

Modelling Interpretation of Interpersonal Experiences Based on Cognitive Schema Theory

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Abstract. How different individuals interpret the same interpersonal experience differently is one of the key areas of interest in psychiatry. In certain psychiatric disorders, such as major depression and schizophrenia, interpretation of interpersonal experiences become distorted leading to psychopathologies such as overvalued ideas, depressive cognitions, and delusions. The exact mechanism of this process in psychiatric disorders is poorly understood and this paper introduces a model for understanding this mechanism using Cognitive Schema Theory. The mental state of an individual is considered as a dynamic process changing from one state to another in relation to interpersonal experiences. Interpretation of an interpersonal experience is determined according to the mode of relevant cognitive schema and the current mental state. It is expected that this model may assist in improving the aetiological understanding of psychiatric disorders.

Keywords: Cognitive Schema Theory, Mathematical models for psychopathology, Mathematical models in psychiatry

1. Introduction

How individuals interpret their interpersonal experiences have important implications that involve different choices of responses, which may lead to different consequences. For example, at one extreme, an individual may naively interpret most interpersonal experiences as friendly whilst at the other extreme, an individual may interpret even friendly gestures as suspicious or hostile. Understanding the mechanism of his process is one of the key areas of interests in psychiatry in relation to psychopathology of various psychiatric disorders. How can these differences in interpretations of the same situation by different individuals be explained?

In most psychiatric disorders there is some level of distortion in rational interpretation of interpersonal experiences. For example, in major depression, patients often evaluate their interpersonal experiences negatively in relation to himself/ herself and his/her future (e.g. feeling worthless or being negatively evaluated by others)[1],[2]; in paranoid schizophrenia, patients may interpret other people's reactions as persecutory and hostile[3]. One of the main aims of the treatment for psychiatric disorders is to restore a rational level of interpretation of interpersonal experiences either via medications or psychotherapy. For example, in major depression, Cognitive Behaviour Therapy is used to restore rationality amidst excessive negative self-evaluation [4]; in schizophrenia, anti-psychotic medications are used to restore some reality base in the context of extreme persecutory interpretations which are related to paranoid delusions.

Whilst psychiatric disorders are known to cause a significant burden and disability on individuals, they are often undertreated [5]. Unfortunately, the exact mechanism of the aetiological processes of most of the

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psychiatric disorders is poorly understood. Even though there are broader psychological, biological and social causes implicated, the relative prominence of their roles has been debatable [6]. Lack of a deeper understanding in such pathological processes is a major challenge in developing effective treatment strategies for psychiatric illnesses.

The aim of this paper is to propose a model for explaining how different individuals interpret their interpersonal experiences using Cognitive Schema Theory. The proposed model may assist in understanding the processes related to development of psychopathology in psychiatric disorders.

The next section of the paper briefly introduces the Cognitive Schema Theory as the conceptual basis for the proposed model. The process of developing the model is presented as a sequence of stages consisting of developing a conceptual model, formulating a mathematical model, and then translating the mathematical model into an algorithm. Finally, using MATLAB this algorithm is programmed and the simulated results are discussed.

2. Cognitive Schema Theory

There are many conceptual theories in psychiatry/psychology for understanding individuals' tendencies to interpret and react in interpersonal situations. For example, these include Object Relations Theory [6], Ego Psychology [7], and Self-psychology [8]. Cognitive Schema Theory introduced by Jeffrey Young provides a rich psychological framework for understanding individuals' perceptual interpretations of their interpersonal experiences. The core constructs of this theory is known as cognitive schemas, which are defined as pervasive character traits that develop in relation to adverse early life experiences [9]. Eighteen cognitive schemas have so far been identified and they can be assessed using the self-report Young Schema Questionnaire. An important characteristic of cognitive schemas is, they are dynamic structures, which undergo different modes (over-activation or under-activation) in relation to individual's emotional states.

3. Conceptual Model

In order to conceptualise the process of interpreting interpersonal experiences, let us consider the cognitive schema of *mistrust*. Any given interpersonal experience can be described as a gradient in relation to a continuum of 'trustful' at one extreme, 'neutral' in the middle and 'mistrustful' at the other extreme. Interpretations of interpersonal experiences in this situation simply involve classifying any given experience as trustful, neutral or mistrustful. The points of demarcation of these categories are determined by the state of the cognitive schema (i.e. cognitive schema mode) and the interpretations of previous experiences(Fig.1). If the cognitive schema is over-activated, then it lowers the threshold for interpreting interpersonal experiences as mistrustful. On the other hand, if it is under-activated it lowers the threshold for interpreting interpersonal experiences as trustful. Similarly, according to empirical observations, if an individual is consecutively experiencing trustful experiences, then it may lower the threshold for interpreting experiences as trustful whilst consecutive mistrustful experiences may lower the threshold for interpreting experiences as mistrustful. This is indicated by the feedback loop in Fig.1.

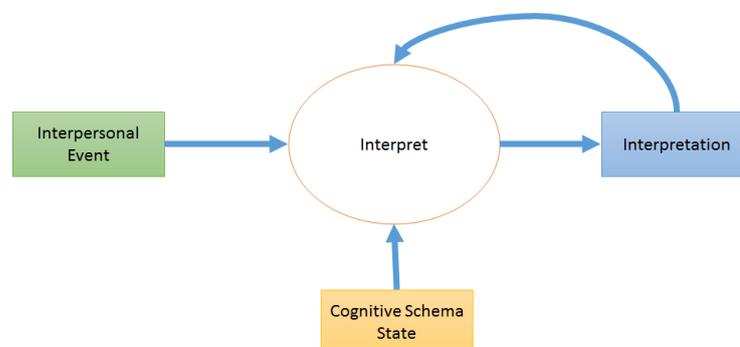


Fig. 1: Conceptual Model.

4. Mathematical Model

States of any given cognitive schemas have previously been modelled as a dynamical system using environmental influence and genetic vulnerability as follows[10]: $S_{n+1} = S_n r + g$, where S_n and S_{n+1} are the successive states of the cognitive schemas; r is the level of environmental influence; g is the level of genetic influence/vulnerability.

For this initial model presented in this paper, we consider that the state of relevant cognitive schema remains unchanged for the duration of time considered. Also, we only consider one cognitive schema, $C_2 = \text{Mistrust}$ in this model, since it provides examples that can easily be understood by the readers without a clinical background. The rest of the cognitive schema can also be studied using the same model.

Extending the model of genetic environmental interactions on cognitive schema state, we represent the state of any given cognitive schema as a continuous variable in the interval $[0,1]$ and define the following function.

$$\psi : C_i \rightarrow [0,1], i = 1, 2 \dots 18$$

Assuming S_n represents the n th state of i th cognitive schema, $\psi(C_i) = S_n$ is satisfied. The cognitive schema modes (underactive, neutral and overactive) can be defined by the following step function, which uses two arbitrary cut-off points, $l_1, l_2 \in [0,1]$ that can be determined using subjective clinical judgement.

$$\phi(\psi(C_2)) = \begin{cases} \text{Underactive,?} & \psi(C_2) \leq l_1 \\ \text{Neutral,?} & l_1 < \psi(C_2) \leq l_2 \\ \text{Overactive,?} & \psi(C_2) > l_2 \end{cases}$$

Similarly, we define the following function to appraise any interpersonal experience, E_n unbiasedly using the same interval.

$$\Omega : E_n \rightarrow [0,1], n = 1, 2, 3 \dots$$

For an interpersonal experience E_n , three interpretations, namely ‘Trustful’, ‘Neutral’, ‘Mistrustful’ can be represented as different states on a continuum in the interval $[0,1]$ in which zero represents the maximum level trustfulness whereas one represents the maximum level of mistrustfulness. Whilst we assume that the three cognitive schema modes remain unchanged in this model, individual’s perceptual interpretations of their interpersonal experiences is a dynamic process, in which any interpretation of a given experience, $\Omega(E_n)$ can take only one of the three outcome states, $X_n \in \{\text{Trustful}, \text{Neutral}, \text{Mistrustful}\}$. These three states continue to fluctuate from one state to another according to the following formula using three parameters: 1) cognitive schema mode, $Z_k = \phi(\psi(C_2))$ where $k = 1, 2, 3$ corresponds to $Z_1 = \text{underactive}$, $Z_2 = \text{Neutral}$ and $Z_3 = \text{overactive}$; 2) nature of the interpersonal experience, $\Omega(E_n)$; 3) current mental state, X_n .

$$X_{n+1} | X_n \wedge \Omega(E_n) \wedge Z_k = \begin{cases} \text{Trustful,?} & \Omega(E_n) \in [t_{1k} + \theta) \\ \text{Neutral,?} & \Omega(E_n) \in [t_{1k} + \theta, t_{2k} + \theta) \\ \text{Mistrustful,?} & \Omega(E_n) \in [t_{2k} + \theta, 1) \end{cases} \quad (1)$$

where, t_{1k}, t_{2k} are cut-off points with different threshold levels determined according to subjective clinical judgement, whereas θ is defined as follows:

$$\pi(X_{n-2}, X_{n-1}) = \theta = \begin{cases} -\alpha, & X_{n-1} = \text{Trustful} \wedge X_{n-2} = \text{Trustful} \\ \alpha & X_{n-1} = \text{Mistrustful} \wedge X_{n-2} = \text{Mistrustful} \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

where $\alpha \in [0,1]$.

Equation (2) incorporates the empirical observation that if an individual is consecutively experiencing ‘trustful’ interpersonal experiences, then it may lower the threshold for interpreting the next interpersonal experience as trustful. Similarly, if an individual is consecutively experiencing ‘mistrustful’ events, then it may lower the threshold for interpreting the next interpersonal event as mistrustful. For simplicity, this model only uses the two previous consecutive interpretations of interpersonal experiences. In future work, this model can be refined by extending the number of consecutive experiences considered.

5. Algorithm

The above model was developed into an algorithm (Fig.2), which consists of a main program that uses two functions, namely *findTheta()* and *interpret()* for determining θ and interpreting interpersonal experiences respectively. These two functions correspond to equations (2) and (1) respectively. Interpretations of interpersonal experiences are stored in an array named, *interpretations[]* whereas interpersonal experiences are stored in an array named *experiences[]*. The first For-loop in Fig.2 starts from $i = 3$ because it requires determining θ using the previous two interpretations: *interpretations[1]* and *interpretations[2]*. These two interpretations are determined in the same way using $\theta = 0$. In order to make the algorithm short and simple, the steps for determining these two steps were omitted.

```

//Declare and initialize variables
numberOfEvents: an integer;
interpretations[] = an array of real numbers of size numberOfEvents;
schemaState: an element of {underactive, neutral, overactive};
experiences[] = an array of random numbers within the interval [0,1]
// cut-off points
t11,t12,t21,t22,t31,t32;

FOR i=3 TO numberOfEvents
    theta = findTheta(interpretations[i-2], interpretations[i-1]);
    IF schemaStates==underactive THEN
        interpretations[i]=interpret(experiences[i],t11+theta,t12+theta);
    ELSE IF schemaStates==neutral THEN
        interpretations[i]=interpret(experiences[i],t21+theta,t22+theta);
    ELSE IF schemaStates[i]==overactive THEN
        interpretations[i]=interpret(experiences[i],t31+theta,t32+theta);
    END
END
END
END

//j and k are the consecutive interpretations
FUNCTION theta=findTheta(j,k)
BEGIN
    theta=0;
    IF (k==trustful AND j==trustful) THEN
        theta=-alpha;
    ELSE IF (k==mistrustful AND j==mistrustful) THEN
        theta=alpha;
    END IF
END IF
END

// e: interpersonal experience
// l: first cut-off point
// u: second cut-off point
FUNCTION interpretation=interpret(e,l,u)
BEGIN
    IF e<=l THEN
        interpretation=trustful;
    ELSE IF (e>l AND e<=u) THEN
        interpretation=neutral;
    ELSE IF e>u THEN
        interpretation=mistrustful;
    END
END
END
END

```

Fig. 2: Pseudocode for the algorithm.

6. Simulation of the Model

The above algorithm was programmed in MALAB and simulated using three hypothetical individuals with three different modes of Mistrust cognitive schema in relation to a randomly generated series of interpersonal experiences (i.e. random numbers representing $\Omega(E_n)$). The model parameters were initialized

using values determined according to subjective clinical judgement (Table-1). Fig.3 represents a sequence of randomly generated experiences with their interpretation using the function Ω on y axis. Fig.4-6 represents the interpretations of these experiences by the three individuals with underactive, neutral and overactive modes of Mistrust cognitive schema respectively. For the purpose of graphical representation we have mapped the three cognitive schema modes, trustful, neutral, mistrustful onto -1,0,1 respectively.

Parameter	Value
t_{11}	0.5
t_{12}	0.7
t_{21}	0.35
t_{22}	0.6
t_{31}	0.15
t_{32}	0.4
α	0.05

Table. 1: Model parameters and their values used in the simulation.

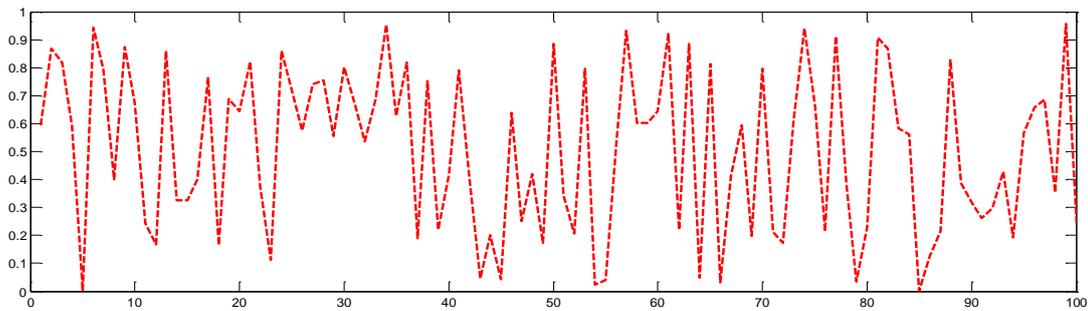


Fig. 3: Sequence of randomly generated interpersonal experiences.

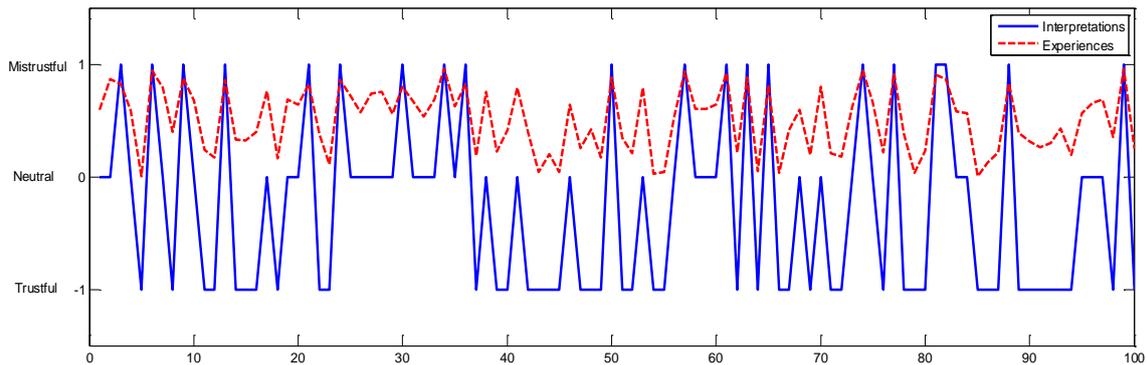


Fig. 4: Interpretation of the random interpersonal experiences when $Z_1 = \text{underactive}$.

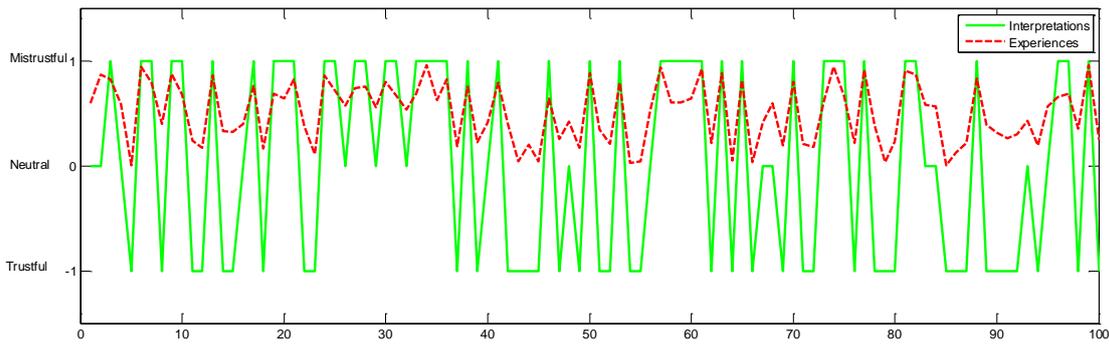


Fig. 5: Interpretation of the random interpersonal experiences when $Z_2 = Neutral$.

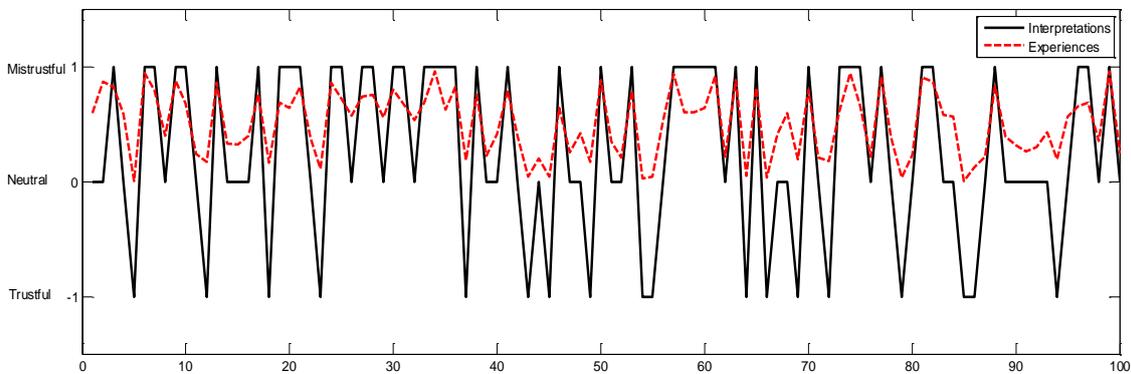


Fig. 6: Interpretation of the random interpersonal experiences when $Z_3 = overactive$.

It was expected that the individual with an overactive cognitive schema mode tends to overestimate the experiences as mistrustful and/or underestimate the experiences as trustful, whereas the individual with an underactive cognitive schema mode tends to overestimate experiences as trustful and/or underestimate experiences as mistrustful. The simulation results described in Fig.7 indicate that the overactive cognitive schema mode has resulted in underestimating the experiences as trustful whereas underactive cognitive schema mode has resulted in slightly overestimating experiences as trustful compared to the neutral schema mode. Also, both underactive and overactive cognitive modes have overestimated experiences as neutral, compared to the neutral schema mode.

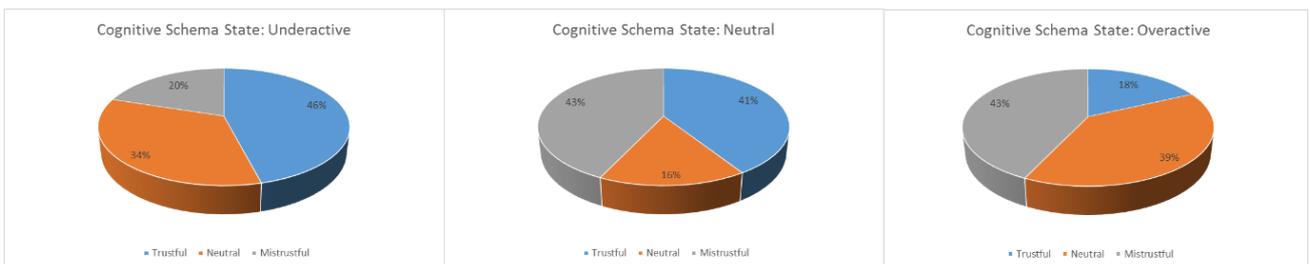


Fig. 1: Summary results of the interpretations of simulated interpersonal experiences.

7. Discussion

Based on the Cognitive Schema Theory, the proposed model is able to describe how different individuals, who experience the same interpersonal experience, may make different interpretations based on the modes of their cognitive schemas. Whilst this model has used only one cognitive schema, the rest of the cognitive schemas can also be studied in a similar manner. As described previously, modes of any cognitive schema are in a dynamic state influenced by environmental experiences. Therefore, this initial model, in which schema modes are considered static, can be expanded by introducing a feedback loop representing cumulative interpersonal experiences over a defined period of time, to change cognitive schema modes dynamically. Importantly, using longitudinal observations on how an individual interprets his/her interpersonal experiences, this model can be used to fit data from such observations, and then derive estimates for cognitive schema states.

8. Conclusion

Using Cognitive Schema Theory, this paper has introduced an initial model for studying how different individuals, who experience the same interpersonal experience may interpret it in different ways. This model can be expanded by incorporating other cognitive schemas and also the behavioural responses that are associated with different cognitive schema modes. Importantly, such an expanded model may provide a useful environment for simulating different clinical scenarios that are difficult to study via real life experiments. It is expected that this model will serve as a useful tool for a better understanding of the aetiology associated with psychiatric disorders and, consequently, promote the development of more effective treatments and preventive strategies.

9. References

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