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A Designing Framework for Ant Colony Algorithm for Managing Cognitive Insomnia

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Abstract: Insomnia, a condition characterized by poor sleep quality, significantly impacts cognitive function, mood, and overall well-being. Traditional treatments like medication and psychological therapies, while effective, often come with limitations such as high costs and limited scalability. This study addresses these challenges by proposing an Ant Colony Optimization (ACO) algorithm-based approach to create a dynamic support network for individuals suffering from insomnia. The ACO algorithm, inspired by the foraging behavior of ants, is employed to optimize the selection of social support providers from an individual's network based on their preferences and available resources. The proposed algorithm, named Ant Colony algorithm in Provision Support for Insomnia individuals (ACPSI), was developed to identify the most suitable support paths by automating the formation of social support networks. The methodology involves defining problem parameters, initializing population variables, and refining potential solutions through an iterative process. The system also integrates data from social media platforms to assess mental health and predict insomnia susceptibility. The findings suggest that the ACPSI model effectively optimizes the selection of support providers, potentially leading to improved management of insomnia through enhanced social support. This approach offers a scalable, low-cost solution by leveraging existing social networks and technological advancements. The study concludes that the ACPSI model could be a valuable tool in managing insomnia, reducing its cognitive and emotional impacts, and improving overall patient outcomes.

Keywords: Ant Colony Algorithm, Social Networks, Design, Optimization, Insomnia

Introduction

The concept of Ant Colony Optimization (ACO) was initially introduced by Marco Dorigo in the 1990s as part of his Ph.D. thesis. Inspired by the foraging behavior of ants in search of food, this algorithm was developed to solve complex optimization problems, including the well-known traveling salesman problem (Afshar *et al.*, 2015). Over time, ACO has been applied to address various challenging optimization problems, such as assisting individuals with insomnia. One such problem is provision support, which involves selecting the best providers along the shortest path to aid those seeking help with insomnia (Ataie-Ashtiani and Ketabchi, 2011).

Ants are highly social insects that form colonies and exhibit specific behaviors driven by their goal of finding food. When searching for food, ants explore the area around their colonies, repeatedly moving from one location to another (Banadkooki *et al.*, 2020). During their movements, they release a chemical substance called pheromone onto the ground. Pheromone trails serve as a means of communication among ants. When an ant discovers a food source, it collects as much as it can carry and leaves pheromone marks along its return path, the intensity and quality of which depend on the food's quantity and quality (Bolin, 2014). Other ants can detect these pheromone trails and follow them, relying on their sense of smell. The concentration of pheromones on a particular path influences the likelihood of ants choosing that path and as more ants follow it, the amount of pheromones on the path increases.

Insomnia refers to a condition characterized by inadequate sleep quality, difficulty in falling and staying asleep, frequent nighttime awakenings, or waking up earlier than desired (Alfano *et al.*, 2008). These symptoms can have negative repercussions during the day, such as diminished cognitive abilities, reduced productivity, fatigue, feelings of depression, irritability, impaired decision-making, decreased motivation, and changes in mood (Baglioni *et al.*, 2010). Researchers have taken a keen interest in cognitive vulnerability models that elucidate the relationship between insomnia, mood dysregulation, and cognitive impairments (Barclay and Ellis, 2013). When insomnia becomes a primary concern, a detrimental cycle known as insomnia-anxiety-insomnia can develop, resulting in emotional instability, impulsiveness, restlessness, excessive sleepiness during the day, reduced alertness, and progressive cognitive decline over time (Harvey, 2002).

Furthermore, insomnia incurs significant economic expenses, including healthcare and social care costs, as well as productivity losses due to missed work days (Lancee *et al.*, 2017). Traditional methods of addressing insomnia, such as medication and psychological therapies, are expensive, time-consuming, and not easily scalable to cater to diverse populations. To assist individuals with insomnia, various digital applications have been developed, including mobile apps, wearable sensors, and software agents (Lancee *et al.*, 2017a-b; Lauriola *et al.*, 2019; Shallcross and Visvanathan, 2016). However, these technologies must possess the capability to comprehend a person's functioning process, such as their psychological state, and offer appropriate interventions based on the individual's estimated condition (Rateb *et al.*, 2025). Presently, the widespread utilization of crowdsourcing and the increasing adoption of social media has opened up new avenues for effectively managing insomnia through social support, leveraging low-cost and widely available sensors that are already integrated into people's daily lives (Alfano *et al.*, 2008; Barclay and Ellis, 2013).

This study explores the potential of utilizing social media as a crowdsourcing tool for assessing and monitoring mental health. Platforms like Facebook are gaining popularity among individuals, providing them with a means to express their thoughts and emotions regarding various everyday occurrences. The paper focuses on the development of an ant colony algorithm to form a support provision selection. This approach lays the foundation for a dynamic application that suggests support networks based on the information available on social media platforms. The contribution of this research can be summarized into three main aspects. Firstly, it involves determining the preferences for different types of social support from the perspectives of both the seekers and providers using a pheromone model (Section 5.1). Secondly, it proposes an ant colony algorithm approach for automated selection, aiming to identify an optimal subset of the patient's social network members who can collectively offer the most effective support (Section 5.2). Lastly, Section 6 encompasses the software design aspect of the study.

Common Treatments for Insomnia

There is a range of methods to help people to cope with insomnia. These include pharmacological treatment (medication), psychological techniques, and finally, social support (Lancee *et al.*, 2017a). First, medication is an effective way of helping to manage insomnia. However, it is not without problems. For example, benzodiazepines can affect a person's coordination and concentration if the dose is too high (Harvey, 2002). Second, the psychological therapies that are proven to have a positive effect to change a person's thought and behavior patterns to manage their insomnia (Lancee *et al.*, 2017b) include three therapies. First, Cognitive Behavioral Therapy (CBT) is a type of psychotherapy that focuses on changing unhelpful or unhealthy thoughts, beliefs, attitudes, and behaviors. It is based on the idea that our thoughts, feelings, and behaviors are interconnected and that changing negative thoughts and maladaptive behaviors can improve emotional well-being. CBT is commonly used to treat a variety of mental health conditions, including depression, anxiety, and insomnia. In the context of insomnia, CBT aims to identify and alter the thoughts and behaviors that contribute to poor sleep. Second, Relaxation Training (RT) is a therapeutic technique designed to reduce stress and anxiety by teaching individuals how to relax their muscles and calm their minds. This training typically includes methods such as deep breathing exercises, progressive muscle relaxation, meditation, and visualization. Relaxation training is often used as part of a broader treatment plan for conditions like insomnia, where the goal is to reduce the physical and mental tension that can interfere with sleep. Moreover, Supportive Therapy (ST) is a type of therapy that focuses on providing emotional support, encouragement, and advice to help individuals cope with life's challenges. Unlike more directive or structured therapies, supportive therapy is non-judgmental and empathetic, offering a safe space for individuals to express their thoughts and feelings. It is often used to help people manage stress, anxiety, and depression and it can be a key component in the treatment of insomnia, where emotional support can play a crucial role in improving sleep quality. Third, social support can be defined as the care or help from others that an individual can feel, notice, or accept (Izmailova *et al.*, 2018).

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Social Support and Social Support Networks

Social Support

Social support can be studied as an interpersonal interaction that includes the recipients and providers and their thoughts and how these unfold over time (Beck, 2008). The groups of people around a person that can provide help are called "social support networks". It refers to the provision of psychological and material resources from the social network deliberated to promote an individual's ability to cope with insomnia (Izmailova *et al.*, 2018).

The term "social support" has been interpreted in somewhat different ways, but it was referred here to Cobb (Bavafa *et al.*, 2018) describes social support as knowledge that leads to a person feeling that they are cared for, that they loved and thought highly of and that they are a part of a social network that will reciprocate their feelings and actions. List the kinds of social support that can be provided, including informational, emotional, instrumental, and companionship support.

Extensive literature has extensively discussed the benefits, either physical or psychological, associated with receiving social support (Beck, 2008; Milkins *et al.*, 2016). Previous research has demonstrated that individuals with lower levels of social support are more susceptible to various diseases and experience slower recovery, including cardiovascular disease, inflammation, and compromised immune system functioning (Rateb *et al.*, 2025). Conversely, higher levels of social support have been linked to numerous positive health outcomes, such as quicker recuperation from coronary artery surgery, reduced vulnerability to herpes outbreaks (Rateb *et al.*, 2017), and a decreased likelihood of age-related cognitive decline (Rateb *et al.*, 2016).

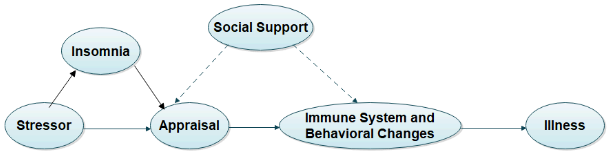

Fig. 1: The buffering hypothesis

Social support can promote health by employing an insomnia buffering theory, which aims to mitigate or alleviate the effects experienced by individuals with insomnia. The buffering hypothesis, as depicted in Figure (1), posits that social support serves as a protective buffer, diminishing the impact of insomnia-related events by reducing their perceived threat. Additionally, social support may reduce the physiological and behavioral changes resulting from insomnia, thereby aiding in the prevention of illness (Izmailova *et al.*, 2018). Buffering, in this context, refers to the mediating role of social support between individuals with insomnia and their health outcomes (Cheng *et al.*, 2024).

A Social Support Network refers to a group of people—such as family, friends, colleagues, and community members—who provide emotional, practical, and sometimes financial assistance to an individual. This network plays a crucial role in helping individuals cope with stress, manage challenges, and maintain their well-being. Social support can take many forms, including emotional support (e.g., listening and providing empathy), informational support (e.g., offering advice or guidance), and tangible support (e.g., helping with tasks or providing financial assistance).

Examples of Social Support Networks:

1. Family and Friends:
   Example: A person going through a difficult time, such as a job loss, may receive emotional support from close family members who listen to their concerns and provide encouragement. Friends might offer to help by reviewing their resumes or connecting them with job opportunities.
2. Support Groups:
   Example: Individuals dealing with a health condition, such as cancer, may join a support group where they can share experiences and receive advice from others who are in similar situations. This network provides emotional and informational support
3. Community Organizations:
   Example: A community center might offer programs for elderly individuals, providing both social interaction and practical assistance, such as meal deliveries or transportation services. This network helps older adults maintain their independence and well-being.
4. Workplace Support:
   Example: In a work environment, colleagues might form a support network to help each other with job-related challenges, such as collaborating on projects or offering mentorship. This can include providing advice, sharing resources, or simply being available to talk through problems
5. Online Social Networks:
   Example: Online forums or social media groups dedicated to specific interests or issues (e.g., parenting, mental health, hobbies) can serve as a support network by allowing individuals to connect with others who share similar experiences and can offer advice, support, and encouragement

Social Support Ties Network Theory

Researchers on social support often distinguish between two social relationships when referring to the sources of social support: Strong ties and weak ties. The strength of connections between individuals can vary widely, influenced by factors like the nature of their interactions, how often they communicate, the level of closeness, and how long they've known each other (Rateb *et al.*, 2017; Milkins *et al.*, 2016). A strong tie typically characterizes close relationships within a personal network, such as family members or close friends, who often provide substantial support. Conversely, weak ties involve individuals who communicate frequently but aren't considered close. For instance, research indicates that individuals with long-term goals may struggle to find informational support from close acquaintances, perceiving them as lacking relevant expertise. However, when seeking emotional support, they are more inclined to turn to close relationships (Cheng *et al.*, 2024). Additionally, support types like instrumental aid and companionship are typically associated with strong tie preferences (Rateb *et al.*, 2016).

Social Support Networks

As the adoption of social media platforms continues to grow, there is a belief that the ongoing streams of evidence derived from users' posting activity on Social Networking Sites (SNS) can provide insights into their psychological states and social environments. The aim is to leverage this data on individuals' social and psychological behaviors to predict their susceptibility to insomnia in a non-intrusive and detailed manner (Rateb *et al.*, 2016). For instance, users of platforms like Facebook and Twitter openly share their emotions and thoughts in their daily lives. The language and emotions used in these posts can often reveal feelings of guilt, worthlessness, self-liking hatred, and helplessness or hopelessness (Cheng *et al.*, 2024). Additionally, since social networks provide an unbiased collection of an individual's language and behavior, both as a support recipient and provider, the profiles and attributes within the social network are closely associated with personality traits. The "Big Five" model represents five domains of personality dimensions, namely Openness, Conscientiousness, Extroversion, Agreeableness, and Neuroticism. For instance, individuals with higher levels of neuroticism may express their need for emotional support through expressions of unpleasant emotions (Rateb *et al.*, 2025).

Crowdsourcing

Crowdsourcing refers to the process of obtaining work, services, and support from a large group of people, typically online and through open calls. Implementing crowdsourcing systems in the context of health problems can yield innovative and creative solutions that differ from those generated by domain experts. Recent research suggests that crowdsourcing can be utilized to identify causal factors related to behavioral outcomes. For example, a study mentioned by Milkins *et al.* (2016) employed crowdsourcing to discover new childhood predictors of obesity.

Various crowdsourcing techniques have been developed to enhance positive psychological interventions and improve an individual's well-being. These techniques include positive reappraisal, goal-setting and planning, leveraging signature strengths, and performing acts of kindness. An example of a recent crowdsourcing application is Panoply (Izmailova *et al.*, 2018), which assists users in generating healthy and positive reappraisals of challenging situations related to insomnia. Panoply receives support from crowd workers. The therapeutic approach underlying this application draws inspiration from research in the fields of emotion regulation, cognitive neuroscience, and clinical psychology, primarily focusing on the concept of cognitive reappraisal. Therefore, this study presents a study that utilizes a crowdsourcing methodology to build a substantial collection of Facebook posts shared by individuals who have experienced insomnia disorders.

Crowdsourcing is the process of obtaining input, ideas, services, or content by soliciting contributions from a large group of people, typically from an online community. Social support networks in this study form like crowdsourcing. Instead of relying on a few experts, crowdsourcing taps into the collective intelligence and diverse perspectives of many individuals to solve problems, generate ideas, or complete tasks. In the context of this study, crowdsourcing is relevant as it can be used to gather insights, data, and solutions from a wide audience to optimize social support networks for individuals with insomnia. By leveraging the collective knowledge and experiences of a large group, the study can develop more effective and personalized support systems that better address the specific needs of those suffering from insomnia. This approach enhances the scalability and adaptability of the proposed solutions, making them more practical and widely applicable.

Proposed Solution

The Ant Colony Algorithm (ACO) is a bio-inspired optimization technique based on the behavior of ants when they search for food. In nature, ants find the shortest path between their colony and a food source by laying down pheromones, which are chemical trails that guide other ants. Over time, the path with the most pheromone becomes reinforced, indicating it is the most efficient route. Develop an ant colony algorithm to construct an automated pheromone model for individuals with insomnia. This model will be utilized to dynamically select appropriate members from social networks based on their available resources and preferences. The three sections below provide a clear definition of this approach. The ACPSI Algorithm is an optimization technique inspired by the behavior of real ants when they search for food. Ants find the shortest path between their colony and a food source by laying down pheromones, which guide other ants along the same path. Over time, the path with the strongest

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pheromone trail, indicating the shortest and most efficient route, is reinforced.

In the context of social support networks for insomnia, the Ant Colony Algorithm is applied to optimize the selection of social support providers. This algorithm simulates how ants find the best path by identifying the most effective support connections within an individual's social network. The algorithm assesses factors like availability, proximity, and compatibility to select the most suitable support providers, much like how ants choose the best route based on pheromone strength. The algorithm helps dynamically form and optimize social support networks tailored to individual needs, thereby enhancing the management of insomnia through improved social support. This approach is particularly useful for creating a scalable, low-cost solution that leverages existing social networks and technological advancements to support individuals suffering from insomnia.

Application in social support networks for insomnia: The ACPSI Algorithm is applied to optimize social support networks for individuals with insomnia. The algorithm simulates the way ants find the best path by identifying the most effective support connections within a person's social network. It selects the most suitable support providers based on factors like availability, proximity, and compatibility, much like ants choose the best route based on pheromone strength. This approach helps in dynamically forming and optimizing support networks that are tailored to the individual's needs, thereby improving the management of insomnia through enhanced social support. The proposed solution involves developing an ant colony algorithm to construct an automated pheromone model for individuals with insomnia. This model dynamically selects appropriate members from social networks based on their available resources and preferences. The ant colony algorithm methodology includes defining problem parameters, initializing population variables and iteratively refining potential solutions through local search algorithms. The algorithm emphasizes preferences in structuring relationships, allowing for the description of members who offer various types of support. Figure (2) outlines the framework for matching support as presented in this study.

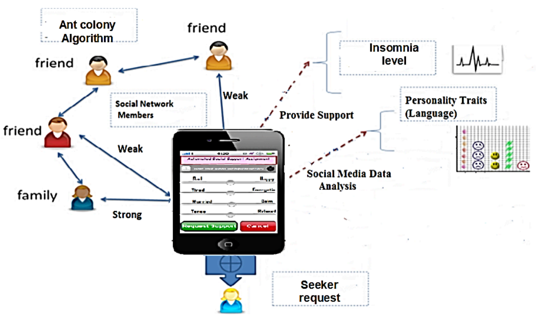

Fig. 2: The proposed framework for the pheromone model

Figure (2) shows the main theories and concepts in the proposed framework, extracted from social support network ties and buffering hypothesis theories from insomnia viewpoints.

Materials and Methods

The Ant Colony Optimization Algorithm (ACO) finds applications in diverse areas of environmental and water resources management (Afshar *et al.*, 2015). These applications include water distribution system design (Kumar & Reddy, 2006; Moeini & Afshar, 2009), optimal management of coastal aquifers (Ataie-Ashtiani & Ketabchi, 2011), water quality (Bolin, 2014; Heidari *et al.*, 2020), optimal operation of reservoirs (Szemis *et al.*, 2014; Tharwat *et al.*, 2018), runoff forecast and management (Cheng *et al.*, 2024) and interdisciplinary environmental problems (Abualhaj *et al.*, 2024; Owida *et al.*, 2024).

To understand how real ants optimize the distance between their colony and food, let's consider their behavior. Ants communicate through a substance known as pheromone, which they deposit along their paths on the ground. When an ant follows a particular path, it can recognize the return route by relying on the pheromone it has previously deposited. Other ants can also detect pheromones left by their counterparts, indicating that another ant has moved in that direction. The exchange of messages occurs through the placement of pheromones on the ground, creating a "pheromone trail" in the environment (Kumar & Reddy, 2006). Pheromones enable ants to locate food sources that have already been identified by fellow ants. However, these pheromones gradually dissipate and evaporate over time. The two main concepts behind the ant colony optimization algorithm are pheromone depletion and pheromone evaporation.

The initial step in optimization using ACO involves defining a suitable model, which plays a crucial role in the algorithm. One of the key components of the ant colony algorithm is the "pheromone model." For hybrid optimization problems, the model is defined as follows:

$$Model = (S, C, f)$$

A pheromone model designed for a hybrid optimization problem comprises the following elements (Bolin, 2014):

- A search space is denoted as S, which encompasses a defined set of decision variables. Each candidate solution $s \varepsilon S$ represents a complete specification of problem variables, where each decision variable has values that satisfy the constraints specified in the set for a given compound optimization problem
- C represents a set of constraints imposed on the problem variables
- An objective function that needs to be minimized. It should be noted that minimizing an objective

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function, such as f, is equivalent to maximizing the objective function -f. Therefore, any hybrid optimization problem can be reformulated as a minimization problem

During the search process, the ant colony algorithm utilizes and updates pheromone values. These parameters enable the modeling of the potential distribution of various components of the solution within the ant algorithm. The values of the pheromone and the candidate solution (i.e., the values of the problem variables) are inherently interconnected (Tharwat *et al.*, 2018; Shambour *et al.*, 2024). As the evolutionary process unfolds, pheromone values increase for candidate solutions that are closer to the overall optimal solution while decreasing for less favorable solutions. Consequently, the strength of pheromone attraction towards good solutions intensifies, guiding the search for the optimal solution among other artificial ants.

Ant Colony Algorithm on Social Provision

The social provision ant colony algorithm comprises two primary components. The initial phase involves defining problem parameters and initializing population variables. Subsequently, an iterative process unfolds, where the ant colony algorithm progresses through three key steps. During each iteration, artificial ants propose potential solutions, refined further through a local search algorithm. Ultimately, the pheromone levels are adjusted.

As depicted in Figure (2), the Pheromone model integrates pertinent data from all members within social networks and potential support seekers. This model scrutinizes both immediate and long-term relationships to ascertain preferences in support exchange. Moreover, it monitors the well-being of support recipients, including factors like insomnia levels, which are pivotal in triggering the ant colony algorithm.

In this study, the ant colony optimization algorithm is employed, which operates under the assumption that each component within the system serves as a potential resource. The objective of this model is to determine the most efficient route to select the appropriate support providers, considering both their capabilities and the type of assistance they offer. Instead of focusing on individual or direct matching between requested and provided support, the algorithm emphasizes preferences in structuring relationships. This allows for the description of members who offer various types of support and the utilization of these preferences. At the onset of the ACPSI algorithm, a set of constraints is defined, including the desired number of preferred providers the percentage of allocated support, and a level of acceptance capacity that must be initialized first (see ACPSI for details).

An Ant colony Algorithm in Provision Support for Insomnia individuals (ACPSI)

Input: medical neurological, pain, negative events, psychiatric disorders, number of support providers (n), acceptable capacity level, tie preferences.

Output: A set of selected providers.

Process: Repeat steps S1-S21 until one of the stopping criteria is satisfied.

S1: Check Insomnia level and need for help to start the process.

Stop if insomnia is less than the threshold or no more support providers can be assigned.

S2: Simultaneously, check the intensity of insomnia level for the provider.

Stop if the intensity of the insomnia level is greater than the threshold; otherwise, go to S3.

S3: Check the provider's acceptable capacity (*Ac*).

Stop if acceptable capacity is *greater than the threshold; otherwise, go to S4.*

S4: Determine the provider's ratio of helping (*Pr*).

S5: Evaluate support seeker preference (needed support (*Ns*)).

$Ns= Sr/n$

Where needed, support is computed by dividing the requested support(Sr) by the number of providers (by averaging the value of requested support)

If support is needed greater than or equal to the threshold, then go to S6; otherwise, stop.

S6: Evaluate provision preference (provided support (*Ps*)).

If provided support is greater than or equal to the threshold, then go to S7; otherwise, go to S13.

S7: Determine assigned support from the provider (*As*).

$As=Pr*Ac$

S8: Determine the support needed for the seeker (*Ns*).

S9: Check provided support (*Sp*) compared to needed support (*Ns*).

If provided support is less than needed support, then stop; otherwise, go to S10.

S10: Update insomnia level (*Is*).

$Is= (1- \Sigma Ps/Ns)$

S11: Check the counter for a number of providers (*c*).

If c is less than or equal to n, then go to S12; otherwise, stop.

S12: Check the total amount of support provided by the provider.

If the total amount of support provided is greater than the threshold, then go to S14; otherwise, go to S13.

Members with a high support provision will be chosen first and so forth.

S13: Increase the counter and repeat *S2.*

S14: Select the provider and repeat *S2.*

Software Design

This section will show the process of designing a prototype version of the system that will be tested out and refined before being given to individuals who are in the process of reducing insomnia. Many factors have been learned from interactions with patients in the design of the system and are concerned with the seamless integration of the several components so that users have a successful experience when interacting with it.

Design Principals

When designing any system to be used in real-world situations, our target population (social network members) must be taken into account. The user should be given a clear motivation for using the system and should be provided with ease of use in all interactions. So, all parts of the system must be worked together in ways that minimize user involvement and frustration with the workings of these components and their interdependence on one another. In order to provide a description of the system, Figure (3) describes the major components of the proposed system.

Figure (3) shows the four major components of the system to finally select needed support in order to describe user interaction of the system; Figure (4) describes the framework of the ACPSI Algorithm.

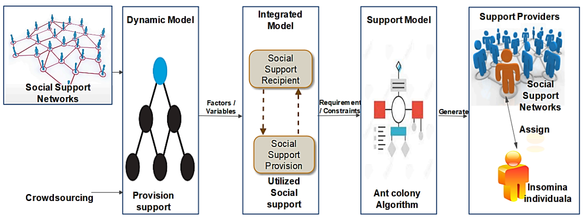

Fig. 3: The ACPSI system components

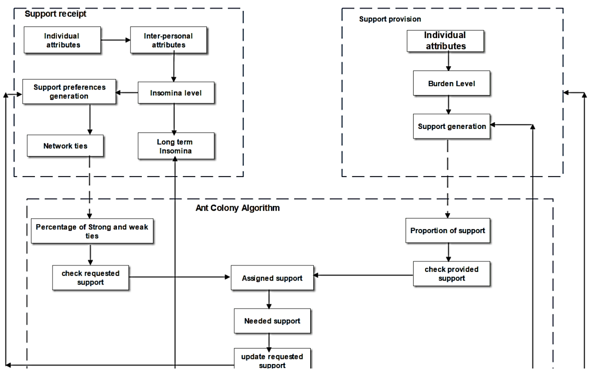

Fig. 4: The ACPSI framework

Figure (4) shows that users will interact with the system through the login in the user interface. The patient and system will carry out a routine interaction where the system serves as a "mirror" to the person's behavior. The major steps in the system in order to accept support, are (a) Measure the insomnia level of social support seeker needs before the matching process, (b) Evaluate social support members' preferences (seekers and provision) by building a pheromone model, (c) Match support provider through ant colony algorithm and finally (d) Measures insomnia level of support seekers needs after matching process.

Results

Many simulations have been performed to discover interesting patterns among individuals who support tie preference behaviors. Some anticipated patterns can be discovered with variations in individual and inter-personal attributes. This study deals with two individual conditions (Table 1) exposed almost to the same set of insomnia stressful events. Table (1) summarizes the values of these profiles.

Table 1: Individual profiles

Individuals Profiles					
	Negative event	Personal resources	Personality attributes	Situational demands	Burden level
A	0.6	0.3	0.7	0.8	0.9
B	0.6	0.3	0.8	0.9	0.8

Based on this, two scenarios are presented. The duration of our simulation was initialized at 1,000 time points under these flexibility and proportional settings.

To analyze the ant colony algorithm results from the model presented in Section 5. Two insomnia conditions have been simulated; namely, (1) No support is assigned and (2) Dynamic support assignment.

In the first condition, no support is provided to help individuals. During this simulation, the outcomes from these conditions are measured using the individual's long-term insomnia and requested social support that the recipient needs. These results show that the selection of the right support members has a substantial impact on the course of the long-term insomnia of the support recipient.

For simplicity, the current simulations used the following parameter settings: t = 0.3, flexibility rates = 0.3, and regulatory rates = 0.5. These settings were obtained from previous systematic experiments to determine the most suitable parameter values in the model. These experimental results will be discussed in detail below.

Results # 1: No Support Provided. In case the person is more vulnerable to stress, the long-term insomnia increases more quickly and therefore, it takes more time for the person to recover. For this case, Figure (5) shows the effect of the highly requested support, which represents an increase in high long-term insomnia. This condition is one of the precursors to developing depression if no support is given in the future (Bolin, 2014). Similar findings can be found in Hajizadeh *et al.* (2011) and Harvey (2002).

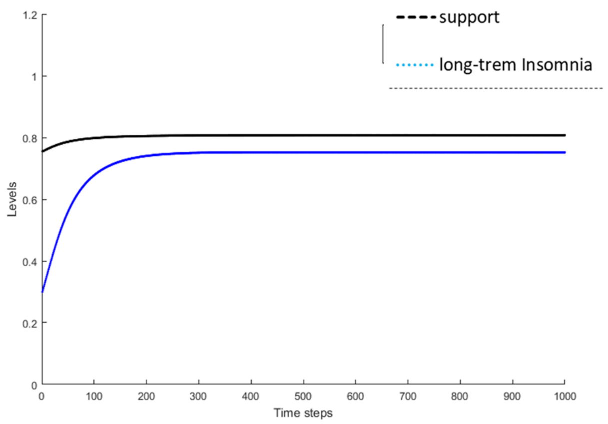

Fig. 5: Person with no support provided

Results # 2: Dynamic Support Assignment. In this scenario, a person receives support from suggested members by the ant colony approach. Figure (6) shows a more consistent and gradual decrease in a long-term insomnia level compared to no support assignment. For this scenario, it can be seen that the intensity of insomnia is decreasing and this potentially shows that a person is accepting social support and improving social interaction within a social support network. This condition occurs almost within the majority of individuals when they receive the right support from their support members (Baglioni *et al.*, 2010; Hajizadeh *et al.*, 2011; Bolin, 2014).

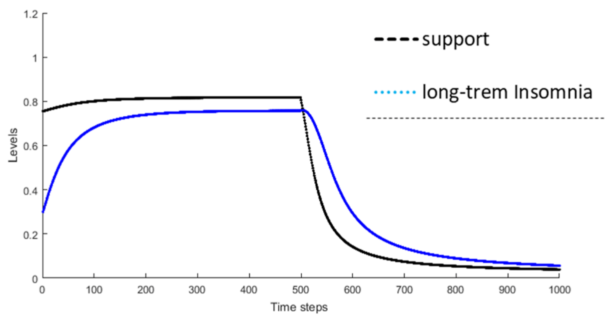

Fig. 6: Person with dynamic support provision

The results of this study underscore the potential of the Ant Colony algorithm in the Provision Support for Insomnia (ACPSI) model to improve insomnia management by optimizing social support networks. Compared to traditional methods, such as pharmacological and psychological therapies, ACPSI offers a scalable and cost-effective alternative.

Discussion

The dynamic support assignment demonstrated in the simulations suggests that algorithm-based support networks may help mitigate long-term insomnia, especially when compared to scenarios with no structured support. This finding aligns with previous research suggesting that targeted social support can play a crucial role in managing insomnia by providing emotional and practical assistance. However, while ACPSI offers a promising approach, several factors require further exploration. First, traditional insomnia treatments often incorporate personalized therapeutic components, such as Cognitive Behavioral Therapy for Insomnia (CBT-I), which are highly effective but costly and less adaptable to individual networks. ACPSI addresses scalability but lacks the therapeutic depth offered by interventions like CBT-I. Future research should consider how ACPSI might integrate or complement these established methods, potentially through hybrid approaches.

Comparatively, the reliance on social media data and online networks as a support basis introduces unique limitations. Unlike structured therapies, social media-derived data can vary widely in quality, introducing biases that may affect the accuracy of the model. Previous studies on social media's role in mental health indicate that while online interactions can be supportive, they are often limited by the type of relationships fostered through these platforms. A critical challenge for ACPSI will be to ensure that the algorithm prioritizes quality and relevance in social support, as not all connections in online networks are equally supportive.

Furthermore, when compared to similar studies in algorithmic health support, such as models for anxiety and depression management, ACPSI's focus on insomnia fills a notable gap in bio-inspired algorithm applications. However, these comparable models often incorporate real-time health data, such as heart rate or sleep patterns, from wearable devices, enhancing their adaptability. Integrating such real-time metrics could allow ACPSI to respond to users' immediate health needs more effectively, ensuring that support interventions align closely with fluctuations in insomnia severity. In sum, while the ACPSI model shows potential in optimizing social support for insomnia, further refinement is needed. By addressing these challenges and drawing on established treatments and recent algorithmic health interventions, ACPSI could evolve into a highly personalized tool that not only provides support but also aligns closely with clinical standards for insomnia management.

Conclusion and Future Work

This study presented the development and application of the Ant Colony Optimization (ACO) algorithm, specifically tailored to create dynamic social support networks for individuals suffering from insomnia. Currently, a prototype of the entire model has been developed. An initial experiment will be conducted to assess whether our model can effectively reduce insomnia levels. Subsequently, a pilot study of the complete system will be undertaken to evaluate its long-term effectiveness before introducing it to the target population. The inclusion of social media within this system offers additional advantages beyond those achievable through internet-based and computer-mediated communication alone. With these efforts, it is hoped that this work will contribute to solving real-world problems.

By leveraging the natural foraging behavior of ants, the ACPSI (Ant Colony algorithm in Provision Support for Insomnia individuals) model effectively identified and optimized the selection of social support providers based on individual preferences and network resources.

Key Findings:

1. Effectiveness of the ACPSI Model: The algorithm demonstrated significant potential in enhancing the management of insomnia by improving the quality and suitability of social support. Simulations showed that dynamically assigned support networks led to a marked reduction in insomnia severity over time compared to scenarios without structured support.
2. Integration with Social Media: The inclusion of social media data to assess mental health and predict susceptibility to insomnia added a layer of personalization to the support network, ensuring that the selected providers were not only available but also contextually relevant to the individual's needs
3. Scalability and Cost-Effectiveness: The study highlighted the ACPSI model as a scalable and cost-effective solution, leveraging existing social networks and technological tools. This approach offers a practical alternative to traditional insomnia treatments, which can be costly and less adaptable to individual needs.

Limitations:

While the ACPSI model offers promising results, several limitations warrant consideration:

- Data dependency: The model relies on social media data to assess support needs and availability. This may introduce biases, as not all individuals openly share their mental health status online, potentially affecting the model's accuracy.
- Population diversity: The study's simulations may not fully capture the varied social, cultural, and demographic factors influencing support networks in different populations. Testing with diverse samples is essential for broader applicability
- Algorithmic assumptions: Assumptions within the algorithm, such as fixed thresholds for insomnia levels and support preferences, may not suit all users. These thresholds could require customization based on individual variability in insomnia and support needs

Contributions:

- The research contributes a novel approach to the management of insomnia, expanding the use of ACO algorithms beyond conventional applications in routing and scheduling
- The study also underscores the importance of integrating digital tools, like social media, in the development of personalized healthcare solutions.
- Furthermore, it provides a foundation for future research to explore the long-term effects of dynamically optimized support networks on chronic health conditions.

Future Directions

- While the ACPSI model has shown promising results, future studies should focus on real-world implementation and testing to validate its effectiveness across diverse populations.
- There is also an opportunity to refine the algorithm further, incorporating additional data sources and improving the accuracy of support provider selection.

In conclusion, this research provides a valuable framework for enhancing insomnia management through the innovative use of ACO algorithms and social support networks, offering a pathway to more personalized and effective treatment strategies.

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Author's Contributions

Roqia Rateb: Software, resources, writing original draft, supervision, methodology, conceptualization, formal analysis, review & editing.

Amal Shorman, Areej Alshorman, and Laith H. Baniata: Supervision, methodology, conceptualization, writing—original draft.

Ahmad Sami Al-Shamayleh: Methodology, conceptualization, review & editing.

Ethics

This article does not contain any studies with human participants or animals performed by any of the authors.

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