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# Comparison of Anxiety Treatments in Dissociative Identity Disorder Using Quantitative Methods

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## Abstract

Dissociative Identity Disorder (DID) is a severe form of post-traumatic stress disorder (PTSD) caused by chronic and severe traumatisation (especially during childhood). Although recent studies have shed light on describing DID and distinguishing it from other PTSDs in the last few decades, but the diagnosis and treatment of DID remains to be a challenge. Therefore, describing and analyzing DID has become a prominent topic for researchers. The most known treatment for DID is personality intergration, but there have not been enough studies to compare DID treatments quantitatively. Thanks to the recent studies, it is known that DID patients often suffer from major depression and anxiety mood disorders. Thus, it is important how to manage the mood states in DID patients. In this study, Petri nets as a mathematical model was used to describe and compare anxiety treatments for DID. The average of 121000 stochastic simulation runs on the proposed quantitative model revealed that Cognitive Behavioral Therapy (CBT) alone can not be a suitable anxiety treatment, but the combination of Dialectical Behavioral Therapy and Drug Therapy can significantly treat anxiety in DID patients. The results show that such quantitative models can be useful not only for treatment comparison, but also identifying more effective treatments.

**Keywords:** dissociative identity disorder, anxiety, mood disorder, Petri nets

## 1. Introduction

One of the severe types of post-traumatic stress disorder (PTSD) is called Dissociative Identity Disorder (DID). DID was first known as Multiple Personality Disorder using controversial psychiatric diagnosis, but the aetiology of DID is under debate for decades (Simone Reinders et al., 2012). The trauma model states that DID is caused by chronic and significant traumatisation during childhood (Reinders & Veltman, 2021). DID patients often suffer from mood disorders such a major depression and anxiety. It was shown that when the level of anxiety increases in a DID patient, cognitive inhibitory functioning reduces (Dorahy et al., 2005). Therefore, it is so important to manage anxiety in DID patients.

The known treatments for DID and managing anxiety in DID patients are: 1) Dialectical Behavior Therapy (DBT) (Foote & Van Orten, 2016); 2) Cognitive Behavioral Therapy (CBT), which can be used in various personality disorders (Matusiewicz et al., 2010); 3) Antianxiety Drug Therapy such as Alprazolam (Xanax), Clonazepam (Klonopin), Chlordiazepoxide (Liberium), Diazepam (Valium), and Lorazepam (Ativan). Note that, to this day, there is no medicine to treat DID directly, but these drug-based treatments are used to manage anxiety level in DID patients. Unfortunately, same as most drug-based therapies, Antianxiety therapies are not without side effects. The most common side effects for Antianxiety Drug Therapy are depression, mood swings,

low arousal mood, and thoughts of suicide. Thus, choosing the most efficient treatment with manageable side effects is very important; 4) Other treatments such as hypnosis. In this study, the known treatments were compared quantitatively, to suggest effective anxiety treatments for DID patients.

Anxiety is a common type of mood disorders. Therefore, to analyze the relation between DID and anxiety, it is important to quantitatively describe mood regulation. Fortunately, quantitative psychologists have already used such models to identify new treatments for different types of mood disorders (Ortiz et al., 2015; Mehraei, 2018). One of the most frequent used approaches to quantitatively describe mood is the dimensional structural one, where two almost independent dimensions are considered to be Pleasure/Valence (P) and Arousal (A) (Mehrabian & Russell, 1974). To explain mood in more details, some quantitative psychologists may divide each of Pleasure and Arousal dimensions to sub-dimensions. As examples, Watson and Tellegen have partitioned Pleasure dimension to Positive Activation and Negative Activation (Watson & Tellegen, 1985), and Thayer described Arousal dimension using four sub-dimensions (Thayer, 1990). Mehrabian even described mood not only by P and A dimensions, but also added a third almost independent dimension named Dominance (Mehrabian, 1996), which were used for mood prediction using time series (Mehraei and Akcay, 2017). However, Pleasure and Arousal dimensions are the most frequently used dimensional structural mood model and they were even used to discover new treatments for mood disorders (Mehraei, 2018).

In this study, Stochastic Hybrid Petri Nets (SPNs) as a quantitative mathematical model was used to describe the relation between Pleasure and Arousal mood dimensions with DID. In addition, the proposed SPNs model was used to compare known anxiety treatments for DID patients quantitatively, and was used to identify the potential most effective combination of treatments.

## **2. Materials and Methods**

### **2.1. Stochastic Petri Nets (SPNs)**

It is challenging task to describe complex biological and psychological systems quantitatively. In the last few decades, Stochastic Petri nets (SPNs) as mathematical models were used to describe and analyze the structure and behavior of such systems. For instance, SPNs were used to model plasmid ColE1 replication (Goss & Peccoud, 1998), the gene regulatory pathway of *Physarum polycephalum* (Marwan et al, 2005), enteric bacteria phosphate regulation (Castaldi, 2012), mood states (Mehraei, 2017), p16-mediated pathway (Bashirov & Akcay, 2018), and mood related neurotransmitters (Mehraei, 2022).

Classical Petri nets contain five main components named places, transitions, arcs, functions, and initial markings. To describe logical behavior of dynamic systems, classical Petri nets can be used as a useful tool, but to efficiently model quantitative behavior of dynamic systems, a more powerful tool should be used. Especially, if the system is a complex one. It is vivid that the occurrence of biochemical reactions in any biological systems conditionally (depending on presence or absence of the other conditions in the system) follows stochastic process. Classical Petri nets can cover the stochasticity of the occurrence of biochemical reactions. Thus, extending Classical Petri nets to SPNs is essential to overcome this. This can be possible by considering

stochastic transitions in SPNs instead of deterministic ones. The deterministic models can be useful as approximations, but a SPN model which can calculate the average of several stochastic simulation runs can be more efficient to describe complex biological and psychological systems. Fortunately, computer science made it possible to calculate and find the simulations results in a short amount of time which couldn't be feasible by human beings manually.

## **2.2. The Proposed Quantitative Model**

The proposed Stochastic Hybrid Petri nets (SHPNs) model was created using Snoopy software tool (Heiner et al, 2012). Hybrid property was added because the places in the proposed SPN model can be either discrete or continuous. The proposed SHPNs model contains 11 places (6 continuous and 5 discrete ones). The discrete places were used to represent: 1) Three distinct personality alters in a hypothetical DID patient; 2) Personality Switch between alters; 3) Drug Therapy. The continuous places were considered to represent: 1) Level of Anxiety; 2) Level of personality effect on mood (three places were considered because the hypothetical DID patient have 3 alters); 3) Level of Pleasure mood dimension; 4) Level of Arousal mood dimension. The model contains 31 transitions: 1) Six stochastic transition to represent interactions between 3 distinct alters; 2) Five stochastic transitions to show the effect of each Personality on mood dimensions; 3) Activation of Anxiety, which depends on intensity of personality switches (a stochastic one); 4) Two stochastic transitions to represent the effect of Anxiety on Pleasure and Arousal mood dimensions; 5) A stochastic transition to show the effect of drug therapy on mood dimensions; 6) Twelve stochastic activation and natural degradation for six continuous places. The proposed model contains 70 arcs to connect places with transitions (69 direct arcs and 1 inhibitory arc, which was used to show the presence or absence of a drug therapy). The Snapshot of the proposed SHPN model without considering the transitions related to activation and natural degradation is illustrated in Figure 1.

Five treatments were considered to be compared using this SHPNs model: 1) Treatment I: Integration using DBT. To simulate this, lower rate for personality switches was considered; 2) Treatment II: CBT. It was simulated by manipulation the weight of personality effects on mood dimensions; Treatment III: Anti-Anxiety drug treatment. As it is clear on Figure 1, its presence can influence mood dimensions directly; Treatment IV: Combination of Treatments I and III; Treatment V: Combination of Treatments II and III.

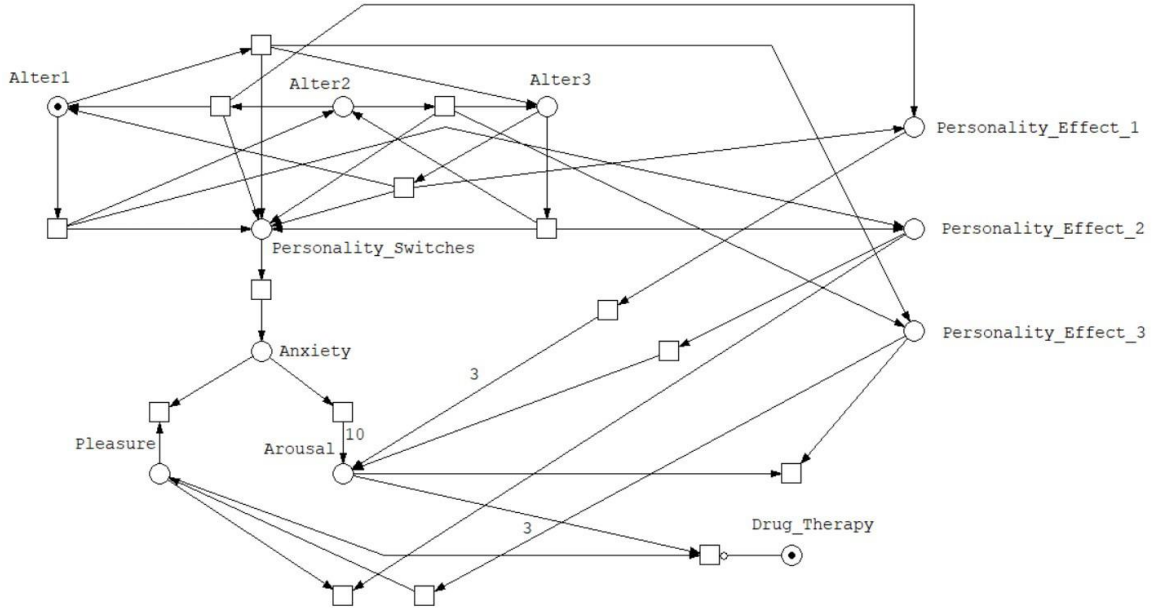


Figure 1: Snapshot of the proposed SHPN model

### 3. Results and Discussions

To obtain simulations results, Snoopy software tool was used (Heiner et al, 2012). One personality alter was selected randomly to have the initial marking of 1. The initial marking of Drug Therapy place was considered as 1, too. The number of steps in a single simulation run was considered as 50 (also known as 50 Petri time or 50 pt). The steady level was obtained by 121000 stochastic simulation runs. Thus, the simulation results were calculated by finding the average of 121000 stochastic simulation runs at 50 pt with p-value less than 0.001 (more than 99.9% confidence level).

The comparison of simulation results of the treatments using SHPN model on Snoopy with the control group (DID patients with anxiety) revealed that: 1) Treatment I increased Pleasure mood dimension and decreased Arousal mood dimension by 1.5-fold and 1.4-fold, respectively. Therefore, DBT is a suitable anxiety treatment in DID patient; 2) Treatment II increased Pleasure mood dimension and decreased Arousal mood dimension by 1.5-fold and 1.1-fold, respectively. Unfortunately, the results show that the decrease of Arousal level is not significant enough. Although CBT is an effective treatment for DID patients, it does not help the level of their anxiety; 3) Treatment III decreased both Pleasure and Arousal mood dimension by 6-fold and 3.2-fold, respectively. Although the Arousal level was decreased significantly using drug therapy, it did the same for Pleasure level. Therefore, the side effect of this treatment is having depression, which is in line with the claimed side effects of such Anti-Anxiety drugs; 4) Treatment IV has decreased both Pleasure and Arousal mood dimensions by 2.3-fold and 10.2-fold, respectively. These results show a significant decrease in Arousal level, which is very effective to avoid anxiety, but it significantly decreases the Pleasure level, too. The advantage of this treatment comparing to Treatment III is the higher Pleasure level. These results suggest that DBT treatment is essential when a patient goes through drug-therapy to avoid depression and other medicine side effects; 5) Treatment V decreased both Pleasure and Arousal mood dimensions by 2.3-fold 4-fold,

respectively. The results shows that CBT can be as effective as DBT to deal with medicine side effects, but it is not as effective as DBT to decrease the Arousal level. The simulation results were summarized in Table 1.

Table 1: Simulation results in the proposed SHPN model based on number of fold changes comparing to the Control group. The control group is related to DID patients with anxiety. Significant results with less than 0.001 p-value were shown using \* character.

	<b>P</b>	<b>A</b>
Control	1	1
Treatment I	1.5*	-1.4*
Treatment II	1.5*	-1.1
Treatment III	-6*	-3.2*
Treatment IV	-2.3*	-10.2*
Treatment V	-2.3*	-4*

#### 4. Conclusion

In this study, SHPN mathematical modeling was used to compare the known anxiety treatments and the combination of these treatments in DID patients. The average of 121000 stochastic simulation runs at 50 Petri time on the SHPN model (performed on Snoopy platform (Heiner et al, 2012)) with less than 0.001 p-value (very high confidence level) revealed that: 1) Integration using DBT alone is not only beneficial for DID patients, but it can also decrease their anxiety level; 2) Although CBT is known to be an effective treatment for DID, it does not decrease the anxiety level in DID patients significantly. The combination of CBT and drug therapy showed a promising result though. However, the side effect of the drug can lead to depressive mood for such patients; 3) Drug therapy alone can decrease Arousal mood level significantly, but it does the same to Pleasure mood level, which can lead to major depression mood disorder; Therefore, such a treatment can't be recommended unless the anxiety in DID patients is at its highest level; 4) The combination DBT and antianxiety drug therapy is the most effective anxiety treatment in DID patients because it decreases the anxiety level significantly and the side effect is not as dangerous as using drug therapy alone.

This study shows how beneficial such mathematical models can be to compare various treatments in both psycho and drug therapies. Such predictions in high level of confidence can save money and time by avoiding all possible physical tests on patients. However, at this stage, such methods remain as theories and it is out of scope of this study to validate the results in practice. In the future studies: 1) A group of clinical psychologists, psychotherapists, cognitive scientists can validate these simulation results by practicing them on human subjects; 2) Such SHPN models can be used to compare anxiety treatments and even identify new treatments in other disorders.

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