An Agent Model for a Human's Social Support Network Tie Preference during Depression

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Abstract

Seeking support from their environment is important for people suffering from a depression. People usually have different social networks to which they are attached with different ties. In this paper, a computational model is presented that describes the selection of network members for seeking support based on the strength of the tie to people in the network and personal characteristics. The model has been implemented in a simulation environment. Simulations of different scenarios show that specific personality traits and environmental settings indeed lead to a pattern of social disengagement or a preference for strong or weak tie support. A mathematical analysis proofs that such equilibria are indeed a consequence of the model.

Keywords: depression, social support networks preference, simulation model

1. INTRODUCTION

Depression is one of the most prevalent psychological disorders, reflected by a strong mood involving sadness, despair, or hopelessness lasts for weeks, months, or even longer [3. More often, it causes pain and suffering not only to those who have a disorder, but also to those who care about them. People who are experiencing the development of depression seek help from people in their environment. There are patterns in help-seeking behaviour among depressed people, especially with history of onset. It is often possible to relate such conditions with individual's ability to choose which people to rely on [1] [14].

The groups of people around a person that can provide help are called "social support networks". Generally, the social support network is referred to a social network's provision towards psychological or material resources deliberated to promote an individual's ability to cope with stressors [5][6]. This kind of a social construct provides a stress-buffering mechanism, which aims to eliminate or to reduce harmful effects of stressful experiences by providing less-negative interpretations of unpleasant events, and suitable coping styles [5][16]. Most of the social support interaction is a social interpersonal process that mainly focused on the reciprocal exchange of information. The outcome of the interaction is broadly categorized as to improved individual health. It is highly dependent on the specific circumstances, but it is primarily related to previous social experiences and types of relationships within members in the social support networks (support provider). An important mechanism behind the support-seeking behaviour is the selection of social support networks based on the strength of the tie with the people in the network. Social support ties selection answers the question of individual's preferences towards certain individuals within the social support networks [16]. This paper presents a model that describes this selection process. It provides a human agent model that simulates social support ties preferences, which specifically relates to several individual attributes, with respect to a persons reaction to stressful events. There are many situations where can be useful when implemented in a software agent. For example, it could provide the basis for a personal agent that suggests social support network members to contact according to an individual's preferences during the formation of stress or recurrence in depression.

The present paper is organized as follows; Section 2 describes theoretical concepts of social support tie preference. From this perspective, a formal model is designed and formulated (Section 3). Later, in Section 4, several simulation traces are presented to illustrate how this model satisfies the expected outcomes in social support ties preference. In Section 5, a detailed mathematical analysis is performed, in order to identify equilibria in the model. Finally, Section 6 concludes the paper.

2. SOCIAL SUPPORT NETWORK TIES PREFERENCE

Over the past several decades, researchers from a variety of domains have focused on the relationship between social support processes and mental health. For example, researchers in a communication domain have contributed to the development of theories and understanding of social support provisions, by providing foundations on inter-relation on supportive messages, positive appraisals, and coping behaviors such as Weak Tie/Strong Tie Support Network Theory [2][10].

2.1. Weak Tie/Strong Tie Support Theory

The Weak Tie/Strong Tie Support Network Theory explains how individual coordinates the support-seeking process while managing the relational concerns and individual needs [12]. Strong tie is a relationship typically between individuals in a close personal network. Close associates such as family, spouses, and friends are frequently acknowledged as a strong tie support provider. While, a weak tie is typically occurs among individuals who communicate on relatively frequent basis, but do not consider them as close acquaintances [1][6]. The individual's need for support influences the selection of support providers from relationship [7][16]. For example, several studies have shown that many individuals with long-term perspectives (*future goal orientation*) having difficulty to attain appropriate informational support from close friends or acquaintances since they feel this group of people has limited skills or knowledge towards individuals' problems [2]. However, if the individuals' intention to seek for the emotional support (*emotional goal orientation*) is higher, then they tend to choose a weak tie support over strong tie [9][11]. Individual characteristics are highly related to personality traits (*neurotic*), individual's risk in stress (vulnerability / *risk of mental illness*), and expected support (*expected amount of support*) from social support members [8][15].

In addition, predilection to seek support appears to be rooted in individual's support orientation (either emotion or future orientation goal), closeness in relationship (*intimate relational history*) and support member expected obligation (*role obligation*) [14][16]. This combination explains the condition where one may oblige to provide support for those who are close, but may feel it a burden if a loved one needs a great support and it can lead to conflict (*relational complication*). Without further motion to overcome this, it will later increase the risk of relational erosion (*social disengagement*) through a series of prolonged dissatisfaction in relationships (*relational dissatisfaction*) [5][10]. As a result, individual tends to avoid from seeking support, which is one of the outcomes in depression [12][14].

Another characteristic that involves in selecting social support ties is interpersonal trust (*trust in support*). When individual is ensured about the predictability of the social support tie (especially in a weak tie network), he or she will develop a secure sense of attachment towards trusting others [6][16]. This trust concept reflects that trusting individuals beyond the strong tie support network is more likely to view a support seeking behaviour as an appropriate course of action regardless of the potential risks in trust [16]. It is one of the main precursors to seek and receive help [5]. Within the support provision, it is also equally important to assume that support providers always to be reliably available and willing to give support during challenging time.

3. MODELING APPROACH

This section discusses the details of the dynamic model. Several works discussed in the previous section heavily motivates the characteristics of the proposed model.

3.1 Formalizing the Human-Agent Model Relationship

In this model, three main components are interacting to each other to simulate support-seeking behaviours. These components are grouped as; inter-personal and individual attributes, support preference generation, relationship erosion rocess, stress component, and support feedbacks. Intially, negative events acts as a stimulus trigger the stress component. This stress condition is amplified by individual attributes such as risk of stress (or risk of mental illness) and neurotic personality and accumulates to develop a long-term stress condition [3]. With the existence of short-term stress, the support preference generation is generated, pertinent to the individual and inter-personal attributes [6]. Similar information also will be channelled to the social erosion component. Social erosion component acts to diminish individual's ability in seeking help [14]. After the social support tie preference is selected, then the support feedbacks are received. To simplify the interaction, this model assumes all support feedbacks received provide a positive effect towards human agent well-being (stress-buffering mechanism) [5]. Finally, the social support feedback also will be used to reduce the relationship erosion effect within individual [2][15]. The details of this model are shown in Fig. 1.

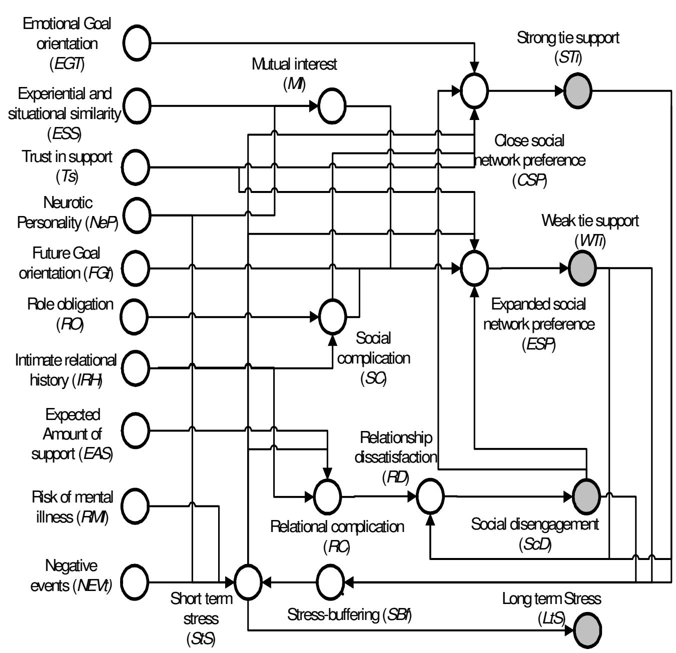

Figure 1. Global Relationships of Variables Involved in the Social Support Ties Preference

To support the design of the model (as shown in Fig. 1), the dynamic model was developed. This model involves a number of instantaneous and temporal relations, which will be discussed in greater detailed below.

3.2 Instantaneous Relations

The instantaneous relations are derived from several formulae, namely; mutual interest (*MI*), social complication (*SC*), relationship complication (*RC*), relationship dissatisfaction (*RD*) , short- term stress (*StS*), stress-buffering (*SBf*), close social network preference (*CSP*), and expended social network preference (*ESP*). These relations were designed as given by the following formulae.

$$MI(t) = \alpha_{mi}.ESS(t).(1\text{-}NeP(t)) \quad (1)$$

Mutual interest is calculated using the combination of experiential situational similarity (*ESS*) and positive personality (contrary to neurotic personality (*NeP*)). Parameter α_{mi} represents the contribution factor pertinent to individual personality.

$$SC(t) = \beta_{sc}.IRH(t).RO(t) \quad (2)$$

The effect of social complication is determined by multiplying the value of intimate relational history (*IRH*) and role obligation (*RO*). This relation explains the aspect of support personal resources expectation. The proportional factor for social complication is determined by β_{sc}.

$$RC(t) = \gamma_{rc}.EAS(t).IRH(t) + (1\text{-}\gamma_{rc}).[RMI(t).StS(t)] \quad (3)$$

Relational complication is measured using the proportional contribution (determined by γ_{rc}) of the expected support (*EAS*) and intimate relational history (*IRH*) with the risk of stress (*RMI*) and short-term stress (*StS*).

$$RD(t) = \eta_{rd}.RC(t).(1\text{-}STi(t)).(1\text{-}WTi(t)) \quad (4)$$

Relational dissatisfaction is determined by η_{rd} times relational complication when no support is given (neither from strong tie (*STi*) nor weak tie (*WTi*)).

$$StS(t)= [\psi_{sts}.NEVt(t) + (1\text{-}\psi_{sts}).RMI(t).NeP(t)].(1\text{-}SBf(t)) \quad (5)$$

The level of short-term stress depends on the relation between the stress buffering (SBf) level and the proportion contribution of negative events (*NEVt*), risk of stress (*RMI*), and neurotic personality (*NeP*). Here, ψ_{sts} represents the proportional contribution factor for this relation.

$$SBf(t) = \varphi_{sbf}.[\eta_{sbf}.STi(t)+ (1\text{-}\eta_{sbf}).WTi(t)].(1\text{-}ScD(t)) \quad (6)$$

Stress buffering is calculated using the presence of support and the level of social disengagement (*ScD*). In this relation, a high social disengagement level (*ScD* → 1) will cause stress buffering becomes less effective.

$$CSP(t) = \gamma_{csp}.[\beta_{csp}.EGt(t) + (1\text{-}\beta_{csp}).Ts(t).(1\text{-}SC(t))].(1\text{-}ScD(t)).StS(t) \quad (7)$$

The level of close social network preference depends to the level of emotional goal orientation (*EGt*), short-term stress, trust in support (*Ts*), social complication and social disengagement. The amount of preference will increase if there is a presence of short-term stress and low social disengagement. Parameter β_{csp} regulates the contribution of preference selection attributes, while γ_{csp} represents the contribution factor in overall relation.

$$ESP(t)= \psi_{esp}.[\eta_{esp}.FGt(t) + (1\text{-}\eta_{esp}).Ts(t).MI(t).(1\text{-}SC(t))].(1\text{-}ScD(t)).StS(t) \quad (8)$$

Close social network preference is calculated using the level of future goal orientation (*FGt*), short-term stress, trust in support, mutual interest, social complication and social disengagement. ψ_{esp} represents the proportion factor and η_{esp} provides a proportional contribution factor in expanded social network preference attributes.

3.3 Temporal Relations

In addition, there are four temporal relationships are involved, namely strong-tie preference (*Sti*), weak-tie preference (WTi), social disengagement (*ScD*), and long-term stress (*LtS*). The rate of change for all temporal relationships are determined by flexibility parameters, $\varphi_{sti,}$, ϕ_{wti}, η_{scd}, and β_{lts} respectively. These parameters determine

$$STi(t+\Delta t)= STi(t) + \varphi_{sti}.(1\text{-}STi(t)). (CSP(t)\text{-}\psi_{sti}.STi(t)).(STi(t)).\Delta t \quad (9)$$

Here, strong-tie preference builds or reduces over time. When *CSP* is higher than the previous strong-tie preference multiplied with the contribution factor, ψ_{sti}, then the strong-tie preference increases. Otherwise, it decreases depending on its previous level and contribution factor. This condition also can be used to explain for the rest of all temporal relations, according to their respective parameters and attributes. It should be noted that the change process is measured in a time interval between *t* and *t+Δt*. In addition, the social disengagement is referring to the concept of not-seeking support or withdrawal from having one.

$$WTi(t+\Delta t)= WTi(t) + \phi_{wti}.(1\text{-}WTi(t)).(ESP(t)\text{-}\eta_{wti}.WTi(t)).(WTi(t)).\Delta t \quad (10)$$

$$ScD(t+\Delta t)=ScD(t)+\eta_{scd}.(1\text{-}ScD(t)).(RD(t)\text{-}\psi_{scd}.ScD(t)).(ScD(t)).\Delta t \quad (11)$$

$$LtS(t+\Delta t)=LtS(t)+\beta_{lts}.(1\text{-}LtS(t).(StS(t)\text{-}\xi_{lts}.LtS(t)).(LtS(t)).\Delta t \quad (12)$$

Using all defined formulas, a simulator has been developed for experimentation purposes; specifically to explore interesting patterns and traces that explains the behaviour of the human agent model. This simulator is developed under a visual programming platform. It allows a graphical user interface for experimental and parameters settings purposes. All simulation results will be generated and stored in spreadsheets for further analysis.

4. SIMULATION RESULTS

A number of simulations have been performed, intended to explore some interesting patterns in human-agent social support-tie preference behaviours. With several variations of the individual and inter-personal attributes, some expected patterns can be found. In this paper, there are three individual conditions will be dealt under two different stressors events (prolonged and fluctuated events). Table 1 outlines the values of these individual profiles.

Table 1. Individuals Profiles

Individuals	Profiles ***(EGt, FGt, ESS, NeP, IRH, EAS, RMI, RO)***
A	*0.8,0.1,0.1,0.5,0.9,0.8,0.5,0.8*
B	*0.1,0.8,0.9,0.5,0.1,0.8,0.5,0.1*
C	*0.4,0.6,0.6,0.1,0.3,0.3,0.3,0.1*

The duration of the simulation is up to 1000 time points, with these simulation parameters settings; Δt=0.3, $\varphi_{sti}= \phi_{wti}=\eta_{scd}$ β_{lts}=0.2, $\psi_{sts}=\eta_{sbf}=\beta_{csp}=\eta_{esp}=0.5$, $\alpha_{mi}=\beta_{sc}=\gamma_{rc}=\eta_{rd}=\varphi_{sb\,f}=\gamma_{csp}=$ ψ_{esp}=0.8. These experimental results will be discussed in detail below.

Case # 1: Exposure in Prolonged Stressor Events

During this simulation, all types of individuals have been exposed to an extreme case of stressor events. This kind of pattern is comparable to the prolonged stressors throughout a lifetime.

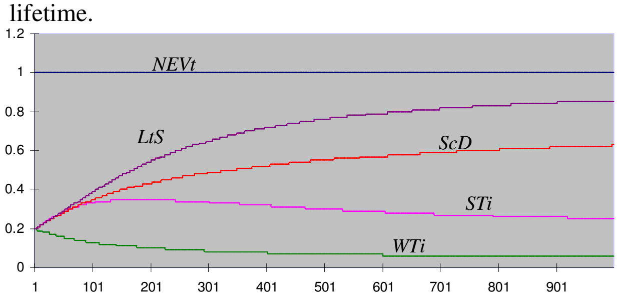

Figure 2. Support Preferences for Individual A

For the first individual (individual A) (according to Fig. 2), tends to disengage from seeking support after long period of exposure in negative events. This characteristic is in line with the findings reported in [5]. It explains the conflict of overburden from overwhelming expected supports, and new role obligations towards individual with such characteristic and negative events. This individual is prone to the risk in developing potential onset. Similar event was also simulated for individual B (with tendency in a weak tie support, highly neurotic personality, too high-expectation in support, and high risk in mental illness). This individual has a preference over a weak tie support over strong tie. As is shown in Fig. 3, this individual lesser long-term stress effect, and capable to main its support ties. However, without a proper action, this individual tends to gradually developing a potential risk of long-term stress that will lead to the recurrence in depression.

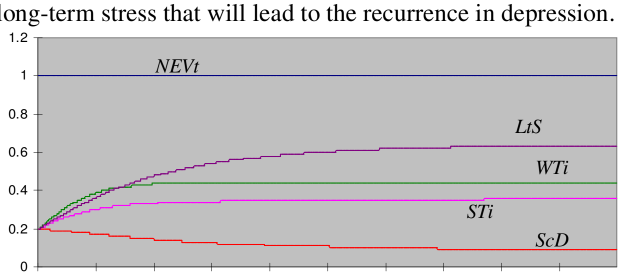

Figure 3. Support Preferences for Individual B

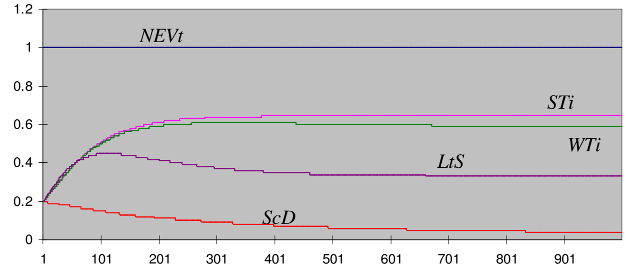

Figure 4. Support Preferences for Individual C

As can be seen from Fig 4, individual C, with normal personality attributes (less neurotic, moderate expectation, balance support seeking attributes) indicates a gradual reduction in a long-term stress. This individual tends to be stable in seeking and receiving support from both social network ties.

Case # 2: Exposure Fluctuated Stressor Events

In this experiment, two kinds of stressors were introduced. The first stressor is one with a very high constant, and is followed by the second one, with a very low constant stressor event.

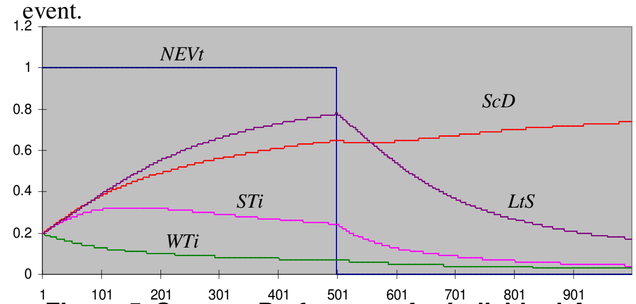

Figure 5. Support Preferences for Individual A

From Fig. 5 it can be seen that individual A gets to develop a social withdrawal pattern, even without the presence of negative events. Moreover, such individual attributes affect that individual's perception towards support and social interaction.

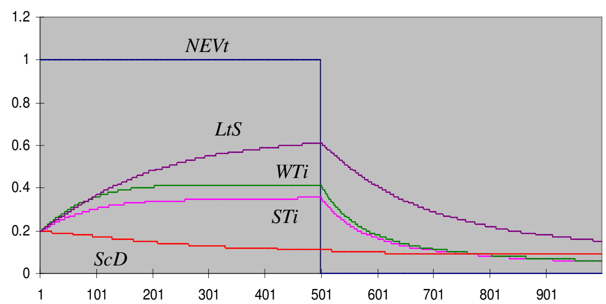

Figure 6. Support Preferences for Individual B

Meanwhile, as in shown in Fig. 6, individual B has much lower long term stress effect, and develop a positive feedback towards a better wellbeing. Note that both support ties preference levels are suddenly dropped. The reason of this condition is support-seeking behaviour only occur when individual is facing negative events. In this connection, it is worth noting this result is based from the concept that social support network tie is coherent with the stress buffering effect, rather a typical social interaction during a normal daily life [2][6].

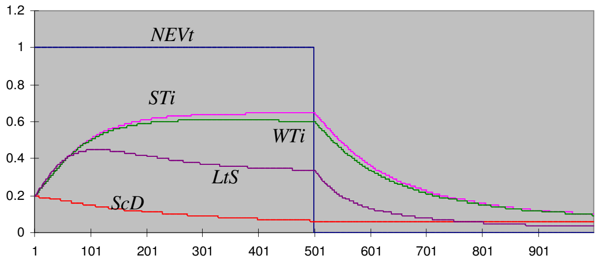

Figure 7. Support Preferences for Individual C

As for individual C (Fig. 7), it shows a better buffering effect compared to both individuals. In addition, it can be seen both support tie preferences are decreasing rapidly after the absent of negative events. This precursor has already been mentioned during previous discussion.

5. FORMAL ANALYSIS

One of the aspects that can be addressed by a mathematical analysis is which types of stable situations are possible. To this end equations for equilibria can be determined from the model equations. This can be done to assume constant values for all variables (also the ones that are used as inputs). Then in all of the equations the reference to time *t* can be left out, and in addition the differential equations can be simplified by cancelling, for example $STi(t+\Delta t)$ against $STi(t)$. This leads to the following equations:

$$MI = \alpha_{mi}.ESS.(1\text{-}NeP) \quad (13)$$
$$SC = \beta_{sc}.IRH.RO \quad (14)$$
$$RC = \gamma_{rc}.EAS.IRH + (1\text{-}\gamma_{rc}).[RMI.StS] \quad (15)$$
$$RD = \eta_{rd}.RC.(1\text{-}STi).(1\text{-}WTi) \quad (16)$$
$$StS = [\psi_{sts}.NEVt + (1\text{-}\psi_{sts}).RMI.NeP].(1\text{-}SBf) \quad (17)$$
$$SBf = \varphi_{sbf}.[\eta_{sbf}.STi + (1\text{-}\eta_{sbf}).WTi].(1\text{-}ScD) \quad (18)$$
$$CSP = \gamma_{csp}.[\beta_{csp}.EGt + (1\text{-}\beta_{csp}).Ts.(1\text{-}SC)].(1\text{-}ScD).StS \quad (19)$$
$$ESP = \psi_{esp}.[\eta_{esp}.FGt + (1\text{-}\eta_{esp}).Ts.MI.(1\text{-}SC)].(1\text{-}ScD).StS \quad (20)$$
$$\varphi_{sti}.(1\text{-}STi).(CSP - \psi_{sti}.STi).(STi) = 0 \quad (21)$$
$$\phi_{wti}.(1\text{-}WTi).(ESP - \eta_{wti}.WTi).(WTi) = 0 \quad (22)$$
$$\eta_{scd}.(1\text{-}ScD).(RD - \psi_{scd}.ScD).(ScD) = 0 \quad (23)$$
$$\beta_{lts}.(1\text{-}LtS).(StS\text{-}\xi_{lts}.LtS).(LtS) = 0 \quad (24)$$

Assuming the parameters φ_{sti} ϕ_{wti}, η_{scd}, β_{lts} nonzero, from the equations (21) to (24), the following cases can be distinguished:

$STi = 1$ or $CSP = \psi_{sti}.Sti$ or $STi = 0$
$WTi = 1$ or $ESP = \eta_{wti}.WTi$ or $WTi = 0$
$ScD = 1$ or $RD = \psi_{scd}.ScD$ or $ScD = 0$
$LtS = 1$ or $StS = \xi_{lts}.LtS$ or $LtS = 0$

Theoretically spoken this amounts to $3^4 = 81$ possible equilibria. Note that the last equation (24) is isolated from the others, and therefore can be handled separately. But for the other three still 27 possibilities remain. Also given the other equations (13) to (20) with the 10 input variables, this makes it hard to come up with a complete classification of equilibria. However for some typical cases the analysis can be pursued further.

Case $STi = 1$ $WTi = 1$ $ScD = 0$:
For this case, by equation (18) it follows that
$SBf = 1$
and hence by equation (17)
$StS = 0$
Moreover, from (16) it follows that
$RD = 0$
From this the other variables can be determined; from (13) to (15) it follows:
$MI = \alpha_{mi}.ESS.(1\text{-}NeP)$, $SC = \beta_{sc}.IRH.RO$,
$RC = \gamma_{rc}.EAS.IRH$
Finally, from (19) and (20) it follows
$CSP = 0$, $ESP = 0$

Case $ScD = 1$:
For this case, by equation (18), (19) and (20) it follows that
$SBf = 0$, $CSP = 0$, $ESP = 0$,
Moreover, by equation (17) it follows
$StS = \psi_{sts}.NEVt + (1\text{-}\psi_{sts}).RMI.NeP)$
and from (16) it follows that
$RD = \eta_{rd}.RC.(1\text{-}STi).(1\text{-}WTi)$
which is *0* in case one of *STi* or *WTi* is *1*. Finally the other variables can be determined; from (13) to (15) it follows:
$MI = \alpha_{mi}.ESS.(1\text{-}NeP)$, $SC = \beta_{sc}.IRH.RO$
$RC = \gamma_{rc}.EAS.IRH + (1\text{-}\gamma_{rc}).[RMI.StS]$
$= \gamma_{rc}.EAS.IRH + (1\text{-}\gamma_{rc}).[RMI.\ \psi_{sts}.NEVt + (1\text{-}\psi_{sts}).RMI.NeP)]$

Case $StS = 0$:
From equation (17) it follows that this is equivalent to:
$[\psi_{sts}.NEVt + (1\text{-}\psi_{sts}).RMI.NeP].(1\text{-}SBf) = 0$
This can (only) occur in the following subcases:
$[\psi_{sts}.NEVt + (1\text{-}\psi_{sts}).RMI.NeP] = 0$ or $SBf = 1$
Assuming ψ_{sts} nonzero and not *1*, this is equivalent to:
$NEVt = 0$ and $RMI = 0$ or $NEVt = 0$ and $NeP = 0$
or $SBf = 1$
By equation (18) the latter case $SBf = 1$ is equivalent to
$\varphi_{sbf}.[\eta_{sbf}.STi + (1\text{-}\eta_{sbf}).WTi].(1\text{-}ScD) = 1$
Assuming η_{sbf} nonzero and not 1, this is equivalent to
$\varphi_{sbf} = 1$, $STi = 1$, $WTi = 1$, $ScD = 0$
So for this subcase, the case $STi = 1$ $WTi = 1$ $ScD = 0$ applies. Therefore from the analysis above addressing the latter case it follows
$RD = 0$, $MI = \alpha_{mi}.ESS.(1\text{-}NeP)$
$SC = \beta_{sc}.IRH.RO$, $RC = \gamma_{rc}.EAS.IRH$
$CSP = 0$, $ESP = 0$

Case *StS = 1*

For this case, from equation (17) it follows that the case is equivalent to:

$[\psi_{sts}.NEVt + (1-\psi_{sts}).RMI.NeP].(1-SBf) = 1$

Assuming ψ_{sts} nonzero and not *1,* this is equivalent to:

$NEVt = 1, RMI = 1, NeP = 1, SBf = 0$

By equation (18) $SBf = 0$ is equivalent to

$\varphi_{sbf}.[\eta_{sbf}.STi + (1-\eta_{sbf}).WTi].(1-ScD) = 0$

Assuming φ_{sbf} and η_{sbf} nonzero and η_{sbf} not *1*, this is equivalent to:

$STi = 0$ and $WTi = 0$, or $ScD = 1$

The latter sub case was already addressed above. Continuing with the former subcase $STi = 0$ and $WTi = 0$ for this subcase from equation (16) it follows that

$RD = \eta_{rd}.RC$

6. DISCUSSION

In this paper a computational model is presented that describes the selection of support networks for patients suffering from a depression. Based on the Weak Tie/Strong Tie Support Network Theory, the personality characteristics of a person are related to the preference for a specific support network and the overall willingness of seeking support. The effect of the support on the stress buffer and indirectly on the mood of the patient is also described. Together, these elements provide a dynamic model that can be used to simulate the development of a depression in a person and the role and support from the social environment. The model has been implemented in different scenarios that represent specific personality traits and environmental settings indeed lead to a pattern of social disengagement or a preference for strong or weak tie support. A mathematical analysis proofs that such equilibria are indeed a consequence of the model.

This model can be used as the basis for a personal software agent that supports a person suffering from depression [3] [4]. Such a system could monitor the mood of the patient and suggest, based on knowledge about the personality traits of the patient and a simulation of the benefit of the support from people form a specific network, a person to contact to seek help from. In addition, the model could be used by a therapist for analyzing the role of specific personality traits in the development of the depression and the use of the social network of the patient. This analysis could possibly be used as basis for interventions.

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