UNIVERSITI TEKNOLOGI MARA

RULER & OPTION SCALE: DEVELOPMENT OF AN INTERVAL MEASUREMENT TECHNIQUE

ROHANA BINTI YUSOFF

Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Statistics)

Faculty of Computer and Mathematical Sciences

September 2019

ABSTRACT

Motivated by the on-going debate between researchers on whether data from rating scales such as Likert and Likert-type scales are ordinal or interval level, this research had set out to grasp the actual problems that fuelled the debate. The problems are threefold i) the absence of a rating scale that is unanimously accepted by all researchers as interval level, ii) unclear definition of an interval rating scale, and iii) no comprehensive method to establish a rating scale as an interval scale. These are the research gaps this research identified. Research objectives was fourfold, i) to identify the features of a rating scale that could be accepted as interval level, to design the layout, and to name the scale as Ruler & Option (RO) scale, ii) to determine the usability of RO scale and its consistency compared to 7-point Likert scale, iii) to compare validity and reliability coefficients of data collected using RO scale with the validity and reliability coefficients of data collected using 7-point Likert scale, and iv) to establish RO scale is interval conceptually and mathematically by giving a clear definition of an interval scale and to examine the interval property of RO scale using Rasch model and Double Cancellation axiom. Seven different sample surveys were conducted with different sample sizes ranging from 10 to 610 respondents. In addition, this study also analysed eight samples of simulated data with 500 respondents in each sample. Statistical softwares used in this study were SmartPLS (v.3.2.8), IBM-SPSS AMOS 24.0, and Winsteps 4.3.4 for Rasch analysis. Programming language R was used to simulate data and the algorithm to check Double Cancellation axiom was written in Java language. This study concluded that RO scale should have three main features, a ruler that starts from 0% to 100 % with meaningful zero point, three "no opinion" options, and clearly defined operational procedure as the basis for measurement. RO scale is interval by definition of an interval scale based on six features. Results from usability study showed that RO scale was usable, that is RO scale was easy to use, rating using RO scale was as quick as rating using 7-point Likert scale, RO scale was legible because the markers on the ruler enabled easy reading of data, RO scale satisfices because it offers infinite choices of points to opinionated respondents as well as "no opinion" options to non-opinionated respondents. Results from two separate studies showed that RO scale was functional to researchers because researchers were able to make analyses and conclude with meaningful statements. Results from test-retest analysis showed that RO scale was more consistent than 7-point Likert scale. Validity and reliability coefficients of RO scale were higher than validity and reliability coefficients of 7-point Likert scale. Data from RO scale highly fitted the Rasch model but did not satisfy Double Cancellation axiom. Hence RO scale did not attain the interval level set by Additive Conjoint Measurement axioms. From the results of Double Cancellation checks on 3x3 matrices, the ratio of the proportion of 3x3 matrices that satisfied Double Cancellation axiom to the proportion that violated Double Cancellation axiom was 3.8 to 1. This ratio was called Interval Ratio. The main contributions of this study are i) an interval rating scale named Ruler & Option (RO) scale, and ii) a clear definition of an interval rating scale, and iii) a comprehensive method to evaluate rating scales using usability, consistency, data validity and reliability, and Interval Ratio. Further exploration of strength and weakness of RO scale and its interval property either using empirical data or new theory is recommended for future research.

ACKNOWLEDGEMENT

Firstly, I would like to express my utmost gratitude to my Creator, Allah the Most Loving and the Most Beneficient. There is no appropriate term to express my gratitude to Allah who had granted me a peek through a window to His unbounded treasury of knowledge, guided me, and gave me strength throughout this PhD journey. I observed that there are two situations in a person's life that will make him or her in dire need of Allah's mercy. The two situations are i) when one is facing a challenge, and ii) when one is in need of guidance. I found that doing PhD put me in both situations. As such my PhD journey was not only a journey to seek knowledge but also a journey to seek Allah's mercy.

Secondly, my gratitude and thanks go to my supervisor Prof Dr Roziah Mohd Janor for being patient and always willing to spare her precious time with me. She is an intellectual person with a strong and determined personality which indirectly motivates me to continue this study. After failing two proposal defences, I thought she would discourage me of pursuing the research topic. Surprisingly not even a single negative word was uttered by her, and that really made me perservered in completing this PhD journey. She is also a kind hearted person and approachable enough to maintain a good relationship with her students.

Thirdly, my appreciation goes to the management of University Teknologi MARA who provided the facilities for citation and referencing, online databases, and discounted study fees to its staff. Thank you for providing such a conducive environment to postgraduate students.

Finally, this thesis is dedicated to my husband and my children especially my eldest daughter Norulhidayah and my second eldest daughter Noor Munirah for being very supportive and helpful during difficult times in my PhD journey. Having supportive family members was most helpful especially in times when motivation was low. As a form of gratefulness to everyone who had contributed to the completion of this study, I ask Allah to continue to shower His blessings on everyone as well as on the University Teknologi MARA. Hopefully all efforts and time spent in completing this thesis will be rewarded in the hereafter.

TABLE OF CONTENTS

		Page
CONFIRMATION BY PANEL OF EXAMINERS		**ii**
AUTHOR'S DECLARATION		**iii**
ABSTRACT		**iv**
ACKNOWLEDGEMENT		**v**
TABLE OF CONTENTS		**vi**
LIST OF TABLES		**x**
LIST OF FIGURES		**xiii**
CHAPTER ONE: INTRODUCTION		**1**
1.1	Research Background	1
1.2	Motivation	3
1.3	Problem Statement	4
1.4	Research Questions	13
1.5	Research Objectives	13
1.6	Limitations and Scope of Research	14
1.7	Organization of the Thesis	14
1.8	Contributions of the Research	15
CHAPTER TWO: LITERATURE REVIEW		**17**
2.1	Measurement Theories	17
2.2	Discrete, Continuous and Ordinal Variables	20
2.3	Measurement Scales in Social Science	21
2.4	Several Shortcomings of Likert scale	24
2.5	Approaches Presented by Researchers	25
	2.5.1 Mathematical Modelling.	25
	2.5.2 Continuous Line Segments	26
2.6	Scales for Measuring Intangible Variables	26
2.7	Usability of Rating Scales	27

2.8 The Thermometer Analogy 28
2.9 Don't Know (Dk) Option in Scales 30
2.9.1 Proponents of DK option 31
2.9.2 Category Chosen by Non-Attitudes 32
2.9.3 Opponents of DK Option 33
2.9.4 Position of 'Don't Know'(DK) Option 34
2.10 Axiomatic Measurement Theory (AMT) and Rating Scales 35
2.10.1 The Conjoint Measurement 36
2.10.2 Additive Conjoint Measurement (ACM) 36
2.10.3 Results of Double Cancellation Test 39
2.10.4 Issues in the Calculation of Probabilities in a Conjoint Matrix 42
2.10.5 The Rasch Model 42
2.10.6 Rasch Model and Construct Validity 44
2.10.7 Rasch Model and Additive Conjoint Measurement 44
2.10.8 The need for both Double Cancellation Checks and Rasch Model Fit 46
2.10.9 Previous Works 47
2.11 Summary of Literature Review 52
2.11.1 Scale Properties 52
2.11.2 Usability Features 52
2.11.3 Two Conditions for a Scale to be Interval 53
2.11.4 Previous Results as reference 54

CHAPTER THREE: RESEARCH METHODOLOGY 55
3.1 Stage 1: Design Ruler & Option (RO) Scale Layout 60
3.1.1 Conduct Sample Survey I to refine RO Scale Design 62
3.2 Stage 2: Analyse RO Scale's Usability and Consistency 63
3.2.1 Conduct Sample Survey II to gauge the usability criteria: Easy to use, Needs no complicated explanation, and Legible. 64
3.2.2 Conduct Sample Survey III to show that RO scale is Functional 65
3.2.3 Conduct Sample Survey IV to show the Usability Criterion: Satisfice in the sense that the Scale Provides Enough Options including Options for "no opinion" 67
3.2.4 Conduct Sample Survey V to test the Usability Criterion: Doesn't take