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# **RESEARCH ARTICLE**

# CLINICAL TEACHER

# Measurement of uncertainty tolerance revisited

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# Abstract

Introduction: Uncertainty tolerance (UT) is attracting increasing attention in medical education due to the numerous challenges associated with uncertainty in professional life. Inconsistencies in analysing the relationship between UT and moderators may arise from inadequate measurement methods. Most instruments were formulated before the most widely accepted framework was published. Our aim was to investigate the validity of an UT scale using an actual framework to corroborate with better and accurate instruments.

Methods: A total of 1052 students were invited. Various psychometric methods were used to explore validity of the TAMSAD scale in light of actual framework. Classic exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were performed. Secondly, content item classification was triangulated with exploratory graph analysis (EGA), and the new EFA, CFA, and cognitive diagnostic modelling (CDM) analysis were conducted. The reliability was calculated using Cronbach's alpha and McDonald's omega.

Results: A total of 694 students (65.9%) responded to the questionnaire. The reliability of the TAMSAD scale was 0.782. The initial EFA revealed no clear interpretable dimensions. The TAMSAD scale items can be classified into sources of uncertainty. The EGA has three dimensions, and the new EFA led to a 17-item TAMSAD scale with the following three dimensions: ambiguity, complexity, and probability. These dimensions lead to better adjustment fit indices in the new CFA and CDM analyses. Conclusion: We found evidence that the TAMSAD scale can be considered a multidimensional scale, organised in terms of sources of uncertainty.

#### INTRODUCTION 1

Dealing with uncertainty is a constant feature of a physician's work life and has an unequivocal impact on their professional life.<sup>1</sup> How physicians manage uncertainty is increasingly attracting attention, mainly owing to discussions around clinical reasoning,<sup>2</sup> evidence-based medicine,<sup>3-5</sup> shared decision making,<sup>6</sup> and the COVID-19 pandemic.<sup>7</sup> Low uncertainty tolerance (UT) is related to low psychological well-being,<sup>8</sup> including low resilience,<sup>9</sup> high work-related stress,<sup>10</sup> and

burnout,<sup>9,11,12</sup> lower satisfaction after shared-decision encounters,<sup>13</sup> and negative attitudes towards unserved patients.<sup>14</sup> In addition, Harden et al.<sup>15</sup> considered that to achieve appropriate decision-making skills, clinical reasoning, and judgement, medical students must learn to cope with uncertainty, which the authors understood to be part of a set of high-order competences (meta-competences). A recent scoping review<sup>16</sup> identified a few studies that explored educational methods to enhance UT. Although this is a fundamental learning outcome in medical education, interventions must be supported by solid evidence.

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Uncertainty tolerance is a fundamental learning outcome in medical education; thus, interventions must be supported by solid evidence.

Difficulties in designing interventional studies stem from the fact that we are vet to understand how experts deal with uncertainty and how they have learnt to manage it.<sup>17,18</sup> Moreover, how to accurately measure this phenomenon remains unanswered. Gowda et al.<sup>19</sup> designed a course (Observation and Uncertainty in Art and Medicine) to help students deal with uncertainty. Although acceptance of uncertainty was one theme that emerged from qualitative data, they identified no difference between the pre- and post-tests in the scale chosen to measure UT. One possibility is that the scale did not accurately measure what was expected. If one considers UT as a purely cognitive and emotional personality trait, it may be difficult to design an instrument capable of detecting small variations that occur with educational interventions. The size of the scale may add difficulties in detecting differences between groups. Another issue is that UT for undergraduate students may have differences in experiential content compared with physicians' UT.

The Tolerance of Ambiguity in Medical Students and Doctors (TAMSAD)<sup>20</sup> scale is a 29-item Likert scale first published in 2015 by Hancock et al. To our knowledge, this is the first scale to carefully consider the content validity of medical students' UT. By understanding that UT can be associated with personal epistemology and professional identity development<sup>21</sup> and thus can be learned from appropriate exposure, the scale items attempt to contextualise clinical and learning experiences. The concept of uncertainty used by the authors is 'the response to an ambiguous situation'.<sup>20</sup> An ambiguous situation can be a vague, unknown, unreliable or indefinite situation. The original reliability was good (Cronbach's alpha of 0.80), and researchers obtained further validity evidence for the scale in 2020.<sup>22</sup>

By understanding that UT can be associated with personal epistemology, the TAMSAD scale items attempt to contextualise clinical and learning experiences. In 2017, Hillen et al.<sup>23</sup> proposed a conceptual framework for researchers to have a common ground in discussing the subject of UT and advancing knowledge. Similar to Hancock et al., they considered 'uncertainty' to be a response to a feature of reality. However, for Hillen et al. uncertainty is 'the conscious awareness of ignorance', and 'ambiguity' is a 'specific feature of information that produces uncertainty'.<sup>23</sup> A qualitative analysis of various uncertainty and ambiguity scales (including the TAMSAD scale) revealed that aspects other than ambiguity were important sources of uncertainty in the health profession. Their final model considered ambiguity, complexity and probability as sources of uncertainty. They also emphasised that responses to uncertainty (the metacognitive state) can be cognitive, behavioural or emotional. Consequently, this framework considers uncertainty and UT as primarily multidimensional concepts.

Ambiguity, complexity, and probability are sources of uncertainty. Consequently, UT is a primarily multidimensional concept.

Recently, Stephens et al.<sup>24</sup> highlighted inconsistencies in analysing the association between UT and outcomes or characteristics, such as gender, may be a consequence of inadequate measurement methods. They conducted a review and meta-analysis of the reliability of different UT scales and found that alpha was significantly higher when applied to physicians than when applied to medical students. As a step towards the refinement of UT measurement among the medical student population, this work aimed to analyse conceptual and construct validity of the TAMSAD scale in light of conceptual framework of Hillen et al.

# 2 | METHODS

The TAMSAD scale was translated into Brazilian Portuguese using the Beaton's methodology.<sup>25</sup> A pilot study involving 36 general physicians resulted in changes to the wording of the items. Thirteen judges with experience in clinical uncertainty, medical education and psychometry were then invited to evaluate the translated scale, and a content validity ratio (CVR)<sup>26</sup> was calculated for each item. None of the items had a CVR below the critical value (0.538).

A total of 1052 students from the first to the last year of medical graduation were invited by the main researcher to participate either online (due to social restrictions during the COVID-19 pandemic) or on paper after they were informed of the research significance. Participants were invited during the period between September 2020 and February 2021. To gather evidence of concurrent validity, the

Physicians' Reaction to Uncertainty (PRU) scale was applied in addition to the TAMSAD scale.<sup>27</sup> The PRU scale is already available in Brazilian Portuguese<sup>28,29</sup> and has high reliability worldwide,<sup>10,11,24</sup> but has no contextual items pertaining to medical students. The PRU scale is inversely related to the tolerance of uncertainty, and has two dimensions: (1) stress from uncertainty and (2) reluctance to disclose uncertainty and mistakes. Individuals were excluded if any of the TAMSAD or PRU scale items were missing.

All the items that were negatively related to UT were reversed before analysis. The entire sample was divided into two random samples using the Statistical Package for Social Sciences (SPSS) Version 22. The first sample was employed for exploratory factor analysis (EFA) and the second for confirmatory factor analysis (CFA). Both factor analyses were performed using jamovi software (Version 1.6.23). Reliability was also calculated using JASP (Version 0.16.4) to obtain confidence intervals. McDonald's omega was calculated using CFA with a nonparametric bootstrapped interval. The extraction and rotation methods were identical to those used by the original authors of TAMSAD. As some difficulties in the dimensions emerged, an exploratory graph analysis (EGA) in R (Version 4.1.1) was performed using the entire sample. EGA is a statistical technique that allows researchers to explore the underlying structure of the data and identify patterns and relationships among variables by identifying communities of items displayed in a network.<sup>30,31</sup> In the context of cross-cultural measurement, EGA can help clinical teachers understand how the items are related to each other and whether they align with the intended construct in a different cultural context.

Three researchers in our group first independently classified each item in light of the framework of Hillen et al., in terms of the source of uncertainty and type of response, and then discussed it until consensus was reached. Each item can be coded in more than one source and response, for example Item 1: 'I would enjoy tailoring treatments to individual patient problems' was classified as complexity and probability (source) and cognitive and behavioural (response).

Three data sources were triangulated to interpret possible dimensions of TAMSAD: (1) exploratory graph analysis; (2) Hillen et al. classifications of TAMSAD items in terms of source and response to uncertainty (part of the original paper<sup>23</sup> shared by Prof. Paul Han); and (3) classification of TAMSAD scale items into sources of uncertainty (ambiguity, probability or complexity) and individual's possible response (emotional, behavioural or cognitive) made by our researchers. With this material as a guide, a new EFA was conducted to determine whether items would be grouped into content classification on the basis of Hillen et al.'s framework.

Finally, a cognitive diagnostic modelling analysis (CDMA) was performed on the classification of TAMSAD scale items on the basis of the sources of uncertainty. CDMA is a statistical modelling technique that focuses on understanding the myriad of cognitive processes involved in the responses of the study participants to each one of the items of the measurement tool, even if these answers involve more than one construct in a single item,<sup>32,33</sup> which overcomes a limitation of older psychometric paradigms. Therefore, this analysis was chosen considering that it may reflect the complexity of the TAMSAD scale. E CLINICAL TEACHER

In the context of UT in medical practice, CDMA can help clinical teachers evaluate whether the items in the measurement tool effectively capture the expected specific cognitive attributes associated with each item. CDMA analysis can provide insights into the strengths and weaknesses of individual items, the overall classification accuracy of the measurement tool and of each one of the measured attributes.

The CDMA was performed using the Generalised Deterministic Inputs, Noisy And gate model (G-DINA) Version 2.9.3 in R. For this analysis, the scores of each item were reclassified into binary categories on the basis of the median score. The Q-matrix validation was conducted using the proportion of variance accounted for (PVAF) method. The suggested modifications to the Q-matrix are included in the supporting information.

The total scores of the TAMSAD and PRU scales were tested for normality (Kolmogorov–Smirnov and Shapiro–Wilk) and indicated no normal results. Three versions of the TAMSAD scale (without domain analysis and with domain analysis) were then correlated with the PRU scale using Spearman's correlation. A high rho ( $\rho$ ) coefficient<sup>34</sup> was interpreted as evidence that the measures are related to the same psychological attribute.

# 3 | RESULTS

A total of 694 students (65.9%) agreed to participate in this study. Two individuals had failed to include all data on the TAMSAD scale and thus were excluded (0.001%). The reliability of the 29 items measured by Cronbach's alpha and McDonald's omega were 0.782 (95% CI 0.758–0.804) and 0.782 (95%CI 0.747–0.809), respectively. We observed that one item (22) was negatively correlated with the rest of the scale (item-rest correlation of –0.026). Moreover, in 'if item dropped' analysis, reliability would rise if Item 22 was excluded. After considering that the item had double negative wording, which would explain the misunderstanding of the real meaning of the item, we consulted with the author, Hancock et al., and decided to exclude Item 22 from the Brazilian version of the TAMSAD scale. The final 28-item Brazilian version of the TAMSAD scale (Br-TAMSAD) had a McDonald's omega of 0.790 (95%CI 0.757–0.818) and Cronbach's alpha of 0.790 (95%CI 0.767–0.812).

EFA of the 28-item Br-TAMSAD revealed no clear, interpretable dimensions (Table 1). Although some items repeated the original distribution pattern, there was no clear structure that was robust to cross-cultural adaptation. Similarly, the CFA did not corroborate a unidimensional construct (data not shown).

Exploratory graph analysis was performed to better analyse dimensionality (Figure 1). The data revealed that the items can be organised into three dimensions, indicating multidimensionality. However, CFA with the factors suggested by the EGA did not show good adjustment: CFI = 0.764, TLI = 0.744, SRMR = 0.0708, RMSEA = 0.055 (0.049–0.061, 90% CI), and X^2/df = 2.05. We triangulated with a coding sheet from Hillen et al. and coded the items into sources and responses to uncertainty (see Table S1). Considering the content classification of the items, we attempted a new exploratory

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**TABLE 1** Exploratory Factor Analysis of the 28-item Br-TAMSAD.

Factor loadings (above 0.300)							
	1	2	3	4	5	6	
T1				0.408			
T2R					0.382		
Т3	0.327						
T4				0.375			
T5R			0.509				
Т6							
T7R							
T8R					0.451		
Т9	0.418						
T10		0.611					
T11R	0.477						
T12		0.435				0.326	
T13R					0.487		
T14R	0.425						
T15						0.456	
T16R			0.310				
T17R	0.533						
T18R	0.385		0.325				
T19R	0.593						
T20R					0.300		
T21R	0.394						
T23		0.449	0.389				
T24		0.643					
T25		0.452		0.311			
T26R			0.460				
T27R				0.403			
T28		0.322		0.374			
T29				0.465			

*Note*: 'Principal axis factoring' extraction method was used in combination with a 'varimax' rotation. The number of factors was determined using a parallel analysis.

factor analysis to maintain the three dimensions on the basis of the sources of uncertainty. In all attempts, Items 5 and 18 were grouped together in a factor with Item 23. On the basis of these items, we hypothesised that 'novelty' can be interpreted as a source of uncertainty for medical students. Table 2 exhibits the results of the two different arrangements of the 17 items into either three (TAMSAD-17-3) or four (TAMSAD-17-4) dimensions (including the novelty source of uncertainty). The data from the CFA and reliability analysis are shown in Table 3.

To gather further evidence of multidimensionality, we conducted a cognitive diagnostic modelling analysis (Q matrix in Table S2) considering three sources of uncertainty (ambiguity, complexity and probability). We established a test-level accuracy of 0.7219, and an attribute accuracy of 0.8974 for ambiguity, 0.9198 for complexity, and 0.8584 for probability. The goodness-of-fit parameters were acceptable (SRMR = 0.0589 and RMSEA = 0.0329 [90%Cl 0.0280-0.0376]).

To acquire evidence of concurrent validity, we correlated versions of the TAMSAD scale with the PRU scale. The PRU scale in our sample had reliability measures of 0.799 (Cronbach's alpha) and 0.802 (McDonald's omega). Spearman's analysis was performed between the whole scale and between the dimensions of the scales. As expected, we found negative and moderate correlations between PRU and Br-TAMSAD (rho = -0.524; p < 0.001), TAMSAD-17-3 (rho = -0.444; p < 0.001) and TAMSAD-17-4 (rho = -0.474;p < 0.001). Between dimensions of PRU and possible dimensions of TAMSAD, we found negative and moderate correlation between 'Stress from uncertainty' and domain of 'Ambiguity' (TAMSAD-17-3: rho = -0.527; p < 0.001 and TAMSAD-17-4; rho = -0.511; p < 0.001) and 'Novelty' in TAMSAD-17-4 (rho = -0.420; p < 0.001). Weak and negative correlations were identified between 'Reluctance to disclose uncertainty and mistakes' and versions of the TAMSAD scale (data not shown). Correlations between the different versions of the TAMSAD scale are exhibited in the supporting information (Table S3).

# 4 | DISCUSSION

We found evidence of validity of the TAMSAD scale in medical students, even after cross-cultural adaptation. In addition, we found evidence of the concurrent validity of the TAMSAD scale when comparing this scale with the worldwide PRU scale. The TAMSAD scale has the advantage of face validity for use in the medical student population considering that it is, to our knowledge, the only scale developed with this feature and its items have contexts that are appropriate for this use. Stephens et al.<sup>24</sup> revealed that the reliability of UT scales increased when healthcare contextual items were included. Another advantage of contextual scales may be a better chance of detecting small variations that may occur during medical education, in contrast to the UT scales based on personality traits.<sup>35</sup> In terms of the correlation between the TAMSAD and PRU scales, we found that few behavioural responses were described in TAMSAD scale items, which corroborates the finding of low correlation with the behavioural dimension of the PRU 'Reluctance to disclose uncertainty and mistakes'.

Our results point to multidimensionality in the TAMSAD scale and how it probably approaches different sources of uncertainty. The TAMSAD's original exploratory analysis did not reveal an unequivocally unidimensional scale. The classification of items using Hillen et al. framework showed that many items can be classified by researchers as either having more than one source or more than one response to uncertainty, which may generate difficulties in EFA. Cognitive diagnostic modelling is another way to analyse the intrinsic multidimensionality of the TAMSAD scale. Our preliminary analysis demonstrates that this can be an area for further research on UT measures.



FIGURE 1 Exploratory graph analysis of 29 items of TAMSAD. PDF–Additional files.

Our results point to multidimensionality in the TAMSAD scale and how it probably approaches different sources of uncertainty. While analysing the patterns of responses to the TAMSAD items, we uncovered a possible new source of uncertainty, as interpreted by students. Although this result was unforeseen, it persistently emerged during the EFA. Hillen et al. defined ambiguity as a 'lack of reliability, credibility, or adequacy of information;' complexity as 'features of information that limit understanding;' and probability as 'randomness or indeterminacy of future outcomes'. We interpreted that novelty characterises information that is not ready to be classified. It may also describe anticipation of difficulties in dealing with new, unstructured and unfamiliar situations. With adequate adjustment indices, the TAMSAD items can be organised in either three or four domains.

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TABLE 2 Two proposals of TAMSAD's dimensionality after exploratory factor analyses based on sources of uncertainty.

Original Item		Proposal with 3 dimensions (TAMSAD-17-3)	Proposal with 4 dimensions (TAMSAD-17-4)
1	I would enjoy tailoring treatments to individual patient problems.	NI	NI
2	I have a lot of respect for consultants who always come up with a definite answer.	NI	NI
3	I would be comfortable if a clinical teacher set me a vague assignment or task.	NI	NI
4	A good clinical teacher is one who challenges your way of looking at clinical problems.	NI	NI
5	What we are used to is always preferable to what is unfamiliar.	Probability	Novelty
6	I feel uncomfortable when people claim that something is 'absolutely certain' in medicine.	Probability	NI
7	A doctor who leads an even, regular work life with few surprises, really has a lot to be grateful for.	NI	NI
8	I think in medicine it is important to know exactly what you are talking about at all times.	NI	NI
9	I feel comfortable that in medicine there is often no right or wrong answer.	Ambiguity	Probability
10	A patient with multiple diseases would make a doctor's job more interesting	Complexity	Complexity
11	I am uncomfortable that a lack of medical knowledge about some diseases means we cannot help some patients.	Ambiguity	Ambiguity
12	The unpredictability of a patient's response to medication would bring welcome complexity to a doctor's role	Complexity	Complexity
13	It is important to appear knowledgeable to patients at all times.	NI	NI
14	Being confronted with contradictory evidence in clinical practice makes me feel uncomfortable.	Ambiguity	Ambiguity
15	I like the mystery that there are some things in medicine we'll never know.	Probability	Probability
16	Variation between individual patients is a frustrating aspect of medicine.	Probability	Probability
17	I find it frustrating when I cannot find the answer to a clinical question.	Ambiguity	Ambiguity
18	I am apprehensive when faced with a new clinical situation or problem.	NI	Novelty
19	I feel uncomfortable knowing that many of our most important clinical decisions are based upon insufficient information.	Ambiguity	Ambiguity
20	No matter how complicated the situation, a good doctor will be able to arrive at a yes or no answer.	Probability	Probability
21	I feel uncomfortable when textbooks or experts are factually incorrect.	Ambiguity	Ambiguity
22	There is really no such thing as a clinical problem that cannot be solved.	NI	NI
23	I like the challenge of being thrown in the deep end with different medical situations.	Complexity	Novelty
24	It is more interesting to tackle a complicated clinical problem that to solve a simple one.	Complexity	Complexity
25	I enjoy the process of working with a complex clinical problem and making it more manageable.	Complexity	Complexity
26	A good job is one where what is to be done and how it is to be done are always clear.	NI	NI
27	To me, medicine is black and white.	NI	NI
28	The beauty of medicine is that it's always evolving and changing.	Complexity	Complexity
29	I would be comfortable to acknowledge the limits of my medical knowledge to patients.	NI	NI

Note: Not included items (NI).

TABLE 3 Reliability and confirmatory factor analysis of two proposed dimensionality arrangements of TAMSAD.

	Reliability		Confirmatory factor analysis					
	McDonald's omega (95%Cl)	Cronbach's alpha (95%Cl)	CFI	TLI	X^2/df	RMSEA	SRMR	
TAMSAD-17-3	0.763 (0.725-0.791)	0.757 (0.730-0.782)	0.908	0.892	1.81	0.0482	0.0555	
TAMSAD-17-4	0.772 (0.739-0.802)	0.769 (0.743–0.793)	0.917	0.900	1.77	0.0471	0.0544	

While analysing TAMSAD responses, we uncovered a possible new source of uncertainty: novelty.

The multidimensionality of the construct and its measurement tools imply that the development of UT concerning each source of uncertainty may vary. This implies that certain interventions might contribute to the development of one source of uncertainty while having limited effects on others. We believe that clinical teachers should utilise a multidimensional UT assessment tool in intervention studies. This would enable a comprehensive understanding of which aspects of UT are enhanced by specific types of interventions. Referring back to Gowda's example,<sup>19</sup> it is possible that interventions utilising arts might play a significant role in fostering tolerance for ambiguity, while their impact on tolerance for probability might be less pronounced. Moreover, interventions discussing evidence-based medicine could predominantly influence tolerance for probability rather than ambiguity.

Multidimensionality implies that interventions may impact the tolerance of specific uncertainty sources while having limited effects on others.

Our study has several strengths and limitations. We explored new evidence for the validity of TAMSAD using a myriad of psychometric methods. Consequently, we can affirm that the evidence for the multidimensionality of the TAMSAD scale is robust. However, the number of items used to determine the internal structure of the EFA and CFA was drastically reduced. Thus, isolated domains are expected to have low reliability. To address this problem, researchers worldwide must collaborate to refine the TAMSAD scale, just as the PRU scale was refined.<sup>27,36</sup>

# 5 | CONCLUSION

We found evidence that TAMSAD can be considered a multidimensional scale, probably in consonance with the framework of Hillen et al. Psychometric analysis indicated that novelty is possibly processed by medical students as a different source of uncertainty than previously described.

### AUTHOR CONTRIBUTIONS

Paula Cristina Eiras Poço: Conceptualisation (equal); investigation (lead); formal analysis (lead); writing—original draft preparation (lead); writing review and editing (equal). Carlos Fernando Collares: Formal analysis (equal); methodology (lead); writing—review and editing (equal). Ahmed Haydar: Formal analysis (equal); writing—original draft preparation (equal); writing—review and editing (equal). Victor Braga de Oliveira: Investigation (equal); writing—original draft preparation (equal); writing—review and editing (equal). Victor Braga de Oliveira: Investigation (equal); writing—original draft preparation (equal); writing—review and editing (equal). Milton de Arruda Martins: Conceptualisation (equal); writing—review and editing (lead). Patricia Zen Tempski: Conceptualisation (lead); project administration; formal analysis (equal); writing—review and editing (equal).

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### CONFLICT OF INTEREST STATEMENT

All authors declare no conflicts of interest.

### DATA AVAILABILITY STATEMENT

Data available on request from the authors

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## ETHICAL APPROVAL

This study was approved by the Ethics Board of the Hospital das Clínicas of the Faculty of Medicine of the University of São Paulo (CAAE:34776220.7.0000.0068), following ethical principles of Declaration of Helsinki (1964). All participants signed a consent form before answering the questionnaire. Before analysis, all data was anonymized, thus preserving the identity of participants.

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### SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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