Normale	Le patient perçoit les 2 points avec un écart de 5 mm ou moins sur la

		pulpe de l'index et de 12 mm ou moins sur l'éminence thénar.
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#### 4. Proprioception

Les mobilisations passives spécifiques sont évaluées au niveau d'une articulation à la fois.

Les positions de départ, le positionnement spécifique des mains de l'examineur, et les directions des mouvements à tester sont décrites dans l'annexe 2 (à la fin du document).

Les articulations proximales (épaule et coude) sont mobilisées dans une amplitude d'environ un quart du volant articulaire libre. Les articulations distales (poignet et doigts) sont mobilisées dans la totalité de l'amplitude articulaire libre. (Spasticité).

La durée de la mobilisation doit être comprise entre 2 et 3 secondes.

Pour montrer la procédure au patient, 3 mouvements d'essais sont permis (le patient ayant les yeux ouverts). Chaque articulation est ensuite mobilisée 3 fois. On demande au patient, avec des questions spécifiques, d'indiquer de façon verbale ou non-verbale la direction du mouvement testé. Si le patient est incapable de déterminer le sens du mouvement, on lui demande alors simplement d'identifier (de façon verbale ou non-verbale) la présence ou non d'un mouvement.

#### Critères de cotation pour la proprioception

Cotation	Sensation	Précisions
0	Absente	Le patient ne perçoit pas de mouvement.
1	Altérée	Le patient perçoit le mouvement, mais la perception de sa direction n'est pas correcte lors des 3 essais.
2	Normale	Le patient perçoit correctement la direction du mouvement lors des 3 essais.

**Le score somesthésie (EmNSA-SS)** correspond à la somme des points obtenus pour les items de la sensibilité superficielle, de la discrimination de 2 points et de la proprioception.

## 5. Stéréognosie

L'objet est positionné dans la main du patient, en dehors du champ de vision, pour une durée maximale de 30 secondes. L'identification se fait par la dénomination, la description ou l'identification de l'objet avec sa paire (objet identique). L'identification par paire est réalisée uniquement si le patient présente un trouble de la communication. Le côté atteint est évalué en premier. L'objet peut être déplacé dans la main du patient par l'examineur.

### Critères de cotation pour la stéréognosie

Cotation	Sensation	Précisions
<b>0</b>	Absente	Incapable d'identifier l'objet de quelque manière que ce soit.
<b>1</b>	Altérée	Certaines caractéristiques de l'objet sont identifiées ou une description de l'objet est ébauchée.
<b>2</b>	Normale	L'objet est correctement nommé et/ou identifié.
<b>9</b>	Non testable	Aphasie sévère par exemple

### Liste des objets requis :

- Bandeau en tissu pour recouvrir les yeux (si difficultés à maintenir les yeux fermés)
- Pièce de 5 centimes
- Pièce de 50 centimes
- Stylo bille
- Crayon de papier
- Peigne
- Ciseaux
- Eponge
- Gant de toilette
- Tasse
- Verre

**Le score stéréognosie (EmNSA-ST)** correspond à la somme des points obtenus pour les 10 objets.

**Définition des points de contact pour l'évaluation du toucher léger, de la pression, du piquer et de la discrimination du piquer/toucher.**

**A - Doigts**

- 1 Face palmaire de la phalange distale du 5<sup>ème</sup> doigt.
- 2 Face palmaire de la phalange distale du 3<sup>ème</sup> doigt.
- 3 Face palmaire de la phalange distale du 1<sup>er</sup> doigt.

**B - Main**

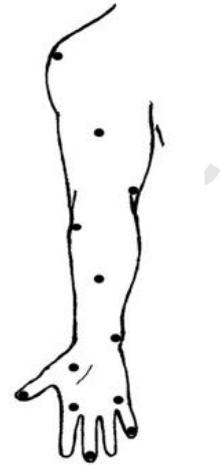
- 1 Face palmaire, 2<sup>nd</sup> métacarpien en distalité.
- 2 Face palmaire, 5<sup>ème</sup> métacarpien en distalité.
- 3 Au centre de l'éminence thénar.

**C – Avant-bras**

- 1 Styloïde ulnaire, face antérieure.
- 2 Milieu de l'avant-bras, face antérieure.
- 3 2 cm en distalité du pli de flexion du coude, face antérolatérale.

**D - Bras**

- 1 2 cm en proximalité du pli de flexion du coude, face antéro-médiale.
- 2 Milieu du bras, face antérieure.
- 3 2 cm en distalité de l'acromion, face latérale.



## Positions de départ pour l'évaluation de la proprioception

Pour les articulations proximales (épaule et coude) le patient est assis le bras le long du corps.

Pour le poignet et le pouce, le patient est en position assise, face à une table, coude fléchi à 90° et avant-bras en supination.

Les articulations proximales (épaule et coude) sont mobilisées dans une amplitude d'environ un quart de leur volant articulaire libre. Les autres articulations (poignet et doigts) sont mobilisées dans la totalité du volant articulaire libre.

Articulations	Mouvements du segment	Question à poser au patient	Position des mains de l'examineur		
			Main distale (mobile)	Main proximale (fixe)	Illustration
<b>Pouce</b>	Flexion et extension de la phalange distale du pouce.	« Est-ce que je fléchis ou est-ce que j'étends le pouce ? »	Placer le pouce latéralement et l'index médialement sur la phalange distale.	Fixer la phalange proximale entre pouce et index.	
<b>Poignet</b>	Flexion et extension du poignet. Position de départ : coude entre 20 et 30° de flexion.	« Est-ce que je fléchis ou est-ce que j'étends le poignet ? »	Positionner le pouce sur la partie latérale et l'index sur la partie médiale de la main du patient.	Fixer l'extrémité distale de l'avant-bras.	
<b>Coude</b>	Flexion et extension du coude. Position de départ : coude à 90° de flexion.	« Est-ce que je fléchis ou est-ce que j'étends le coude ? »	Saisir l'avant-bras en distalité, le pouce sur la face ventrale et les autres doigts sur la face dorsale.	Fixer l'extrémité distale de l'humérus.	
<b>Epaule</b>	Abduction et adduction de l'épaule. Positionner le coude à 90° de flexion et écarter suffisamment le bras pour permettre le mouvement.	« Est-ce que le bras se rapproche ou s'éloigne de vous ? »	Saisir l'avant-bras en distalité, le pouce sur la face ventrale et les autres doigts sur la face dorsale.	Saisir le coude fléchi en berceau.	

**Table 1.** Characteristics and clinical scores (n = 50).

Characteristics	Scores
Age (years), median (min-max)	61.7 (22-77)
Sex (male; female), n (%)	35 (70); 15 (30)
Type of stroke (ischemic; hemorrhagic), n (%)	37 (74); 13 (26)
Time since stroke onset (m), median (min-max)	3.1 (1.1-319.1)
Side of paresis (right; left), n (%)	26 (52); 24 (48)
Dominant hand <sup>a</sup> (right; left), n (%)	48 (96); 2 (4)
Aphasia <sup>b</sup> , n (%)	14 (28)
FMA-M UL scale, median (min-max)	33.5 (4-66)
Motor impairment <sup>c</sup> , n (%)	
Severe (score $\leq$ 27)	22 (42)
Moderate (score 28-57)	18 (36)
Mild (score 58-66)	11 (22)
FMA-S UL scale (/28), median (min-max)	25.5 (0-28)
Light touch subscale (/20)	18 (0-20)
Proprioception subscale (/8)	8 (0-8)
EmNSA-SS UL scale (/44), median (min-max)	41.5 (1-44)
Tactile sensation subscale (/32)	30 (0-32)
Discrimination subscale (/4)	3 (0-4)
Proprioception subscale (/8)	8 (0-8)
EmNSA-ST UL scale (/20), median (min-max)	11.5 (0-20)

FMA-M UL, motor subscale of the Fugl-Meyer Assessment for the upper limb (0-66); FMA-

S UL, sensory subscale of the Fugl-Meyer Assessment for the upper limb; EmNSA-SS/ST

UL, Erasmus modified Nottingham Sensory Assessment Somatosensory/Stereognosis components for the upper limb

<sup>a</sup>Dominant hand was defined as the writing hand before onset of stroke.

<sup>b</sup>Aphasia was classified using the subscale of aphasia severity from the Boston Diagnostic Aphasia Examination [28].

<sup>c</sup>Motor impairment was classified by FMA-M UL levels [40].

**Table 2.** Concurrent-criterion validity assessed by Spearman's rank correlation coefficient between EmNSA-SS UL and the FMA-S UL (n = 50).

EmNSA-SS UL	FMA-S UL		
	Light touch subscale	Proprioception subscale	Total score
Tactile sensation subscale	0.75*	-	-
Proprioception subscale	-	0.77*	-
Total score	-	-	0.74*

EmNSA-SS UL, Erasmus modified Nottingham Sensory Assessment Somatosensory component for the upper limb; FMA-S UL, Fugl-Meyer Assessment Sensory component for the upper limb.

\*  $P < 0.001$  (two tailed).

**Table 3.** Internal consistency, floor and ceiling effect of the EmNSA UL and the FMA-S UL (n = 50).

Internal consistency <sup>a</sup>	Floor effect (%)	Ceiling effect (%)
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	EmNSA UL	EmNSA UL	FMA-S UL	EmNSA UL
Total score				
Somatosensory component (n = 22)	0.961	0	2	14
Stereognosis component (n = 10)	0.941	18	-	2
Subscales of EmNSA-SS				
Tactile sensation (n = 16)	0.954	2	4	36
Two-point discrimination (n = 2)	0.852	30	-	30
Proprioception (n = 4)	0.821	4	4	52

EmNSA-SS/ST UL, Erasmus modified Nottingham Sensory Assessment

Somatosensory/Stereognosis component for the upper limb; FMA-S UL, Fugl-Meyer

Assessment Sensory component for the upper limb.

<sup>a</sup> Internal consistency was reported as Cronbach  $\alpha$  coefficient.

**Table 4.** Intra- (n = 48) and inter-rater (n = 46) reproducibility of the EmNSA UL scale and subscales.

		ICC (95% CI)	MDC95	mDiff (95% CI) <sup>a</sup>
EmNSA-SS total score (/44)	Intra-rater	0.92 (0.86–0.95)	12.3	0.65 (-0.63–1.93)
	Inter-rater	0.92 (0.87–0.96)	14.6	0.91 (-0.31–2.14)
Tactile sensation (/32)	Intra-rater	0.88 (0.79–0.93)	8.6	0.27 (-0.89–1.43)
	Inter-rater	0.90 (0.83–0.95)	14.1	0.93 (-0.07–1.94)
Discrimination of two-point (/4)	Intra-rater	0.89 (0.82–0.94)	1.9	0.08 (-1.14–0.31)
	Inter-rater	0.71 (0.53–0.83)	2.5	-0.07 (-0.42–0.29)

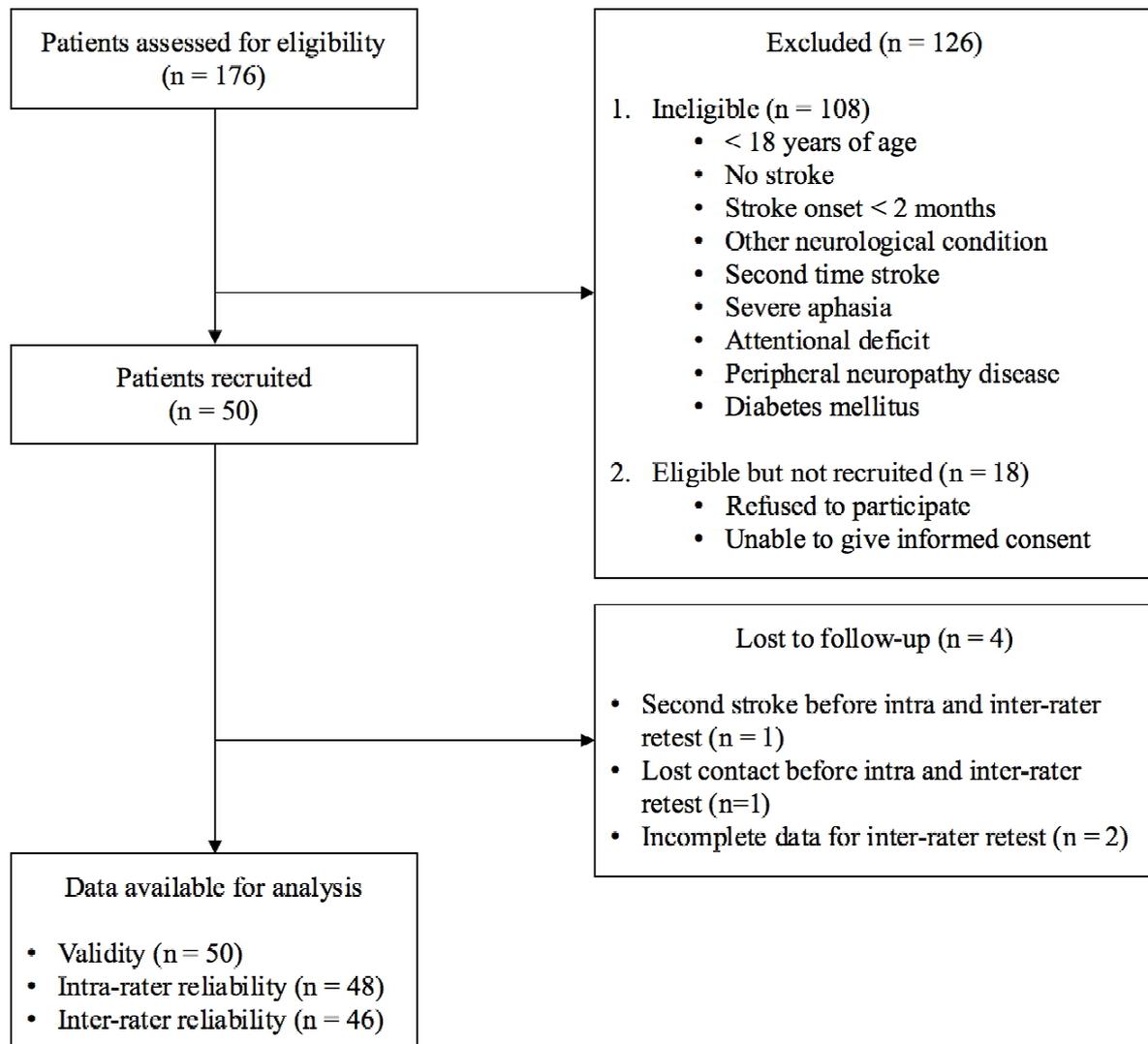
Proprioception (/8)	Intra-rater	0.86 (0.77–0.92)	4.4	0.29 (-0.01–0.60)
	Inter-rater	0.71 (0.53–0.83)	3.5	0.04 (-0.48–0.57)
EmNSA-ST (/20)	Intra-rater	0.92 (0.76–0.97)	23.1	1.67 (0.97–2.37) <sup>b</sup>
	Inter-rater	0.84 (0.74–0.91)	27.5	2.00 (0.94–3.06) <sup>b</sup>

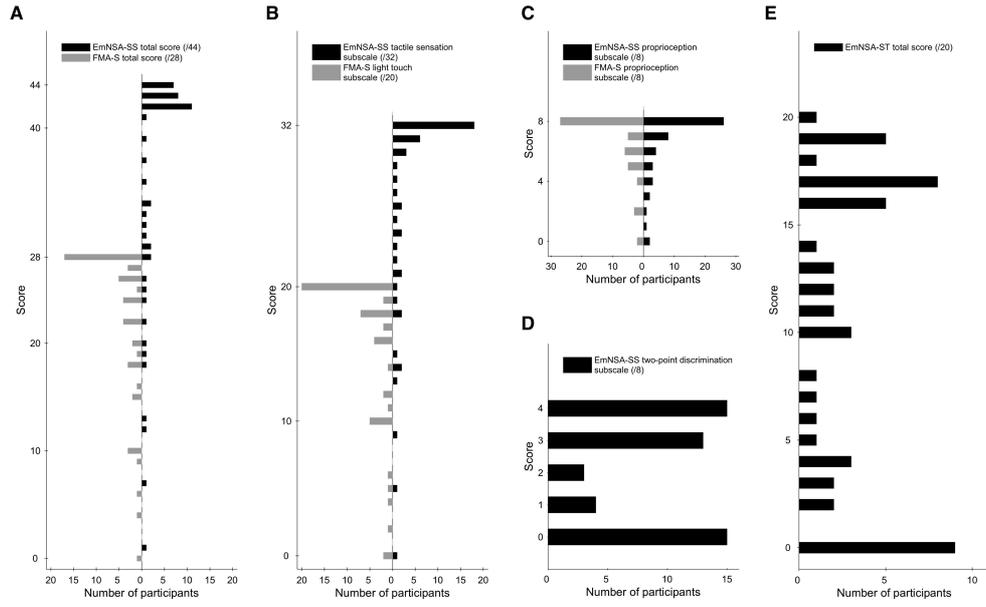
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EmNSA-SS/ST UL, Erasmus modified Nottingham Sensory Assessment for Somatosensory/Stereognosis component for the upper limb; ICC, intraclass correlation coefficient; MDC95, minimal detectable change with 95% confidence interval

<sup>a</sup>Bias present for EmNSA-ST due to 95% confidence interval (95% CI) of the mean difference (mDiff) not including zero, indicating systematic bias from recall of items.

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