# Investigation of Copycat Suicides using Agent-Based Modeling

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## Abstract

Suicide is one of the leading causes of death, and the rate of suicide-related death is increasing worldwide. Suicide is associated with significant social, economic and health-system cost. The occurrence of suicide sometimes leads to a "copycat" effect, which is historically prevalent in adolescents or younger adults. Preventive intervention strategies during the transition of suicide progression may help to stop an outbreak of suicide contagion. In this study, we examine the effect of an intervention (e.g., psychotherapy or medication) on Agents who are in different states of suicide progression (i.e., ideation, planning, attempt or survivors). An agent-based model is used to examine the dynamics of suicide progression in a distance-based network population. Each agent may move on to suicidal ideation, concrete planning, attempted or completed suicide with or without the influence of any index suicide. If the index suicide happens in a community, the nearest agents within some particular distance come to know about this event (risking triggering of a point suicide cluster). If a celebrity attempts suicide, all the agents in the population happen to know about it from mass media (risking a mass suicide cluster). Information relating to all influential and non-influential suicide attempts is recorded: whether these attempts were lethal and whether the person committed suicide was a celebrity. Intervention is provided to agents, who are at high risk

of suicide. Community-based postvention is also provided following an index suicide. After 15 simulation runs (with random seed), this study reveals that adopting such intervention strategy significantly decreases the rate of suicide progression. This is a baseline study for the investigation of suicide contagion in an agent-based population.

# 1 Background

According to the World Health Organization (WHO), about 800,000 suicides occur worldwide yearly, and there are countless numbers of people who attempt suicide [1]. About 1.4% of all deaths are relating to suicide [1]. Suicide is one of the leading causes of deaths in the United States [2] and is associated with significant social, economic and health system cost [3]. Suicide attempts sometimes result in hospitalization or permanent disability, requiring long-term care and loss of income [3]. The total cost associated with each completed suicide and each attempted suicide were estimated to be $397,000 (U.S.) and $33,000 (U.S.), respectively [3]. Suicide can be contagious [4], and sometimes can result in a "copycat" state [5]. Media has a significant effect on the spread of copycat suicide [6], which is quite common among adolescents and younger adults. The rate of copycat suicide among younger adults and adolescents is increasing over time [7]. In the literature, two types of clusters have been recognized regarding suicide: mass clusters (localized in time) and point clusters (confined in both space and time) [8, 9]. A mass cluster is usually related to media publicized suicides or celebrity suicides, whereas a point cluster is related to geographically localized suicides [9]. For example, visits to Emergency Departments (ED) due to self-harm or suicide attempts increases following the announcement of celebrity suicides [10]. Literature [11] suggests that about 23.4% of total suicide attempts follow a celebrity suicide. Copycat suicide is also associated with age, sex, and means of suicide [12, 13, 11]. For example, suicide suddenly increased among young females using charcoal burning following a media report of celebrity suicide in Taiwan [12]. The same pattern was also observed in the study conducted by Ji et al. (2014) where the authors found that suicide increase was more prominent in the group of people with the same characteristics (age, sex, the method used to commit suicide) as of the celebrity [13]. In another study, Cheng et al. (2007) found that males had a higher risk of imitating suicide following news of a celebrity suicide on media [11].

Given the high rate of suicide in the U.S., Centers for Disease Control and Prevention [14] stated that program directors and health authorities should focus on suicide

prevention activities to reduce the increasing rate of suicide.

## 1.1 Related Work

As mentioned above, suicide is related to the social, economic and health system cost; therefore, to deliver early-stage person-centered or community-based suicide prevention strategies and counseling support, the decision-makers need to know when the circumstances surrounding a suicide are transitioning to an epidemic ("copycat") state. To date, several studies [15, 16, 17] have been conducted to provide community-level intervention to decrease the burden of suicide. For example, Wasserman et al. (2015) found that the effects of school-based suicide prevention program significantly decreased the incidence of suicidal ideation and suicide attempts in adolescents studying in ten European Union countries [15]. Capp et al. (2001) developed culturally appropriate intervention following consultation with an Aboriginal community on the south coast of New South Wales [16]. Such intervention increased the level of confidence to identify people who are at high risk of suicide, intention to provide help to those people, and overall knowledge about suicide [16]. Motohashi et al. (2007) offered locality-based suicide prevention intervention in six rural towns in Japan [17]. The authors found that there was about a 51% reduction in suicide rates per 100,000 population [17]. A systematic review was conducted by Fountoulakis et al. (2011) to review community-based intervention for suicide prevention in the literature [18]. The authors mentioned that the reporting of the effectiveness of community-based suicide prevention programs to reduce suicide rate are limited, although such preventive programs are popular [18]. Motohashi et al. (2007) also found that most intervention programs did not use repeated intervention or long-term intervention or networking within a community [17]. Instead, studies were more focused on general public education about suicide prevention and training of gatekeepers.

There has been a significant decline in the rate of suicide in the U.S., Canada and European countries in the past two decades [19]. Such reduction suggests that the existing intervention strategies are somewhat efficient; there is still a chance to reduce

the suicidal rates. One limitation of the locality or community-based intervention (i.e., psycho-educational) is that they are unable to reach the targeted group, who are at risk of suicide or have significant mental disorders [17]. Therefore, Fountoulakis et al. (2011) stressed the need for more research which will recognize the crucial elements of an effective localized-level intervention for the prevention of suicides.

## 1.2   Objectives of the Study

Hiegel and Hipple (1990) mentioned that some people are more likely to commit suicides if they are closely affected by an index suicide [20], especially for suicides taking place at school or small community [21]. Given the limitation in the literature, we are focused on investigating means of reducing the contagion of suicide by providing preventive intervention for a targeted population who are at high risk of progressing through the suicidal states (i.e., ideation, concrete planning, attempt and commit). Celotta (1995) applied a postvention approach following some index suicides in a school-setting in Maryland, USA [21]. Keeping this in mind, in our study, we will examine such effect of a postvention strategy in the population following a suicide attempt.

There are two broad objectives. We want to examine the combined effect of preventive intervention on

1  individual agents, who are at different states of suicide progression (i.e., suicidal ideation, concrete planning, suicide attempt). Individuals receive counseling or medication support from health-care providers.

2  closest community (e.g., friends, family or classmates), where a person within that community has attempted suicide few days ago. Such intervention may help to identify the population at risk of suicide better and preventing them from progressing through the suicide contagion. In the end, this intervention should reduce the rate of copycat suicide in a population.

# 2    Model Specification

We used AnyLogic 8.1 simulation software to create an agent-based network model that provides the daily ground truth scenario of both copycat and non-copycat suicide progression. In this model, an agent is considered to be in a distance-based network, where each agent is connected to 50 other agents. Following the statechart in Figure 2.1, each agent starts in a state with no suicidal ideation but can move to either having thought of suicide, concrete planning, or an attempt. Some attempters may survive and some may not.
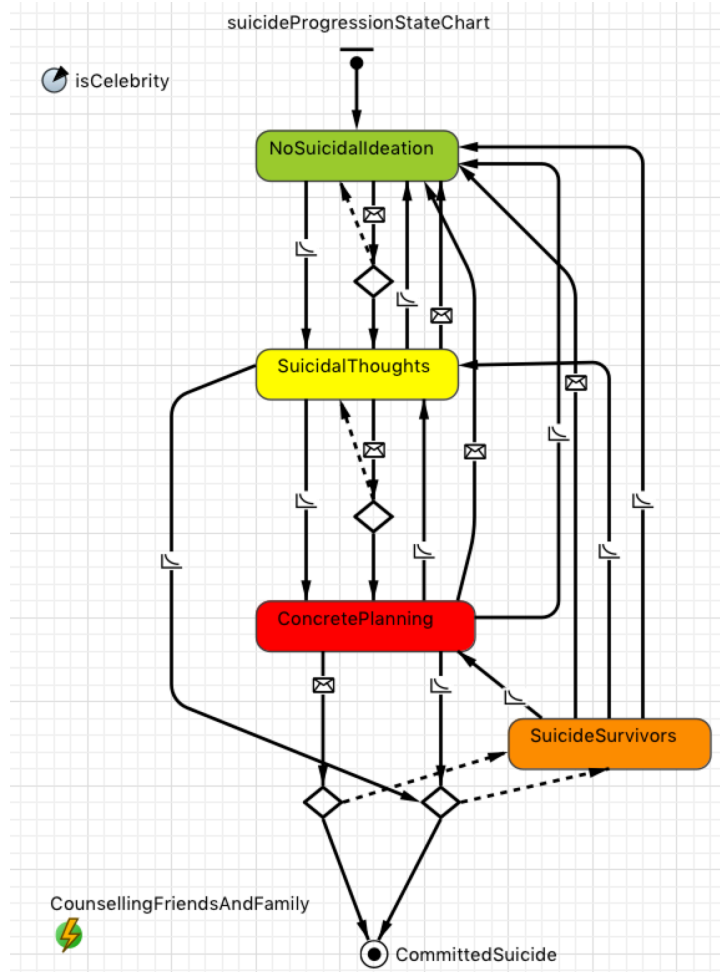


Figure 2.1: Suicide progression within individual agent (person)

There are two types of transitions represented in the model: (1) rate transitions,

where each agent can progress through the statechart over time, and, (2) message-based transitions, where agents in the network may come to know about a suicide attempt and may progress through the statechart according to the agent's current state. These message-based transitions help us to understand the progression of suicide attempts when contagion is in effect.

We consider heterogeneity in the form of celebrity status (celebrity or non-celebrity). When a non-celebrity person attempts suicide, only the people in that particular agent's immediate connections come to know about this event. When a celebrity attempts a suicide, all agents in the population come to know about it. Through this heterogeneity, we can examine copycat suicide attempts following the broadcast of celebrity suicide attempt in the mass media.

Since males and females have different rate of progression through the suicide statechart, we have also considered this heterogeneity into our model. The probability that a male commits suicide is 0.483 [2]. Therefore, while assigning the transition rates for suicide progression for each agent, we have incorporated this probability to set up the sex-specific hazard rate.
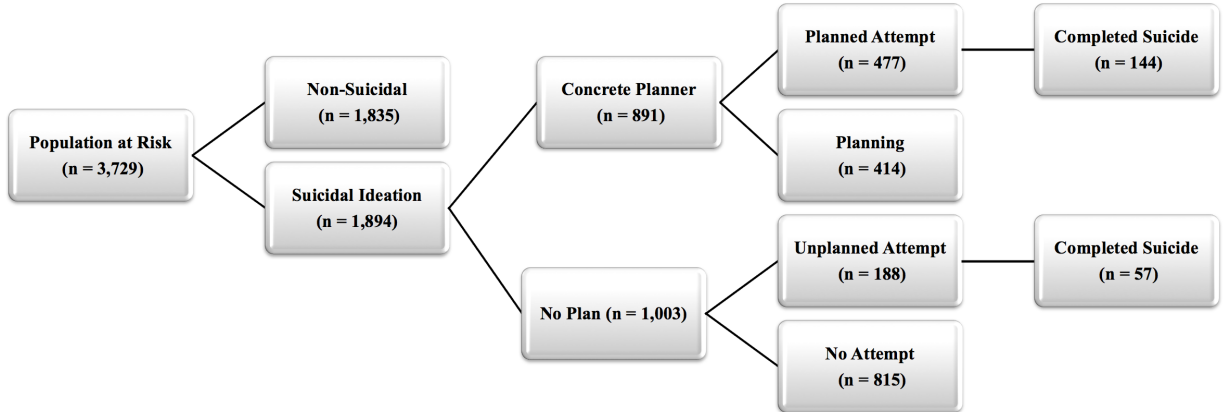


Figure 2.2: Pathways to suicide progression in at-risk population (retrieved from [22, 23]) in a year

From the study by Conner et al. (2007) [23] and Jans et al. (2012) [22] the pathways to suicide progression can be generated (see Figure 2.2) to incorporate the rates of

agents progressing through the state-chart in Figure 2.1. Conner et al. (2007) presented the pathways until planned and unplanned attempts [23]. 30% of the suicide survivors make lethal suicide attempts in their lifetime [22].

The general hazard rates of progressing through the state-chart are given in Table 2.1. About 51.7% of the rates will be for women, and 48.3% will be for men to incorporate the male-female heterogeneity.

Table 2.1: Daily hazard rates of suicide progression through the statechart per day (direct transitions)

| Direct Transition Name | Daily Hazard Rate |
|---|---|
| Development of suicidal ideation | 0.0021 |
| Suicidal ideation to concrete planning | 0.0009 |
| Suicide attempt given concrete planning | 0.0015 |
| Suicidal ideation to commit suicide | 0.1927 |
| Successful suicide attempt | 0.0008 |

Table 2.2: Probabilities of suicide progression through the statechart (message transitions)

| Message Transition Name | Daily Hazard Rate |
|---|---|
| Developing suicidal ideation given exposure | 0.0003 |
| Developing concrete planning given exposure | 0.0003 |
| Successful suicide attempt given exposure | 0.0002 |

# 3 Scenarios

In this section, we discuss different scenarios considered in this study to examine the effectiveness of interventions in suicide progression among individuals, as well as the effectiveness of postvention in a population.

## 3.1 Scenario Descriptions

Studies show that community-based suicide intervention may reduce odds of concrete planning by 50% and odds of suicide attempts by 45% [15, 17]. According to the American Foundation for Suicide Prevention, 90% of the people who died by suicide suffered from a mental disorder (e.g., schizophrenia, major depression, mood disorder, etc.) [24]. Medication (e.g., clozapine, lithium, etc.) along with counseling services (e.g., psychotherapy, electroconvulsive therapy, etc.) are helpful for reducing the risk of suicidal progression among individuals [24]. Prescribing medication among mentally disordered patients decreased the rate of suicide by 80% per 100,000 population.

In light of such dramatic reductions in the rate of suicide attempts possible as the effect of an intervention, concrete planning, or completed suicide in a high-risk population, we incorporate rates of recovery in our study. From each state of state of suicide progression, the rate to move back to a less harmful state is 0.80 per day for each agent. As was mentioned above, 30% of the suicide survivors make lethal suicide attempts in their lifetime [22]. Therefore, the rate for a suicide survivor to move back to concrete planning is (30/100)/365 per day. The hazard rates of recovery through the intervention in the suicide progression statechart are given in Table 3.1

In our study, whenever an agent makes a suicide attempt, it delivers a message to the people living nearby (i.e., community), which triggers them to move back to no suicidal ideation state (from any other state). This way, the intervention is applied in the community following an index suicide. To accommodate this, we created a bidirectional network, where several connected individuals who are living nearby are defined as "friends and family". This network also includes classmates and neighbors.

Table 3.1: Daily hazard rates of recovery through the suicide progression state-chart for individual agents

| Direct Transition Name | Daily Hazard Rate |
|---|---|
| Recovery from suicidal ideation | 0.80 |
| Concrete planning to no suicidal ideation | 0.80 |
| Concrete planning to suicidal ideation | 0.80 |
| Suicide attempt to no suicidal ideation | 0.90 |
| Suicide attempt to suicidal ideation | 0.07 |
| Suicide attempt to concrete planning | 0.0008 |

## 3.2   Findings From Scenario Runs

We have two different scenarios to test for this experiment. One set of simulation experiments runs without taking into account any intervention. Another set of experiments take into account the intervention among individual agents, as well as among community. After running each of the scenarios for 15 realizations with a population of 12,000 agents, we found the total burden of suicide contagion at different stages of the progression. The resulting plots are given in Figure 3.1.

From Figure 3.1, we can see that the cumulative counts of suicidal ideators by the end of the study period are about 13,000 in the baseline group and approximately 250 in the intervention group. The cumulative number of concrete suicide planners is a little more than 200, which dramatically reduces to close to zero after providing intervention in the population. A similar pattern is also observed in the total counts of suicide survivors, where the intervention reduces the overall numbers of suicide survivors from approximately 250 to 4. Following the intervention, there is only one agent, who committed suicide at the end of the study period, when no intervention is present, whereas, no one made a lethal suicide attempt after having received the intervention.
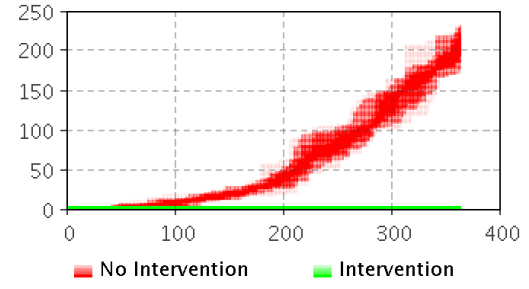
We also examine the pairwise comparison among these two scenarios to see if such reduction in the suicide progression is statistically significant. We consider two indepen-
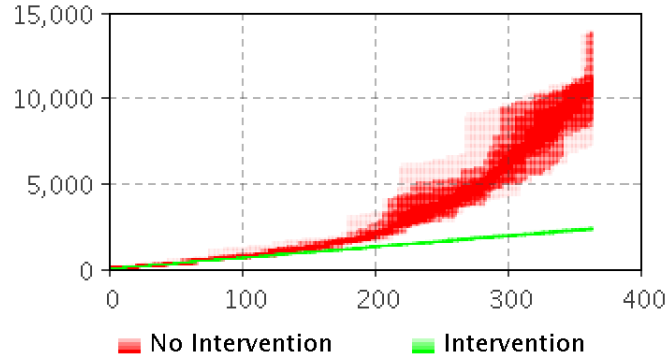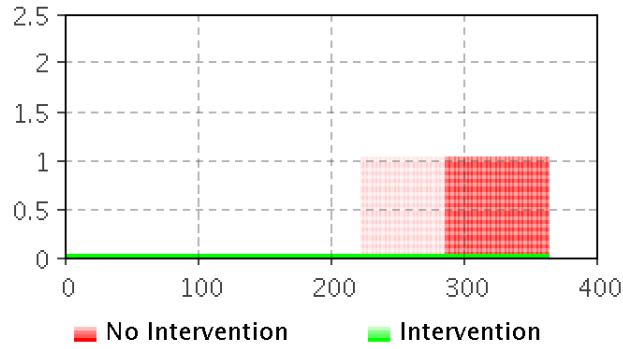
(a) Suicidal Ideators
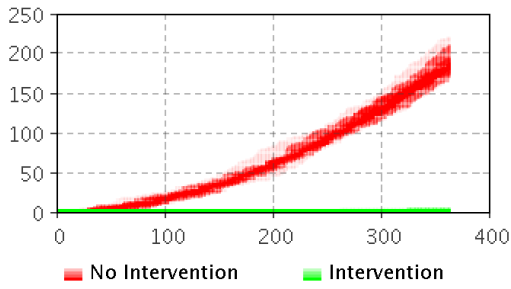


(b) Concrete Suicide Planners



(c) Suicide Survivors



(d) Completed Suicides

Figure 3.1: Cumulative counts of agents at different states of suicide progression with and without any intervention (15 simulation realizations for each scenario).

dent sample one-tailed t-statistic to test if the overall average of suicide progression is greater in intervention group compared to non-intervention group. Summary statistics (mean, standard deviation [SD], number of simulation runs [n]) along with a pairwise t-test (test statistic [t], degrees of freedom [df], standard error [SE]) from these two scenarios are presented in Table 3.2.

Table 3.2: Summary statistics and pairwise comparison between intervention and non-intervention groups (15 simulation runs for each scenario with random seed).

| Suicide Progression States | No Intervention | | | Intervention | | | Two sample one-tailed t-test | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | n | Mean | SD | n | t | df | SE | p-value |
| Suicidal Ideation | 10863.13 | 1985.54 | 15 | 2349.27 | 62.54 | 15 | 16.60 | 28 | 512.92 | <0.0001 |
| Concrete Planning | 187.8 | 14.03 | 15 | 1.2 | 1.15 | 15 | 51.34 | 28 | 3.64 | <0.0001 |
| Incomplete Suicide | 208.73 | 18.43 | 15 | 0.4 | 0.63 | 15 | 43.75 | 28 | 4.76 | <0.0001 |
| Committed Suicide | 0.133 | 0.352 | 15 | 0 | 0 | 15 | 1.47 | 28 | 0.091 | 0.07668 |

We see from Table 3.2 that there is a significant reduction (at a 5% level of significance) in the counts of suicide progression after implementing community-based intervention along with individual agent-specific intervention. There is no substantial reduction in the number of total suicides after the study period.

When no intervention is present, a total of 184 people attempted suicides by the end of the study after having been influenced by any previous index suicide. Among them, 42 people attempted suicides multiple times. Only one celebrity attempted suicide, which contributed to such high number (n = 111) of influential suicide attempts. The only suicide happened without multiple attempts. Moreover, this lethal suicide in non-intervention group was not influenced by any celebrity suicide attempt.

Since the interest of this research lies in copycat suicide attempts, we have explored the message transition pattern among agents following an index suicide attempts. Figure 3.2 shows that there is a sudden high peak of message transmissions about suicide attempt news either in the community or mass media (for the celebrity) within the first 3.5 months of the study. Such sudden spread of message justifies the high num-
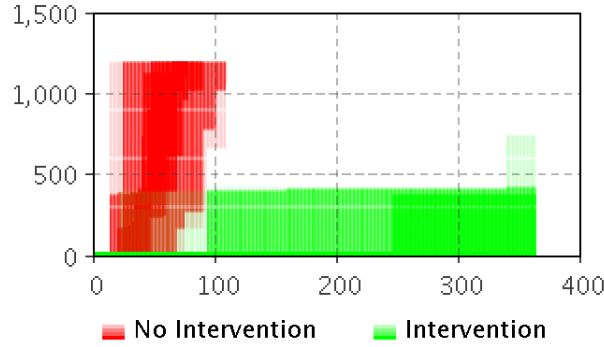
Figure 3.2: Message transition counts among individuals following an index suicide attempt.

ber of suicidal ideation, concrete planning, attempts when no intervention is present in the population. Implementing intervention support in the community dramatically reduces the spread of suicide-related news in a community. Such reduction in message transitions is possible because of the decrease in suicide progression among agents.

# 4 Learning

The primary learning of this study is that community-based postvention along with individual-level intervention significantly reduces the rate of suicide progression as well as suicide contagion. One strength of this study is that we have provided repeated intervention to people, who exposed repetitive tendency to progress through suicidal stages. As mentioned in Section 1.1 that most intervention strategies do not consider repeated intervention or long-term intervention [17]. The current study provides a step towards addressing that gap in the existing literature.

One of the most significant challenges was that the message transitions among individuals made the model very slow. Following an index suicide, the message exploded in the population. Therefore, experimenting the scenarios with a higher number of agents was not possible. We considered 12,000 agents in the population. For model calibration, we need to experiment with scenarios with 100,000 population. A larger population size may give the rate of suicide progression per 100,000 population, which

makes it easier to compare with the rates existing in the literature. For this, we initiated the statechart in a way that it only includes vulnerable population, who are at a high risk of suicide. Investigation of copycat suicide should be done in general agents with calibration. We could have studied the spread of suicide-related news in the media in a particular cluster(s) and how it can be prevented following an index celebrity suicide attempt. This would help us to compare between two suicide clusters with or without publication/broadcasting about suicide-related news of celebrities. Currently, only the nearby agents are receiving intervention support after hearing the news of a suicide attempt. In addition to provide intervention, preventing mass media from publishing suicide-related news may help us to study the pattern in suicide progression following a celebrity suicide attempt [11].

We also could have considered a cluster-specific network, where certain individuals will lie in certain clusters. This may give the chance to study enhanced clustered suicide attempts, where index suicide attempt only influences agents in that particular cluster. This helps to research suicide contagion, which in turn may help health-care providers to implement a community-based intervention in high-risk clusters.

Socio-demographic variables (e.g., age group, marital status, level of education, employment status, ethnicity, mental disorder) are crucial factors in suicide-related studies since different people have different chance to attempt suicide [25, 26]. Such risk factors could be considered to make the population more dynamic in the study of suicide progression.

# 5 Future Work

In Section 4, we have explained some ideas regarding how we could have done the model differently. Based on that discussion, we can consider enhanced clustered networks for agents in the population. We can consider implementing the model in a larger population to get rates of suicide closer to empirical data. We will also consider the different heterogeneity to make the model dynamic.

We will consider local celebrity that can be defined in a more precise way. Local

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celebrity will be an influential member of the community, for example, political leader or member of association [2]. Such agents have less influence than a media celebrity [2].

We will consider one side-by-side System Dynamics (SD) modeling approach to simultaneously investigate the dynamics of suicide progression in the individual agents, as well as in the population. The individual agents' behavior towards suicide changes the collective behavior of the system. This facilitates to study the complex systems of suicide.

We will apply modern machine learning algorithm (Hidden Markov Model or Particle Filtering) to predict the copycat suicide states given the current situation of suicide progression. Such classification method may help law-enforcement authority or healthcare providers to provide intervention in a community to prevent suicide contagion.

# 6   Conclusions

In this study, we have shown that a geographically local network in an agent-based model is useful to understand the individual dynamics of copycat suicide, which imposes a high public health burden. Providing intervention in the form of either medication or psychotherapy at community level significantly prevents agents to progress through suicidal ideation, concrete planning or making an attempt (either lethal or non-lethal). A celebrity suicide attempt triggers the initiation of suicide contagion in the mass population. Despite the limitations, this is a baseline study for the investigation of copycat suicide in an agent-based population. Future studies with more defined intervention parameters and investigating prevention of mass media from publishing celebrity suicide-related news may advance this baseline model. Such advanced model will help policy-makers, health-care providers and law-enforcement authority to act in the prevention of suicide outbreaks.

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