WSJET

Warith Scientific Journal of Engineering and Technology

Journal homepage: wsjet.uowa.edu.iq

TOWARDS A COMPANION ROBOT: A COGNITIVE AGENT MODEL OF THE DYNAMICS OF LONELINESS

Hayder M. A. Ghanimi[1,2*], Shaymaa H. Nowfal[3]

[1]Department of Computer Science, College of Computer Science and Information Technology University of Kerbala, Karbala, Iraq

[2]College of Sciences, University of Warith Al-Anbiyaa, Karbala, Iraq.

[3]Medical Physics Department, College of Applied Medical Sciences, University of Kerbala, Karbala, Iraq

[*]Corresponding author *E-mail address:* hayder@uok.edu.iq

ARTICLEINFO

Keywords:
Loneliness
Mathematical Modelling
Cognitive Agent Modelling
Intelligent Intervention
Simulation Analysis

ABSTRACT

Loneliness is a prevalent and global problem for all people, and it can adversely affect their quality of life. Many research investigations have confirmed the negative psychological impacts of loneliness on people's the unwanted impact of loneliness. Yet, these interventions are missing the power of reasoning to predict the onset of loneliness. Consequently, this paper presented the work of developing a computational cognitive agent model of loneliness using a causal networking modeling approach by relying on discrepancy model as a benchmark to serve as analytics engine for a companion robot design. Loneliness determinants and their causal relationships were identified from the literature and formalized to construct the intended cognitive agent model. Furthermore, simulation analyses under various parameter settings were implemented to explore the causal relationships among the identified loneliness determinants and those simulations revealed similar behaviors or patterns to existing literature. The designed cognitive agent model was evaluated using both of mathematical analysis and automated logical analysis. These two evaluation approaches have proved the correctness of the designed model. The developed computational loneliness agent model with little tuning can serve as a core analytical engine for intelligent technologies such as robots to control and monitor the adverse effects of loneliness.

1 Introduction

Loneliness has become an emerging public health issue that has grabbed the attention of research recently and one of the main issues that the World Health Organization (WHO) is constantly emphasizing because of growing concerns [1], [2] that loneliness is a negative psychological factor that negatively affects individuals and their quality of life and carries a lot of health risks [3]. Given loneliness, it is not a fixed trait, but rather it is exacerbated or mitigated through social interactions [4]. If left unattended, it will severely affect cognition, emotion, behavior, and health [5]. The importance of this issue, especially at older ages, is exacerbated by their inability to primarily access their supportive resources and use social interactions appropriately as in the past [6– 8]. Loneliness occurs more frequently in old age and is an increasing challenge for older adults [9]. Community studies have reported that rates of severe loneliness among adults aged 65 and over range from 2% to 16%, while at any time feeling up to Also in a 2020 report from the National Study on Trends in Health and Aging, before the coronavirus outbreak, researchers found that 24% of adults living in the community aged 65 years or older in the United States (about

https://doi.org/10.57026/wsjet.v1i1.2
Received 13 September 2024; Received in revised form 25 December 2024; Accepted 26 December 2024; Available online 1 January 2025

7.7 million people) were socially isolated. 4% (1.3 million people) suffer from severe social isolation [10]. Moreover, during the phase of the COVID-19 pandemic, quarantine measures, social distancing, cancellation of community activities and other welfare issues have led to increased levels of social isolation and loneliness [11].

Loneliness is a painful personal feeling with negative connotations accompanying the perception that one's social needs are not being met by the quantity or quality of social relationships. Thus, loneliness is not related to social isolation and a limited number of means of communication, but also represents the perception that these relationships are not satisfying enough [1]. individuals may feel lonely while sur-rounded by others, or they may be excellent on their own, so the experience of loneliness for all A person will be different [4]. That is, it is a subjective state of the individual, it may be actual or imagined, and it must be dealt with psychologically because negative psychological changes affect individuals [1]. The feeling of loneliness in the elderly results from a state of mind as a result of thinking about the fear of death, forgetfulness, disability, or exposure to diseases that prevent them from leading their lives in the usual way [7], [8], [12].

Loneliness has a significant impact on overall health, with poor social attachment found to be associated with a 29% increased risk of coronary heart disease and a 32% increased risk of stroke [7], [13]. In the Netherlands, 30 to 45% of the adult population feels lonely [12]. Compared to 50% in Australia [14]. The risk of loneliness is equivalent to smoking 15 cigarettes a day. Not only that, but it also exceeds the health risks associated with obesity [15]. Loneliness has been linked to poor day-time performance, decreased physical activity, subjective personality, and poor mental performance in older adults [5]. It is also linked to depression, which, over time, may lead to health-related biological changes [5]. Research also indicates its association with increased rates of suicide, depression, functional decline, and, subsequently, a higher mortality rate [14]. One can conclude that loneliness is a critical negative factor that seriously affects people's lives. Therefore, there must be an urgent need to investigate its impact under discussion and find easy solutions to develop appropriate ways to help intelligently monitor and control its effects on people. This is done through digital technology interventions, especially the use of the Internet, to reduce loneliness in the elderly, but bearing in mind that it is not considered an addictive method that leads to loneliness [16–18]. But the individuality of the experience of loneliness and isolation makes it difficult to provide standard interventions. There is no one-size-fits-all approach. It is necessary to communicate personally with the person and communicate his feelings, and it should serve as a pathway between the single individual and the appropriate intervention through the formation of a mechanism or application or perhaps a robot suitable for this purpose.

The importance of the research lies in achieving this goal. Therefore, a cognitive factor model (computational model) for loneliness must be designed using the psychological and mental factors of the loneliness with their relationships. Depending on the fact that this type of model has been widely used recently to control psychological phenomena such as burnout [19] and the cognitive load of intense reading [20]. and the stress reaction during stressful events [21]. The idea is to develop such a model to help reduce in depth through visual illustrations of loneliness dynamics and how causal factors are linked together. This understanding can be used as a thinking engine for smart applications such as virtual agents or a bot capable of performing human-like thinking. Where lonely people can receive appropriate support and competent assistance. Hence, this research work aims to develop a cognitive agent model of loneliness using differential equations based on a directed lattice approach [22], where the agent model analyzes the influence of a group of factors and leads to creating a first step towards eliminating loneliness suffering for individuals by using it as an intervention tool. Therefore, this study used a network modelling technique based on a temporal causal network approach. She focused on understanding the main causes that may be the basis of loneliness. The above reasons are sufficient to justify the reasoning for the modelling approach and its implementation to develop a cognitive factor model of loneliness.

2 Underlying Concepts in Loneliness

Loneliness has many definitions, one of which describes it as a painful feeling that accompanies the realization that the social needs of the individual are not being adequately met [5]. On the other hand, loneliness is generally understood as the discrepancy between a person's preferred level of social communication and their actual level of social communication. Whereas the latter is an objective state of having minimal social contact with other individuals, so being alone is not necessarily indicative of loneliness, as many people live alone and report frequent social contact and have active social engagements.

Because the experience of loneliness is so subjective, psychologists generally con-sider loneliness to be a fixed trait. Everyone has different assignment points for the unit, and each individual fluctuates around these points

according to his life circumstances. Individuals' levels of loneliness usually remain relatively constant during adulthood. Until the age of 75 to 80 years, this condition increases and leads to long-term loneliness which increases people's risk of physical illness and shorter life span [23]. Loneliness has been linked to increased brain deposits of beta-amyloid, a biomarker of Alzheimer's disease in older adults. Loneliness is also defined as a perception of social and emotional isolation. Because lonely individuals view the social world as threatening and actual, they expect more negative social interactions. This causes a person to have more stress, pessimism, anxiety and low self-esteem. [5]. In addition, loneliness has harmful effects on mental and physical health and social well-being. In addition to mental illness, depression, cognitive impairment, dementia, Alzheimer's disease, and even premature death, it also negatively affects physical performance, poor sleep quality, lowers body immunity, and increases the risk of many diseases [24]. It found that people who are socially isolated and lonely often suffer from the worst quality of life. As a result of the many risks of loneliness, the problem of loneliness may become similar to an epidemic unless sufficient attention is paid to the prevention and mitigation of its effects and risks.

Individuals' feelings of loneliness may be either episodic (short-term loneliness) or chronic (long-term loneliness), depending on each individual's circumstances and perceptions [7]. Some studies have found that chronic loneliness (long-term loneliness) is closely related to the incidence of many diseases and their impact on health, as it was found to cause a 29% increase in coronary heart disease and a 32% in-crease in the risk of stroke [25].

To determine the mechanism of loneliness and try to reach a specific solution to eliminate it, a lot of previous literature reviews and theories are used, which is based on the concept of loneliness, which discussed how to find theoretical ways to explain the feeling of loneliness through the presence of several factors that affect loneliness in individuals in terms of reducing or exacerbating it. As a result, the unit was determined through several factors related to and affecting it, as follows:

One of the theories studied how personality is related to the risk of loneliness in women and men, and they found that neurotic personality is significantly associated with an increased risk of loneliness [26]. The role of social skills in loneliness has also been demonstrated. As low social skills increase loneliness and thus increase the risk of depression [27]. In another theory, loneliness has been closely related to implicit hypervigilance towards social threats as increased social threats increase loneliness [28]. On the other hand, models and research have found that positively affects significantly predict a decrease in loneliness [29]. While other research has linked social isolation and loneliness to negative effects on various physical and mental conditions resulting from high blood pressure, heart disease, even obesity and weak immune system, in addition to the negative effects of various life conditions [30]. While adaptive coping strategies are considered a very important factor in confronting and reducing loneliness, as they act as a preventive factor used to reduce the harmful effects of life stresses when they occur (such as loneliness) [31]. In contrast, maladaptive coping strategies prevent a person's ability to adapt to the conditions they are exposed to, which may be difficult [32].

Perceived social isolation, it has a significant and detrimental effect on health and wellbeing. Increasing it increases loneliness. However, one can live with others and still experience perceived social isolation [33]. Whereas the extent to which a person believes he has control over the outcome of an event is called perceived control [34]. Studies have shown that observed control is significantly associated with life satisfaction and well-being, and consequently, loneliness level control [35]. On the other hand, the perceived discrepancy explains why some people remain alone for long periods without feeling lonely, while others can feel lonely even when others are around [36]. As for self-efficacy, it is considered a very important factor, because it is defined as the belief in the individual's abilities to organize and implement the work steps required to manage the situations and circumstances that he may be exposed to, for example, loneliness, as the individual's possession of high self-efficacy can reduce the possibility of being exposed to loneliness [37].

As for cognitive ability, it is a very important factor that can be defined as a general mental ability that includes thinking, solving problems and difficulties, where maintaining satisfactory cognitive performance is an essential part of maintaining mental health from aging resulting from loneliness and reducing cognitive ability from loneliness and its effects [38]. While many studies have been conducted to investigate the relationship between loneliness and quality of life, because improving the quality of life for individuals is one of the central and fundamental issues that the World Health Organization constantly emphasizes that improving the quality of life of individuals would reduce negative conditions and loneliness [6–8]. On the other hand, the existence of the desired social needs, which are considered basic human needs, are important for each individual, and when they

are not met and provided to him, there are many risks, including causing mental and physical health problems. Accordingly, meeting social needs is very important to maintain well-being and quality of life [39]. While the Coping, which is described as the ability to deal with difficult situations, is an important factor in reducing loneliness. In addition to the coping skills that are used to achieve this [40]. As for actual social contact, it refers to the different ways in which individuals help other people. It plays an important and positive role in the health and well-being of individuals [41]. On the other hand, the term "positive influence" refers to an individual's tendency to experience positive emotions and interact with others and life challenges in a positive way and thus the ability to resist loneliness [42, 43].

While Precipitating events create a mismatch between a person's actual social relationships and his or her social needs or desires, changing one of these two factors without corresponding change in the other can lead to loneliness [44]. All these factors effect on the quality of life, which explain how loneliness occurs and why it is at different levels for individuals. Table 1 provides an overview of the formalized concepts and their meaning.

Table 1 Nomenclatures of Related Concepts.

No.	Concepts	Formalization
1	Precipitating event	*Pe*
2	Actual Social contact	*As*
3	Self-efficacy	*Se*
4	Personality	*Pr*
5	Cognitive ability	*Ca*
6	Desired social need	*Dc*
7	Perceived	*Pd* discrepancy
8	Perceived isolation	*Pi*
9	Social skills	*Ss*
10	Perceived control	*Pc*
11	Social threat	*St*
12	Adaptive coping	*Ac* strategies
13	Maladaptive coping	*Mc* strategies
14	Coping skills	*Cs* 15
15	Negative affects	*Na*
16	Short-term loneliness	*Stl*
17	Long term loneliness	*Ltl*
18	Precipitating event	*Pe*

3 Computational agent model

Depending on the fact that loneliness is a state of mind resulting from a psychological phenomenon. Research in psychology aims to know and explain the theoretical structure of behavior and thought. and that most human psychological processes are so complex that they can only be understood based on the observation of behavior. Since the functioning of the human brain is complex and has a significant impact on behavioral flexibility, computer modeling is the most convenient way to explain processes and their interactions. Computational modeling is used because of its ability to increase the level of detail of a process and increase the volume of input and output interactions.

Computational models are used as experimental tools to investigate human behavior and cognitive functions such as attention, learning, decision making, etc. The results of the simulations are used to demonstrate that the models explain the cogn1itive mechanisms of the desired domain. In psychology, cognitive modeling is a useful method

for studying the human mind. Cognitive modeling has been described as: “Cognitive modeling is a method of studying the human mind. It is used to explain the structure and processes of the human mind. Cognitive modeling is therefore de-scribed as “artificial psychology.” Cognitive modelers attempt to understand how human memory works, how it is organized to reflect reality, and how it is used to regulate behavior. Cognitive modeling has extended beyond cognition to various psychological processes that include social and emotional factors.

From these grounds, this study uses a computational modeling approach to model the cognitive process of loneliness.

4 Conceptual Model

The first step to development the cognitive agent model is achieved by designing based on the network-oriented modelling approach. As the concepts of loneliness discussed in section 2. Fig.1. shows different components of the model. These com-ponents are grouped into two categories, External factors (the precipitating event, actual social contact, self-efficacy, personality, cognitive ability) that have a relationship with other internal factors and consequently access to loneliness (short-term loneliness, long-term loneliness) and impact on quality of life. the figure shows two types of nodes: the white nodes represent different model states while dark nodes represent the accumulative effects of the model’s conditions.

4.1 Formalization

This stage involves formulating the loneliness related factors into formal representations, and characteristics to produce an executable model show in Fig.1. relying on the agent-based modelling method, formal models are increasingly used to study social dynamics. Agent-based modelling has become one of the most successful techniques due to its flexibility in exploring human interaction that is considered complex [45]. The agent-based modelling method has been adopted in many previous studies and literature, with effective results [19], [21]. This method often deals with individual behavior, so it is used with loneliness because

loneliness is individual behaviour that varies from person to person [46]. In the formalization, all nods are linked to have arrange of value between 0 (low) and 1 (high). The new value of states results based on the interaction between these factors through time was selected. All identified factors are formalized are presented in Table 1. It will include mathematical specifications (Differential Equations) for creating executable mathematical equations from factors (It will be shown in the next section). The formal model will be the result of this stage to represent the relationship between the various factors of the module in the interaction of an application on a smartphone using messaging or a robot.

4.2 Formalization the internal factors

In this section, the cognitive factor model of loneliness will be designed by under-standing the relationships that were studied in section 3 and representing them with differential equations, where the graphic design will later turn into a numerical representation ready for simulation and mathematical analysis.

In this formal model, the impact of internal factors on loneliness and quality of life change will be calculated and then formalized on the graphs.

The effect of adaptive coping strategies calculated based on the interaction between (St) and (Pi) negatively affect it and that the (Pc) has a positive effect, as for the perceived isolation, it is based on the interaction between (Ss, As, Ca, Cs) with (Pd). Maladaptive coping strategies derive their effectiveness from the effect of (Pi, St) with the opposite effect of (Pc). (Ss) is a positively influential factor on the level of perceived control. In contrast, both (Pd, Pi) are considered inappropriate negative factors.

$$\mathrm{AC}(t) = (1 - (\varphi_{\mathrm{Ac}}.\mathrm{St}(t) + (1 - \varphi_{\mathrm{Ac}}).\mathrm{Pi}(t))).\ (\mathrm{Pc}(t)) \quad (1)$$

$$\mathrm{Pi}(t) = (1 - (\varphi_{\mathrm{Pi}}.\ \mathrm{ca}(t) + \varphi_{\mathrm{Pi}}.\mathrm{As}(t) + \varphi_{\mathrm{Pi}}.\ \mathrm{Cs}(t-1) + \varphi_{\mathrm{Pi}}.\mathrm{Ss}(t))).\mathrm{Pd}(t) \quad (2)$$

$$Mc(t) = (1 - Pc(t)).\ (\beta Mc.\ Pi(t) + (1 - \beta Mc).\ St(t)) \quad (3)$$

$$Pc(t) = (1 - (\varphi\_Pc.\ Pi(t) + (1 - \varphi\_Pc).\ Pd(t))).\ (Ss(t)) \quad (4)$$

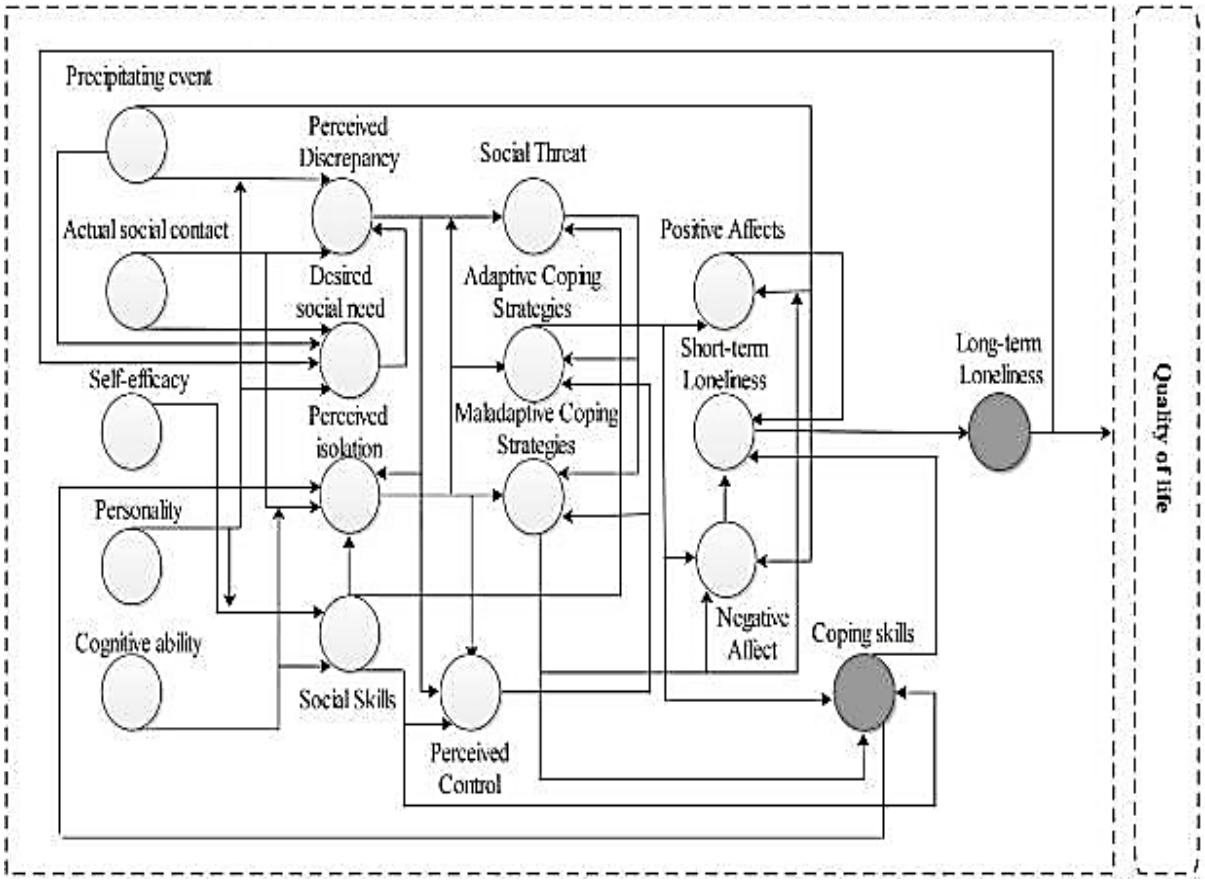

Figure 1 **Cognitive agent model of loneliness**

(Pd, Pi) increasing them increases the feeling of social threat, while (Ss) it is considered to have the opposite effect. As for (Ca, Pr, Se) all of them are directly related to social skill and work to increase it. In the positive affect (Mc, Pe) they have the opposite effect on it, and the opposite effect of (AC). (Ac) forms an inverse relationship with the negative affect, while (Mc, Pe) are suitable for the occurrence of the negative affect. A decrease in (Cs and Pa) leads to an increase in loneliness in the short term and vice versa for (Na)

$$St(t) = (\omega\_St.\, Pd(t) + (1 - \omega\_St).\, Pi(t)).\, (1 - (Ss(t)) \quad (5)$$

$$Ss(t) = (\gamma\_Ss1.\, Ca(t) + \gamma\_Ss2.\, Pr(t) + \gamma\_Ss3.\, Se(t)) \quad (6)$$

$$Pa(t) = (1 - (\beta\_Pa.\, Mc(t) + (1 - \beta\_Pa).\, Pe(t))).\, (Ac(t)) \quad (7)$$

$$Na(t) = (1 - Ac(t)).\, (\alpha\_Na.\, Mc(t) + (1 - \alpha\_Na).\, Pe(t)) \quad (8)$$

$$Stl(t) = (1 - (\mu\_Stl\; Cs(t-1) + (1 - \mu\_Stl).\, Pa(t)).\, (Na(t)) \quad (9)$$

Having factors (As, Pr) with (Pe, Ds) together we get in proportion to the perceived discrepancy. We note in desired social need that (As,Pr) have an inverse relationship with (Ds) due to other factors (pe, Ltl) that have less influence on (Ds), that is, they have a direct relationship. In coping skills, results from (Ss, AC)). The effect that increases the incidence of coping skills, unlike (Mc) in terms of the effect is less. Stl is used to control the rate of change of loneliness in the long term.

$$Pd(t) = (1 - (\tau\_Pd1.\, As(t) + (1 - \tau\_Pd1).\, Pr(t))).\, (\tau\_Pd2.\, Pe(t) + (1 - \tau\_Pd2)\, .\, Ds(t)) \quad (10)$$

$$Ds(t) = (1 - (\tau\_Ds1.\, As(t) + (1 - \tau\_Ds1).\, Pr(t))).\, (\tau\_Ds2.\, Pe(t) + (1 - \tau\_Ds2).\, Ltl(t-1)) \quad (11)$$

$$Cs(t + \delta t) = Cs(t-1) + (((\sigma\_Cs.\, Ss(t) + (1 - \sigma\_Cs).\, Ac(t)).\, (1 - Mc(t))) - Cs(t-1)).\; Cs(t-1).\, (1 - Cs(t-1).\, \delta t \quad (12)$$

$$Ltl(t + \delta t) = Ltl(t-1) + \mu\_Ltl.\, (Stl(t) - Ltl(t-1)).\, (1 - Ltl(t-1)).\, (Ltl(t-1)).\, \delta t \quad (13)$$

5 Simulation Results

Based on the identified factors that have been formalized in the previous step In this section, will be used in an executable environment (MATLAB) to be simulated. Then some results of simulation of loneliness are discussed (Fig.2., Fig.3., Fig.4.), for the settings of the base and multiple factors that generate more variables for loneliness behaviors. These factors are in and of themselves deterministic meaning that every time a simulation is run with specific settings, the result will be the same. It should be noted that exogenous factors customer perceptions of loneliness are consistent in simulations. However, the rest of the concepts for each factor and group concepts are dynamic. For each time step, the time values are updated with current visualizations for that relevant point in time. Indirectly, the past is presented at each point in time, since the updating mechanism occurs dynamically. For example, the value of social threat or perceived control of the previous time step is partially considered at the next point in time. This process is repeated at each time step (scenario duration 500 time points), making the prior perception of the factor indirectly present in the current perception. In addition, these simulations used the following parameter settings: maxLimY = 1.2, minLimX = 0, Delta(t) = 0.3, numStep=500. and parameters for weightage the equation (β ,α,φ_(Ac ,Pc) , ω , μ_stl)=0.5, (γ ,τ_Pd2,τ_Ds1)=0.3, (τ_Pd1,τ_Ds2)=0.7, (μLtl , $\sigma \varphi Pi$) = 0.9, 0.8 ,0.25.

The following initial settings have been selected for three real individuals/agents. They represent three different basic levels, namely: little lonely (Agent #1), intense loneliness (Agent #2) and (Agent #3) almost average.

Table 2 Base or External Factor

Concept \ Agent	1	2	3
Precipitating event	0.1	1	0.9
Actual social contact	0.6	0.1	0.1
Self-efficacy	0.8	0.2	0.4
Personality	0.8	0.1	0.7
Cognitive ability	0.9	0.4	0.2

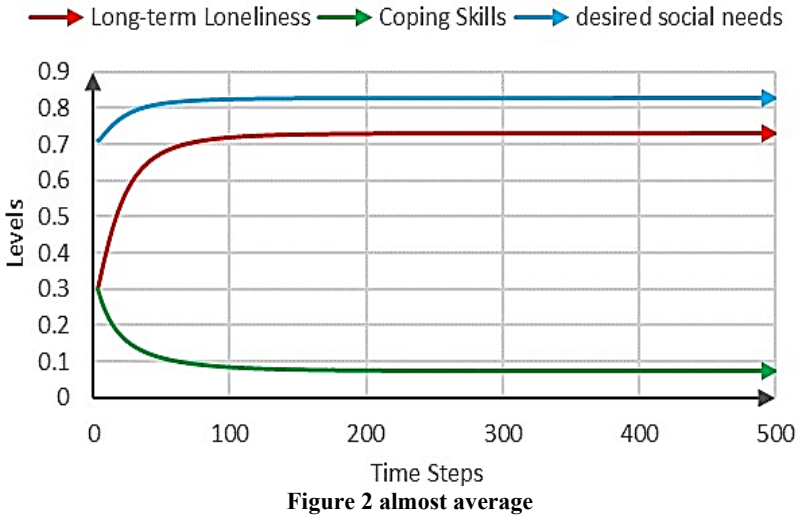

Figure 2 almost average

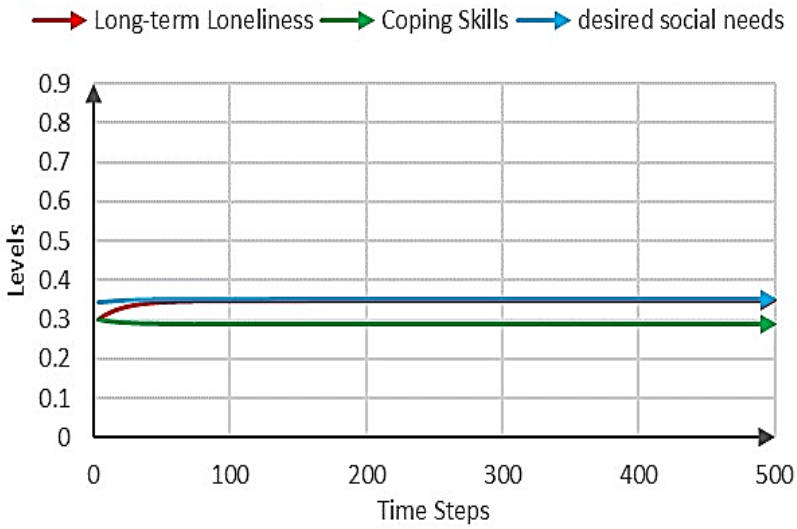

Figure 3 intense loneliness

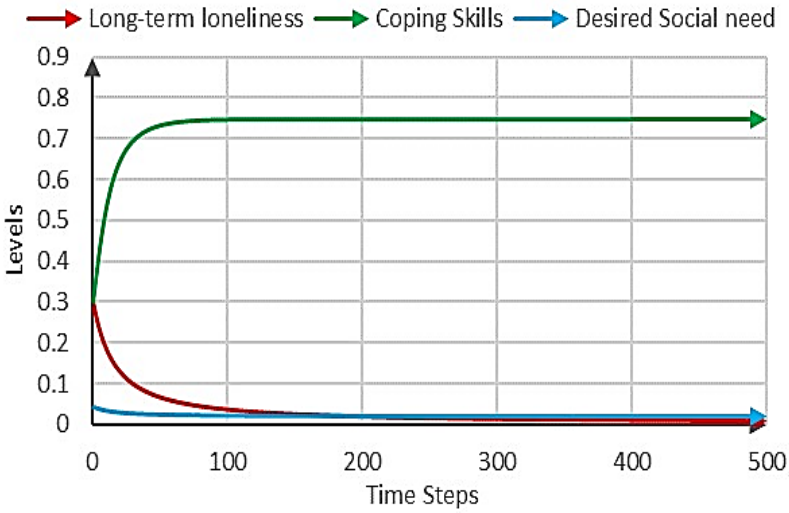

Figure 4 little lonely

The figures illustrates the internal validity process of the cognitive agent model of loneliness. the model can be verified to ensure its results are indeed adhering to psychological and cognitive literature. To attain this, a temporal trace language (TTL) has been developed to check whether the model behaves as it should be or not by running several simulations and verifying them against the patterns available in the literature and previous empirical studies [47]. The importance of TTL resides in its supports for the specification of both qualitative and quantitative aspects and subsumes specification languages based on differential equations. It allows explicit reference to time points and time durations, which enables the modelling of the dynamics of continuous real-time phenomena. This dedicated language is built on atoms state (γ, t) |= p, meaning that state property P holds in trace γ (simulation points of states over time). Using this concept, many simulation traces including the one shown in section 4 are used to be verified against the identified patterns from the literature, and the results were confirmed.

P1: long term loneliness is high when maladaptive coping is high.

For all time points t1 and t2 in trace γ,

If at time point t1 the level of Ltl is s1,
and at time point t2 the level of Ltl is s2,
and at time point t1 the level of Ma is b1,
and at time point t2 the level of Ma is b2,
and s2>=s1, and t1<=t2, then b2>=b1

∀γ: TRACE, ∀t1, t2: TIME, ∀s1, s2, b1, b2: REAL state (γ, t1) |= has_value (short_term_loneliness, s1) & state (γ, t2) |= has_value (short_term_loneliness, s2) & state (γ, t1) |= has_value (long_term_loneliness, b1) & state (γ, t2) |= has_value (long_term_loneliness, b2) & s2 > = s1 & b2 >= b1 & t2 >= t1 ⇒ b2≥ b.

After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your journal for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper.

6 Conclusion

Loneliness is a serious concept to be controlled or monitor via various possible technologies. A network-oriented approach was used to design a cognitive agent model to serve as an analytical tool for a companion robot that tackle the negative ramifications of loneliness. The designed model was mathematically constructed using differential equations. The mathematical model was also simulated, and the simulation patterns shown a realistic behavior that represents the real behaviour of dynamics of loneliness. The future work of this work is to tune the designed model to serve as an engine for the designing of a companion robot.

7 References

[1] B. d'Hombres, M. Barjaková, and S. V. Schnepf, "Loneliness and Social Isolation: An Unequally Shared Burden in Europe," *SSRN Electron. J.*, 2021, doi:10.2139/ssrn.3823612.

[2] S. G. S. Shah, "Background: Loneliness is an emerging public health issue and its burden is increasing in developed countries. Loneliness is associated with social, emotional, physical and mental health issues. Tackling," vol. 29, p. 2019, 2019.

[3] P. CM, S. C. I, C. KE, C. M. Perissinotto, I. Stijacic Cenzer, and K. E. Covinsky, "Loneliness in Older Persons: A Predictor of Functional Decline and Death," *Arch. Intern. Med.*, vol. 172, no. 14, pp. 1078–1084, Jul. 2012, doi: 10.1001/ARCHINTERNMED.2012.1993.

[4] C. M. Masi, H.-Y. Y. Chen, L. C. Hawkley, and J. T. Cacioppo, "A Meta-Analysis of Interventions to Reduce Loneliness," *Personal. Soc. Psychol. Rev.*, vol. 15, no. 3, pp. 219–266, Aug. 2011, doi: 10.1177/1088868310377394.

[5] L. C. Hawkley and J. T. Cacioppo, "Loneliness Matters: A Theoretical and Empirical Review of Consequences and Mechanisms," *Ann. Behav. Med.*, vol. 40, no. 2, pp. 218–227, Oct. 2010, doi: 10.1007/s12160-010-9210-8.

[6] B. Fees, P. Martin, L. P.-T. J. of Gerontology, and U. 1999, "A model of loneliness in older adults," *academic.oup.com*, Accessed: Oct. 29, 2021. [Online]. Available: https://academic.oup.com/psychsocgerontol ogy/article-abstract/54B/4/P231/693063.

[7] *Social Isolation and Loneliness in Older Adults*. Washington, D.C.: National Academies Press, 2020.

[8] H. Arslantaş, F. Adana, F. Abacigİl ErgİN, D. Kayar, and G. Acar, "Loneliness in Elderly People, Associated Factors and Its Correlation with Quality of Life: A Field Study from Western Turkey," *Iran. J. Public Health*, vol. 44, no. 1, p. 43, 2015, Accessed: Mar. 09, 2022. [Online]. Available: /pmc/articles/PMC4450013/.

[9] Singh and N. Misra, "Loneliness, depression and sociability in old age," *Ind. Psychiatry J.*, vol. 18, no. 1, pp. 51–55, Jan. 2009, doi: 10.4103/0972-6748.57861.

[10] T. K. M. Cudjoe, D. L. Roth, S. L. Szanton, J. L. Wolff, C. M. Boyd, and R. J. Thorpe, "The Epidemiology of Social Isolation: National Health and Aging Trends Study," *Journals Gerontol. - Ser. B Psychol. Sci. Soc. Sci.*, vol. 75, no. 1, pp. 107–113, Jan. 2020, doi: 10.1093/GERONB/GBY037.

[11] N. J. Donovan and D. Blazer, "Social Isolation and Loneliness in Older Adults: Review and Commentary of a National Academies Report," *Am. J. Geriatr. Psychiatry*, vol. 28, no. 12, pp. 1233–1244, Dec. 2020, doi: 10.1016/j.jagp.2020.08.005.

[12] E. Schoenmakers, "WHY AND HOW TO TALK ABOUT LONELINESS," *J. Soc. Interv. Theory Pract.*, vol. 29, no. 4, p. 4, Jul. 2020, doi: 10.18352/JSI.646.

[13] N. K. Valtorta, M. Kanaan, S. Gilbody, S. Ronzi, and B. Hanratty, "Loneliness and social isolation as risk factors for coronary heart disease and stroke: systematic review and meta-analysis of longitudinal

observational studies," *Heart*, vol. 102, no. 13, pp. 1009–1016, Jul. 2016, doi: 10.1136/HEARTJNL-2015-308790.

[14] V. E. Etk, L. Faktörler, and D. E. E. R. Lmes, "Assessment of Loneliness, Quality of," vol. 15, no. 1, pp. 81–88, 2012.

[15] J. Holt-Lunstad, "The Potential Public Health Relevance of Social Isolation and Loneliness: Prevalence, Epidemiology, and Risk Factors," *Public Policy Aging Rep.*, vol. 27, no. 4, pp. 127–130, 2017, doi: 10.1093/ppar/prx030.

[16] C. Wilson, "Is it love or loneliness? Exploring the impact of everyday digital technology use on the wellbeing of older adults," *Ageing Soc.*, vol. 38, no. 7, pp. 1307–1331, Jul. 2018, doi: 0.1017/S0144686X16001537.

[17] W. J. Chopik, "The Benefits of Social Technology Use Among Older Adults Are Mediated by Reduced Loneliness," vol. 19, no. 9, pp. 551–556, Sep. 2016, Accessed: Mar. 10, 2022. [Online]. Available: https://www.liebertpub.com/doi/abs/10.108 9/cyber.2016.0151.

[18] S. Sum, R. Mathews, … I. H.-C. &, and U. 2008, "Internet use and loneliness in older adults," *liebertpub.com*, Accessed: Oct. 29, 2021. https://www.liebertpub.com/doi/abs/10.108 9/cpb.2007.0010.

[19] H. M. A. Ghanimi, "A Cognitive Agent Model of Burnout for Front-line Healthcare Professionals in Times of COVID-19 Pandemic," *Int. J. Intell. Eng. Syst.*, vol. 15, no. 2, pp. 348–360, 2022, doi: 10.22266/ijies2022.0430.32.

[20] H. Moham med and A. L. I. Ali, "AN AMBIENT AGENT MODEL FOR READING COMPANION ROBOT DOCTOR OF PHILOSOPHY Permission to Use," 2019.

[21] H. Mohammed, A. A. Aziz, N. ChePa, A. H. M. Shabli, J. A. Abu Bakar, and A. Alwi, "A computational agent model for stress reaction in natural disaster victims," *Lect. Notes Electr. Eng.*, vol. 376, pp. 817–827, 2016, doi: 10.1007/978-981-10-0557-2_78.

[22] S. Interactions, *Network-Oriented Modeling*.

[23] L. Hawkley, J. Luebering, and E. Rodriguez, "Loneliness | psychology | Britannica," *Encyclopedia Britannica*, 2018. https://www.britannica.com/science/lonelin ess (accessed Mar. 18, 2022).

[24] S. Söderlund, "Kirjallisuuskatsaus: Iäkkäiden yksinäisyys ja ryhmätoiminta sen lieventäjänä," 2017.

[25] M. Dan Brennan, "Chronic Loneliness: Effects on Mental Health and Ways to Treat It." https://www.webmd.com/mentalhealth/what-to-know-about-chronicloneliness (accessed Mar. 19, 2022).

[26] H. Ormstad, G. Eilertsen, T. Heir, and L. Sandvik, "Personality traits and the risk of becoming lonely in old age: A 5-year follow-up study," *Health Qual. Life Outcomes*, vol. 18, no. 1, pp. 1–5, 2020, doi: 10.1186/s12955-020-01303-5.

[27] Fauziyyah and S. Ampuni, "Depression Tendencies, Social Skills, and Loneliness among College Students in Yogyakarta," *J. Psikol.*, vol. 45, no. 2, p. 98, 2018, doi: 10.22146/jpsi.36324.

[28] S. Cacioppo, M. Bangee, S. Balogh, C. Cardenas-Iniguez, P. Qualter, and J. T. Cacioppo, "Loneliness and implicit attention to social threat: A highperformance electrical neuroimaging study," *Cogn. Neurosci.*, vol. 7, no. 1–4, pp.138–159, Oct. 2016, doi: 10.1080/17588928.2015.1070136.

[29] E. J. Davidson, C. T. Taylor, C. R. Ayers, N. E. Quach, X. M. Tu, and E. E. Lee, "The Relationship Between Loneliness and Positive Affect in Older Adults," *Am. J. Geriatr. Psychiatry*, 2021, doi: https://doi.org/10.1016/j.jagp.2021.11.002.

[30] National Institute of Aging, "Social isolation, loneliness in older people pose health risks | National Institute on Aging," *NIH*, 2019. https://www.nia.nih.gov/news/socialisolation-loneliness-older-people-posehealth-risks (accessed Mar. 19, 2022).

[31] Golemis *et al.*, "Young adults' coping strategies against loneliness during the COVID-19-related quarantine in Greece," 2021, doi: 10.1093/heapro/daab053.

[32] A. Pietrangelo, "Maladaptive Behavior: Causes, Connection to Anxiety, and Treatment," 2020. https://www.healthline.com/health/maladap tive-behavior#causes (accessed Mar. 19, 2022).

[33] R. Clair, M. Gordon, M. Kroon, and C. Reilly, "The effects of social isolation on well-being and life satisfaction during pandemic," *Humanit. Soc. Sci. Commun.*, vol. 8, no. 1, pp. 1–6, 2021, doi: 10.1057/s41599-021-00710-3.

[34] "Perceived Behavioral Control: Definition and Relation to Stress - Video & Lesson Transcript | Study.com." https://study.com/academy/lesson/perceive d-behavioral-control-definition-andrelation-to-stress.html (accessed Mar. 19, 2022).

[35] Y. Hong, L. Liu, L. Rongmao, and R. Lian, "The relationship between perceived control and life satisfaction in Chinese undergraduates: the mediating role of envy and moderating role of self-esteem," *Curr. Psychol.*, Jun. 2020, doi: 10.1007/s12144020-00863-5.

[36] D. Perlman, "European and Canadian Studies of Loneliness among Seniors," *Can. J. Aging / La Rev. Can. du Vieil.*, vol. 23, no. 2, pp. 181–188, 2004, doi: 10.1353/cja.2004.0025.

[37] K. Cherry, "Self-efficacy: Why believing in yourself matters," *Retrieved Febr.*, vol. 21, p. 2017, 2016, Accessed: Mar. 19, 2022. [Online]. Available: https://www.verywellmind.com/what-isself-efficacy-2795954.

[38] D. Ispas and W. C. Borman, "Personnel Selection, Psychology of," *Int. Encycl. Soc. Behav. Sci. Second Ed.*, pp. 936–940, 2015, doi: 10.1016/B978-0-08-097086-8.22014X.

[39] L. C. Mair , H. Zweiacher , S. Waldstein and A. B. Z. M. Evans, "University of Maryland, Baltimore County, Baltimore, Maryland, 2. National Institute on Aging, Baltimore, Maryland, 3. University of Maryland, Baltimore, Baltimore, Maryland," p. 2010, 2010.

[40] "Coping Skills | SkillsYouNeed." https://www.skillsyouneed.com/ps/copingskills.html (accessed Jun. 10, 2022).

[41] "Social Support -IResearchNet." http://psychology.iresearchnet.com/socialpsychology/interpersonalrelationships/social-support/ (accessed Jun. 10, 2022).

[42] B. L. Fredrickson, "The Role of Positive Emotions in Positive Psychology: The Broaden-and-Build Theory of Positive Emotions," *Am. Psychol.*, vol. 56, no. 3, p. 218, 2001, doi: 10.1037/0003-066X.56.3.218.

[43] E. L. Garland, B. Fredrickson, A. M. Kring, D. P. Johnson, P. S. Meyer, and D. L. Penn, "Upward Spirals of Positive Emotions Counter Downward Spirals of Negativity: Insights from the Broaden-and-Build Theory and Affective Neuroscience on The Treatment of Emotion Dysfunctions and Deficits in Psychopathology," *Clin. Psychol. Rev.*, vol. 30, no. 7, p. 849, Nov. 2010, doi: 10.1016/J.CPR.2010.03.002.

[44] S. Shibahara *et al.*, *Isolation and*, vol. 2, no. 5. 1983.

[45] Models and A. Modelling, "Agent-Based Models," 2022.

[46] O. A. Fakoya, N. K. McCorry, and M. Donnelly, "Loneliness and social isolation interventions for older adults: A scoping review of reviews," *BMC Public Health*, vol. 20, no. 1, pp. 1–14, Feb. 2020, doi: 10.1186/s12889-020-8251-6.

[47] L. Dahlberg, K. J. McKee, A. Frank, and M. Naseer, "A systematic review of longitudinal risk factors for loneliness in older adults," *Aging Ment. Heal.*, vol. 26, no. 2, pp. 225–249, 2022, doi: 10.1080/13607863.2021.1876638.