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Original article

Simplified evaluation of CONsciousness disorders (SECONDs) in individuals with severe brain injury: A validation study

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ABSTRACT

Background: The Coma Recovery Scale-Revised (CRS-R) is the gold standard to assess severely brain-injured patients with prolonged disorders of consciousness (DoC). However, the amount of time needed to complete this examination may limit its use in clinical settings. Objective. We aimed to validate a new faster tool to assess consciousness in individuals with DoC.
Methods: This prospective validation study introduces the Simplified Evaluation of CONsciousness Disorders (SECONDs), a tool composed of 8 items: arousal, localization to pain, visual fixation, visual pursuit, oriented behaviors, command-following, and communication (both intentional and functional). A total of 57 individuals with DoC were assessed on 2 consecutive days by 3 blinded examiners: one CRS-R and one SECONDs were performed on 1 day, whereas 2 SECONDs were performed on the other day. A Mann-Whitney U test was used to compare the duration of administration of the SECONDs versus the CRS-R, and weighted Fleiss' kappa coefficients were used to assess inter-/intra-rater reliability as well as concurrent validity.
Results: In the 57 participants, the SECONDs was about 2.5 times faster to administer than the CRS-R. The comparison of the CRS-R versus the SECONDs on the same day or the best of the 3 SECONDs led to "substantial" or "almost perfect" agreement (kappa coefficients ranging from 0.78 to 0.85). Intra-/inter-rater reliability also showed almost perfect agreement (kappa coefficients from 0.85 to 0.91 and 0.82 to 0.85, respectively).
Conclusions: The SECONDs appears to be a fast, reliable and easy-to-use scale to diagnose DoC and may be a good alternative to other scales in clinical settings where time constraints preclude a more thorough assessment.

1. Introduction

The nosology of disorders of consciousness (DoC) is vast because after a period of coma, individuals may evolve to an unresponsive wakefulness syndrome (UWS), a minimally conscious state (MCS) minus (MCS-) or plus (MCS +), and potentially emerge from this MCS (EMCS; see Table 1 for diagnostic criteria). These diagnostic categories are defined by the clinical presence of specific behavioural signs. Moreover, the rate of misdiagnosis is substantial (i.e., 40%) when relying on only medical consensus rather than validated tools [1–3]. Therefore, the use of standardized, sensitive and validated scales is crucial given that the diagnosis greatly affects patient care (e.g., treatment, end-of-life decisions) [4–6].

Although the Coma Recovery Scale-Revised (CRS-R) [7] is the recommended diagnostic scale, it is time-consuming, requires training and provides total scores that do not reliably reflect individuals' level of consciousness at the single-subject level [8–10]. The assessment duration becomes an even bigger issue given that recent recommendations highlight the importance of repeating CRS-R assessments [11–13]. The time that should be allocated to these evaluations by clinicians rarely corresponds to the clinical field reality.

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Table 1
Current disorders of consciousness (DoC) classification.

DoC	Diagnostic criteria
Coma	No arousal (eyes closed)
Unresponsive wakefulness syndrome (UWS; vegetative state)	Arousal (eyes opened) with no internal and/or external awareness [32,33]
Minimally conscious state *minus* (MCS-)	Arousal with signs of internal and/or external awareness (e.g., visual pursuit) [24]
Minimally conscious state *plus* (MCS+)	Arousal with language-related signs of consciousness (i.e., command-following, intentional communication, intelligible verbalization) [34]
Emergence from the minimally conscious state (EMCS)	Arousal with recovery of functional communication and/or use of objects [24]

We proposed to validate a new short assessment tool that could be easily implemented in daily practice to determine the level of consciousness in individuals with severe brain injury: the Simplified Evaluation of CONsciousness Disorders (SECONDs). Its administration was expected to be significantly faster than the CRS-R. We further examined congruent diagnoses between the SECONDs and the CRS-R, between raters and regarding test–retest.

2. Material and methods

2.1. Participants

People were prospectively recruited from April 2017 to October 2019 at the University Hospital of Liège, Belgium, while undergoing a 1-week hospitalization for DoC diagnosis and prognosis purposes, as well as in 3 rehabilitation centers (i.e., specialized programs dedicated to DoC) in Belgium. Inclusion criteria were the presence of severe acquired brain injury, prolonged DoC (i.e., at least 28 days since injury), $\geq$ 18 years old, no history of neurological or psychiatric deficit, ability to speak French, and medical stability (e.g., absence of mechanical ventilation, sedation, infection). Each individual was assessed by 3 different examiners who were experienced in behavioral assessment of DoC. Overall, a team of 8 examiners performed all the assessments both at the hospital and rehabilitation centers.

This study was approved by the ethics committee of the hospital and University of Liège and by the 3 local ethics committees of the rehabilitation centers. Written informed consent was obtained from the participants' legal surrogates.

2.2. Material

2.2.1. Simplified Evaluation of CONsciousness Disorders (SECONDs)

The SECONDs includes 8 items of increasing complexity and is derived from the CRS-R (Fig. 1): arousal response (UWS; scored 1), localization to pain (MCS-; scored 2), visual fixation (MCS-; scored 3), visual pursuit (MCS-; scored 4), oriented behaviors (MCS-; scored 5), command-following (MCS+; scored 6), intentional communication (MCS+; scored 7) and functional communication (EMCS; scored 8). The total score corresponds to one diagnosis and ranges from 0 = coma, 1 = UWS, 2-5 = MCS-, 6-7 = MCS+ to 8 = EMCS. The items were chosen because they were among the most frequently observed in the MCS [14] and because of their importance for the diagnosis of EMCS (i.e., functional communication) [7]. Recent findings indicated that the 5 most frequently observed items in the CRS-R allow for detecting 99% of MCS individuals. Consequently, when time is limited, one could select these items (i.e., reproducible movement to command, visual pursuit and fixation, automatic motor response and localization to pain) [14]. The guidelines for adaptation and scoring of the items are presented in Supplemental Data (Table S1). They were based on previously published studies and clinical experience. The protocol was elaborated after discussion between experts (i.e., neurologists, neuropsychologists, physiotherapists), all experienced in the assessment of DoC and specialized in the administration of the CRS-R. The superiority of the mirror to detect visual fixation and pursuit [15] led to the selection of this stimulus. A criterion of time instead of angular width was chosen to address administration issues related to people with oculomotricity impairments following cranial nerves lesions as well as practical difficulties in estimating angular width without dedicated tools [16]. Similarly, given that the best results while testing communication were obtained with autobiographical questions, we designed a fixed set of these questions [17]. Finally, command-following scoring was set at 2 of 3 trials instead of 3 of 4 in the CRS-R. The aim was to avoid frequent situations in which individuals showed 2 responses out of 4 trials, thus not reaching the threshold to be scored in the CRS-R, although the reproducibility of the response was clinically unequivocal given the chosen command (i.e., not a spontaneous movement) or given subsequent evaluations. Moreover, it was then similar to how command-following was tested in the Full Outline of UnResponsiveness (FOUR) [18], a scale widely used in intensive care units, where the SECONDs might be a valuable tool. This modification could help avoid confusion for clinicians. All these changes were made to save maximal time without compromising the accuracy of the detection of consciousness, and they also limit fatigue, which may yield better focus and collaboration.

2.2.2. Coma Recovery Scale-Revised (CRS-R)

The CRS-R [7] consists of 6 subscales assessing auditory functions (i.e., consistent movement to command, reproducible movement to command, localization to sound, auditory startle, or none), visual functions (i.e., object recognition, object localization and reaching, visual pursuit, visual fixation, visual startle, or none), motor functions (i.e., functional object use, automatic motor response, object manipulation, localization to noxious stimulation, flexion withdrawal, abnormal posturing, or none), oromotor/verbal functions (i.e., intelligible verbalization, vocalization/oral movement, oral reflexive movement, or none), communication (i.e., functional, intentional, or none) and arousal (i.e., attention, eye opening without/with stimulation, or none). The sum of all 6 sub-scores is a total score ranging from 0 to 23. Because the CRS-R sub-scores do not reflect continuous values, they should not be added up. The scoring form shows which behavior corresponds to which diagnosis.

2.3. Procedure

Four behavioral assessments were performed on 2 consecutive days. On 1 day, a CRS-R and a SECONDs were administered (i.e., concurrent validity). A time of 45 to 60 min between the end of the first evaluation and the beginning of the second evaluation was imposed to limit fluctuations in responsiveness while avoiding fatigue. On the other day, 2 SECONDs were performed (i.e., inter-rater validity) and the same timeframe was established between the 2 evaluations. The order of assessment (CRS-R and SECONDs) was randomized and the CRS-R was performed following its original guidelines [7,19]. In addition, the order of both days (CRS-

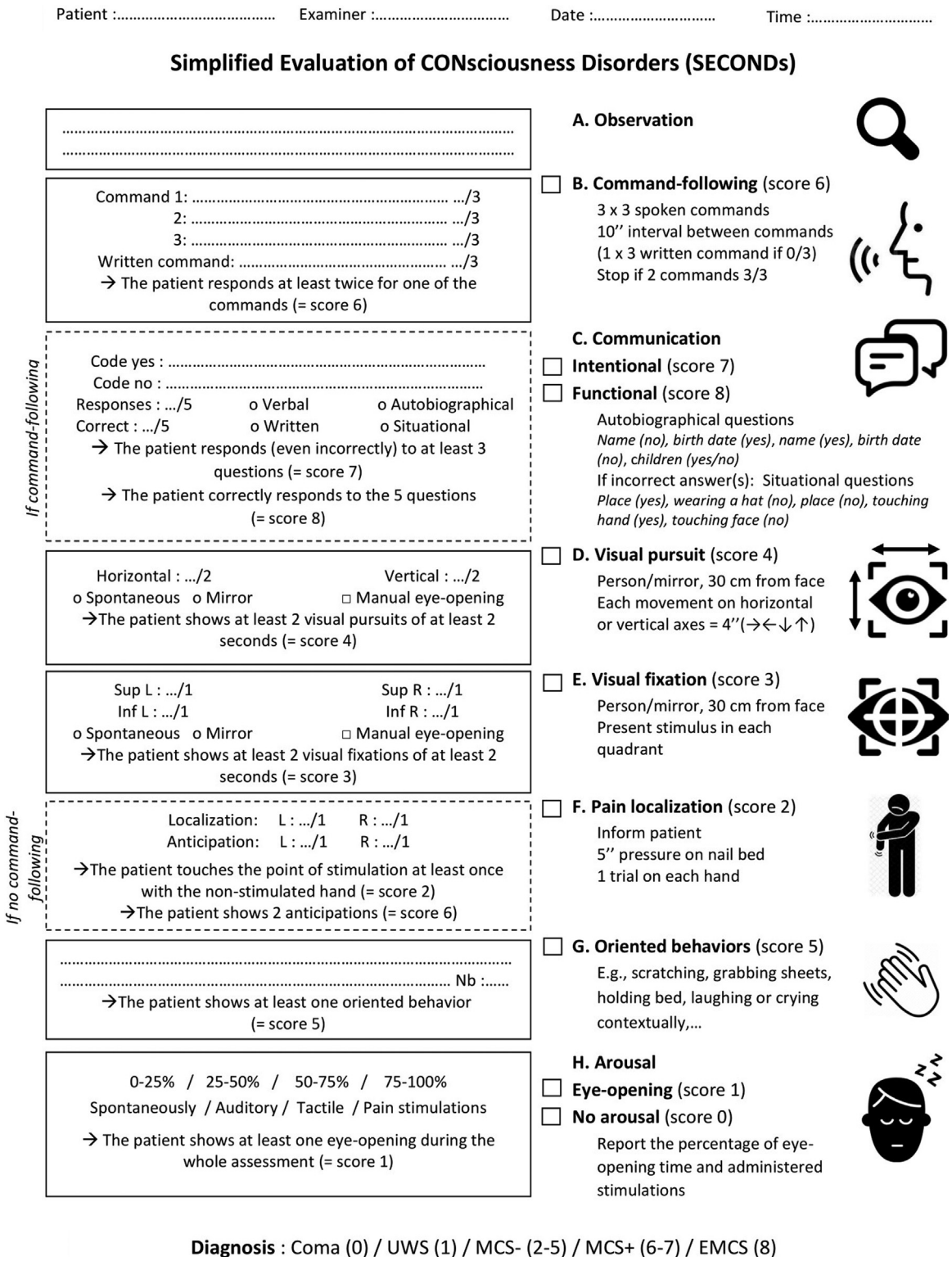

Fig. 1. Administration of the Simplified Evaluation of CONsciousness Disorders (SECONDs). We recommend administration of at least 5 SECONDs in a short time period (e.g., 10 days) to reduce misdiagnosis rates [11].

R/SECONDs and SECONDs/SECONDs) was randomized, so that half of the participants were assessed with the CRS-R on the first day and the other half on the second day. Three examiners were randomly assigned to the 4 evaluations (Fig. 2). The administration duration of each assessment was recorded.

The examiners were blinded to the participants' medical diagnosis and medical history and remained blinded regarding the results and type of commands previously tested during all other behavioral assessments, including both SECONDs and CRS-R.

2.4. Statistical analyses

Descriptive statistics were used for participant characteristics. Age and time since injury are expressed as mean (SD) and sex and

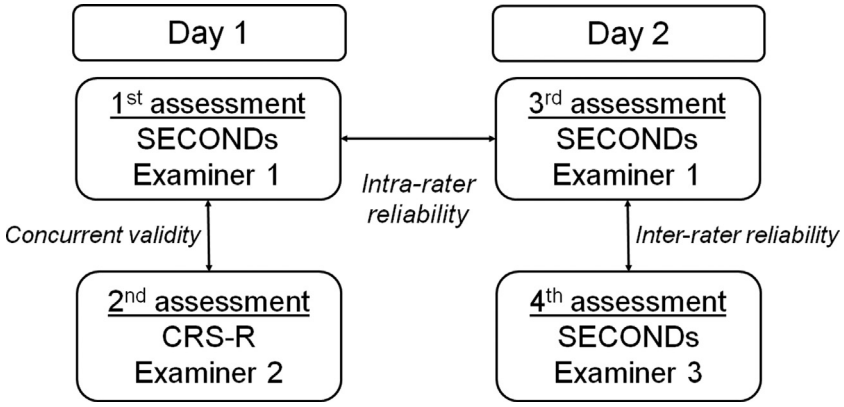

Fig. 2. Illustration of the procedure and validation protocol of the SECONDs. In this example, the examiners were randomly assigned to the evaluations as follows: 1) the first examiner administered the Coma Recovery Scale-Revised (CRS-R) assessment; 2) the second examiner administered the SECONDs occurring pre-/post-CRS-R on the first day as well as one SECONDs on the second day; 3) the third examiner administered the remaining SECONDs (on the second day).

etiology as number (%). Because of the skewed data distribution, the difference in administration duration between the SECONDs and CRS-R was assessed by Mann-Whitney U test. Results were considered significant at $p < 0.05$.

The degree of agreement was calculated by using weighted Fleiss' kappa coefficients (K_W) for 3 measures:

- concurrent validity (i.e., CRS-R vs SECONDs on the same day, and CRS-R vs best SECONDs diagnosis);
- intra-rater reliability (i.e., SECONDs vs SECONDs by the same examiner);
- inter-rater reliability (i.e., SECONDs vs SECONDs on the same day by 2 different examiners).

A value < 0 was considered "poor agreement", 0 to 0.2 "slight agreement", 0.21 to 0.4 "fair agreement", 0.41 to 0.6 "moderate agreement", 0.61 to 0.8 "substantial agreement", 0.81 to 0.99 "almost perfect agreement" and 1 "perfect agreement" [20]. As a first step, we took into account the 3 main diagnostic entities in chronic DoC, namely the UWS, MCS and EMCS. As a second step, we repeated the analysis by subclassifying the MCS (i.e., MCS- and MCS +) according to the latest diagnostic criteria for MCS+ (i.e., command-following, verbalization and/or intentional communication) [21].

Because previous studies showed that kappa analysis should not be the only method used to examine concurrent validity [22], we also used Spearman correlation for skewed data between the CRS-R total scores (out of 23) and the best SECONDs scores as well as the scores of the SECONDs performed on the same day (out of 8).

3. Results

We included 60 individuals in the study. The final sample consisted of 57 patients (24 traumatic brain injuries, 14 anoxic and 19 other non-traumatic brain injuries; 23 women; mean age = 48 years; standard deviation [SD] = 16 years, range = 18-85 years; median time since injury = 5.5 weeks, inter-quartile range [IQR] = 2.8–11.7, range = 0.9–196.9 months) after excluding 3 patients because of protocol violations (i.e., one with time since injury 25 days, one with randomization error and one who was not French-speaking). All individual data are reported in Supplemental Data (Table S2).

The median administration time was shorter with the SECONDs than the CSR-R (7 min; IQR 5-9; and 17 min; IQR 12-22; W = 8791, $p < 0.001$).

According to CRS-R assessments, our sample included 12 UWS, 14 MCS-, 14 MCS+ and 17 EMCS participants. The same-day SECONDs diagnosed a total of 14 UWS, 13 MCS-, 14 MCS+ and 16 EMCS participants, and the best SECONDs diagnosed a total of 13 UWS, 11 MCS-, 14 MCS+ and 19 EMCS participants.

When only considering the 3 main diagnostic entities (i.e., UWS, MCS and EMCS), we found substantial agreement between the CRS-R and the SECONDs administered on the same day ($K_W = 0.79$; 48/57; 84.2%) and almost perfect agreement between the CRS-R and the SECONDs' best diagnosis ($K_W = 0.84$; 50/57; 87.7%). The intra- and inter-rater reliability showed almost perfect agreement ($K_W = 0.91$; 53/57; 93% and $K_W = 0.820$; 49/57; 86%).

When considering the sub-categories of the MCS (i.e., UWS, MCS-, MCS+ and EMCS), the concurrent validity was substantial for the CRS-R and the SECONDs performed on the same day ($K_W = 0.78$; 41/57; 71.93%) and almost perfect for the CRS-R and the SECONDs' best diagnosis ($K_W = 0.85$; 46/57; 80.7%) (Table 2). The intra- and inter-rater reliability remained with almost perfect agreement ($K_W = 0.85$; 46/57; 80.7% and $K_W = 0.85$; 47/57; 82.46%).

Table 2 reports the number of diagnostic discrepancies between the SECONDs and the CRS-R, accounting for the extended diagnostic classification (i.e., sub-classifications of MCS into MCS- and MCS +). When considering the SECONDs performed on the same day as the CRS-R, 16/57 (28%) participants showed diagnostic disagreement between both scales. Overall, 6 participants had a better diagnosis with the "same-day SECONDs" than the CRS-R and 10 had a better diagnosis with the CRS-R. These differences were due to discrepancies in the absence or presence of visual pursuit (detected in 3 participants with the CRS-R only and in 1 participant with the SECONDs only), command-following (detected in 4 participants with the CRS-R only and in 3 with the SECONDs only), functional communication (detected in 1 participant by the CRS-R only and in 2 participants by the SECONDs only) or use of objects (detected in 2 participants by the CRS-R but not assessed by the SECONDs). Furthermore, 11/57 (19%) participants showed diagnostic disagreement between the best SECONDs and the CRS-R. Seven had a better diagnosis when considering the best SECONDs as compared with the CRS-R and 4 had a better diagnosis with the CRS-R (i.e., the 3 participants with visual pursuit and 1 of the participants with command-following as detected by the CRS-R only).

Finally, the CRS-R total score was correlated with the score of the SECONDs performed by another examiner on the same day ($r_s = 0.91$, $S = 3110.2$, $p < 0.001$). Likewise, the CRS-R total score was correlated with the score of the best of the 3 SECONDs ($r_s = 0.92$; $S = 2343.8$, $p < 0.001$).

Table 2
Number of patients showing agreements and discrepancies between the Coma Recovery Scale-Revised (CRS-R) and the Simplified Evaluation of CONsciousness Disorders (SECONDs).

		Same-day SECONDs				Best SECONDs			
		UWS	MCS-	MCS+	EMCS	UWS	MCS-	MCS+	EMCS
CRS-R	UWS	11	1	0	0	10	2	0	0
	MCS-	3	8	3	0	3	8	3	0
	MCS+	0	4	8	2	0	1	11	2
	EMCS	0	0	3	14	0	0	0	17

Left: comparison between the CRS-R and the SECONDs administered on the same day. Right: comparison between the CRS-R and the best SECONDs diagnosis. Shaded cells show disagreement in diagnosis. Light grey cells include patients with a better diagnosis using the SECONDs versus the CRS-R. Dark grey cells include patients with a better diagnosis using the CRS-R versus the SECONDs. Specifically, P3 was diagnosed as MCS- with the SECONDs and UWS with the CRS-R, whereas the opposite was found in P1, P6 and P31. Regarding both categories of MCS, P21, P28 and P55 were diagnosed as MCS+ with the SECONDs and MCS- with the CRS-R, whereas the opposite was observed in P2, P26, P54 and P57. Finally, P33 and P50 were diagnosed as EMCS with the SECONDs and MCS+ with the CRS-R, whereas the opposite was found in P18, P24 and P38. UWS, unresponsive wakefulness syndrome; MCS-, minimally conscious state minus; MCS+, minimally conscious state plus; EMCS, emergence from the minimally conscious state.

4. Discussion

The SECONDs was developed to allow clinicians to accurately and rapidly assess level of consciousness in daily care. The elaboration of this scale was inspired by the CRS-R [7], which is the current recommended assessment tool for the diagnosis of DoC. Our main findings show that the SECONDs was 2.5 times faster to administer on average than the CRS-R. In other words, if a healthcare professional is given 60 min weekly to assess patients, the assessment of 8 patients would be possible by using the SECONDs instead of 3 patients with the CRS-R. As expected, substantial concurrent validity was found between the SECONDs and CRS-R diagnoses in individuals with prolonged DoC, as well as almost perfect agreement with regard to intra- and inter-rater reliability.

However, we noticed discrepancies between the SECONDs and the CRS-R in 28% of DoC individuals when both assessments were performed on the same day. Patients' diagnoses are determined by the highest level of consciousness observed [13]. In our case, 10 participants had a better diagnosis with the CRS-R versus 6 with the SECONDs performed on the same day. Using repeated assessments (i.e., best of the 3 SECONDs), the discrepancies decreased to 19%, with 7 participants showing better SECONDs diagnosis versus 4 with better CRS-R diagnosis. These results suggest that, within the same time window, those repeated SECONDs assessments would more frequently allow for detecting the highest level of consciousness as compared with one CRS-R.

Inconsistencies between both scales were mainly associated with the detection of behaviors assessed differently in the SECONDs versus the CRS-R (Table 2):

- visual pursuit;
- command-following;
- functional communication.

Regarding visual pursuit, the SECONDs requires that the eye movement last at least 2 sec to be considered as a visual pursuit, unlike the CRS-R, which requires an eye movement of 45°. Even if the discrepancies may be due to within-day variability of visual tracking [23], the repetition of the SECONDs did not allow for detecting visual pursuit in 3 participants who showed this sign with the CRS-R, so the SECONDs criteria for this item might be more conservative.

The second item responsible for the discrepancies between both scales was command-following. The number of requested trials might have affected some diagnoses. Specifically, the SECONDs considers 2 of 3 successful trials as a sufficient proof of command-following capacity, whereas the CRS-R requires 3 of 4 successful trials. This led to one participant being diagnosed as MCS+ by the SECONDs and MCS- by the CRS-R ("move your leg": 2 of 3 [SECONDS] and 2 of 4 [CRS-R]). The type of movements prompted by the different examiners, which could not be controlled due to the blinding process, might also have affected the detection rate of this behavior. For example, P21 showed an adequate response for only the command "move your leg", which was not asked during the CRS-R administration, whereas P26 showed an adequate response for only the command "move your head", which was not tested with the SECONDs.

Third, the "functional communication" item of the SECONDs requires 5 correct answers to 5 yes/no questions, whereas the CRS-R requires correct answers to 6 questions. Moreover, the SECONDs includes autobiographical questions when assessing communication, which is not the case with the CRS-R. In line with previous research [17], DoC individuals provided better answers when using autobiographical questions (e.g., name recognition) than situational questions. Given that this item did not lead to discrepancies between the SECONDs and the CRS-R when considering the best SECONDs diagnosis, the differences in the diagnoses given on the same day are more likely due to a fluctuation in cognitive abilities.

Of note, the item "functional use of objects" included in the CRS-R also enabled the diagnosis of 2 participants as EMCS (i.e., P24 and 38), but these individuals had a diagnosis of MCS with the SECONDs. It is noteworthy that these are the only discrepancies linked to items that are not included in the SECONDs. According to Giacino et al. (p. 351) [24], "[the] recovery from MCS to higher states of consciousness occurs along a continuum in which the upper boundary is necessarily arbitrary." The functional use of objects was consequently chosen as a criterion of EMCS along with functional communication because these behaviors are typically observed during recovery of consciousness. Nevertheless, the attentional resources necessary for object use, which highly depends on motor function, are considered lower than those required for accurate yes/no communication by some authors [25]. Besides, the recovery of functional communication is a more critical milestone in rehabilitation than the use of objects.

Taking everything into account, evidence-based guidelines are lacking regarding the best way to assess visual pursuit, the number of trials and type of commands required for command-following, or the type and number of questions that should be administered to assess communication in individuals with DoC. For example, the well-known Glasgow Coma Scale (GCS) [26] and the FOUR [18], which are used in acute settings, require 1 and 3 different commands, respectively. This lack of guidelines was also highlighted by a recent review that recommended international consensus development on definitions, operational criteria and

assessment procedures for visual pursuit and fixation [27]. Therefore, future studies should aim for evidence-based (or at least consensus-based) guidelines regarding the best stimuli and procedures to assess responses classically associated with diagnostic criteria (e.g., visual pursuit/fixation, command-following, functional communication and object use).

The SECONDs presents several advantages, because the use of a scale that is fast to administer may allow for repeated assessments, decrease the effect of the duration on patients' fatigue or collaboration and, consequently, reduce the misdiagnosis rate in this population [11]. The SECONDs is more likely to be implemented efficiently in settings where time constraints preclude a comprehensive assessment of the level of consciousness in these individuals and could be used in rehabilitation to easily track their progress over time. With this in view, further studies should focus on the validation of the SECONDs in acute settings such as intensive care units, where it could be compared to other bedside assessment scales such as the GCS or the FOUR. Our scale additionally offers the advantage of providing a total score corresponding to one diagnosis (from 0 = coma, 1 = UWS, 2-5 = MCS-, 6-7 = MCS+ to 8 = EMCS). By contrast, the CRS-R total score cannot be used to infer the diagnosis. A CRS-R cut-off score of 10/23 has been associated with high sensitivity to the presence of signs of consciousness (i.e., individuals in a MCS-, MCS + or EMCS), although 22% of individuals demonstrating conscious awareness based on CRS-R diagnostic criteria had total scores < 10 and were therefore considered to be unconscious based on the cut-off [8]. Also, the SECONDs provides an easy-to-use assessment that requires less material (i.e., only a mirror) and potentially a shorter training (given the low number of items) as compared with the CRS-R, whose reliability was shown to be influenced by raters' level of experience [28]. However, the smaller number of items tested in this shorter scale precludes the examiner from assessing auditory, visual and (oro-)motor functions as thoroughly as with the CRS-R. The SECONDs also does not solve the problem of aphasia in evaluating consciousness after severe brain injury [29], which was highlighted with the CRS-R [30], and does not bring new clues to better detect the presence of cognitive-motor dissociation at the bedside [31]. Further investigations are necessary to judge how much these 2 aspects affect the SECONDs' scores.

This inaugural study of the SECONDs presents several limitations. First, because our study was performed in one main hospital (for 30/57 patients) and 3 rehabilitation centers (for 27/57 individuals), an external validation in a larger sample is needed. Moreover, even if the total number of included individuals is robust ($n = 57$), they form a very heterogeneous population spread across the spectrum of DoC profiles, and thus, the number of individuals in each diagnostic category is limited. Here we did not include repeated CRS-R because our 2-day protocol was built to optimize measures related to concurrent validity as well as intra-/inter-rater reliability. Hence, other studies should consider a comparison of SECONDs vs CRS-R diagnoses based on repeated assessments [11,12]. A prospective longitudinal study should further assess the predictive value of our scale with regard to the degree of functional recovery. Because this new tool was developed at the request of clinicians internationally in order to meet the field constraints efficiently, the next major step should be to focus on the validation of the scale in English and other languages as well as its characteristics when used routinely by healthcare professionals.

In conclusion, the SECONDs is a fast, promising and convenient tool to assess the level of consciousness in individuals with DoC. This tool could be easily implemented in clinical and research settings to decrease misdiagnosis and consequently optimize treatment decisions in these patients.

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Disclosure of interest

The authors declare that they have no competing interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.rehab.2020.09.001.

References

[1] Schnakers C, Vanhaudenhuyse A, Giacino J, Ventura M, Boly M, Majerus S, et al. Diagnostic accuracy of the vegetative and minimally conscious state: clinical consensus versus standardized neurobehavioral assessment. BMC Neurol 2009;9:35.
[2] Stender J, Gosseries O, Bruno MA, Charland-Verville V, Vanhaudenhuyse A, Demertzi A, et al. Diagnostic precision of PET imaging and functional MRI in disorders of consciousness: A clinical validation study. Lancet 2014;384:514–22.
[3] van Erp WS, Lavrijsen JCM, Vos PE, Bor H, Laureys S, Koopmans RTCM. The vegetative state: Prevalence, misdiagnosis, and treatment limitations. J Am Med Dir Assoc 2015;16 [85.e9-85.e14].
[4] Thibaut A, Bruno MA, Ledoux D, Demertzi A, Laureys S. tDCS in patients with disorders of consciousness: Sham-controlled randomized double-blind study. Neurology 2014;82:1112–8.
[5] Chatelle C, Val M, De, Catano A, Chaskis C, Seeldrayers P, et al. Is the Nociception Coma Scale-revised a Useful Clinical Tool for Managing Pain in Patients With Disorders of Consciousness? Clin J Pain 2016;32:321–6.
[6] Demertzi A, Ledoux D, Bruno M-A, Vanhaudenhuyse A, Gosseries O, Soddu A, et al. Attitudes towards end-of-life issues in disorders of consciousness: a European survey. J Neurol 2011;258:1058–65.
[7] Giacino JT, Kalmar K, Whyte J. The JFK Coma Recovery Scale-Revised: Measurement characteristics and diagnostic utility. Arch Phys Med Rehabil 2004;85:2020–9.
[8] Bodien YG, Carlowicz CA, Chatelle C, Giacino JT. Sensitivity and Specificity of the Coma Recovery Scale–Revised Total Score in Detection of Conscious Awareness. Arch Phys Med Rehabil 2016;97:490–2.
[9] Chatelle C, Bodien YG, Carlowicz C, Wannez S, Charland-Verville V, Gosseries O, et al. Detection and Interpretation of Impossible and Improbable Coma Recovery Scale-Revised Scores. Arch Phys Med Rehabil 2016;97:1295–300 [.e4].
[10] Annen J, Filippini MM, Bonin E, Cassol H, Aubinet C, Carrière M, et al. Diagnostic accuracy of the CRS-R index in patients with disorders of consciousness. Brain Inj 2019;33:1409–12.
[11] Wannez S, Heine L, Thonnard M, Gosseries O, Laureys S. The repetition of behavioral assessments in diagnosis of disorders of consciousness. Ann Neurol 2017;81:883–9.
[12] Giacino JT, Katz DI, Schiff ND, Whyte J, Ashman EJ, Ashwal S, et al. Practice guideline update recommendations summary: Disorders of consciousness. Neurology 2018;91:450–60.

[13] Kondziella D, Bender A, Diserens K, van Erp W, Estraneo A, Formisano R, et al. European Academy of Neurology guideline on the diagnosis of coma and other disorders of consciousness. Eur J Neurol 2020;1–16.
[14] Wannez S, Gosseries O, Azzolini D, Martial C, Cassol H, Aubinet C, et al. Prevalence of coma-recovery scale-revised signs of consciousness in patients in minimally conscious state. Neuropsychol Rehabil 2017;1–10.
[15] Wannez S, Vanhaudenhuyse A, Laureys S, Brédart S. Mirror efficiency in the assessment of visual pursuit in patients in minimally conscious state. Brain Inj 2017;31:1429–35.
[16] Wannez S, Hoyoux T, Langohr T, Bodart O, Martial C, Wertz J, et al. Objective assessment of visual pursuit in patients with disorders of consciousness: an exploratory study. J Neurol 2017;264:928–37.
[17] Nakase-Richardson R, Yablon SA, Sherer M, Nick TG, Evans CC. Emergence from minimally conscious state: Insights from evaluation of posttraumatic confusion. Neurology 2009;73:1120–6.
[18] Wijdicks EFM, Bamlet WR, Maramattom BV, Manno EM, McClelland RL. Validation of a new coma scale: The FOUR score. Ann Neurol 2005;58:585–93.
[19] Schnakers C, Majerus S, Giacino J, Vanhaudenhuyse A, Bruno M-A, Boly M, et al. A French validation study of the Coma Recovery Scale-Revised (CRS-R). Brain Inj 2008;22:786–92.
[20] Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159–74.
[21] Thibaut A, Bodien YG, Laureys S, Giacino JT. Minimally conscious state ''plus'': diagnostic criteria and relation to functional recovery. J Neurol 2019.
[22] Tooth LR, Ottenbacher KJ. The κ statistic in rehabilitation research: An examination. Arch Phys Med Rehabil 2004;85:1371–6.
[23] Candelieri A, Cortese MD, Dolce G, Riganello F, Sannita WG. Visual Pursuit: Within-Day Variability in the Severe Disorder of Consciousness. J Neurotrauma 2011;28:2013–7.
[24] Giacino JT, Ashwal S, Childs N, Cranford R, Jennett B, Katz DI. The minimally conscious state. Neurology 2002;58:349–53.
[25] Nakase-Richardson R, Yablon SA, Sherer M, Evans CC, Nick TG. Serial yes/no reliability after traumatic brain injury: Implications regarding the operational criteria for emergence from the minimally conscious state. J Neurol Neurosurg Psychiatry 2008;79:216–8.
[26] Teasdale G, Jennett B. Assessment of coma and impaired consciousness. Lancet 1974;304:81–4.
[27] Overbeek BUH, Eilander HJ, Lavrijsen JCM, Koopmans RTCM. Are visual functions diagnostic signs of the minimally conscious state? An integrative review. J Neurol 2018;265:1957–75.
[28] Lovstad M, Froslie KF, Giacino JT, Skandsen T, Anke A, Schanke AK. Reliability and diagnostic characteristics of the JFK coma recovery scale-revised: exploring the influence of rater's level of experience. J Head Trauma Rehabil 2010;25:349–56.
[29] Majerus S, Bruno MA, Schnakers C, Giacino JT, Laureys S. The problem of aphasia in the assessment of consciousness in brain-damaged patients. Prog Brain Res 2009;177:49–61.
[30] Schnakers C, Bessou H, Rubi-Fessen I, Hartmann A, Fink GR, Meister I, et al. Impact of Aphasia on Consciousness Assessment: A Cross-Sectional Study. Neurorehabil Neural Repair 2014;29:41–7.
[31] Edlow BL, Chatelle C, Spencer CA, Chu CJ, Bodien YG, O'Connor KL, et al. Early detection of consciousness in patients with acute severe traumatic brain injury. Brain 2017;140:2399–414.
[32] Laureys S, Celesia GG, Cohadon F, Lavrijsen J, León-Carrión J, Sannita WG, et al. Unresponsive wakefulness syndrome: a new name for the vegetative state or apallic syndrome. BMC Med 2010;8:68.
[33] Laureys S, Boly M. The changing spectrum of coma. Nat Clin Pract Neurol 2008;4:544–6.
[34] Bruno MA, Vanhaudenhuyse A, Thibaut A, Moonen G, Laureys S. From unresponsive wakefulness to minimally conscious PLUS and functional locked-in syndromes: Recent advances in our understanding of disorders of consciousness. J Neurol 2011;258:1373–84.