Adv in Health Sci Educ (2015) 20:113–130
DOI 10.1007/s10459-014-9510-z

Medical student and junior doctors' tolerance of ambiguity: development of a new scale

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Received: 4 November 2013 / Accepted: 5 May 2014 / Published online: 20 May 2014

Abstract The practice of medicine involves inherent ambiguity, arising from limitations of knowledge, diagnostic problems, complexities of treatment and outcome and unpredictability of patient response. Research into doctors' tolerance of ambiguity is hampered by poor conceptual clarity and inadequate measurement scales. We aimed to create and pilot a measurement scale for tolerance of ambiguity in medical students and junior doctors that addresses the limitations of existing scales. After defining tolerance of ambiguity, scale items were generated by literature review and expert consultation. Feedback on the draft scale was sought and incorporated. 411 medical students and 75 foundation doctors in Exeter, UK were asked to complete the scale. Psychometric analysis enabled further scale refinement and comparison of scale scores across subgroups. The pilot study achieved a 64 % response rate. The final 29 item version of the Tolerance of Ambiguity in Medical Students and Doctors (TAMSAD) scale had good internal reliability (Cronbach's α 0.80). Tolerance of ambiguity was higher in foundation year 2 doctors than first, third and fourth year medical students (-5.23, $P = 0.012$; -5.98, $P = 0.013$; -4.62, $P = 0.035$, for each year group respectively). The TAMSAD scale offers a valid and reliable alternative to existing scales. Further work is required in different settings and in longitudinal studies but this study offers intriguing provisional insights.

Keywords Ambiguity · Epistemology · Medical education · Tolerance · Uncertainty

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Introduction

The practice of medicine involves inherent ambiguity and uncertainty, arising from limitations of knowledge, diagnostic problems, ambiguities of treatment and outcome, and unpredictability of patient response (Geller et al. 1990). The ability of physicians to tolerate ambiguity is therefore of significant interest, with implications for doctors' mental health and wellbeing, staff retention in the medical profession, and specialty choice. For example, low tolerance of ambiguity has been linked with low patient and physician satisfaction, increased risk of physician burnout (Lim 2003; Cooke et al. 2013), more negative attitudes towards underserved populations (Wayne et al. 2011), and personality traits such as dogmatism, conformity and rigidity (Budner 1962; Furnham and Ribchester 1995). It has also been argued that evidence-based complex decision making, which requires the integration of individual patient perspectives and research evidence that may be incomplete, poor quality or conflicting, is only possible if the clinician is able to understand the limits of their own, and of scientific, knowledge and manage the associated uncertainty (Knight and Mattick 2006).

It is therefore understandable that undergraduate medical education has been encouraged to introduce educational strategies that will increase medical students' tolerance of ambiguity (Luther and Crandall 2011). However, the challenges are formidable. There is a fundamental lack of conceptual clarity around the term 'tolerance of ambiguity' and whether it can change over time in individuals or populations, or what strategies might enable it to change. There may also be unintended consequences associated with increasing all medical students' tolerance of ambiguity (Hancock and Mattick 2012). Crucially, the tools available to measure tolerance of ambiguity are crude, despite over 60 years of research, and this provides a particular barrier for the evaluation of educational strategies aimed at increasing learners' tolerance of ambiguity.

This paper aims to seek conceptual clarity around tolerance of ambiguity, to offer a measurement scale that can support the evaluation of educational strategies and to make use of a modern validity assessment framework to evaluate the validity of the scale for use in undergraduate medical students and foundation doctors. It also aims to make some tentative insights into whether the tolerance of ambiguity of populations of students changes during medical school.

Defining ambiguity and uncertainty

The Collins English dictionary defines ambiguity as "vagueness and uncertainty of meaning" and uncertainty as "not known, reliable or definite". These definitions are conceptually similar and are often used interchangeably. However, a distinction has been made by some authors, including Greco and Roger (2002), who suggest that uncertainty is the response to an ambiguous situation, akin to the period of anticipation prior to the confrontation with a potentially harmful event. *Tolerance of ambiguity* has been defined as "the way an individual (or group) perceives and processes information about ambiguous situations or stimuli when confronted by an array of unfamiliar, complex or incongruent clues" (Furnham and Ribchester 1995). Indeed, an individual who is intolerant of ambiguity may experience stress when encountering an ambiguous situation, avoid ambiguous stimuli, seek clarity or act prematurely (Furnham and Ribchester 1995). *Intolerance of ambiguity* has been defined as the tendency to perceive or interpret ambiguous situations as actual or potential sources of psychological discomfort or threat (Norton 1975). In these definitions, ambiguity can exist in a situation that is novel, unfamiliar or complex, or when

the cues are contradictory. Other authors point out that tolerance of ambiguity might mean not only coping well in ambiguous situations but actively seeking out and thriving in them (Budner 1962). This suggests the need for a potentially multidimensional construct of tolerance of ambiguity.

For this study, we used the Collins English dictionary definition of ambiguity and consider ambiguity to be the stimulus; and Greco et al.'s definition of uncertainty and consider uncertainty to be the response to an ambiguous situation. Therefore ambiguity and uncertainly are not fully synonymous, with tolerance of ambiguity being more wide ranging than tolerance of uncertainty, although they are closely related. In reality, it is likely that avoidance of uncertainty is correlated with intolerance of ambiguity (Furnham and Ribchester 1995). These definitions suggest that tolerance of ambiguity is closely aligned with personal epistemologies, although we are not aware of medical education literature that has explored this interface or overlap. The next section will explore the personal epistemological frameworks used by individuals when learning and making decisions, and the implications for this study.

Personal epistemology and tolerance of ambiguity: State versus trait?

Epistemology is a branch of philosophy that considers what it is to 'know': how we understand, integrate, justify, and apply knowledge. Early empirical data and theoretical models suggest that *personal epistemologies* change and develop over time, although there is less consensus about how this happens. Models of personal epistemology therefore describe development from a lay understanding of science, where science is considered to be based on certainties and 'truths', to an understanding that is more contextual and fluid (Knight and Mattick 2006; Norton 1975). Research in this field has a long tradition starting with the works of Polanyi (1966) who tells us there is no such thing as objective factual science because all knowledge is understood through our own 'worldview', and Perry's developmental work on the nine stages of maturation (1968). However, in terms of the developmental perspective, early models tend to suggest linear development along an essentially unidimensional scale. More recent models challenge this view, suggesting that personal epistemology can have multiple dimensions, sometimes moving 'backwards' along the scale, and is likely to be topic/context specific. For example, in a recent study, first year medical students viewed anatomical knowledge as concrete and certain, whilst accepting that more ambiguity exists within the social sciences. In addition, students also progress to a more contextual and fluid understanding at a different rate for aspects of the same topic (Knight and Mattick 2006).

Hammer and Elby (2002) agree that how an individual makes sense of a situation depends on the context of the situation but suggest individual variation in how the context activates the personal *epistemological resources* at their disposal. Some individuals may make use of a more static framework, based on beliefs surrounding the certainty and unchanging nature of science. Others make use of more dynamic framework, believing that scientific knowledge stems from evidence and changes and expands with everyday life. These frameworks are made up of different epistemological resources that we learn throughout our lives, including beliefs such as knowledge can be accumulated, and knowledge can be checked.

There are a number of implications of the work on personal epistemologies for our study of tolerance of ambiguity. First there is clear overlap of ideas and we would hypothesise that an individual with a more sophisticated personal epistemology would be more tolerant of ambiguity. Secondly, we conclude that we should be open to the possibility that

tolerance of ambiguity will change over time, given appropriate environmental conditions and contextual exposure, rather than thinking of tolerance of ambiguity as a stable trait or personality variable as originally proposed by Budner (1962). In other words, a change in learning context could encourage students to think differently about knowledge and evidence, and/or use different epistemological resources. This opens up exciting possibilities for educational strategies within medical school (Luther and Crandall 2011) perhaps involving early clinical and research exposure, and supported reflection. Finally, any attempt to measure a medical student's or doctor's tolerance of ambiguity would need to do so in clinical context, since the cues experienced in this context will activate the individual's epistemological resources and determine the level of ambiguity experienced by the individual practicing doctor.

Implications for measuring tolerance of ambiguity

From this analysis, we propose that a scale to measure tolerance of ambiguity amongst populations of medical students and junior doctors would need to: (1) contain items that are clinically contextualised; (2) have sufficient number and range of items to be sensitive to subtle changes; (3) be open to the possibility that tolerance of ambiguity is a multidimensional construct; and (4) demonstrate good validity evidence (Downing 2003).

The most widely used scale to date is the original Budner scale (1962) or variations thereof. This scale has 16 items and good construct validity (Sidanius 1988). However, it conceptualises tolerance of ambiguity as a single dimensional personality measure, the items are not clinically contextualised, and the internal reliability is poor (Cronbach's α 0.49 in the original report). Therefore this scale does not meet our four criteria above for a measurement tool for use with medical students. A four item modified Budner scale was used by Geller et al. (1990) which contains 3 items taken directly from the original Budner scale. Whilst two of the items were clinically contextualised and the Cronbach's alpha score did increase marginally (0.56), the other reservations still apply. In addition, the small number of items means the scale is unlikely to be sensitive to change. A more recent publication by Geller et al. (1993) introduced a new scale which has an improved internal reliability (Cronbach's α 0.75) but is not clinically contextualized, contains only seven items (reduced from 18 during the pilot study) and is unidimensional. The "Physicians reaction to uncertainty scale" (Gerrity et al. 1990) comes closest to meeting our criteria, being clinically contextualised, containing 61 items and acting as a multidimensional measure. However the focus is very much on practicing physicians, is not validated for use in medical students and seeks to measure reaction to uncertainty rather than tolerance of ambiguity.

Therefore, to our knowledge, no scales exist that meet our requirements and can answer our question about change in tolerance of ambiguity during medical school.

Medical students' tolerance of ambiguity

Little empirical data exist about whether tolerance of ambiguity increases or decreases in medical students during undergraduate education and that which does exist are conflicting and potentially flawed due to the limitations identified in the measurement scales used. Budner (1962) suggests that tolerance of ambiguity may be higher in third year medical students than first years, although this was only found in one of the two medical schools studied and the differences were not statistical significant. In contrast, Geller et al. (1990) showed no difference between levels of ambiguity recorded in medical students ($n = 86$) in their first, second and fourth year of study in a cross sectional study in one medical

school and concluded that selection may be more important than education and training in influencing tolerance of ambiguity amongst physicians. In postgraduate medical training, Deforge and Sobal (1991) used the original Budner scale with 59 family practice residents in America and found higher tolerance of ambiguity in third year residents compared to first years. Their paper also claimed that medical students were more tolerant of ambiguity than the first year residents, however it is unclear if the 'slightly different' score referred to reached statistical significance. Recently, Geller hypothesised that those students entering medical school with a higher baseline tolerance of ambiguity may show an increase during medical school, while those less tolerant at baseline may show a reduction (Geller 2013).

The tolerance of ambiguity of different subgroups has also been explored, albeit with the same poor scales. Geller et al. (1990) reported that female medical students had a higher level of tolerance of ambiguity than male students, while Deforge and Sobal (1991) found no gender differences in family practice residents. Medical students who were 'older' when they started medical school also had a higher tolerance of ambiguity, although the cut off for this is unclear (Geller et al. 1990).

Similarly, the association between tolerance of ambiguity and choice of medical specialty has been considered and this is perhaps the area of greatest consensus, although again we note the concerns about the data on which these conclusions are made. Budner (1962) reported that first to third year medical students who wished to pursue a 'less structured' career (e.g. psychiatry) were more tolerant of ambiguity; whereas those who wished to pursue the most structured careers (e.g. surgery, obstetrics and gynaecology) were more intolerant of ambiguity. Geller et al. (1990) confirmed that medical students wishing to pursue a career in psychiatry were more tolerant of ambiguity than those wishing to pursue a career in surgery. Furthermore Geller et al. (1993) reported that psychiatrists were more tolerant of ambiguity than obstetricians, paediatricians and family practitioners. Given that the entry criteria for core psychiatry training in the UK include the "capacity to deal with ambiguity & uncertainty in clinical life" then perhaps this is not surprising (Royal College Psychiatrists 2013).

In summary based on the current literature, which is challenged by the methodological tools available, we can tentatively propose that tolerance of ambiguity may be associated with specialty choice and some demographic markers such as age and gender. It remains unclear whether tolerance of ambiguity changes during medical school but initial evidence suggests it may increase when working as a doctor, albeit a limited range of specialties have been explored.

Study aims and research questions

The aims of this study are twofold;

1. To design a measurement scale for tolerance of ambiguity in medical students and junior doctors that is clinically contextualised but still relevant for first year medical students, that treats tolerance of ambiguity as a complex construct that may have multiple dimensions and be open to change, and that has a good internal reliability but has sufficient items that is likely to be sensitive to change. To use the results obtained to evaluate the validity of our scale in the population studied.
2. To offer some provisional insights into the associations between tolerance of ambiguity and stage in undergraduate/postgraduate training, demographics such as gender, entry status (e.g. prior degree) and prospective career choices.

The process of evaluating the validity of this scale involves developing a scientifically sound validity argument to support the intended interpretation of test scores for ambiguity and their relevance to the proposed use in the undergraduate medical student and foundation doctor population. The guidelines that we shall follow for this purpose are set out by the American Educational Research Association, American Psychological Association, National Council on Measurement in Education (1999) and have been applied directly to the medical education context by Downing (2003).

We hypothesise that tolerance for ambiguity will increase during medical education as students gain research skills and clinical experience, coupled with support for reflective practice, that allow them to develop new ways to activate and apply their epistemological resources; and that female participants who are older, have a prior degree on entering medical school, and/or wish to become psychiatrists will have a higher tolerance of ambiguity.

Methods

Item generation

First, a literature review was undertaken to identify the definitions, theories, empirical research and existing scales relevant to tolerance of ambiguity. Eight medical education colleagues at a medical school in South West England were then asked to send us scenarios highlighting examples of ambiguity in medicine and medical education. Using the themes identified from the literature and the scenarios as a guide, 49 draft items were generated (by KM and LM). Each item was placed into one of three subscales depending on what it was measuring; 'tolerance of ambiguity, seeks out and thrives in ambiguous situations', 'tolerance of ambiguity, but seeks to reduce ambiguity', or 'intolerance of ambiguity'. Individual scale items were developed, ensuring that they were clear, short, focused and had good face validity (Oppenheim 2008). Four of these items were taken directly from the modified Budner scale used by Geller et al. (1990) and a further seven were taken from the original Budner scale (1962), although slightly modified to include the medical context. Therefore in total 10 items were taken from the original Bunder scale. All items were written as statements to which respondents were asked to score their agreement on a five-point Likert-type scale ranging from 'strongly disagree' (1) to 'strongly agree' (5), with the midpoint score being 'neutral' (3). This differs from the six point likert scales used previously by both Budner (1962) and Geller et al. (1990). The items focused on tolerance of ambiguity within a medical context, whilst ensuring the content was appropriate for first year medical students, but also relevant for junior doctors.

Item validation

The same eight colleagues reviewed the draft items. They were asked to give their opinion in the form of a numerical rating (1–5) on the quality of the item and asked to provide text comments on individual items in terms of (1) their relevance to the construct of tolerance of ambiguity; (2) their clarity; (3) their format; and (4) whether they would be understood by the range of target subjects, from first year undergraduate medical students to foundation year doctors (junior doctors in their first 2 years after graduating from medical school). The experts were given the opportunity to reword or remove any items they felt inappropriate. If two experts suggested an item was removed then it was. Through this

process, 9 items were removed, 14 more were reworded and 2 new items were written, resulting in an initial set of 42 items.

Ten medical students and foundation year doctors reviewed the 42-item scale to ensure that the items were clear and understandable. In addition to scoring their agreement with each item, respondents were asked to provide free text comments and to identify poorly worded or difficult to answer items. Following this initial work (results not shown) one item was removed due to poor face validity and 2 more were reworded, resulting in a final 41-item Tolerance of Ambiguity in Medical Students and Doctors (TAMSAD) questionnaire (Table 1).

Participants and recruitment

Following ethics approval, 411 undergraduate medical students across years 1–5 and 75 foundation doctors, all based in Exeter, were approached and asked to complete the TAMSAD questionnaire. Participants were initially approached by e-mail with a link to a short YouTube video filmed by JH. Following this, the research team attended lectures and small group sessions and handed out paper versions of the questionnaire. Any medical student not seen was sent a copy of the TAMSAD by e-mail and asked to participate. All foundation doctors were provided with electronic versions of the TAMSAD and asked to complete and return electronically. The questionnaire also included demographic questions, entry status (are you a graduate student?) and intentions regarding possible future careers in a range of specialties.

Statistical analysis

Data analysis was conducted in SPSS version 21. We calculated survey response rates within each year group. Negatively worded items were reverse scored prior to analysis. We calculated item response rates and Mahalanobis distances for each respondent and used these to identify, and remove where appropriate, potentially outlying respondents in the data set.

Responses to each item were examined for the distribution of responses, mean response score and standard deviation of response scores. If an item had a mean score below 2 or >4, or if participants did not use the full five-point range of scale responses, then the standard deviation of the scores was examined. If the standard deviation was low, the items were considered for removal from further analysis.

The initial 41-item scale contained the 4 Geller et al. (1990) items and a further 7 items from the original 16 item Budner (1962) scale. We calculated Cronbach's alpha for each of these scales and compared with the values originally reported by those authors. Since we used only 10 of the 16 items from Budner's scale, if we include the 3 also used in the modified Geller scale, we used the Spearman–Brown formula to estimate Cronbach's alpha for the original scale length (Stanley 1971). Due to the item differences and the incorporation of the items into a longer questionnaire these estimates are only proxies for the reliability of the Budner and Geller et al. scales in our sample.

Exploratory factor analyses using a variety of extraction and rotation procedures were used to investigate the possible existence of subscales within the overall scale. Following this, we developed a final TAMSAD scale by removing items which did not improve the value of Cronbach's alpha for the overall scale. We then removed items for which the adjusted item-total correlation with the remaining items was <0.20.

Table 1 The TAMSAD scale

	Item	Mean (likert score)	SD (likert score)	Was the item included in the final 29 item scale?	Corrected item-total correlation
1	I am comfortable to acknowledge that I'll never know everything about medicine	4.28	.97	No	.13
2	Even when there is conflicting information, I prefer to make a decision and move on[a]	3.27	.94	No	.01
3	I would enjoy tailoring treatments to individual patient problems	4.11	.69	Yes	.30
4	I think it is important to attribute a percentage likelihood to a diagnosis or a specific patient outcome	3.45	.91	No	−.05
5	As a doctor I would prefer the clear and definite work of someone like a surgeon to the uncertainties of a psychiatrist[a,c]	3.14	1.24	No	.30
6	I have a lot of respect for consultants who always come up with a definite answer[a]	3.65	.91	Yes	.40
7	I would be comfortable if a clinical teacher set me a vague assignment or task[b]	2.46	1.01	Yes	.30
8	A good clinical teacher is one who challenges your way of looking at clinical problems[b]	4.31	.67	Yes	.27
9	What we are used to is always preferable to what is unfamiliar[a,b,c]	3.16	1.13	Yes	.24
10	I feel uncomfortable when people claim that something is 'absolutely certain' in medicine	3.51	1.01	Yes	.24
11	A doctor who leads an even, regular work life with few surprises, really has a lot to be grateful for[a,b]	2.91	1.01	Yes	.19
12	I enjoy reducing the complexity of medical information to something more tangible	3.95	.80	No	−.08
13	I think in medicine it is important to know exactly what you are talking about at all times[a]	3.22	1.03	Yes	.32
14	'I don't know' are really important words in medicine	4.19	.81	No	.18
15	I would prefer to work in a medical specialty where patients normally get better after treatment[a]	3.92	.85	No	.24
16	I enjoy reducing detailed scientific problems to their core concepts	3.91	.84	No	−.02
17	I feel comfortable that in medicine there is often no right or wrong answer	3.64	.97	Yes	.41
18	A patient with multiple diseases would make a doctor's job more interesting	3.51	.87	Yes	.30

Table 1 continued

	Item	Mean (likert score)	SD (likert score)	Was the item included in the final 29 item scale?	Corrected item-total correlation
19	I am uncomfortable that a lack of medical knowledge about some diseases means we can't help some patients[a]	3.49	.95	Yes	.24
20	The unpredictability of a patient's response to medication would bring welcome complexity to a doctor's role	2.84	.88	Yes	.24
21	It is important to appear knowledgeable to patients at all times[a]	3.37	.99	Yes	.34
22	Being confronted with contradictory evidence in clinical practice makes me feel uncomfortable[a]	3.03	.93	Yes	.41
23	I like the mystery that there are some things in medicine we'll never know	3.20	1.13	Yes	.34
24	Variation between individual patients is a frustrating aspect of medicine[a]	2.20	.95	Yes	.43
25	I find it frustrating when I can't find the answer to a clinical question[a]	3.82	.80	Yes	.40
26	I am apprehensive when faced with a new clinical situation or problem[a,b]	3.10	1.00	Yes	.31
27	I feel uncomfortable knowing that many of our most important clinical decisions are based upon insufficient information[a]	2.95	.86	Yes	.32
28	No matter how complicated the situation, a good doctor will be able to arrive at a yes or no answer[a,b]	2.30	.93	Yes	.28
29	I feel uncomfortable when textbooks or experts are factually incorrect[a]	3.76	.92	Yes	.24
30	There is really no such thing as a clinical problem that can't be solved[a,b]	2.22	.86	Yes	.30
31	It's an exciting feeling when you listen to a patient tell you their symptoms and you just know what disease it is[a]	1.6	.64	No	.06
32	I like the challenge of being thrown in the deep end with different medical situations	3.52	.88	Yes	.33
33	It is more interesting to tackle a complicated clinical problem that to solve a simple one[b]	3.58	.96	Yes	.24
34	In medicine as in other professions, it is possible to get more done by tackling small, simple problems rather than large and complicated ones[a,b,c]	3.33	.85	No	.00
35	I enjoy the process of working with a complex clinical problem and making it more manageable.	3.88	.67	Yes	.20

Table 1 continued

	Item	Mean (likert score)	SD (likert score)	Was the item included in the final 29 item scale?	Corrected item-total correlation
36	A good job is one where what is to be done and how it is to be done are always clear[a,b,c]	2.98	1.04	Yes	.40
37	Medicine has a lot of grey areas because we haven't found the answers yet[a]	4.11	.83	No	.18
38	To me, medicine is black and white[a]	1.58	.73	Yes	.28
39	The beauty of medicine is that it's always evolving and changing	4.27	.70	Yes	.35
40	I enjoy working out which opinion is right in situations where many different opinions are expressed[a]	3.69	.77	No	−.19
41	I would be comfortable to acknowledge the limits of my medical knowledge to patients	4.01	.86	Yes	.27

[a] Negatively worded items that were reverse scored prior to analysis

[b] Taken from the original Budner (1962) scale

[c] Taken from the Geller et al. (1990) scale

The final TAMSAD scale was used to conduct preliminary analyses on the levels of tolerance of ambiguity of medical students and doctors in the study sample. A TAMSAD score for each respondent was calculated as the mean item score (provided there were no more than two missing items) and linearly transformed from the original 1–5 scale to a 0–100 scale using the formula; New score = 25(Old score −1). The distribution of the scores across all respondents was examined for normality. Analysis of variance (ANOVA) was used to explore the possible influence on the TAMSAD score of respondents' year group, gender, graduate entry status and interest in any of seven specialities (medicine, surgery, emergency medicine, general practice/community medicine, psychiatry, paediatrics, radiology). We calculated effect sizes for independent predictors in relation to the magnitude of the standard deviation of the TAMSAD score (Cohen 1988).

Results

Questionnaire analysis

Three of the 314 returned questionnaires had over half of the items unanswered and were excluded from the analysis. The Mahalanobis distance method identified eight potential outliers. One of these had employed an 'answer 1 or 5 strategy' and this questionnaire was also excluded from the analysis, giving an effective response rate of 310/486 (64 %). Response rates varied by year group (Table 2).

Item 31 was removed from the TAMSAD scale because it had the lowest standard deviation of response scores (0.64) and on reflection the researchers felt it could be examining participant 'expertise' rather than their 'tolerance of ambiguity'. Since we wished to investigate the relationship between tolerance of ambiguity and specialty preferences we excluded items 5 and 15, which are clearly linked to such preferences.

Table 2 Response rates by year group

Stage/year of training	Response rate	%
Undergraduate		
1	74/110	67
2	72/112	64
3	34/72	47
4	52/78	67
5	30/39	77
Foundation training		
F1	22/39	56
F2	26/36	72
All	310/486	64

The factor analysis indicated that the remaining 38 TAMSAD items could not be subdivided into a simple set of interpretable factors. Using principal factors extraction there were thirteen factors with eigenvalues >1 but the scree plot suggested a five-factor solution accounting for 33 % of the total variance. However the five factors enabled no simple interpretation (even after applying a Varimax rotation) and numerous items either had no factor loadings >0.3 or loaded moderately on more than one factor ("Appendix"). Use of alternative extraction and rotation methods failed to find any simple solution. The initial Cronbach's alpha score was calculated at 0.75 and we interpreted this as suggesting that the TAMSAD questionnaire was acting as a unidimensional measure of tolerance of ambiguity.

We then looked to improve both the parsimony and reliability of the scale by reducing the total number of items. We found that removal of seven items (1, 2, 4, 12, 16, 34, and 40) increased the internal consistency of the scale to 0.80, while reducing the total number of questionnaire items to 31. Finally we removed two further items (14 and 37) which had adjusted item-total correlations <0.20. Note that item 11, which had an initial item-total correlation of 0.19 (Table 1), was retained at this stage as its item-total correlation with the remaining items was now above 0.20. This left the Cronbach's alpha unchanged at 0.80 indicating that the scale has a good internal consistency (Field 2005) and could be interpreted as a unidimensional measure.

Three of these items had originally been intended to measure 'tolerance of ambiguity but seeks to reduce ambiguity' (4, 12, 16) rather than purely 'tolerance of ambiguity, seeks out and thrives in ambiguous situations'. Therefore it is not surprising that their removal from a scale that appears to be acting in a unidimensional way improves the internal consistency of the scale.

Table 1 shows items means and standard deviations for the original 41 items, indicates those which items came from the original Budner and Geller et al. scales, those which were retained in the final TAMSAD scale and their corrected item-total correlations with the scale.

We estimated the internal consistency reliability of the Geller et al. 4 item scale to be 0.31 and that of the full Budner 16 item scale to be 0.63.

Group differences

Participant scores on the 29-item TAMSAD scale ranged from 38.8 to 86.2 with a mean (SD) of 57.0 (8.8). Using the TAMSAD scale we found that significant differences in

tolerance of ambiguity were associated with participants' year group but not with gender, graduate entry status or possible future career specialty interests (Table 3). Observed mean TAMSAD scores by year group are shown in Fig. 1. First, third and fourth year medical students had significantly lower tolerance of ambiguity than FY2 doctors by 4.62–5.98 scale points. These are moderate effects (0.52–0.68 times the TAMSAD score SD) (Cohen 1988). Tolerance of ambiguity in second and fifth year medical students and FY1 doctors was similar to that in FY2 doctors.

Participants expressing a preference for a possible career in surgery were, on average, 2.52 scale points lower in their tolerance of ambiguity than their peers, while those preferring paediatrics were 2.42 points higher but neither of these differences reached statistical significance at the 0.05 level. Prospective medics, GPs, emergency physicians, psychiatrists and radiologists had equivalent tolerance of ambiguity to their peers.

Discussion

This study aimed to design a scale to measure tolerance of ambiguity in medical students and junior doctors that address the limitations of existing scales, and to pilot it with the target population in one location. After several rounds of refinement, we arrived at a 29-item scale that we named the Tolerance of Ambiguity in Medical Students and Doctors (TAMSAD) scale.

We evaluated the validity of this scale using an established framework set out by the American Educational Research Association, American Psychological Association, National Council on Measurement in Education (1999) and applied to the medical education context by Downing (2003). This framework states that when evaluating the validity of any assessment tool used in medical education five sources of evidence should be considered; content related validity evidence, the response process, the internal structure of the scale, the relationship to other variables and the consequences of using the assessment scale.

Content related validity evidence was provided through the provenance of the items, which were derived from an analysis of the education literature, from medical education theory and from existing tolerance of ambiguity scales. Since we did not want to assume that our scale would be acting as a unidimensional measure of ambiguity, items were initially separated into one of three subscales: 'tolerance of ambiguity, seeks out and thrives in ambiguous situations', 'tolerance of ambiguity, but seeks to reduce ambiguity', and 'intolerance of ambiguity'. Pilot work involved the input of academic staff working in medical education and from medical practitioners working in hospital and community settings. Unlike many previous scales, TAMSAD is context specific which allows it to assess an individual's tolerance of ambiguity in the medical setting. The pilot study achieved a 64 % response rate across the 5 years of medical students and 2 years of foundation doctors.

The response process was considered in the scale development stage as academics and clinicians were asked to remove or reword items that they felt inappropriate or difficult to understand. A pilot study was also completed during which 10 medical students and foundation doctors were asked to comment if they felt that items within the scale were difficult to understand or answer. Finally we ensured that data collected from the scales was accurately transcribed onto the statistical package by performing a thorough check of the data.

Table 3 ANOVA results

Factor	Difference in TAMSAD score	*P* value	LCL	UCL	Adjusted mean TAMSAD score[a]
Gender					
Female	1.03	0.329	−1.04	3.09	59.63
Male	Reference category		–	–	58.60
Entry status					
Graduate entry	2.27	0.168	−0.96	5.49	60.25
Non-graduate entry	Reference category		–	–	57.98
Year group		0.044[b]			
Year 1	−5.23	0.012	−9.33	−1.14	57.11
Year 2	−3.87	0.065	−7.98	0.24	58.47
Year 3	−5.98	0.013	−10.67	−1.28	56.36
Year 4	−4.62	0.035	−8.92	−0.33	57.72
Year 5	−0.08	0.973	−4.77	4.61	62.26
FY1	−2.80	0.277	−7.87	2.26	59.54
FY2	Reference category		–	–	62.34
Specialty preferences[c]					
Medicine	0.92	0.387	−1.17	3.02	59.57
Surgery	−2.52	0.055	−5.09	0.05	57.85
Emergency	1.46	0.214	−0.85	3.77	59.84
GP/community	−1.18	0.287	−3.35	0.99	58.52
Psychiatry	2.22	0.233	−1.44	5.89	60.23
Paediatrics	2.42	0.062	−0.12	4.96	60.32
Radiology	−0.96	0.793	−8.19	6.27	58.63

Dependent variable: tolerance of ambiguity score

LCL Lower 95 % confidence limit for the difference in score, *UCL* upper 95 % confidence limit for the difference in score, *FY* foundation year

[a] Estimated marginal means, adjusted to account for between-group differences in the other variables in the model

[b] *P* value for F test of year group as a factor

[c] Specialty preferences were not exclusive. The reference category is 'No interest in the specialty' in all cases. Adjusted means for respondents not interested in each specialty can be obtained by subtracting the difference given in column 2 from the adjusted mean given in column 6

The internal structure of the TAMSAD scale was explored by measuring its internal reliability (Cronbach's $\alpha = 0.80$). We have interpreted this to mean that the scale is acting as a unidimensional measure of tolerance of ambiguity, which is supported by the improvement in internal consistency observed when we removed three of the four items initially created to measure 'tolerance of ambiguity, but seeks to reduce ambiguity'. The Cronbach's alpha associated with the TAMSAD scale in this population was higher than obtained by previous scales; 0.49 (Budner 1962) and 0.56 (Geller et al. 1990). The Cronbach's alpha associated with the original Geller et al. questionnaire was lower than reported previously in our study population (0.31 in our study compared to 0.56). The expected Cronbach's alpha for the full Budner 16 item scale was 0.63, which was higher than Budner's reported value of 0.49, perhaps due to sample heterogeneity (i.e. if the

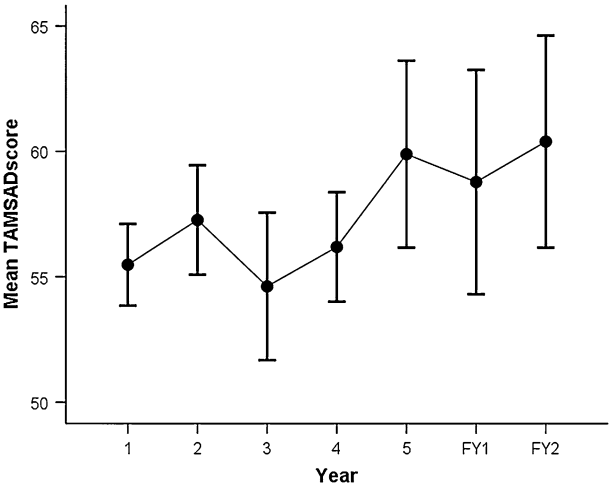

Fig. 1 Observed mean tolerance of ambiguity score (with 95 % confidence interval) by year group. *FY* foundation year

participants in our sample were more varied in their tolerance of ambiguity than were those in Budner's sample then we would expect reliability to be higher).

The relationship of tolerance of ambiguity (as measured by TAMSAD) and other variables, such as stage of training, gender, graduate status and specialty choice, was sought. In our study, foundation year 2 doctors had a higher tolerance of ambiguity than first, third and fourth year medical students; other studies have reached various conclusions about association of tolerance of ambiguity and stage of training. Our study was a cross sectional survey, so conclusions about changes in tolerance of ambiguity over time cannot be made. Wayne et al. (2011) demonstrated that those students with a higher tolerance of ambiguity at the start of medical school showed a smaller deterioration in their attitudes towards underserved populations and other studies have shown that intolerance of ambiguity is associated with distress (Benbassat et al. 2011) and reduced levels of work satisfaction (Bovier and Perneger 2007). In response, Luther and Crandall (2011) recommended that medical schools do more to increase their students' tolerance of ambiguity but a responding commentary cautioned about the possible unintended consequences of doing this, for example resulting in an undersupply of surgical trainees. In reality it is likely that there are multiple factors underpinning any increase in tolerance of ambiguity during medical school, including the increasing maturity of students. Our study showed no significant association between tolerance of ambiguity in prospective surgeons or psychiatrists compared with their peers. Previous research has suggested an association between tolerance of ambiguity and medical career intention (Budner 1962; Geller et al. 1993).

We would argue that the consequences of completing this questionnaire are minimal. Our research suggests that completing the modified 29 questionnaire will take 5–10 min and is unlikely to have a negative impact on participants.

The most important contribution of this study is to provide a valid tool for the research community to apply in subsequent studies. The provisional findings from piloting the scale are broadly supportive of previous research by Budner (1962) and Geller et al. (1990).

As with all studies, our work has a number of methodological strengths and challenges. The strengths of this study include the way in which we carefully defined the constructs of ambiguity and uncertainty, thus ensuring a rigorous process in the development of the scale. Additionally, there were multiple rounds of scale refinement based on target group feedback and on psychometric analysis. The pilot study achieved a large sample size and good response rate. In terms of challenges, data collection only took place in one site, and the study was cross sectional in design rather than longitudinal. These both serve to limit the conclusions that can be drawn in relation to change over time.

Future research

Further work to provide additional evidence for the validity of the TAMSAD scale is now required. One aspect that has not been explored in depth is the cultural sensitivity of the scale. The current study has used the scale in one location in South West England; future work could use the scale in different countries and with more culturally heterogonous populations. The fact that the scale seemed to be acting as a unidimensional measure was unexpected, given the theoretical complexity of the construct of tolerance of ambiguity. It would therefore be helpful to repeat the exploratory factor analysis process with other, larger populations of students to verify this observation. Further qualitative research could also be useful to explore the different aspects of the construct of tolerance of ambiguity in different settings and with different populations.

It will also be interesting to explore associations between tolerance of ambiguity (as measured by TAMSAD) with other variables such as attitudinal markers (e.g. cynicism), observed behaviours (e.g. medical professionalism), cognitive states (e.g. intellectual development) and aspiration (e.g. specialty choice). Specific variables of interest could include attitudes towards underserved populations (Wayne et al. 2011) and intellectual maturation (Perry 1968).

Other work should develop the TAMSAD for use in an online forum. We were able to ensure good response process validity as the scale was only completed on a small scale, mainly on paper. If the scale is to be used on a larger population, then the use of an electronic scale would help to ensure that there are minimal errors when processing data.

Finally, following further validation, this scale could be used in a number of different ways to shed light onto how tolerance for ambiguity might change during medical undergraduate and early postgraduate training. Whilst our cross sectional survey design has provided interesting data, future research involving longitudinal methodologies would enable us to track students through medical school and into early clinical practice, therefore providing insights into the pattern of growth or decline in tolerance of ambiguity during medical school and junior doctor training. Such studies might enable us to draw conclusions about how levels of tolerance of ambiguity vary across different medical schools using different curricula.

Conclusion

The TAMSAD scale developed through this study offers a more valid and reliable alternative to existing scales for medical students and junior doctors. Further work is now required to continue the process of evaluating the validity of this scale in the undergraduate and foundation doctor population. This will be possible through conducting longitudinal studies to explore changes in tolerance of ambiguity, both over time and as a result of

educational interventions. Meanwhile this study offers intriguing provisional insights that warrant further investigation.

Acknowledgments We would like to thank everybody who contributed towards each stage of this study. Our eight medical education colleagues who contributed towards initial item creation, the ten medical students and foundation doctors in Exeter who took part in the initial study pilot and the medical students and foundation doctors in Exeter who completed the TAMSAD questionnaire.

Appendix

See Table 4.

Table 4 Factor analysis

Rotated factor matrix (Loadings <0.1 suppressed)					
	Factor				
	1	2	3	4	5
Q38	.555	.107			
Q28	.518			.115	.170
Q21	.435		.204		
Q06	.433		.155	.101	.242
Q30	.429				
Q14	.391			−.250	
Q36	.373	.205	.140		.148
Q13	.371		.237		.142
Q41	.338		.160		−.150
Q03	.298	.261			−.151
Q01	.253		.231		−.230
Q10	.206	.106	.105	.102	
Q33		.629			
Q08	.126	.510			−.160
Q18		.506	.116		.121
Q35		.437			−.176
Q39	.144	.423	.153	.213	
Q24	.295	.369	.115	.145	.146
Q25			.548	.137	.181
Q23	.111		.499		
Q17	.256	.100	.424	.122	−.123
Q19			.356		
Q20		.200	.315		.180
Q29			.292		.184
Q32		.379	.166	.522	
Q11				.465	.232
Q26		.237	.163	.445	
Q22	.204		.284	.436	
Q40		−.313		−.327	.122
Q07			.249	.315	

Table 4 continued

Rotated factor matrix (Loadings <0.1 suppressed)					
	Factor				
	1	2	3	4	5
Q27	.159		.289	.315	
Q02				−.215	.477
Q12					−.403
Q37			.101		.294
Q16		.199	−.109		−.289
Q34					.268
Q09	.117	.163		.157	.236
Q04					−.153

Extraction method: principal axis factoring

Rotation method: varimax with Kaiser normalization

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