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Contents

Quantitative Analysis of the Relationship Between Three Psychological Parameters Based on Swallowtail Catastrophe Model

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Abstract

A sudden jump in the value of the state variable in a certain dynamical system can be studied through a catastrophe model. This paper presents an application of catastrophe model to solve a psychological problems. Since we will have three psychological aspects or parameters. Intelligence (I), Emotion (E), and Adversity (A), a Swallowtail catastrophe model is considered to be an appropriate one. Our methodology consists of three steps : solving the Swallowtail potential function, finding the critical points up to and including three-fold degenerates, and fitting the model into our measured data. Using a polynomial curve fitting derived from the potential function of Swallowtail Catastrophe Model, relations among three parameters combinations are analyzed. Results show that there are catastrophe phenomena for each relations, meaning that a small change in one psychological aspect may cause a dramatically change in another aspect.

Keywords: swallowtail model, polynomial regression, intelligence, emotion, adversity

1. Introduction

A catastrophe phenomenon arising from psychological problems has first been discussed by Arnold (Arnold, 1992). In that paper , he characterized a creative personality of a scientist, as well as a maniac, by three following parameters: technical profiency, enthusiasm, and achievement. He found that scientist and maniac have differences in their performance dramatically. In fact, the achievement of scientist mainly depended on his technical proficiency and enthusiasm; If enthusiasm was not great, the achievement grew monotonically and fairly slow with technical proficiency; If enthusiasm was sufficiently great then qualitatively dramatically phenomena start to occur due to a small variation in technical proficiency. While for maniac, he concluded that the latter phenomenon would not occur; A maniac having similar enthusiasm with scientist, could not change his achievement because their technical proficiency were different. This phenomena was well modelled by him as Cusp catastrophe model.

Other catastrophe models related to psychological problems were also studied by (Baum, 1987; Brezeale, 2011; Flay, 1978; Cobb, 2010; Meiza, 2006; Scott, 1985). However, their model was limited to Cusp model. To name a few, Van der Maas has constructed a deterministic Cusp Catastrophe for 'political attitude' as a state variable and 'information' and 'involvement' as the two control parameters. Cusp was fitted using R routine in the common use and also used to fit a sudden transition data (van der Maas, 2003). Cusp catastrophe model was also used by (Meiza, 2006) to model the intelligent phenomenon of students (their Intelligences and Emotions) when students from various departments were grouped into one class. Other fitting model based on an application of estimation theory was worked out by Cobb (2010). To some extent, catastrophe model was extended to include more than two control parameters. For instance, (Guo & Wu, 2008) studied relations among three parameters of traffic flow: velocity, density, and flow, by using a Swallowtail Catastrophe model. The butterfly catastrophe model for describing and predicting performance changes in an educational setting was studied by (Guastello, 1987), that included controlled parameters of students such as subject's abilities, intrinsic and extrinsic motivational factors, and organizational climate variables. (Wu et al, 2014) discussed a Butterfly catastrophe model for wheat aphid population dynamics. Until now to our knowledge, catastrophe model for three control parameters, especially for physiological problems, are still limited.

As additional, next, we describe more relation between Intelligence and Emotion. There are some ways to define intelligence. Intelligence cover creativity, personality, character, knowledge, or wisdom. Although not all psychologists agree with these. Usually, intelligence refers to ability or mental capacity in thinking (Encarta,2005). Generally, there are some kinds of intelligence, *i.e.* Intelligence Quotient (IQ), Emotional Quotient (EQ), and Spiritual Quotient (SQ). Although the last kind is still debatable in expert. Besides the previous intelligences, also known Multiple Intelligence (MI) that proposed by Howard Gardner. In particular, we will see the relation and differences between IQ and EQ. Most people know Intelligence Quotient (IQ). IQ is used to determine academic abilities, understand and apply information to skills, logical reasoning, word comprehension, math skills, abstract and spatial thinking, filter irrelevant information. French psychologist Alfred Binet was one of the key developers of IQ test, what later became known as the Stanford-Binet test. While EQ is defined as an individual's ability to identify, evaluate, control, and express emotions. Daniel Goleman is who proposed EQ. As believed for a long time, IQ was be the ultimate measure for success in careers and life in general, but there were some studies that shown a direct relation between higher EQ and successful. From a brain study in Vietnam, there was find that a significant overlap between general intelligence (IQ) and Emotional Intelligence, both in behavioral measures and brain activity. Higher scores on intelligence tests and has a better personality, predicted higher performance on measures of Emotional Intelligence. Also were found many of the same brain regions that used for the two intelligence both (Barbey etc, 2012).

In this paper, we extend the work of Meiza (2006) by adding one extra control parameter, namely *Adversity*, and then apply the Swallowtail Catastrophe to model the intelligent phenomena. We include adversity since it is believed that this aspect will also contribute to one's intelligence ability. It is a person's ability to be able to withstand the difficulties and able to turn challenges into opportunities (Stolz, 2000). The line of our method will follow the idea of (Guo & Wu, 2008). We will apply our method to our measured data. Regression concepts to fit the data to the Swallowtail model are then used.

This paper is organized as follows. In section 2, we propose the methodology. We solve the Swallowtail potential function and find the critical points up to and including three-fold degenerates. We then up with fitting the model into our measured data. In section 3, we present the results and conclusions.

2. Methodology

Instruments

In this research we refer to empirical data of psycho test resulted from the research subjects which are the employees from a company. The data were obtained from three instruments *i.e.* IST, Pauli, and EPPS. In the following a brief explanation of the three psychological measuring instruments is described.

i. The IST Test (*Intelligenz Structure Test*) is one of the psychological tests to measure Verbal, Numerical and Figural level of one's intelligence which developed by Rudolf Amthauer in Germany in 1953. This test is consists of 9 subtests i.e. SE (complete the sentence); WA (find a different word); AN (find the related words); GE (find synonym of words); RA (simple count); ZR (number series); FA (construct the shapes); WU (cube); and ME (remember the words) (Polhaupessy, 1993).
ii. The Pauli Test is an improvement and refinement of the Kraepelin test compiled by Emil Kraepelin a late 19th century psychiatrist who was used as a tool to diagnose brain disorders of Alzheimer's and dementia. This test is perfected in such a way by Professor Pauli making it possible to get data about personality (Sumintardja, 1991).
iii. The EPPS (Edwards Personal Preference Schedule) Test was developed by psychologist and University of Washington Professor Allen L. Edwards. The EPPS Test is a forced choice, objective, non-projective personality inventory. Edwards derived the test content from the human needs system theory proposed by Murray which measures the rating of individuals in fifteen normal needs or motives (Kaplan & Saccuzzo, 2009).

The empirical data was assembly from these three instrument which combination from three aspects *i.e.* Intelligence, Emotion, and Adversity.

The Swallowtail Catastrophe Model

In this part we start with introducing the Swallowtail catastrophe model that we will use. Next, we derive the catastrophe control parameters as function of parameters of our measured data. Analyzing the degenerate critical points of catastrophe potential function is proposed to determine the qualitative properties of potential function at those points. The potential function of Swallowtail catastrophe model is defined by (Gilmore, 1981)

$$F(x) = x^5 + \alpha x^3 + \beta x^2 + \gamma x\,, \qquad (2.1)$$

where α, β, γ are control parameters and x is the state variable. Equilibrium points are obtained by taking the first derivative of Equation (2.1) with respect to x equals to 0, this is given by

$$5x^4 + 3\alpha x^2 + 2\beta x + \gamma = 0\ . \qquad (2.2)$$

Singular points which are a subset of the equilibrium surface of Equation (2.2) are obtained by vanishing the second derivative of Equation (2.1) with respect to x,

$$20x^3 + 6\alpha x + 2\beta = 0 \quad . \tag{2.3}$$

In the sequel, we shall formulate control parameters α, β, γ, as function of the state variable. To this end, we shall proceed as follows.

Next, we shall state β and γ as function of x and α . From Equation (2.3), we obtain

$$\beta = -10x^3 - 3\alpha x \, . \tag{2.4}$$

Substituting Equation (2.4) into Equation (2.2) we find

$$\gamma = 15x^4 + 3\alpha x^2 \, . \tag{2.5}$$

The derivation of γ and β with respect to x , are shown by the following equations,

$$\frac{d\beta}{dx} = -30x^2 - 3\alpha \qquad \text{and} \quad \frac{d\gamma}{dx} = 60x^3 + 6\alpha x \, . \tag{2.6}$$

From these two equations we find

$$\frac{d\gamma}{dx} = -2x \frac{d\beta}{dx} \quad . \tag{2.7}$$

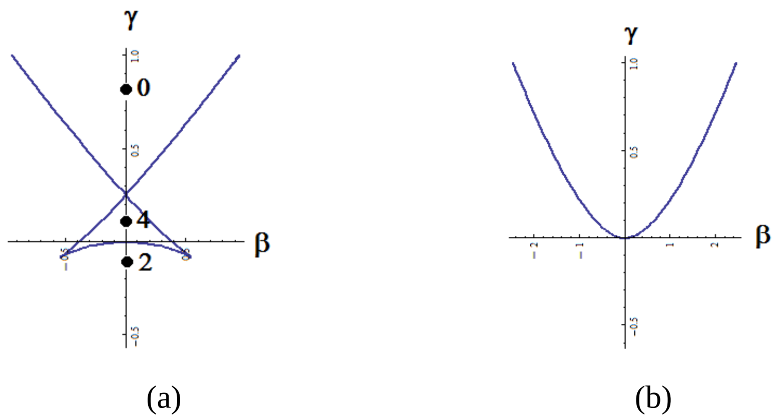


Figure 1. The set of Swallowtail ramification points for $\alpha < 0$ (1a) and $\alpha > 0$ (1b).

From Equation (2.4) and (2.5) we will analyze the relation between γ and β for fixed α. We separate two conditions, $\alpha < 0$ and $\alpha > 0$, and we plot γ as function of β as shown in Figure 1. For $\alpha < 0$ and $\beta = 0$, we analyze the condition along vertical axis γ. For the present case, the solution of Equation (2.2) is given by

$$x^2 = \frac{1}{10}\left[-3\alpha \pm \sqrt{\left(9\alpha^2 - 20\gamma\right)}\right] \tag{2.8}$$

From Equation (2.8) we observe three conditions as follows:

1. $\gamma > \frac{9\alpha^2}{20}$, the equilibrium Equation (2.2) does not have real roots and F in Equation (2.1) does not have a critical point, (Gilmore, 1981)
2. $0 < \gamma < \frac{9\alpha^2}{20}$, the term $\sqrt{(9\alpha^2 - 20\gamma)}$ is a real number and has value less than (-3α). For this, there are 4 critical points for F with 2 points of maximum and 2 points of minimum.
3. $\gamma < 0$, two of the solutions of Equation (2.8) are real numbers and one of them is negative.This F has only two critical points with one maximum point and one minimum point.

Note that catastrophic phenomena will appear for conditions 2 and 3. We can conclude these conditions as seen in Figure 1a. The such points 0, 2, and 4, are show condition 1 to 3 in sequence above (Gilmore, 1981).

Next, we apply the theory to the data. We fit our model by using the empirical data Intelligence score, Emotion score, and Adversity score from 36 employees of a state-owned company. Considering Equation (2.2), which describe a balanced surve surface, we use the following polynomial regression, as a statistical procedure of data analysis,

$$y(x) = x^4 + px^3 + qx^2 + rx + s \ . \tag{2.9}$$

To synchronize Equation (2.9) with Equation (2.2), we use a transformation $z = x + \frac{p}{4}$. Substitute this form into Equation (2.9) we obtain

$$y(z) = z^4 + \left(q - \frac{3}{8}p^2\right)z^2 + \left(\frac{p^3}{8} - \frac{pq}{2} + r\right)z + \left(-\frac{3p^4}{256} + \frac{p^2q}{16} - \frac{pr}{4} + s\right) . \tag{2.10}$$

The form of Equation (2.10) is similar to the balance curved surface of Swallowtail catastrophe model in Equation (2.2). Considering Equations (2.2) and (2.10), we obtain that

$$\alpha = \frac{5}{3}\left(q - \frac{3}{8}p^2\right),\ \beta = \frac{5}{2}\left(\frac{p^3}{8} - \frac{pq}{2} + r\right),\ \gamma = 5\left(-\frac{3p^4}{256} + \frac{p^2q}{16} - \frac{pr}{4} + s\right). \tag{2.11}$$

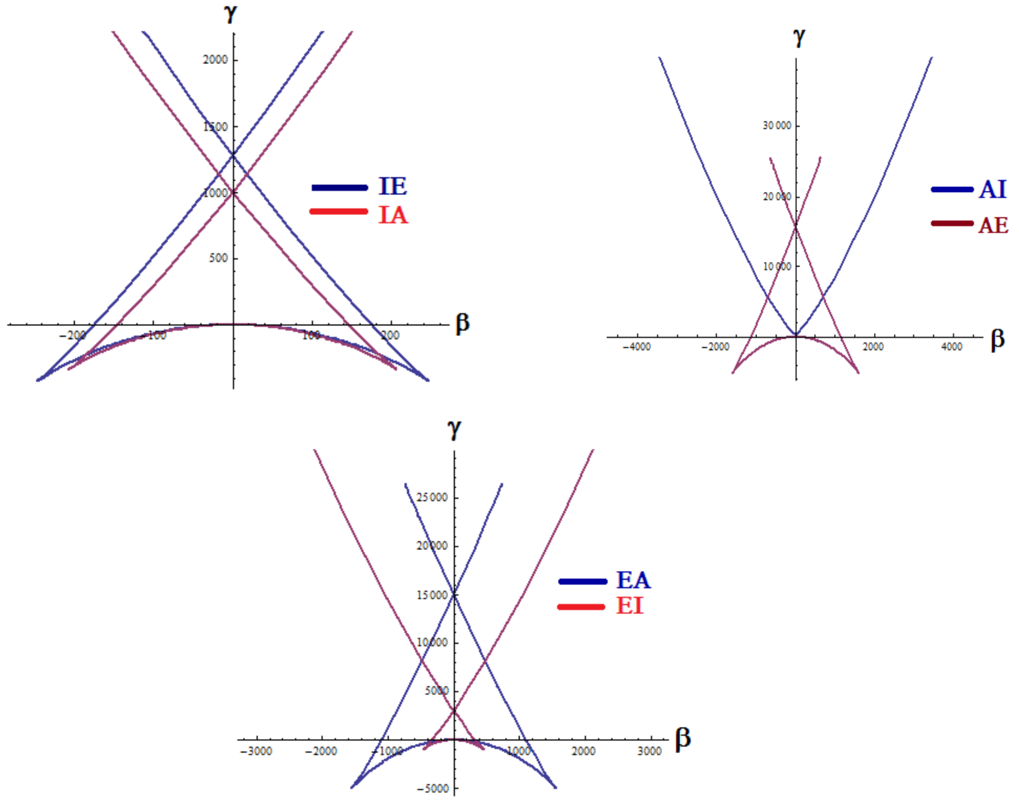
3. Results and conclusion

As the optimization method, we use Fuzzy Linear Programming (FLP). This method we apply to the data with aid by LINGO procedure. On the other step, we also use Maximum Likelihood Estimator to find the best parameter for polynomial regression model. This study is based on our data presented in Figure A in the Appendix. Note that our data, in general, does not show a function property; In the data, one value in horizontal axis may correspond to many values in the vertical axis. Since we shall apply the polynomial regression as a statistical procedure for data analyze, we should have interval or scale data. For that, we take an average for the data having many values. The averaging results are shown in Figure B (1-6). As an illustration of our method, let us consider the data of E respect to I as seen in Figure B(1). In the sequel, we shall note this as I-E case where I acts as *x* and E as *y*. Applying Equation (2.9) to fit the averaging data and then using Equation (2.11), we find three parameters α, β, and γ as seen in the first row of Table 1. The sameline follows for the other cases. All results are presented in Table 1.

Results	α	β	γ
IE	-47.3917	959.3617	-2.1481e+004
IA	-53.400	1195.1	-2.7221e+004
AI	-22.6	27.767	-5.8235e+003
AE	-186.733	338.4092	-4.7012e+005
EI	-182.5563	2240.5	-3.0158e+005
EA	-82.0250	1099.7	-1.3915e+004

Table 1. Results of curve fitting the data by Swallowtail model.

From Table 1, we see that all cases have $\alpha < 0$. Hence, we will meet with the case described by Figure 1a. Using the values of three parameters in Table 1, we plot γ as a function of β given by Equation (2.4) and (2.5). Results of all cases are shown in Figure 2(a-c). As shown in Table 1 in which $\beta > 0$, our data shown catastrophe phenomena.



(a) (b) (c)

Figure 2. The Swallowtail plots for IE-IA case (a), AI-AE case (b), and EA-EI case (c).

In a parameterized dynamical system, bifurcation occurs when a change in parameter causes an equilibrium to split into two. While catastrophe occurs when the stability of an equilibrium breaks down which causing the system to jump into another state (Zeeman, 1982). So, by definition, specific variables can act as bifurcation factors because it will distinguish the subject into two different classifications altogether after a jump occurs. As an illustration, in a presidential election, a fanatic supporter of presidential candidate, namely A, as over time with additional information about the presidential candidate he supports, the supporter may suddenly jump in favor of the presidential candidate B who is the opposite of presidential candidate A. In this research, the specific factor is reviewed various conditions with specific factors alternately between I, E, and A. For example if Adversity as the specific factor. Two people who have the same level of Intelligence but as time goes by, the changes in their Emotions can lead to an Adversity leap (jump) where they can have a totally different or the opposite Adversity. In psychological view, we may interpret as follow. Two people who are equally Intelligent but have different Emotion, can have different performances altogether when faced with problems. In this case both will be on different Adversity.

The first man may have collapsed over time, but the second man can instead turn the obstacle into an opportunity or perceive the obstacle as a challenge he has to pass.

In psychological view, we may interpret as follows. For EI and EA cases (Figure 2c), we choose γ in the certain value i.e. 5000 (see Figure 2c). As refer to Figure 1a, we say γ is in the condition 2. If we move this value along γ axis ($\beta = 0$) until 10,000, then EA is still in catastrophic phenomenon, but EI is not. We can say that small change in EI would not change dramatically for Intelligence, but not for Adversity. Adversity will likely change even by small variation in Emotion.

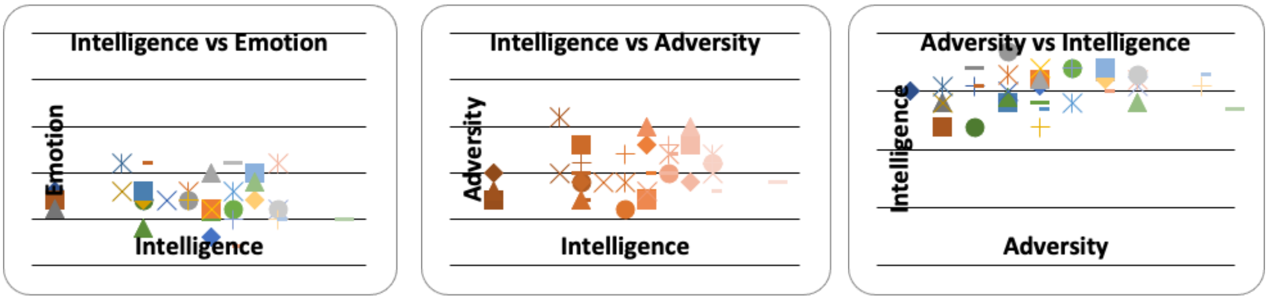
As the same line, we can conclude for the others cases as follow. In Figure 2a, for IE and IA cases, the small change of Intelligence will lead a dramatically change for Emotion, but not for Adversity. Just like for AI and AE cases in Figure 2b. The small change of Adversity will lead a dramatically change for Emotion, but not for Intelligence.

In general, application of Swallowtail catastrophe model to our data, can be concluded that the interaction between Intelligence, Emotion, and Adversity which serves Emotion and Adversity as the control variable, while Intelligence as the response (state) variable, gives the relationship is not as strong compared to the case of Emotion paired with Adversity or otherwise. So, if someone Emotions improved only slightly, the Adversity will dramatically increase. Vice versa. Meanwhile, if Emotion and Adversity each paired with Intelligence, the slight changes in both these aspects will not increase dramatically Intelligence.

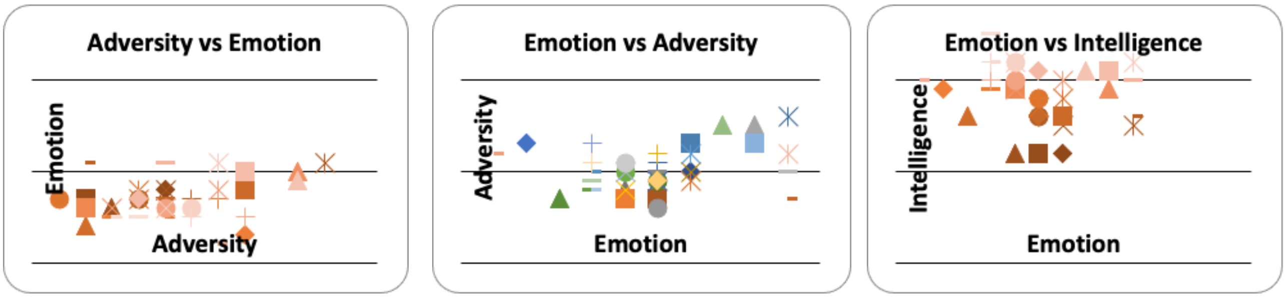
The new present paper offers to the literature or the benefits offered by the results of this study that is if in an institution that can know which factors are the most significant effect on the performance of work then can be attempted ways to improve these factors.

Appendix

The raw data in Figure A (1-6) are the distributions of Intelligence, Emotion, and Adversity scores. We get the scatter plots of each pair Intelligence vs Emotion scores, Intelligence vs Adversity scores, Adversity vs Intelligence scores, Adversity vs Emotion scores, Emotion vs Intelligence scores, and Emotion vs Adversity scores. In Figure B (1-6), we get the averaging results from raw data.

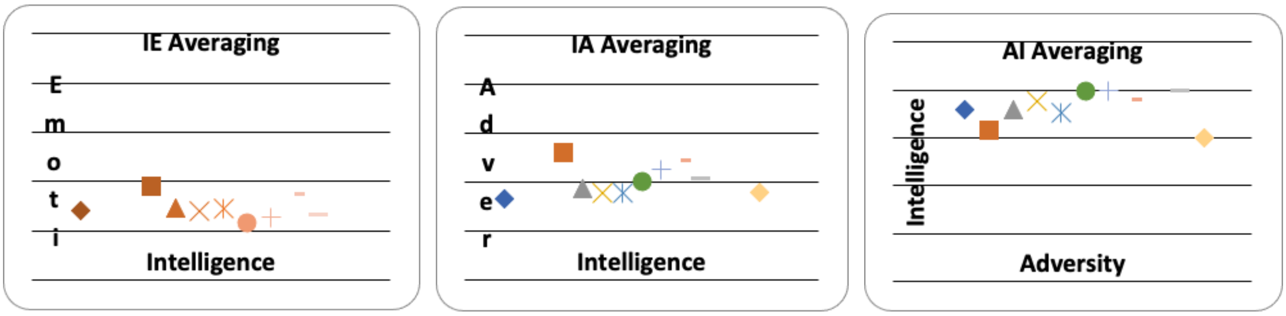


(1) (2) (3)



(4) (5) (6)

Figure A. Scatter plot of raw data



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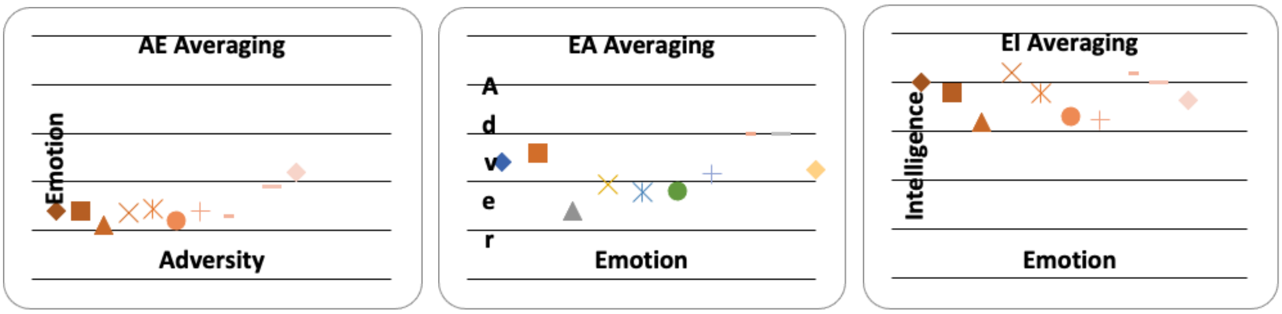

(4) (5) (6)

Figure B. Averaging results from raw data

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