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RESEARCH

Convergence and equating norms between the Telephone Interview for Cognitive Status (TICS), the MMSE and the MoCA in an Italian population sample

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Abstract

Background This study aimed at testing the convergence and deriving equating norms between the Telephone Interview for Cognitive Status (TICS) and the Mini-Mental State Examination (MMSE) and the Montreal Cognitive Assessment (MoCA) in an Italian population sample.

Methods Four-hundred and eighty two healthy Italian native-speaker (300 females; age: 57.8 ± 15.5, *range* = 20–94; education: 13.1 ± 3.8, *range* = 5–25) underwent the TICS (*range* = 1–41), MMSE and MoCA. An additional *Delayed Recall* of the 10-word list was administered as the last task of the TICS to compute a further total ($TICS_{\&}DR$; *range* = 1–51). Convergence between the TICS/$TICS_{\&}DR$ and in-person screeners was tested *via* Bonferroni-corrected Spearman's coefficients, whilst equating norms were derived *via* a Log-linear Smoothing Equipercentile Equating (LSEE) approach. A two one-sided test (TOST) procedure was run to test the equivalence between empirical and LSEE-derived scores.

Results TICS scores converged with both MMSE (r_s=0.34; p<.001) and MoCA scores (r_s=0.42; p<.001)– the same being true for the $TICS_{\&}DR$ (MMSE: r_s=0.36; p<.001; MoCA: r_s=0.42; p<.001). Cross-walks were estimated to derive TICS/$TICS_{\&}DR$ scores from the MMSE/MoCA, and vice-versa. The algorithm could not compute the conversions for TICS, MMSE and MoCA scores < 22, <21 and < 14, respectively. TOST procedures revealed that all comparisons yielded equivalence except for those aimed at deriving TICS from MMSE scores and $TICS_{\&}DR$ from both the MMSE and the MoCA.

Discussion The Italian TICS validly captures examinees' cognitive efficiency as measured by MMSE or MoCA; derived cross-walks between the TICS and MMSE/MoCA allows for a flexible use of in-person and telephone-based screeners.

Keywords Telephone interview for cognitive status · Mini-mental state examination · Montreal cognitive assessment · Teleneuropsychology · Equating · Cognitive screening

Background

Within the field of teleneuropsychology, telephone-based cognitive screening (TBCS) instruments ease, by relaying on a widespread an ubiquitously accepted *medium*, the provision of first-level cognitive examinations by bridging down geographical, logistic, economic and socio-cultural barriers limiting the access to such a facility, also reducing lost-to-follow-up phenomena [1–6]. Moreover, thanks to their high degree of practicability, TBCS tests facilitate the implementation and completion of large-scaled, decentralized epidemiological/interventional studies [1; 2; 5; 6].

In order for examiners to confidently employ TBCS tests to the abovementioned aims, it is fundamental to demonstrate their convergent validity toward in-person cognitive screening measures [7]. This feature is in fact relevant to determine whether these tests measure the same construct of traditional, paper-and-pencil screeners regardless of the different administration modality [8].

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A related approach to further promote examiners' employment of TBCS tests lies in delivering norms to convert their scores to those yielded by in-person cognitive screeners– and vice-versa– *via* test equating procedures [9]. These statistical techniques aim at generating cross-walks between two or more different outcome measures that are typically addressed to the same conditions(s), in order to (1) avoid between-examiner heterogeneity in test adoption, (2) increase assessment consistency when different tests are administered over time, as well as (3) help the implementation of retrospective analyses of data collected with either one of the equated tests [9–11]. Hence, with specific regard to TBCS tests, equating techniques would allow a flexible use of in-person and telephone-based tests– in order, for instance, to follow-up over the telephone an examinee that has been tested *de visu* at baseline [9].

In this respect, the international literature has focused on testing the convergence and deriving conversion norms between the Telephone Interview for Cognitive Status (TICS) [12]– the gold-standard TBCS test for overall cognitive efficiency [2; 5]– and common in-person screeners– such as the Mini-Mental State Examination (MMSE) [13].

In Italy, an attempt to deliver convergent validity evidence and equating norms between the TICS and the MMSE has been performed within a seminal validation study for the TICS by Dal Forno et al. [14]. Nevertheless, Dal Forno et al.'s [14] report preceded the official standardization of the Italian TICS delivered in 2022 [15; 16], addressed a relatively restricted ($N=109$) and heterogeneous sample (i.e., including both patients with Alzheimer's disease dementia and healthy controls). Moreover, these Authors [14] did not embrace up-to-date statistical techniques to derive cross-walks between the two tests– such as the Log-linear Smoothing Equipercentile Equating (LSEE) [17], which is currently regarded as the gold-standard approach to this aim within the literature on cognitive screeners [9]. Moreover, no evidence of convergent validity and conversion algorithms between the TICS and the second most widely used in-person cognitive screening tool, namely the Montreal Cognitive Assessment (MoCA) [18], have been provided in Italy.

With these premises, the present study aimed at (1) testing the convergence and (2) deriving, *via* the LSEE approach, equating norms between the TICS and both the MMSE and the MoCA in an Italian population sample.

Methods

Participants

Four-hundred and eighty-two healthy participants were prospectively recruited between 2023 and 2024 among Authors' personal acquaintances, through advertising at the University of Milano-Bicocca as well as within cognitive screening campaigns promoted by IRCCS Istituto Auxologico Italiano. A non-probability, snowball sampling approach was employed with regard to the first listed source of recruitment, whilst a non-probability, convenience one (i.e., based on participants' spontaneous referrals) was adopted in respect to the two last recruitment sources. The following exclusion criteria were addressed: (1) developmental and/or acquired central nervous system disorders; (2) psychiatric diseases; 2) psychotropic medication intake and substance use disorders; (3) severe, uncompensated general-medical conditions; (4) uncorrected sensory deficits. No compensation was given to participants.

Materials

Participants underwent the Italian TICS (*range*=1–41) [16], MMSE (*range*=0–30; Foderaro et al.'s [19] version) and MoCA (*range*=0–30; 7.1 version [20]).

TICS and MoCA items were grouped as previously described: TICS-Orientation (*range*=0–12), -Memory (*range*=0–12), -Attention and Executive Functioning (*range*=0–9) and -Language (*range*=1–8); MoCA-Visuo-Spatial (*range*=0–4), -Executive Functioning (*range*=0–4), -Language (*range*=0–5), -Attention (*range*=0–6), -Memory (*range*=0–5) and -Orientation (*range*=0–6) [16; 20]. A Delayed Recall of the 10-word list was also administered as the final task of the TICS (TICS-Delayed Recall; *range*=0–10), with the respective total score being also computed ($TICS_{\&}DR$; *range*=1–51). The MMSE was instead subdivided as follows: MMSE-Orientation (including Spatial and Temporal Orientation items; *range*=0–10); MMSE-Attention (including the Serial subtraction/Backward spelling item; *range*=0–5); MMSE-Memory (including Immediate Recall and Delayed Recall items; *range*=0–6); MMSE-Language (including Naming, Repetition, Command, Reading and Writing items; *range*=0–8). The Constructional Praxis item was forcedly left out of any of these groupings, and thus accounted for only within the MMSE global score.

Procedures

Data collection was performed by licensed psychologists and psychology trainees that underwent an in-depth training for test administration rules. In-person sessions (duration: 15–30’) were conducted in quiet and distraction-free rooms at the hospital (IRCCS Istituto Auxologico Italiano), at the university (University of Milano-Bicocca) or at participants’ homes. During telephone-based sessions (duration: 5–15’), both examiners and examinees were at their respective homes. Prior to the beginning of the telephone-based session, a proxy (i.e., family member or cohabitee) was asked to ensure that no distractions (e.g., loud noises) or facilitations (e.g., paper and pencil and calendars) were present in the room where the test administration took place. Moreover, an in-depth sound check was performed in other to ensure a good quality of the telephone call in accordance with a previously published protocol [21; 22].

In order to explore potential carry-over effects, a subsample of participants ($N=163$) that were randomly selected by relying on a random number table first underwent the telephone-based session with the TICS and then in-person one with the MMSE and the MoCA– whilst the opposite order was addressed for remaining ones. In-person and telephone-based sessions were performed a 5-to-7-day distance. Such an interval was chosen in order to avoid, on one hand, possible carry-over effects, whilst, on the other, in order to rule-out the detection of possible changes due to unknown sources of variance.

During the in-person sessions, a fixed administration order was maintained (i.e., the MMSE first and then the MoCA), with overlapping items from the MMSE and MoCA– i.e., the Serial Subtraction one and a number of those assessing spatial/temporal orientation, respectively– being re-administered only if failed on the previous attempt (in agreement with the procedure described by Dubbleman et al. [23]). Consistently, such items were scored as correct on the MoCA if previously passed on the MMSE.

Statistics

The vast majority of both subscale-level and total scores on the three screeners did not distribute Normally– as indexed by excessive skewness and kurtosis values (i.e., >|1| and|3|, respectively) and visual abnormalities of histograms and Q-Q plots [24]. Therefore, non-parametric tests were employed.

Mann-Whitney *U*-tests were run to test whether the administration order (i.e., in-person first vs. telephone-based first) influenced participants’ performance on the three screeners (i.e., the TICS/TICS$_{\&}$DR, MMSE and MoCA). Moreover, a Sperman’s correlation was run to test the association between MMSE and MoCA scores in order to determine whether the fact that the MMSE was administered first could influence participants’ performance on the MoCA– under the hypothesis that a large correlation (i.e., $r_s \geq 0.50$, according to Cohen’s [25] guidelines) would have suggested that such an administration order did actually affect MoCA scores.

Bonferroni-corrected Spearman’s coefficients were run to test the convergence of the TICS/TICS$_{\&}$DR against the MMSE and MoCA– separately for total and subscale-level scores *via*. According to Hobart et al. [26], who recommend that at least $N=80$ observations be collected to run validity analyses, the present sample was deemed as adequately sized. The magnitude of correlation coefficients were interpreted in accordance with Cohen’s [25] thresholds– i.e., $r_s \leq 0.30$, small; $0.30 < r_s \leq 0.50$, medium; $r_s \geq 0.50$, large.

The LSEE approach was employed to derive equating norms between the TICS/TICS$_{\&}$DR and both MMSE and MoCA scores– and vice versa– *via* the R package *equi* (https://github.com/twolodzko/equi/) [27]. Briefly, the LSEE technique estimates the conversion between two measures by comparing the distribution of their percentile ranks after applying a log-linear function that levels out distribution irregularities [17]. Based on Livingtston’s guidelines [28], a sample of $N=200$ observations is sufficient to run LSEE analyses.

Finally, in order to validate the estimated cross-walks, a two one-sided test (TOST) procedure for dependent measures [29] was employed to determine whether equated scores– computed *via* the *equi* package [27] according to the abovementioned LSEE-based algorithms– were statistically equivalent to empirical ones. Such an approach allows to conclude on the statistical equivalence between two dependent means if the effect size of their difference falls within the equivalence interval– i.e., if it is, at the same time, significantly greater and smaller than the lower and upper equivalence bound, respectively [29]. TOST analyses were run *via* the jamovi macro *TOSTER* [29; 30]. According to Lakens [29], a minimum of 44 observation pairs has been deemed as adequate to perform such a TOST analysis by setting $\alpha=0.05$, $1-\beta=0.9$ and upper and lower equivalence bounds at -0.5 and 0.5, respectively. Such equivalence bounds were selected as a default option in the absence of a specific hypothesis on the smallest effect size of interest [29].

Analyses were run *via* R 4.3.0 (R Core Team, 2023), jamovi 2.3 (the jamovi project, 2022) and IBM® SPSS® Statistics 29 (IBM Corp., 2023). Missing data were excluded pairwise.

Results

Sample stratification according to age, education and sex is displayed in Table 1, whilst Table 2 summarizes participants’ demographic and cognitive features.

Table 1 Sample stratification according to age, education and sex

	Age (M/F)							
Education	35≤	36–45	46–55	56–65	66–75	76–80	≥81	Total
5≤	0/0	0/0	1/1	0/0	2/4	3/7	1/11	7/23
6–8	1/0	3/2	6/3	6/3	2/11	3/8	4/6	25/33
9–13	10/4	8/10	16/41	34/55	10/27	6/4	2/2	86/143
14–16	5/8	0/3	5/13	5/5	7/6	0/0	0/0	22/35
≥17	5/15	0/4	8/19	15/19	8/5	5/3	1/1	42/66
Total	21/27	11/19	36/77	60/82	29/53	17/22	8/20	182/300

Table 2 Participants' background and cognitive measures

N	482
Age (years)	57.8 ± 15.5 (20–94)
Sex (male/female)	182/300
Education (years)	13.1 ± 3.8 (5–25)
MMSE	
Total	29.1 ± 1.2 (21–30)
Orientation	9.8 ± 0.7 (4–10)
Language	7.8 ± 0.4 (6–8)
Memory	5.6 ± 0.7 (3–6)
Attention	5 ± 0.3 (1–5)
MoCA	
Total	25.3 ± 3.2 (14–30)
Visuo-Spatial	3.3 ± 0.9 (0–4)
Executive Functioning	3.3 ± 0.9 (0–4)
Language	4.7 ± 0.5 (2–5)
Attention	5.5 ± 0.9 (2–6)
Memory	2.4 ± 1.7 (0–5)
Orientation	5.9 ± 0.3 (2–6)
TICS	
Total	35.8 ± 2.6 (22–41)
Orientation	11.9 ± 0.7 (5–12)
Memory	7.5 ± 1.9 (1–12)
Attention and Executive Functioning	8.5 ± 1 (2–9)
Language	7.9 ± 0.3 (6–8)
Delayed Recall	4 ± 2.2 (0–10)
$TICS_{\&}DR$	39.8 ± 4.3 (22–51)

Notes MMSE = Mini-Mental State Examination; MoCA = Montreal Cognitive Assessment; TICS = Telephone Interview for Cognitive Status; DR = Delayed Recall

Table 3 Spearman's coefficients among TICS, MMSE and MoCA subscales

	TICS-O	TICS-AEF	TICS-L	TICS-M	$TICS_{\&}DR$
MMSE-O	0.28*	0.14	0.05	0.17*	0.10
MMSE-L	0.03	0.14	0.15§	0.07	0.07
MMSE-M	0.07	0.13	0.02	0.25*	0.27*
MMSE-A	0.11	0.23*	0.06	0.13	0.17*
MoCA-VS	0.14	0.25*	0.13	0.18*	0.13
MoCA-L	0.11	0.26*	0.17*	0.19*	0.13
MoCA-EF	0.09	0.18*	0.11	0.32*	0.23*
MoCA-A	0.13	0.22*	0.16*	0.16*	0.11
MoCA-M	0.06	0.17*	0.03	0.27*	0.31*
MoCA-O	0.29*	0.12	0.04	0.17*	0.12

Notes *significant at $\alpha_{adjusted} = 0.001$; §marginally significant at $\alpha_{adjusted} = 0.001$ (i.e., $p = .001$); MMSE = Mini-Mental State Examination; MoCA = Montreal Cognitive Assessment; TICS = Telephone Interview for Cognitive Status; IP = in-person; O = Orientation; M = Memory; L = Language; AEF = Attention and executive functioning; EF = Executive functioning; A = Attention; DR = Delayed recall; VS = Visuo-spatial

No significant differences were detected on any of the screeners between "in-person first" and "telephone-based first" participants (TICS: $U = 25598.5$; $p = .780$; $TICS_{\&}DR$: $U = 24609$; $p = .335$; MMSE: $U = 25007$; $p = .459$; MoCA: $U = 25234.5$; $p = .596$).

The association between the MMSE and the MoCA was significant but moderate in size ($r_s(482) = 0.41$; $p < .001$)– suggesting that the fixed administration order did not majorly influence participants' scores on the MoCA.

At $\alpha_{adjusted} = 0.013$, moderate, significant associations were detected between the TICS and both MMSE ($r_s(482) = 0.34$; $p < .001$) and MoCA scores ($r_s(482) = 0.42$; $p < .001$)– the same being true for the $TICS_{\&}DR$ (MMSE: $r_s(482) = 0.36$; $p < .001$; MoCA: $r_s(482) = 0.42$; $p < .001$). Similarly, when looking at subscale-level correlations (Table 3), overall consistent patterns of associations, although generally small in size, emerged between the TICS and in-person screeners. More specifically, TICS-Orientation and -Language scores showed overall expected associations with respective MMSE/MoCA subscales, whilst TICS-Attention and Executive Functioning, -Memory and -Delayed Recall ones showed more widespread correlations.

Table 4 reports LSEE-based cross-walks to derive TICS/$TICS_{\&}DR$ scores from the MMSE/MoCA, whilst Table 5 those to derive MMSE/MoCA scores from TICS/$TICS_{\&}DR$ ones. The algorithm could not compute the conversions for TICS, MMSE and MoCA scores < 22, < 21 and < 14, respectively, since these were the lowermost empirical values detected within the present sample.

Table 6 shows the results of TOST procedures for testing the equivalence between LSEE-derived and empirical scores. All comparisons yielded equivalence except for those aimed at deriving TICS from MMSE scores and $TICS_{\&}DR$ from both the MMSE and the MoCA: within both these scenarios, LSEE-derived scored were higher than empirical ones.

Table 4 LSEE-based MMSE-/MoCA-to-TICS and MMSE-/MoCA-to-TICS conversions

TICS from MoCA		TICS from MMSE		$TICS_{\&}DR$ from MoCA		$TICS_{\&}DR$ from MMSE	
MoCA	TICS	MMSE	TICS	MoCA	$TICS_{\&}RD$	MMSE	$TICS_{\&}RD$
14	26	*n.a.*	*n.a.*	14	27	*n.a.*	*n.a.*
15	28	*n.a.*	*n.a.*	15	30	*n.a.*	*n.a.*
16	29	*n.a.*	*n.a.*	16	30	*n.a.*	*n.a.*
17	30	*n.a.*	*n.a.*	17	31	*n.a.*	*n.a.*
18	30	*n.a.*	*n.a.*	18	32	*n.a.*	*n.a.*
19	31	*n.a.*	*n.a.*	19	33	*n.a.*	*n.a.*
20	32	*n.a.*	*n.a.*	20	34	*n.a.*	*n.a.*
21	32	21	22	21	35	21	22
22	33	22	24	22	36	22	25
23	34	23	27	23	37	23	28
24	35	24	28	24	38	24	30
25	35	25	29	25	39	25	31
26	36	26	30	26	40	26	32
27	37	27	32	27	42	27	33
28	38	28	33	28	44	28	36
29	39	29	36	29	46	29	39
30	41	30	41	30	51	30	51

Notes LSEE = log-linear smoothing equipercentile equating; MMSE = Mini-Mental State Examination; MoCA = Montreal Cognitive Assessment; TICS = Telephone Interview for Cognitive Status; DR = Delayed Recall; n.a.=not applicable. Equated scores were rounded up to the nearest decimal

Table 5 LSEE-based MMSE-/MoCA-to-TICS and MMSE-/MoCA-to-TICS&DR conversions

MoCA from TICS		MMSE from TICS		MoCA from $TICS_{\&}DR$		MMSE from $TICS_{\&}DR$	
TICS	MoCA	TICS	MMSE	$TICS_{\&}DR$	MoCA	$TICS_{\&}DR$	MMSE
22	14	22	21	22	14	22	21
24	14	24	22	24	14	24	22
27	14	27	23	27	14	27	22
28	15	28	24	29	15	29	23
29	16	29	25	30	15	30	24
30	18	30	26	31	17	31	25
31	19	31	26	32	18	32	26
32	20	32	27	33	19	33	27
33	22	33	28	34	20	34	27
34	23	34	28	35	21	35	28
35	24	35	29	36	22	36	28
36	26	36	29	37	23	37	28
37	27	37	29	38	24	38	29
38	28	38	30	39	25	39	29
39	29	39	30	40	26	40	29
40	30	40	30	41	26	41	29
41	30	41	30	42	27	42	29
-	-	-	-	43	28	43	30
-	-	-	-	44	28	44	30
-	-	-	-	45	29	45	30
-	-	-	-	46	29	46	30
-	-	-	-	47	29	47	30
-	-	-	-	48	29	48	30
-	-	-	-	49	30	49	30
-	-	-	-	50	30	50	30
-	-	-	-	51	30	51	30

Notes LSEE = log-linear smoothing equipercentile equating; MMSE = Mini-Mental State Examination; MoCA = Montreal Cognitive Assessment; TICS = Telephone Interview for Cognitive Status; DR = Delayed Recall. Equated scores were rounded up to the nearest decimal

Table 6 Results of TOST procedures for the comparison between empirical and LSEE-derived scores

Empirical score		Derived score		t	*p*	Equivalent
TICS	vs.	TICS from MoCA	Between-mean difference	−0.1	n.s.	Yes
35.8±2.6		36±3	Lower equivalence bound	4.2	<0.001	
			Upper equivalence bound	-4.3	<0.001	
	vs.	TICS from MMSE	Between-mean difference	11.2	<0.001	No
		38±3.7	Lower equivalence bound	14.3	<0.001	
			Upper equivalence bound	8	n.s.	
MoCA	vs.	MoCA from TICS	Between-mean difference	0.1	n.s.	Yes
25.3±3.2		25.3±3.2	Lower equivalence bound	3.7	<0.001	
			Upper equivalence bound	-3.4	<0.001	
	vs.	MoCA from $TICS_{\&}DR$	Between-mean difference	-1.8	n.s.	Yes
		25±3.2	Lower equivalence bound	1.8	0.040	
			Upper equivalence bound	-5.3	<0.001	
MMSE	vs.	MMSE from TICS	Between-mean difference	-5.9	<0.001	Yes
29.1±1.2		28.8±1.2	Lower equivalence bound	3.2	<0.001	
			Upper equivalence bound	-15.1	<0.001	
	vs.	MMSE from $TICS_{\&}DR$	Between-mean difference	-6.3	<0.001	Yes
		28.8±1.3	Lower equivalence bound	2.5	0.006	
			Uppeer equivalence bound	-15.2	<0.001	
$TICS_{\&}DR$	vs.	$TICS_{\&}DR$ from MoCA	Between-mean difference	2.3	<0.001	No
39.9±4.3		40.3±4.6	Lower equivalence bound	4.8	<0.001	
			Upper equivalence bound	−0.01	n.s.	
	vs.	$TICS_{\&}DR$ from MMSE	Between-mean difference	12.6	<0.001	No
		43.8±7.2	Lower equivalence bound	14.2	<0.001	
			Upper equivalence bound	10.9	n.s.	

Notes TOST = two one-sided test; LSEE = log-linear smoothing equipercentile equating; MMSE = Mini-Mental State Examination; MoCA = Montreal Cognitive Assessment; TICS = Telephone Interview for Cognitive Status; DR = Delayed Recall

Discussion

The present report provides Italian clinicians and researchers with evidence on the convergent validity of the both the TICS and the $TICS_{\&}DR$ against the two most widespread in-person cognitive screening tests, the MMSE and the MoCA, also delivering straightforward algorithms to convert TICS and $TICS_{\&}DR$ scores to MMSE and MoCA ones (and vice-versa), from a large sample ($N = 482$) of the general population. This study thus adds up to and complements the flourishing Italian literature on teleneuropsychology and, more specifically, TBCS tests [6; 15; 16; 31–34]. Information herewith reported in this respect are of great usefulness also due to the widespread use of the MMSE and the MoCA for cognitive screening aims in Italy [35].

Association and cross-walks between the TICS and the MMSE

In alignment with both with Dal Forno et al.'s [14] seminal report and with the international literature [2; 5], TICS and $TICS_{\&}DR$ scores herewith proved to converge with the MMSE. Interestingly, when looking at subscale-level correlations, rather selective associations were detected with regard to the TICS-Orientation, -Language and -Attention and Executive Functioning, which correlated with the MMSE-Orientation, -Language and -Attention, respectively. At variance, TICS subscales tapping on memory not only showed the expected association with the MMSE-Memory, but also correlated with the MMSE-Orientation (TICS-Memory) or the MMSE-Attention (TICS-Delayed Recall).

As to the present equating norms between the TICS/$TICS_{\&}DR$ and the MMSE, TOST procedures revealed that the MMSE can be safely derived from both the TICS and the $TICS_{\&}DR$, whilst not supporting the opposite conversions (i.e., deriving the TICS/$TICS_{\&}DR$ from the MMSE). It follows that, within a longitudinal scenario, examinees being tested with the MMSE at a given time-point can be confidently followed-up with the TICS/$TICS_{\&}DR$ without losing information on their trends in MMSE scores. At variance, it is not recommended to derive TICS/$TICS_{\&}DR$ scores from the MMSE since this would lead to an overestimation of examinees' performance on the former tests. This last finding might be accounted for by the combination of two elements: on one hand, the narrower theoretical range of the MMSE when compared to the TICS/$TICS_{\&}DR$; on the other, the renowned ceiling effect that characterize the MMSE [36]. As a result, LSEE algorithms had to rely on a restricted range of scores on the MMSE (i.e., from 21 to

30) to derive a much wider range of scores on the TICS/$TICS_{\&}DR$– this most likely leading to the abovementioned overestimation of MMSE-derived TICS/$TICS_{\&}DR$ scores.

Association and cross-walks between the TICS and the MoCA

TICS and $TICS_{\&}DR$ scores also proved to converge with MoCA scores, with the magnitude of these associations being slightly higher when compared to those with the MMSE. Such findings agree with a previous report [37] demonstrating a significant association between a modified version of the TICS [38] and the MoCA. At variance, to the best of the Authors' knowledge, no study to date has tested this correlation by employing the original version of the TICS [12]. As far as subscale-level correlational analyses are concerned, the TICS-Orientation and -Language once again showed quite selective associations: the TICS-Orientation solely correlated with the MoCA-Orientation, whilst the TICS-Language correlated only with the MoCA-Language and -Attention. Similarly, the TICS-Delayed Recall proved to be related solely to the MoCA-Delayed Recall, by nevertheless also correlating with the MoCA-Executive Functioning. Instead, the remaining TICS subscales showed widespread associations with different MoCA subscales: the TICS-Attention and -Executive Functioning correlated with all MoCA subscales except for the MoCA-Orientation, while the TICS-Memory converged with all MoCA subscales.

Moreover, results from the TOST analyses support both TICS-to-MoCA and MoCA-to-TICS conversions. By contrast, as for the MMSE, MoCA-derived $TICS_{\&}DR$ scores proved to be overestimated by the LSEE algorithm– and thus not to be equivalent to empirical MoCA scores. As a result, it is reasonable to infer that the MoCA and the TICS can be safely used interchangeably within the context of repeated-measure assessments (e.g., examinees tested with the MoCA at a given time-point can be followed-up with the TICS and vice-versa), without losing track of their longitudinal changes on the screener at hand. In addition, the $TICS_{\&}DR$ can be confidently estimated from the MoCA, hence implying that when following-up examinees previously tested with the MoCA, the 51-item version of the TICS can be likewise administered.

Limitations and future perspectives

This study is of course not free of limitations. First, since the current cross-walks were derived from healthy individuals, lowermost scores on the three cognitive screening tests were either underrepresented or not represented at all, hence limiting the generalizability of these conversion norms to clinical samples with moderate-to-severe cognitive impairment. In this respect, it should be noted that this phenomenon was especially evident for the MMSE, whose scores, as expected [36], showed a lower degree of inter-individual variability when compared to the other tests. Future studies therefore should be aimed at deriving equating norms between the Italian TICS, MMSE and MoCA in cognitively impaired patients. Second, some of the present conversions (namely, that to derive the TICS score from the MMSE ones and the TICS&DR scores from both the MMSE and the MoCA scores) are not supported by TOST procedures. Hence, great caution is needed when applying and interpreting these cross-walks. Third, some age-education groups were relatively underrepresented within the current sample, especially elderlies over 80 years old. It is therefore advisable to conduct further investigations focusing on this critical age group. Moreover, as also previously mentioned, it is worth highlighting that the magnitude of the associations between the TICS/TICS&DR and the MMSE were weaker when compared to those between the former test and the MoCA– this being true also at a subscale level. Hence, users might rely, with a greater degree of confidence, on the conversions between the TICS/TICS&DR and the MoCA than on that between the TICS/TICS&DR and the MMSE. In this respect, it is also worth reminding users that, generally speaking, cross-walks such as those provided within the current report always have to be employed with caution within clinical settings. In fact, test scores derived from these conversions represent an estimate of examinees' performances, and not necessarily the scores that they would actually obtain.

Conclusions

In conclusions, the Italian TICS validly captures examinees' cognitive efficiency as measured by the most used in-person screening tests, the MMSE and the MoCA; the cross-walks derived to estimate TICS scores based on MoCA scores and, albeit to a lesser extent, MMSE ones, can help examiners track individuals' cognitive *status* through TBCS procedures. The flexibility of the current conversions could be further improved by the availability of Italian cross-walks between the MMSE and the MoCA [10], albeit with the understanding that a slightly different version of the MMSE [39] has been used in this study. The present report hence provides useful information that further supports the employment of the Italian TICS within both clinical settings– e.g., to offer a first-level cognitive assessment to patients that cannot access in-person services, as well as to monitor patients' trajectories over time by reducing the risk of loss-to-follow-up phenomena– and research scenarios– e.g., to facilitate the completion of large-scaled, decentralized studies on cognition in both clinical and non-clinical populations.

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Author contributions ENA: conceptualization, data collection, analyses, drafting, revision; BC, GDL,: data curation, analyses, drafting, revision; SC, LE, CC, AZ, EC, MAS: data curation, revision; FV, VS, NT, NB, BP: resources, revision.

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Data availability Datasets associated with the present study cannot be made publicly available on ethical-legal grounds but have been stored on an online repository (https://doi.org/10.5281/zenodo.15150459) and can be made available upon reasonable request of interested researchers to the Corresponding Author(s), who will forward a request for a data transfer agreement to the relevant Ethical Committee. Data concerning the Telephone Interview for Cognitive Status cannot be made available due to copyright-related reasons.

Declarations

Ethical approval Participants provided informed consent. This study was approved by the Ethics Committee of IRCCS Istituto Auxologico Italiano (I.D.: 25C122, 23C308).

Competing interests E.N.A. and N.B. have edited the official manual of the Italian version of the Telephone Interview for Cognitive Status (TICS) on behalf of Giunti Psychometrics and perceive royalties from Giunti Psychometrics when such a manual is purchased. Giunti Psychometrics holds the copyright of the Italian TICS.

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