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Solving moderated mediation model using interval data on fuzzy elevation

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Abstract: A variable that grounds mediation between dependent and independent variables. These mediator variables take vital parts in the analysis of data which entails numerous variables, exclusively when the dependent and independent variables are affected by other variables. Thus, mediation analysis requires all areas which need regression analysis, especially in psychology, industry, teaching, production area, etc. Mediation has been projected in multiple studies. On the other hand, at times it is more logical to articulate the fuzzy theory data when the variables are not purely distinct. Normally, to articulate the attitude of a persona ‘bad’, ‘moderate’, ‘good’ use fuzzy numbers than using crisp numbers. This paper explains the model of fuzzy moderated mediation using interval data. Also, to find the total, direct and indirect effects psychological data have been applied when the mediator, moderator, and confounding variable subsist.

Keywords: mediation; moderation; moderated mediation; fuzzy mediation; interval data.

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1 Introduction

A statistical process that is about to happen on a mediation which used to dissect how the source of an independent variable on a result is conveyed through an intervening variable (mediator) M . This variable indicates asymmetric relation among variables. When there is a considerable bond between the independent and the dependent variable, mediation exists. The indirect effect is statistically important if there is no major relation between an independent variable towards a dependent variable.

Mediation analysis originates with every case of three variables. The theory of mediation analysis is mainly common in psychology, sociology, and associated fields. Mediators could be psychological, physiological, or biotic. Mediators fluctuate to the easiness of measurement. Mediation analysis is observed as a measurement process, where the mediating process is more precisely measured as a field progresses. The two looms that quantify mediated effects from the regression models based on disparate uses of the parameters $\tilde{a}$, $\tilde{b}$, $\tilde{c}$ and $\tilde{c}'$. The product of $\tilde{a}$ and $\tilde{b}$ parameters $\tilde{a}\tilde{b}$ is the mediated effect. Because $\tilde{X}$ affects $\tilde{Y}$ indirectly through $\tilde{M}$ and the mediated effect is said to be an indirect effect. $\tilde{c}$ is the direct effect, the effect of $\tilde{X}$ on $\tilde{Y}$ after adjustment for $\tilde{M}$.

The chain of these variables explains the process or mechanism of mediation analysis. With several variables, fuzzy analysis has been widely studied. In this paper, fuzzy mediation analysis models using interval data are determined. Confidence intervals and hypothesis tests are also determined. Psychological data have been applied to find the total, direct and indirect effect when the mediator and confounding variable subsist.

2 Literature review

Initially, Zadeh (1965) introduced the concepts of fuzzy set theory under fuzzy environments many researchers have studied the statistical hypotheses testing. Simple slopes were plotted at the interaction conformed to the hypothesised pattern, SD above and below the mean of children's self-regulation in eating as recommended by Whisman and McClelland (2005). Francioli et al. (2016) concerning mediators in psychosocial working conditions-bullying relationships also found the moderating role of a sense of coherence (SOC) in the relationship between psychosocial working conditions (assessed

through the JDC model, Karasek, 1979) and bullying. Manton et al. (1994), Buckley (2005) and Viertl (2011) state that the statistics with fuzzy set theory have been widely studied. Jiryaei et al. (2013) employed the least-squares method. Fuzzy circles, Elsherif et al. (2014) solve the problem of testing fuzzy hypotheses have introduced a new statistical procedure with fuzzy data based on confidence intervals. Ahmid et al. (2022) proposed an intelligent and secure internet of things approach for the healthcare system to monitor the patient heart rate in real-time and from any place.

Several fuzzy mediation analysis models have been proposed in Yoon (2020). Hypothesis tests and confidence intervals are also provided. Numerous psychological data have been applied when the mediator and confounding variable to find the total, direct and indirect effect exists. Akbari and Rezaei (2016) a bootstrap method for inference about the variance is been investigated based on fuzzy data. The mid-width method has been proposed by Akilbasha et al. (2018) for finding the optimal interval solution to an interval biomedical transportation problem. Shahriar et al. (2022) studied why healthcare data is of interest to attackers, followed by two common approaches to protect healthcare data which include blockchain and machine learning. Wu (2009) proposed to construct fuzzy confidence intervals some approaches are there for the unknown fuzzy parameter. Arefi and Taheri (2011) to test fuzzy hypotheses an approach has been developed for vague data upon fuzzy test statistics. The problem of testing statistical hypotheses is a new approach for fuzzy data using the relationship between confidence intervals and hypothesis testing (Chachi et al., 2012).

Li et al. (2019), a moderated mediation model is tested to determine the psychological factors with the relationship between self-esteem and PSU which even contribute to the understanding of PSU and behavioural addiction. Edwards and Konold (2020), this study expedites a regression framework on moderation and mediation into a collective model of moderated mediation. Hongbo et al. (2020), this study deals with the influence of observed job insecurity on the family, the contrivance that ensues, and the moderating effect that could increase employees' family life and delivers visions to societies. Zhang (2021), the study suggests the triadic reciprocal determinism theory and understands the learning that influences through the examination. In expecting a test's impression on learning the highpoints and the test takers' roles acuties on examination and professed self-efficacy.

This paper explains the mediating model with multiple moderators using interval data. For the membership grades, the alpha cut is taken to be 0.5 so as the value gets closer to 1 the model is defined to be fit. The regression is used in this paper to find the direct and indirect pathways and the interaction effect on the moderators. The remainder of the paper is framed as follows. Section 3 is started with the testing of moderated mediation model using large samples with interval data. In Section 4, the direct and indirect effect of the moderated mediation model is presented. In Section 5, the fuzzy approach on moderated mediation model is defined. Results and discussion are given in Section 6. Finally, Section 7 concludes the paper.

3 Testing of moderated mediation model using large samples with interval data

- 1 To test the moderated mediation model using large samples for various factors.
- 2 To test the fuzzy moderated mediation model with interval data.

3.1 Methodology

In this section, the data was collected using random sampling. An online questionnaire was sent and 910 usable responses were collected at the end of the data collection. Data were cleaned and progressed for further analysis. It was decided to conduct moderated mediation model using IBM SPSS PROCESS macro version 3.4 with the two moderators to a mediator. The path values, indirect effect, and total effect of the model are determined. The regression is conducted for the variables and mediator to test the significance of the pathways. This study further tested with the fuzzy model for mediators and moderators using the membership grade function with the α cut to be 0.5.

3.2 Multiple mediation model

The statistical mediation model is classified into various types. In the mediation model if any one of the paths conditionals is not in moderation, then pure mediation takes place. If a model proposes with only one mediator, then it is known as simple mediation. If the model intends with more than one mediator then multiple mediations occur.

In a few circumstances with other assumptions to elucidate an effect of X on Y. In some cases, exploring only one mediator as a part is not adequate. While one premise might offer a mediator M_1 , another theory may offer a changed mediator M_2 for a similar relationship (Hayes, 2009). Bearing in mind, that more than mediators that are not causally interconnected is the most fundamental expansion of the simple mediation model; it is called parallel mediation (Hayes, 2013). Parallel mediation models facilitate researchers to explore diverse mediation theories at the same time (e.g., Guevara and Howell, 2015). The autoregressive modelling is proposed by Gupta et al. (2022) to process ECG signals by estimating their coefficients. The pattern of two mediators would direct to a conceptual model formation like the one shown below. In models with an additional mediator, several precise indirect effects subsist that can be endorsed by one of the mediators. Conceptually, multiple mediations amend in X leads to an adjustment in M_1 (path a_1), and that change in a M_1 leads to change in Y (path b_1). The indirect effect is represented as path ab because it is the result of the two paths that join the interpreter X to the mediator M_1 (path a_1) and path b_1 is the mediator M_1 to the outcome Y. If the indirect effect ab is larger or smaller than zero (i.e., if it is statistically significant), one can assert that several forms of mediation take place (Zhao et al., 2010). Simple mediation is the major basic structure of mediation and permits one to construct inferences about the primary mechanism that unites an independent with a dependent variable.

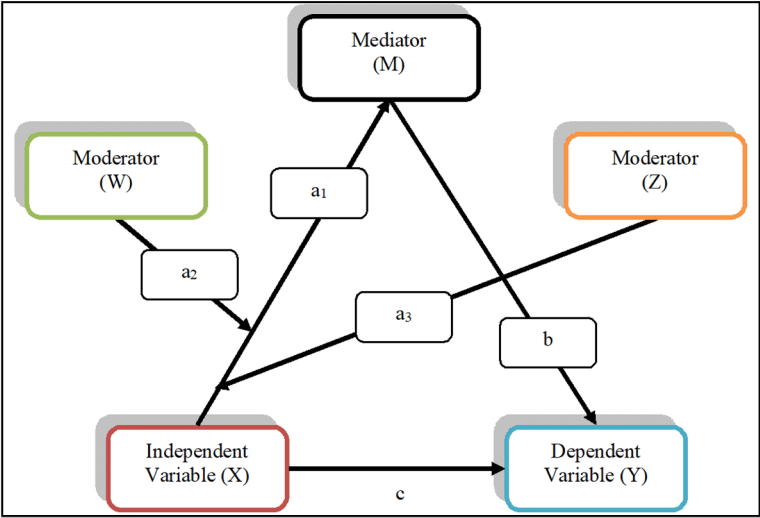
Similarly, X leads to an adjustment in M_2 (path a_2), and that change in M_2 leads to a change in Y (path b_2). The indirect effect is represented as path ab because it is the result of the two paths that join the interpreter X to the mediator M_2 (path a_2) and path b_2 is the mediator M_2 to the outcome Y.

3.3 Moderated mediation model

The model of moderated mediation is often there to determine whether a mediation effect remains constant or not across different contexts and values of the independent variable. For instance, perhaps M mediates the relationship of X tends to Y for one variable but not for another variable. It is important in testing such additional hypotheses for the development of appropriate statistical tests.

There are several ways in which the combination of mediation and moderation may be modelled. Baron and Kenny (1986) in various sources refer to some of these effects as mediated moderation or moderated mediation.

Figure 1 Conceptual diagram of the moderated mediation model (see online version for colours)



Notes: Where X: independent variable, Y: outcome variable, M: mediator, a_1 : effect of X on M, a_2 : effect of X on M, a_3 : effect of X on M, b: effect of M on Y, ab: indirect effect of X on Y, and c: total effect of X on Y.

3.4 Illustration

Let the fuzzy independent variable be X and the fuzzy dependent variable be Y and the fuzzy mediator be M. Let Mo_1 and Mo_2 be the fuzzy moderators. Now, we are about to find the direct effect and indirect effect of path values of the interval data with respect to the fuzzy moderated mediation model.

To find the path values of direct effect and indirect effect of moderation mediation model responses were collected and IBM SPSS PROCESS macro version 3.4 is used for the moderated mediation analysis.

The path values of the direct effect and indirect effect of the moderation mediation model and the interaction effect of the regression between the independent variable and the moderator are mentioned below.

Table 4 Conditional effect of X on Y at values of the moderator (M)

<i>Variables</i>	<i>Effect</i>	<i>SE</i>	<i>T</i>	<i>P</i>	<i>LLCI</i>	<i>ULCI</i>
Truculent	0.2572	0.0608	4.2297	< 0.001	0.1377	0.3766
Anxiety	0.3248	0.0456	7.1281	< 0.001	0.2353	0.4143
Engaged	0.3924	0.0462	8.4848	< 0.001	0.3016	0.4833

4 Direct and indirect effect of moderated mediation model

In this section, we explain the direct and indirect effects of the mediated model with interval data. Also, it is used to determine the interaction effect on the moderators.

In this method, the following linear regression models are fit.

$$M = i_1 + a_1X + a_2W + a_3Z + a_4XW + a_5XZ$$

The regression coefficient c_1 from the equation is called the total effect. Similarly, the direct effect from the equation is regression coefficient c' . For the Z test, consider the lower value of the random sample of given interval data, $S_L = (x_i, i = 1, 2, \dots, n)$ and another random sample of the upper value of the given interval data, $S_U = (y_i, i = 1, 2, \dots, n)$.

$$Z_L = \frac{(\bar{x} - \eta)\sqrt{n}}{\sigma_x} \text{ and } Z_U = \frac{(\bar{y} - \mu)\sqrt{n}}{\sigma_y}$$

The test statistics are

$$Z = \frac{\hat{a}\hat{b}}{SE(\hat{a}\hat{b})} \approx \tilde{N}(0, 1)$$

The standard error of the multiple mediated effects is simplified as:

$$SE(\hat{a}_2\hat{b}_2) = \sqrt{(a_1SE(\hat{b}_1))^2 + (b_1SE(\hat{a}_2))^2 + (a_2SE(\hat{b}_2))^2 + (b_2SE(\hat{a}_1))^2 + (SE(\hat{a})^2 SE(\hat{b})^2)^2}$$

The lower and upper values of $100(1 - \alpha) \%$ confidence interval estimate for β_i based on t distribution with $(n - p - 1)$ degrees of freedom.

The asymptotic 95% confidence interval for the mediated effect is

The indirect effect of X on Y through M by W

$$(a_1 + a_4W + a_5Z)b = a_1b + \underline{a_4bW} + a_5bZ$$

An indirect effect of X on Y through M by Z

$$(a_1 + a_4W + a_5Z)b = a_1b + a_4bW + \underline{a_5bZ}$$

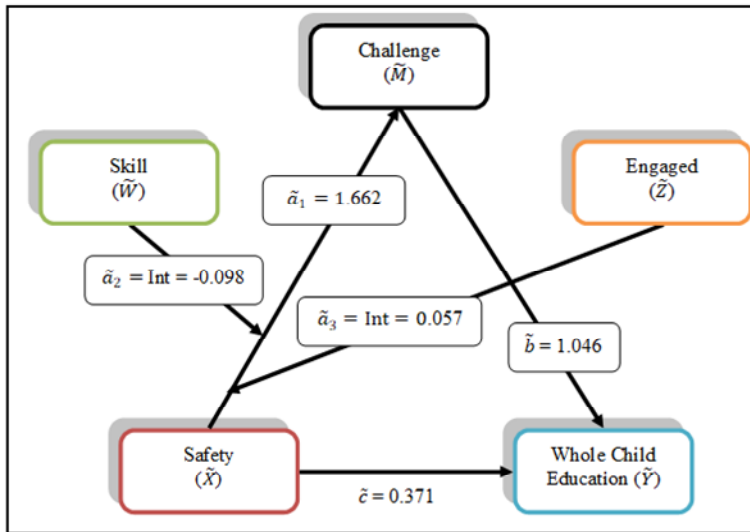
5 Fuzzy approach on moderated mediation model

In this section, we state the fuzziness in the variables used and how the interaction effect would be more effective for the model. This study is not a comparison. This model is tested to find the pathways of the mediators and to find the interaction effect when more than one moderator is used with fuzzy intervals.

Let $\tilde{X}$ be the fuzzy independent variable and $\tilde{Y}$ be the fuzzy dependent variable and $\tilde{M}$ be the fuzzy mediator. Let $\tilde{W}$ and $\tilde{Z}$ be the fuzzy moderators.

Let $\tilde{X} = \{\text{Safety}\}$ and $\tilde{Y} = \{\text{Education of a Child}\}$ and $\tilde{M} = \{\text{Challenge}\}$ be defined on the model. Now, $\tilde{W} = \{\text{skills}\}$ and $\tilde{Z} = \{\text{Engaged}\}$ be the moderators on the model. The MG's of the sample concerning fuzzy sets $\tilde{X}$, $\tilde{Y}$, $\tilde{M}$, $\tilde{W}$ and $\tilde{Z}$ based on the collected information are given for the analysis. Any fuzzy sets can be specified by α -cut. Here α -cut is 0.5.

Figure 3 Fuzzy moderated mediation with the interaction effect of the moderators' skill and engaged (see online version for colours)



6 Results and discussion

The result on fuzzy moderated mediation represents the results of our analysis. Results from a moderated mediation analysis specify that safety is indirectly related to the child's education through its relationship with the mediator as a challenge. First, as seen in the figure, the children who are in safer hands are ready to face any kind of challenges with confidence compared to those children who are safe ($\tilde{a}_1 = 1.662$, $p >= 0.001$) and the lower reported mediator challenge was subsequently related to complete child education ($\tilde{b} = 1.046$, $P < 0.001$).

A 95% bias-corrected confidence interval based on 10,000 bootstrap samples indicated that the indirect effect ($\tilde{a}\tilde{b} = 1.738$) was entirely above zero (0.009 to 0.082). Moreover, children in safer hands are likely to complete their education indirectly gives, ($\tilde{c} = 0.371, P = 0.004$). Similarly, the interaction effect of the moderators such as skills and engagement which indicates that children who are engaged completely with education activities are highly moderate ($\tilde{a}_2 = 0.057$) in completing their education successfully when compared with the students having extra skills, ($\tilde{a}_2 = -0.098$).

7 Conclusions

A fuzzy moderated mediation analysis is proposed in this paper with an Interval data and regression approach. There are more cases where the conditions are not articulated plainly in an actual number. Therefore, it is highly sensible to pertain the fuzzy mediation than standard mediation analysis. Data have been applied to the proposed fuzzy moderated mediation and analysis. The results show that the fuzzy moderated mediation analysis affords the effects that are progressive and more positive and negative effects are more negative. Additionally, the total, direct and indirect effect is highly significant and is relevant to the study. This paper detail about fuzzy moderated mediation analysis, but this theory will be extended to other various mediation and moderation analyses in future research.

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