A Study of Tolerance of Ambiguity of Undergraduate Students at an HBCU

Dr. M. Javed Khan, Tuskegee University

Dr. M. Javed Khan is Professor and Head of Aerospace Science Engineering Department at Tuskegee University. He received his Ph.D. in Aerospace Engineering from Texas A&M University, M.S. in Aeronautical Engineering from the US Air Force Institute of Technology, and B.E. in Aerospace Engineering from the PAF College of Aeronautical Engineering. He also has served as Professor and Head of Aerospace Engineering Department at the National University of Science and Technology,Pakistan. His research interests include experimental aerodynamics, aircraft design and engineering education.

Dr. Chadia A. Aji, Tuskegee University

Chadia Affane Aji is a Professor in the Department of Mathematics at Tuskegee University. Dr. Aji received her Ph.D. and M.S. in Mathematics from Auburn University and a Bachelor in Chemical Engineering from Texas A&M University. Her research interests lie in the areas of numerical analysis, computational applied mathematics, complex analysis, and on improving students' learning in STEM disciplines. Dr. Aji is involved in retention activities at Tuskegee University. She helps designing strategies to assist incoming freshmen cope with first year mathematics classes. She developed teaching modules to improve students' learning in mathematics using technology.

A Study of Tolerance of Ambiguity of Undergraduate Students at an HBCU

Abstract

Real world problems are rarely well-defined, and are usually with incomplete information, in other words epitomes of ambiguity. In contrast, undergraduate students are rarely exposed to the class of problems that they will encounter in their professions. The correlation between students' tolerance of ambiguity as signified by their cognitive models of the world, and academic success has received limited attention. A cross sectional and longitudinal study at a Historically Black College and University (HBCU) is being conducted to establish baselines for the mental models of students and their tolerance to ambiguity. The modified Rydell-Rosen questionnaire was used to understand undergraduate students' ambiguity tolerance. Analysis of cross-sectional data collected indicates little change in tolerance of ambiguity of undergraduate students with time spent in college. This research is supported by NSF Grant# 1832041.

Introduction

The typical learning environment, and assessment of learning dominant in K-16 education promotes a dualistic understanding of the problem space. Students look for the 'right' answer, or the answer the teacher is expecting. Obviously, such learning is rarely applicable to real-life situations which are much more nuanced, lack complete information and usually admit multiple solutions. Real-life problem solving may not have a structured and established solution process with known input-output relationships. Thus, the real-world problem space is uncertain and ambiguous. Schrader, Riggs and Williams [1] capture the progression of complexity of the problem space by differentiating between 'uncertainty' and 'ambiguity' in context of problem solving as follows:

"Uncertainty: Characteristic of a situation in which the problem solver considers the structure of the problem (including the set of relevant variables) as given, but is dissatisfied with his or her knowledge of the value of these variables.

Ambiguity level 1: Characteristic of a situation in which the problem solver considers the set of potentially relevant variables as given. The relationships between the variables and the problem solving algorithm are perceived as in need of determination.

Ambiguity level 2: Characteristic of a situation in which the set of relevant variables as well as their functional relationship and the problem-solving algorithm are seen as in need of determination."

The mismatch between the dualistic learning paradigm of typical undergraduate education and the needs of the real-world problem space is quite stark. McNeill et al. [2] report a typical response of a senior engineering student as "well basically that if you have the right equations then you can solve anything". This student clearly had an understanding, of the problem space to be amenable to a structured, established process with known input-output relationships. Students therefore need to learn how to 'develop adequate conceptual frameworks (make meaning) and apply those frameworks in solving complex ill-structured problems' [3], that is, to function under ambiguity. A discussion on the characteristics of structured and ill-structured problems can be found in [4].

The mismatch challenge is well recognized and is the subject of continued research on understanding learners' response to ambiguity and identifying effective learning environments that would prepare students for the real world [2], [5], [6], [7], [8], [9], [10], [11]. Providing opportunities to undergraduate students to develop tolerance of ambiguity is therefore important. An ill-designed learning environment incorporating ambiguity however can become a daunting experience for students [12], [13], [14], [15].

As part of a larger study, cross-sectional data measuring the tolerance of ambiguity of undergraduate students has been collected at an HBCU to determine the impact of time spent in college. The analysis of this data is discussed in this paper.

Method

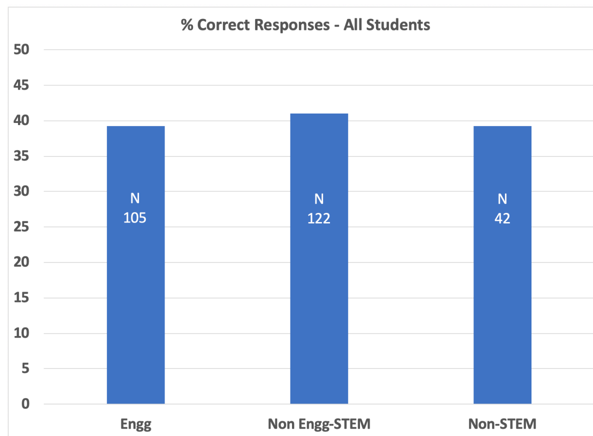
The participants of this between-group quasi-experimental study were undergraduate students from STEM and non-STEM disciplines at an HBCU. The modified Rydell-Rosen Ambiguity Tolerance (AT-20) scale developed by McDonald [16] was administered to the participants. The scale consists of 20 true/false statements of which 16 items are from the original Rydell and Rosen instrument [17], 2 items are from the California Personality Inventory [18], and 2 items are from the Conformity Scale of Barron [19]. As reported by McDonald [16], the AT-20 scale has a stability coefficient of 0.63 (based on a six- month retest). The AT-20 scale has been shown to be free from social desirability bias [16], the most common bias in survey questionnaires as measured by the Marlowe-Crowne Social Desirability scale [20]. The construct validity of the AT-20 was also demonstrated by McDonald [16] through significant correlations with the "Rokeach Dogmation" and the "Gough-Sanford Rigidity" scales. The AT-20 scale is given in Appendix A.

The AT-20 questionnaire was administered as an online fillable form in Fall 2018 to undergraduate students from the various STEM (aerospace engineering, electrical engineering, mathematics, mechanical engineering, chemistry, biology, computer science, sociology, and psychology), and non-STEM majors (political science, and English). The questionnaire administration was repeated in Spring 2019 to students from the STEM and non-STEM majors who had not responded in Fall 2018. The questionnaire included few additional items (gender. academic standing, GPA, design/project experience). These demographic items preceded the AT-20 items. The study was approved by the Institutional Review Board (IRB). The students were invited to respond to the survey through their instructors who were provided copies of the informed consent forms. The survey participation was voluntary. A total of 269 students responded to the survey which included 121 freshmen, 37 sophomores, 54 juniors, and 57 seniors. A detailed breakdown of the respondents is given in Table I. All students self-identified as African-American.

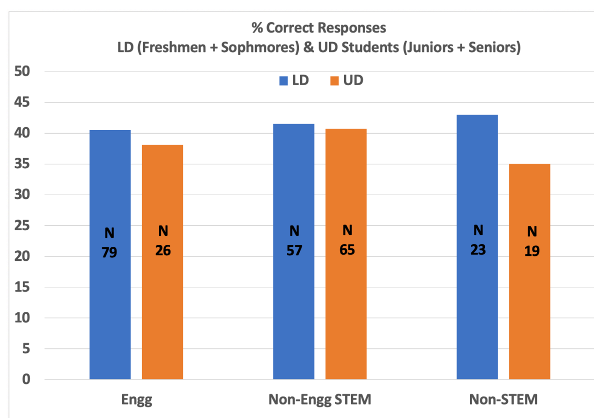
		Engineering	Non-Engineering STEM*	Non-STEM	Total
Freshmen	Female	14	35	10	59
	Male	51	9	2	62
Sophomores	Female	1	9	10	20
	Male	13	3	1	17
Juniors	Female	4	27	5	36
	Male	12	4	1	18
Seniors	Female	3	29	10	42
	Male	7	4	3	15
Total		105	120+2	42	269

*Two non-engineering STEM students declined to provide gender information.
Table I: Demographics of survey respondents

Results and Discussion



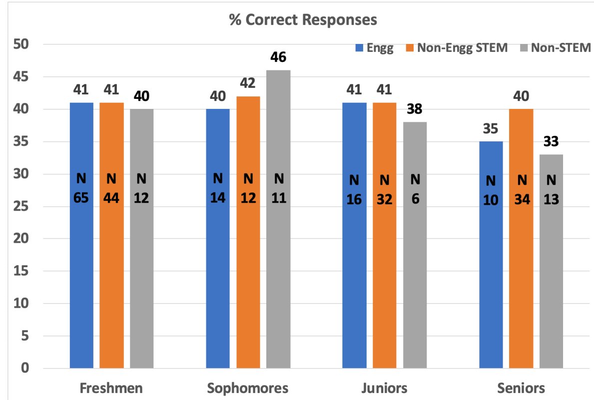
[redacted]



[redacted]

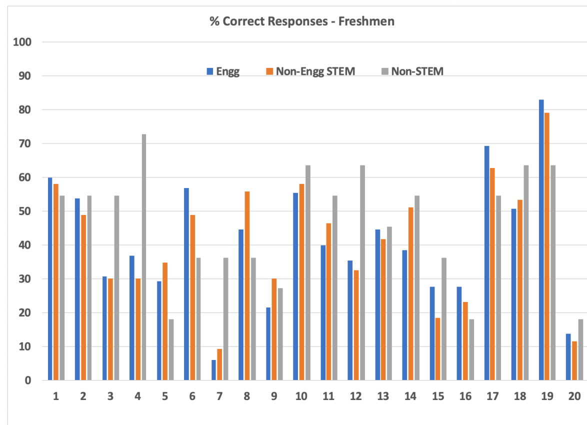
The responses of the students were analyzed to determine the percentage of the average 'correct' answers for each of the 20 statements of the AT-20 survey. A correct response is considered to be a tell-tale of tolerance for ambiguity. The percentage correct responses of each survey respondent were also determined. Fig. 1 shows the average correct responses for all the students who responded to the AT-20 survey grouped by the three categories (engineering students, non-engineering STEM students and non-STEM students). The data shows that the average correct responses of students across disciplines was less than 50%. The data was then de-aggregated based on academic standing (freshmen, sophomores, juniors, and seniors). The average percentage correct responses of lower division (LD) students consisting of freshmen and sophomores and upper division (UD) students consisting of juniors and seniors, are shown in Fig 2. In all three groups there was a reduction in the average percentage correct responses of UD students. A larger (10%) reduction was observed for non-STEM students. However, the changes were not statistically significant ($p < 0.05$, two-tail).

The responses were further de-aggregated for analysis as shown in Fig. 3. There was no difference in the percentage correct responses of freshmen from all the three groups. There was little difference in the average percentage correct responses between the freshmen, sophomore and junior engineering students. However, the average percentage correct responses for senior engineering students were observed to reduce by 5%. The changes in the average percentage correct responses for non-engineering STEM students with time spent in college were small. There was an increase in the percentage correct responses of non-STEM sophomores; however, the average percentage correct responses of seniors in this group were lower by 13% than the sophomores.

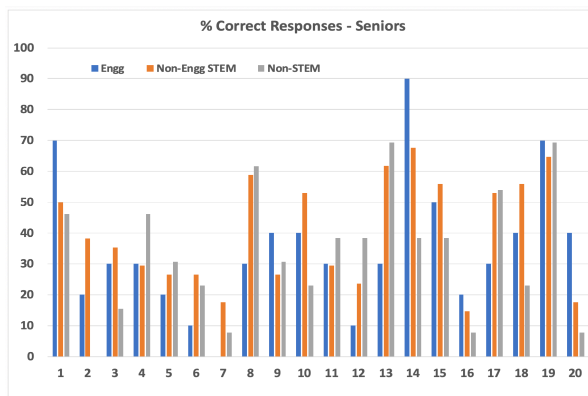


[redacted]

To better understand the impact of time spent in college on tolerance of ambiguity, the average percentage responses to each of the 20 statements were analyzed. Figs. 4a and 4b show the percentage correct responses of freshmen and seniors. A number of observations can be made on this data pertaining to individual and groups of the AT-20 items.

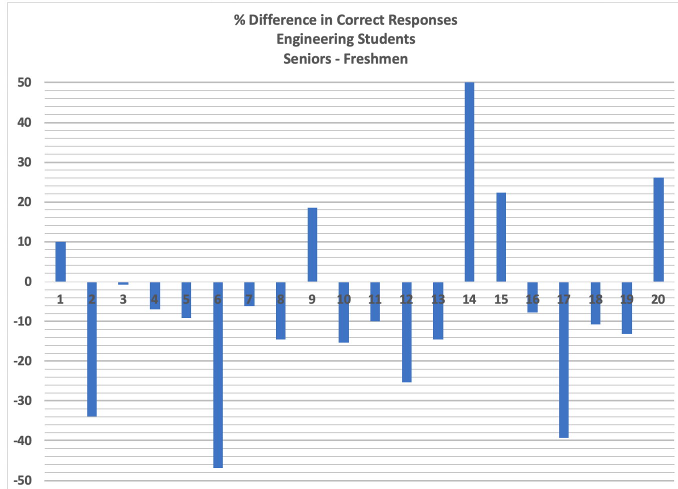


[redacted]



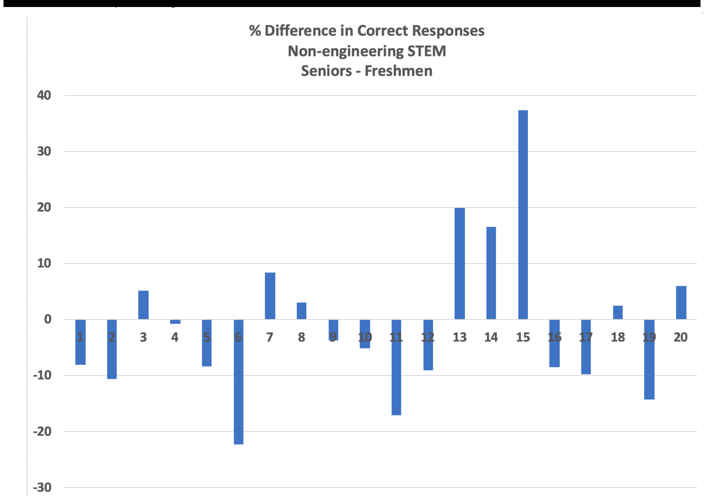
[redacted]

For example, non-STEM freshmen had more percentage correct responses to the statement (item 4) "There is a right way and a wrong way to do almost everything." These responses indicate that freshmen non-STEM students were less rigid or non-dogmatic in their attitudes. Similarly, the average percentage correct responses of the non-STEM freshmen to the statement (item 4) "I would rather bet 1 to 6 on a long shot than 3 to 1 on a probable winner" points to their being more ready to consider non-ambiguous situations. The non-STEM freshmen also showed their preference for a profession which had uncertainties by having a higher average correct score on the statement (item 12) "If I were a doctor, I would prefer the uncertainties of a psychiatrist to the clear and definite work of someone like a surgeon or X-ray specialist." The highest average correct score for engineering freshmen was in response to the statement (item 19) "I like to fool around with new ideas, even they turn out later to be a total waste of time." The engineering seniors had a higher number of correct responses to the statement (item 1) "A problem has little attraction for me if I don't think it has a solution" which indicated their being more comfortable with an ambiguous situation. Engineering seniors also had a higher percentage of correct answers to the statement (item 14) "If I were a scientist, it would bother me that my work would never be completed (because science will always make new discoveries)."



[redacted]

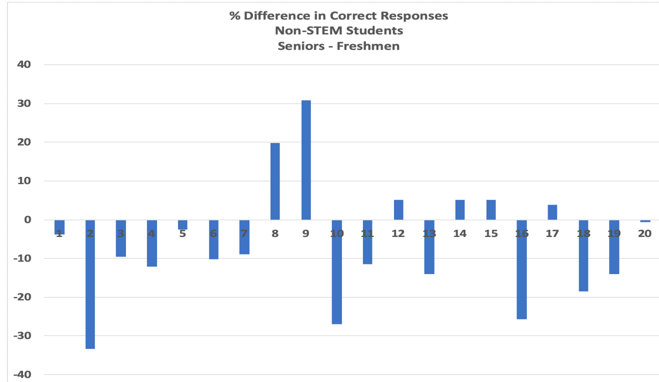
The difference between the responses of seniors and freshmen to the AT-20 was analyzed. Fig. 5 shows the percentage difference in correct responses of engineering seniors and freshmen. It was observed that seniors scored higher on only five out of the twenty items of the AT-20 statements. The percentage correct answers for seniors were lower than those of the freshmen for all the four items (2, 6, 8, 10) that pertain to social situations (which signify ambiguous situations). They average score of seniors was lower on the items 12, 17, 18, and 19 which pertain to ambiguous professional situations. The seniors had higher scores on items 1 and 14 which pertain to ambiguous professional situations. The seniors also had a higher average score on items 9 and 20 which pertain to dualistic understanding of the world.



[redacted]

The percentage difference in the correct scores of seniors and freshmen from non-engineering STEM majors is given in Fig.6. It was noted that seniors from non-engineering STEM majors had higher scores than non-engineering STEM freshmen on only eight out of the twenty questions. The largest positive difference in the correct answers by seniors was observed for item 15 which states "If I were a scientist, it would bother me that my work would never be completed (because science will always make new discoveries)." This result indicated that the non-STEM seniors were more inclined to work on scientific problems regardless of whether their work would provide the final answer or not. The correct responses of the seniors were lower than the freshmen for items (2, 6, 10) that pertain to social situations. The non-engineering STEM seniors did not seem to be comfortable with trying out new ideas in comparison to the freshmen as by the difference in average correct responses to item 19.

The percentage difference in the correct scores of seniors and freshmen from non-STEM majors is given in Fig.7. Non-STEM seniors had a higher correct response average in comparison to the freshmen for six out of twenty items. However, as can be seen from Fig. 7, items 8, 9 had a large difference as compared to the other four items (12, 14, 15, 17). Items 8, and 9 pertain to a dualistic world view and social interaction. The non-STEM seniors were not comfortable with ambiguous professional situations as is seen in their responses to items (13, 16, 18, 19).



[redacted]

Descriptive statistics were determined for the responses of the participants. The ratios of correct responses to total responses (20) are given in Table II. The non-STEM LD students had the highest median (50% correct), while UD students had the lowest median.

Group		N	Median	Min	Max	1st Quartile	3rd Quartile
Eng	LD	79	0.4	0.15	0.70	0.30	0.50
	UD	26	0.4	0.05	0.70	0.30	0.50
Non Eng STEM	LD	55	0.4	0.05	0.75	0.30	0.50
	UD	66	0.4	0.10	0.75	0.30	0.50
Non-STEM	LD	23	0.5	0.10	0.70	0.35	0.55
	UD	19	0.3	0.20	0.70	0.25	0.40

Table II. Descriptive Statistics

Conclusions and Future Work

It was observed from the data as measured by the AT-20 and its analysis that the average score for tolerance of ambiguity of undergraduate students across all disciplines was below 50%. It was also observed that on the average, the time spent in college did not have much impact on their score on the AT-20 survey. There were interesting differences observed between seniors and freshmen on individual items of the AT-20 scale. The seniors had higher correct scores on only few of the items of the AT-20.

The results reported in this paper are the first phase of a three-year project funded by the National Science Foundation Grant # 1832041. Future work includes additional cross-sectional data collection. Additionally, longitudinal tracking data on students who participated in 2018-2019 will be collected to understand the impact of duration of college stay. The data analysis is expected to inform curricular and syllabi changes

References

[1] S. Schrader, W. M. Riggs and R. P. Smith, "Choice over Uncertainty and Ambiguity in Technical Problem Solving," *Journal of Engineering and Technology Management*, vol.10, 1993, accessed on Nov. 30, 2019, https://dspace.mit.edu/bitstream/handle/1721.1/46980/choiceoveruncert00schr.pdf?s

[2] N. J. McNeill, E. P. Douglas, M. Koro-Ljungberg, D. J. Therriault and I. Krause, "Undergraduate Students Beliefs about Engineering Problem Solving," *Journal of Engineering Education*, vol. 105, no. 4, pp. 560–584, 2016
[3] D. Jonassen, J. Strobel and C. B. Lee, "Everyday problem solving in engineering: Lessons for engineering educators," *Journal of Engineering Education*, April 2016, pp 139-151
[4] H. Simon, "The structure of ill-structure problems," *Artificial Intelligence*, vol. 4, 145-180, 1973
[5] B. Aryal, M. D. Nichols and A. Huq, "A qualitative case study exploring student comfort with ambiguity in physics, math, and literature," *The Online Journal of New Horizons in Education* – vol. 8, no. 1, Jan 2018
[6] R. Barwell, "Ambiguity in the Mathematics Classroom," *Language and Education*, vol. 19, no. 2, 2005, pp. 118-126
[7] W. Byers, "How Mathematicians Think Using Ambiguity, Contradiction, and Paradox to Create Mathematics", Princeton, ISBN 9781400833955
[8] E. M. Gray and D. O. Tall, "Duality, Ambiguity and Flexibility: A Proceptual View of Simple Arithmetic," *The Journal for Research in Mathematics Education*, vol. 26, no. 2, 1994, pp. 115–141
[9] A. Kothiyal and S. Murthy, "MEttLE: a modelling-based learning environment for undergraduate engineering estimation problem solving," *Research and Practice in Technology Enhanced Learning*, vol. 13, no. 1, 17. doi:10.1186/s41039-018-0083-y
[10] M. MacGregor and K. Stacey, "Cognitive Models Underlying Students' Formulation of Simple Linear Equations," *Journal for Research in Mathematics Education*, vol.24, no. 3, pp. 217-232, 1993, doi:10.2307/749345
[11] M. Mellone and R. Tortora, "Ambiguity as a cognitive and didactic resource," CERME 9 - Ninth Congress of the European Society for Research in Mathematics Education, Feb 2015, Prague, Czech Republic. pp.1434-1439, Proceedings of the Ninth Congress of the European Society for Research in Mathematics Education.
[12] A. Abell and K. DeVore, "Embracing Ambiguity: A Framework for Promoting Iterative Design Thinking Approaches in Engineering and Design Curricula," ASEE 124th Annual Conference & Exposition, Jun 25-28, 2017, Columbus, OH
[13] J. Hertz, "Confidently Uncomfortable: First-year Student Ambiguity Tolerance and Self-efficacy on Open-ended Design Problems," ASEE 125th Annual Conference & Exposition, Jun 24-27, 2018, Salt Lake City, UT
[14] E. Dringenberg and R. E. H. Wertz, "How do first-year engineering students experience ambiguity in engineering design problems: The development of a self-report instrument," 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana, https://doi.org/10.18260/p.25474
[15] R.L. Tauritz, "How to handle knowledge uncertainty: learning and teaching in times of accelerating change," Chap 19, *Learning for Sustainability in Times of Accelerating Change*, pp. 299-316, Eds. Wals, A. E. L. and Corcoran, P. B. Wageningen Academic Publishers, The Netherlands
[16]. A. P. McDonald Jr., "Revised Scale for Ambiguity Tolerance: Reliability and Validity," *Psychological Reports*, 1970, 26, 791-798. @ Psychological Reports http://www.sgha.net/library/pr0%252E1970%252E26%252E3%252E791.pdf
[17] S. T. Rydell and E. Rosen, "Measurement and some correlates of need-cognition," *Psychological Reports*, vol. 9, no. 1, pp. 139-165, 1966

[18] H. G. Gough, “Simulated pattern on the MMPI,” *Journal of Abnormal and Social Psychology*, vol. 42, pp. 215-225, 1957
[19] F. Barron, “Some personality correlates of independence of judgment,” *Journal of Personality*, vol. 21, 1953, pp. 287-277
[20] D. P. Crowne and D. Marlowe, “A new scale of social desirability independent of psychopathology,” *J Consult Psychol.*, vol. 24, pp. 349-354, 1960

Appendix A

AT-20 Scale (McDonald, 1970) with ‘correct’ responses

1. A problem has little attraction for me if I don't think it has a solution (FALSE)
2. I am just a little uncomfortable with people unless I feel that I can understand their behavior. (FALSE)
3. There is a right way and a wrong way to do almost everything. (FALSE)
4. I would rather bet 1 to 6 on a long shot than 3 to 1 on a probable winner. (TRUE)
5. The way to understand complex problems is to be concerned with their larger aspects instead of breaking them into smaller pieces. (TRUE)
6. I get pretty anxious when I am in a social situation over which I have no control. (FALSE)
7. Practically every problem has a solution. (FALSE)
8. It bothers me when I am unable to follow another person's train of thought. (FALSE)
9. I have always felt that there is a clear difference between right and wrong. (FALSE)
10. It bothers me when I don't know how other people react to me. (FALSE)
11. Nothing gets accomplished in this world unless you stick to some basic rules. (FALSE)
12. If I were a doctor, I would prefer the uncertainties of a psychiatrist to the clear and definite work of someone like a surgeon or X-ray specialist. (TRUE)
13. Vague and impressionistic pictures really have little appeal for me. (FALSE)
14. If I were a scientist, it would bother me that my work would never be completed (because science will always make new discoveries). (FALSE)
15. Before an examination, I feel much less anxious if I know how many questions there will be. (FALSE)
16. The best part of working a jigsaw puzzle is putting the last piece. (FALSE)
17. Sometimes I rather enjoy going against the rules and doing things I am not supposed to do. (TRUE)
18. I don't like to work on the problem unless there is a possibility of coming out with a clear cut and unambiguous answer. (FALSE)
19. I like to fool around with new ideas, even they turn out later to be a total waste of time. (TRUE)
20. Perfect balance is the essence of all good composition. (FALSE)