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An Agent-Based Model for Situational Awareness at Workplace

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Abstract: Self-awareness emotional intelligence symptoms will be unavoidable in the job. These symptoms are generally regarded as acceptable by certain standards, as they are an important part of keeping people informed (or commonly known as situational awareness). However, the most recent research focuses on external components of situational awareness aspects and lacks adaptable methods to deal with the individual's situational awareness dynamics. This study investigated the use of an agent-based modeling strategy for situational awareness in the workplace. It focuses on environmental and personal factors that influence the level of situational awareness at work in a dynamic way. The outcomes included a range of scenarios that corresponded to various personality traits and environmental conditions. Finally, equilibria analysis and automated logical verification were employed to evaluate this computational model in order to check whether there were any conceptual defects, as indicated in the literature. The suggested computational agent-based model has shown rational behavior patterns that are consistent with existing psychology literature on situational awareness in the workplace.

Keywords: Agent-based modelling, Dynamical model, Situational awareness at workplace, Situational awareness.

1. Introduction

Work is ingrained in most people's life, since the majority of today's generation spends the majority of their waking hours at work. Their workplaces become their most important community, to the point of replacing their own family, friend circles, and social clubs. As a result, companies must recognize that employees are more than simply a cost to the company; they have souls, goals, and a need to feel good about their work. If employees are considered as individuals with sensitivities that must be respected and who must co-exist as mutual entities, the workplace must be as humane as conceivable [1]. For example, employees' health problems, stress, burnout, depression, and lower job satisfaction have all been linked to workplace bullying [2].

In organizational psychology, emotional intelligence (EI) is a fundamental concept. EI predicts crucial workplace outcomes [3]. EI has been identified as a valuable personal advantage in negotiating social situations. Advocates emphasize EI's positive benefits on work performance to encourage businesses to integrate it in their hiring and training programs [4].

EI has also been considered in connection to self-awareness. When we consider the feature of self-awareness, we can see that it is defined by a diversity of viewpoints and thinking [5]. For instance, individuals who have increased self-awareness have taken the first step in exploring their own ideas and behaviors, and as a result, they may uncover difficulties that they need to address, for example, by speaking with their own mentor. Self-awareness can be categorized as either an intrapersonal or an interpersonal component [5]. The intrapersonal aspect is concerned with one's own resources and internal state of mind (such as self-confidence [5]), whereas the interpersonal aspect is concerned with one's effect on others (such as situational awareness [6, 7]).

The definition of situational awareness is the ability to detect the elements in the environment within a given volume of time and space, comprehend their meaning, and project their state in the near future [6, 7]. The level of situational awareness factors that are linked with risks at the workplace could indicate a communal cause of undesirable self-awareness emotional intelligence symptoms such as focused awareness, high alertness, or tuned-out while needed self-awareness emotional intelligence symptoms such as relaxed awareness [8, 9].

A study contributed to the evaluation of air traffic control officers' work environments by determining if exploring methodologies for evaluating situation awareness can be used in tower control operations, and analyzing the implications of increased job load on control strategy [10]. When investigating the boundary conditions of the impacts of EI on situational awareness and, as a result, on safety performance, one study focused explicitly on training (in)adequacy. Furthermore, they were concerned with the boundary condition, focusing solely on the interaction impact of the training-related environment, EI, and situational awareness as a single conditional variable [11, 12]. Study research is to find interactions between the most significant person, situational, and organizational elements that influence situation awareness in industrial workplaces. In their analysis, they focused at the cause-effect correlations of only fifteen relevant factors [13]. A research looked at the impact of a few variables (such as fatigue, and sleeping) on safety performance, as well as the role of situation awareness as a mediating factor [14]. However, these research are necessary to explain the non-dynamic degree of situational awareness elements in emergency scenarios where the observable worker behavior/thoughts are invisible. Furthermore, current research mainly addresses external components of situational awareness factors and lacks adaptable mechanisms to deal with the dynamics of the individual's situational awareness.

The used dynamic agent-based computational model is a kind of network oriented modelling that provides a conceptual tool for modeling complicated processes in an organized, intuitive, and simple visualizable way, although the technique discussed here also incorporates the processes' dynamics. Furthermore, by including a temporal dimension, a dynamic perspective can be included [15-17]. However, one of the key perspectives is modeling using networks of temporal–causal interactions called the temporal–causal network modeling approach. The use of this approach makes it simple to incorporate theories and facts from any scientific discipline regarding the dynamics of processes [16-18]. This kind of modelling is still extremely active. For example, The developed cognitive agent model might be useful in the development of a covid-19-aware analytics software agent that can evaluate the mental health of healthcare providers [19].

This paper deals with the mentioned issue by utilizing the dynamic agent-based computational model, main theories of situational awareness level, and factors/barriers that affect the situational awareness of workers. The purpose of this research is to investigate the emergency phenomena of collective worker behavioral processes, which may then be used to predict employees' level situational awareness at work. In the following section, the basic psychological ideas of situational awareness and identifies its primary variables as well as their interplay are explained. In section 3, the context of temporal-causal dynamics of level situational awareness at work is represented using an agent-based computational model. The suggested agent-based mode's simulation and assessment findings are detailed in sections 4 and 5. Finally, the paper's conclusion appears in section 6.

2. Underlying concepts in situational awareness

The workplace aspects are described in terms of the characteristics that must be present in order for a workplace to be mentally healthy. Poor situational awareness was determined to be the primary cause of over 200 aircraft workplace accidents in one study [6, 20]. Control measures based on erroneous situational knowledge might significantly exacerbate an already terrible situation. In other words, identifying characteristics of the workplace that are known to have an influence on employees' psychological reactions to their jobs and working situations. Furthermore, everyone should be aware of their surroundings and any hazards. Each person must think about his or her personal safety as well as the safety of their co-workers[1]. The level of situational awareness elements associated to workplace dangers might suggest a community source of undesired self-awareness emotional intelligence symptoms [5]. Fig. 1 depicts these levels of situational awareness [8, 9].

Tuned-out (white), unaware of the situation and unprepared to deal with it. relaxed awareness (yellow), there is not any special danger. "It is possible that I will have to defend myself today." you believe. You are just aware that the world may be a

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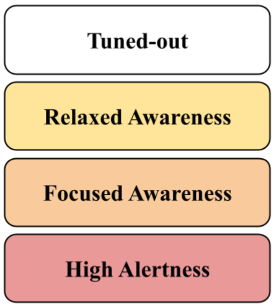

Figure. 1 Cooper's color code of situational awareness

violent place, and you're prepared to defend yourself if necessary. Focused awareness (orange), something is off, and it has piqued your interest. There is a specific warning on your radar. You refocus your attention to see whether there is a danger. The color red signifies a high degree of mental alertness.

The second major underpinning theory is Csikszentmihalyi's flow model [22, 23] in which challenge and skill are replaced by factors. According to Csikszentmihalyi's flow model, low difficulty and high skill indicate factor relaxation. Workers' environmental resources and geographic information systems (complex adaptive systems) influence the tough environment they face, with a shortage of resources and high complex adaptive systems at work potentially increasing the difficulties they face [24, 25]. Experience and job control may have an impact on the workers' skills [26, 27]. The worker's relaxed state may be affected by high amounts of communication and information management at work [28] where workers' communication skills are influenced by their leader's leadership as well as cultural beliefs [29, 30]. During the work, information management is high due to two factors: leadership and environmental resources [31, 32].

Workers' high alertness and attention may result in heightened focused awareness, as well as the worker's complete immersion in complex adaptive systems [33-35]. Workers' information priorities and limited information resources impact their attentiveness at work. Furthermore, a worker's personality may influence his social focus [36, 37]. The person's alertness is affected by their attention and adrenaline rush, and their alertness may be increased by prior high alertness (directed alertness) [38, 39]. Workers' adrenaline rush is improved by strict deadlines and job demands, as well as a lack of communication and information management at work [40-42]. Time pressure among workers has a significant impact on workplace demands, including a lack of job control [43, 44]. Workers' job control is influenced by two factors: their experience and their personality, with the personality of the worker having a greater impact on job control than their experiences [43, 45].

The worker in a tuned-out situation may be entirely absorbed in complex adaptive systems (such as listening to music or playing games) while paying little attention to the surroundings [46, 47].

All of the aforementioned causal principles are necessary to develop a graphical and mathematical representation of the situational awareness agent model, which will be detailed in the next part.

3. Conceptual model for situational awareness

The graphical and numerical conceptual design of the model, as well as the development process of the agent-based model of situational awareness, are depicted in this part. After that, complete explanations of agent-based modeling will be supplied.

3.1 Temporal causal modelling

The state-determined system is used to explain what a dynamical system is, as its present situation constantly defines a unique future behavior [16, 48]. This concept of a state-determined system can be connected to the concepts of temporal factorisation and criterial causation, which were described in [17]. This method is applied to both graphical and numerical representations. The graphical may seem as a complicated network structure with nodes (circles and arrows). For example, a dynamical process (arrow) connects A state (circle) to B state (circle). This is how the criteria for causality are presented.

Mathematical forms can be used to specify dynamical systems. A finite collection of states (or state variables) $A_1, \ldots\ldots, A_n$ is assumed, with functions $A_1(t), \ldots\ldots, A_n(t)$ of time *t* defining how the system evolves over time. This influence on *B* at time *t* is proportional to both the value $A_i(t)$ and the connection weight $\omega_{A,B}$ for each of the states A_i , and is characterized as:

$$\boldsymbol{impact}_{A,B}(t) = \omega_{A,B}A(t) \qquad (1)$$

A combination function ς_A (for example, the sum function) is used to simulate the aggregated influence of numerous impacts $impact_1, \ldots\ldots, impact_n$ of $A_1, \ldots\ldots, A_n$ on state *B* at time *t*, as:

$$\boldsymbol{aggimpact}_B(t) = \varsigma_A\left(\boldsymbol{impact}_{A_1,B}(t), \ldots\ldots, \boldsymbol{impact}_{A_n,B}(t)\right) \qquad (2)$$

Table 1. Formalized concept

Concept	Formalization
Experiences	Ex
Personality	Pr
Resources	Re
Culture	Cu
Leadership	Ls
Limited information resource	Ir
Information priority	Ip
Geographic information systems	Gis
Time pressure	Tp
Challenge	Ct
Skill performer	Sp
Job Control	Jc
Commination	Cm
Information management	Im
Attention	At
Job demand	Jd
Adrenaline rush	Ar
Short-term relaxed awareness	SRa
Short-term focused awareness	SFa
Short-term high alert	SHa
Short-term tuned out	STo
Long-term relaxed awareness	LRa
Long-term focused awareness	LFa
Long-term high alertness	LHa
Long-term tuned out	LTo

Where

$$\boldsymbol{aggimpact}_B(t) = \varsigma_A\left(\omega_{A_1,B}(t), \ldots\ldots, \omega_{A_n,B}(t)\right) \quad (3)$$

The difference between this aggregated effect value $\boldsymbol{aggimpact}_B(t)$ and the current value $B(t)$ of A: $\boldsymbol{aggimpact}_B(t) - B(t)$. In step-by-step time form t to $t + \Delta t$ where Δt, the value of $B(t)$ will rise in the same direction as the value of $\boldsymbol{aggimpact}_B(t)$. This rise is proportionate to the difference between the two values via proportion factor η_B. However, the value of $\boldsymbol{aggimpact}_B(t)$ (which is dependent on other states) may evolve during the convergence phase, making the process even more dynamic. In order to numerically represent a dynamical model, the difference equation is utilized as:

$$B(t + \Delta t) = B(t) + \eta_B\left(\boldsymbol{aggimpact}_B(t) - B(t)\right).\Delta t \quad (4)$$

To model or execute the difference equation formulation above, any numerical dynamical modeling language or software environment, such as Matlab or Excel, can be utilized. The models are declarative, meaning that computational methods for simulation or analysis may be applied to them without affecting the model descriptions [49].

3.2 An agent-based model for situational awareness

Several underlying theories support the proposed temporal-casual model of workplace situational awareness such as the Csikszentmihalyi flow model [22, 23], Cooper's color code. There are several main steps are chosen to model the temporal-casual of workplace situational awareness. These steps are 1) identification of factors, 2) a conceptual model based on identified theories and factors, 3) differential equations are used to formalize, 4) simulation and 5) evaluation.

Based on the literature review, a collection of endogenous or internal (local) and exogenous or external (non-local) features are used to identify factors. Exogenous components (from social and environmental specifications) offer the model with a set of inputs, while endogenous components (from social and environmental specifications or mechanisms) offer the model a set of linkages with factors and theories. Besides, the output of the model are temporal relationships effects of tuned out, relaxed awareness, focused awareness, and high alertness at the workplace. A set of nomenclatures for formal representation is provided in Table 1.

The model's overview is represented in Fig. 2. Note, states (circles) and their dynamics as processes (arrows) are included. Fig. 2. explains the metacognitive (thinking about thinking) of a situational awareness model based on three relationships (exogenous, endogenous, and temporal). Each concept is linked together based on relevant findings in the literature on situational awareness theories, mechanisms, or factors at the workplace.

The job control of workers is affected by two factors which are workers' experience and personality [43,45] in which worker's personality highly affects the worker's job control compared to the worker's experiences.

$$Jc(t) = \mu_{Jc}.Pr(t) + \left(1 - \mu_{Jc}\right).Ex(t) \quad (5)$$

The challenging environment of workers is affected by workers' environmental resources and geographic information systems (complex adaptive systems) where lack of resources and high complex adaptive systems at the workplace may increase the workers' challenges [24, 25]. The workers' skills may affect by their experience and job control [26, 27].

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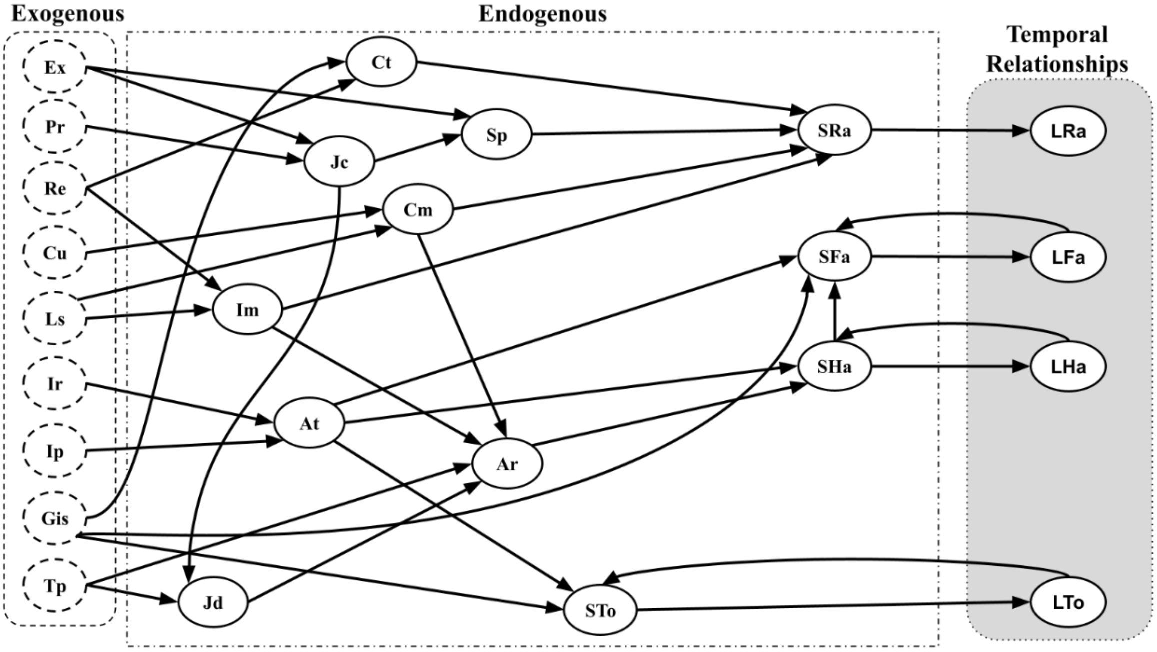

Figure. 2 Conceptual model of situational awareness

$$Ct(t) = Gis(t) . \big(1 - Re(t)\big) \quad (6)$$

$$Sp(t) = \delta_{Sp}.Jc(t) + \big(1 - \delta_{Sp}\big).Ex(t) \quad (7)$$

The communication of workers depends on his/her leadership [29] as well as cultural values affect the workers' communication skills [30].

$$Cm(t) = \alpha_{Cm}.Ls(t) + (1 - \alpha_{Cm}).Cu(t) \quad (8)$$

The communication of workers depends on his/her leadership [29] as well as cultural values affect the workers' communication skills [30].

$$Cm(t) = \alpha_{Cm}.Ls(t) + (1 - \alpha_{Cm}).Cu(t) \quad (9)$$

Information managements are high during the work based on two factors leadership and environmental resources [31,32].

$$Im(t) = \varphi_{Im}.Ls(t) + (1 - \varphi_{Im}).Re(t) \quad (10)$$

At work, attention is influenced by the workers' information priority and limited information resources [36]. In addition, the personality of a worker may affect his social attention [37]. The attention and adrenaline rush affect the alertness of the person [38] and the person's alert may increase by previous high alertness (directed alertness) [39].

$$At(t) = \big(\mu_{At}.Ir(t) + (1 - \mu_{At}).Ip(t)\big). (1 - Pr(t)) \quad (11)$$

$$SHa(t) = \gamma_{SHa}. \big((1 - \sigma_{SHa}).At(t) + \sigma_{SHa}.Ar(t)\big) + (1 - \gamma_{SHa}).LHa(t) \quad (12)$$

The adrenaline rush of workers is increased by time pressure and job demand [40, 41] as well as lack of communication and information management during the work [42].

The workers' time pressure has a strong effect on job demands during the work including low job control [43, 44].

Low challenges and high skills of persons may increase the relaxation of workers including the high communication and information management during the work [22, 23, 28]. This led the worker to a highly relaxed awareness level.

$$Ar(t) = \big(\alpha_{Ar}.Tp(t) + (1 - \alpha_{Ar}).Jd(t)\big) . \Big(1 - \big(\omega_{Ar}.Cm(t) + \omega_{Ar}.Im(t)\big)\Big) \quad (13)$$

$$Jd(t) = Tp(t) . \big(1 - Jc(t)\big) \quad (14)$$

$$SRa(t) = \big(\omega_{SRa}.Sp(t) + \omega_{SRa}.Cm(t) + \omega_{SRa}.Im(t)\big).\big(1 - Ct(t)\big) \quad (15)$$

The highly alert and attention of workers may cause high focused awareness, as well as the worker, might be in a state of being fully absorbed in the complex adaptive systems [33-35].

Table 2. Default configurations

Factors	Case #1	Case #2	Case #3	Case #4
Experiences	0.9	0.9	0.1	0.9
Personality	0.9	0.1	0.1	0.9
Resources	0.9	0.1	0.1	0.1
Culture	0.9	0.9	0.9	0.9
Leadership	0.9	0.1	0.1	0.9
Limited information resource	0.9	0.9	0.9	0.9
Information priority	0.9	0.9	0.1	0.9
Geographic information systems	0.1	0.9	0.9	0.9
Time pressure	0.1	0.1	0.9	0.1

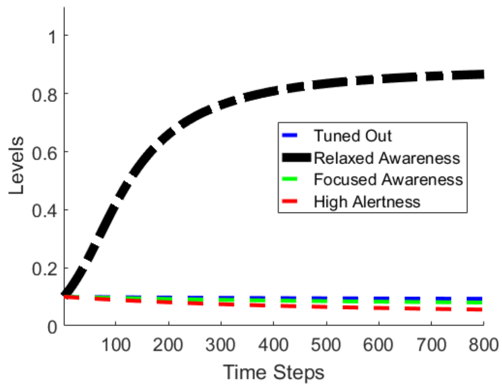

Figure. 3 Case #1 simulation results

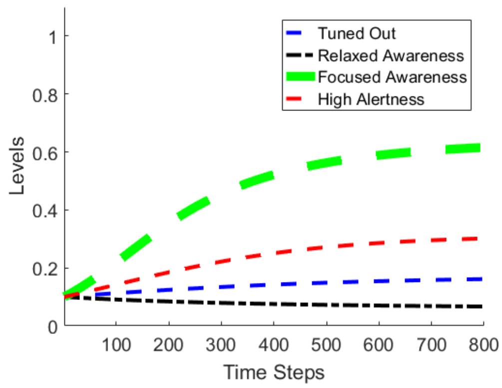

Figure. 4 Case #2 simulation results

$$SFa(t) = \vartheta_{SFa}.\left(\omega_{SFa}.At(t) + \omega_{SFa}.Gis(t) + \omega_{SFa}.LFa(t)\right) + (1-\vartheta_{SFa}).LHa(t) \quad (16)$$

The worker may be completely involved in complicated adaptive systems (such as listening to music or playing games) while paying little attention to the environment [46, 47].

$$STo(t) = \gamma_{STo}.(Gis(t).(1-At(t)) + (1-\gamma_{STo}).LTo(t) \quad (17)$$

Long-term relaxed awareness evolves over time in this situation. As a result, when short-term relaxed awareness is raised, the contribution factor η_{LRa} magnifies the preceding value. In the same vein, this condition could also be used to characterize all temporal relations (focused awareness, high alertness, and tuned out), as well as the parameters and characteristics that correspond to them. The change process is calculated between *t* and *t+Δt*. Furthermore, flexibility rates (nonzero speed factors) η_{LRa}, η_{LFa}, η_{LHa}, and η_{LTo} determine the rate of change for all temporal characteristics throughout time.

A simulator was created for experimentation purposes using all given formulas; in particular, to study notable patterns and traces that represent the dynamics of the level of situational awareness connected with workspace.

$$LRa(t+\Delta t) = LRa(t,l) + \eta_{LRa}.\left(SRa(t,l) - LRa(t,l)\right).\left(1-LRa(t,l)\right).LRa(t,l).\Delta t \quad (18)$$

4. Simulation results

This section describes how a group of fictitious workers in various settings develop behaviours or patterns that have been observed in similar empirical studies. To see how these patterns are related, four fictitious workers are shown: a wealth of knowledge, leadership, and resources, including a strong personality and culture (#1), information that is limited and prioritized, as well as very complicated adaptive systems (#2), as in case 2, but with the added strain of a work deadline (#3), and a worker who devotes his or her complete attention to complex adaptive systems (#4). The preliminary values for each fictitious worker are shown in Table 2. Some settings can be changed during this procedure to achieve different features. For the sake of brevity, the settings following were utilized: $\Delta t = 0.3$, $t\_mix = 800$ (estimated mental duration of worker: 13 hours), regulatory rates (such as γ_{STo}, μ_{At}, and δ_{Sp}) equal to *0.7*, nonzero speed factors (η_{LHa}, η_{LFa}, η_{LRa}, and η_{LTo}) equal to *0.3*, the weights (ω_{SFa}, and ω_{SRa}) equal to *0.33*, and weights (ω_{Ar}) equals *0.5*.

Case #1: a wealth of knowledge, leadership, and resources, including a strong personality and culture: In this situation, the employee has a high level of relaxed awareness at work. Fig. 3. shows the

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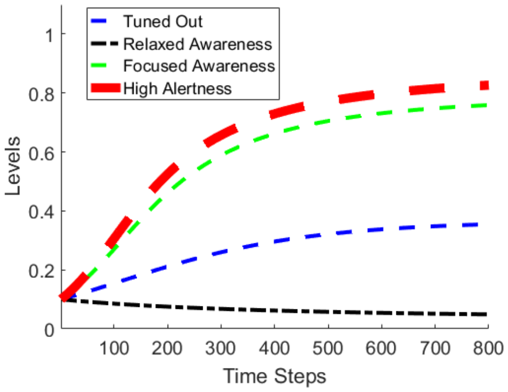

Figure. 5 Case #3 simulation results

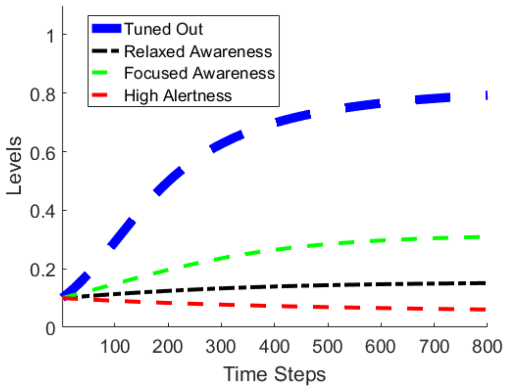

Figure. 6 Case #4 simulation results

simulation traces based on Case #1.

Case #2: information that is limited and prioritized, as well as very complicated adaptive systems: The individual has a high level of focused awareness at work in this situation. Fig. 4 depicts the simulation traces for Case #2.

Case #3: as in case 2, but with the added strain of a work deadline: In this condition, the individual has a high level of high alertness at work. The simulation traces for case #3 are shown in Fig. 5.

Case #4: a worker who devotes his or her complete attention to complex adaptive systems: The person has a high level of tuned out at work when they are in this condition. Fig. 6. Illustrates the simulation traces for case #4.

To summarize these findings, a worker with a high culture and a limited information resource may be exposed to different level of situational awareness at workplace. The aforementioned generated traces properly justify the correlations as described in selected literature. The simulation results, for example, demonstrate that workers with a strong personality and culture, as well as a wealth of information, leadership, and resources, agree with several conclusions provided in section 2.

5. Evaluation

This section examines the mathematical analysis and internal validity processes (automated logical verification) of developed dynamic agent models. The correctness and dependability of models are the primary issues in the construction of any computational cognitive agent model. In this context, model correctness is typically understood to refer to how closely a model's behavior matches its formal specifications. The suggested agent-based model is evaluated using mathematical analysis. The equilibrium or stability points are drawn in mathematical analysis to ensure that the model develops as anticipated. Mathematical analysis' purpose is to find possible equilibrium values for other variables. The temporal-causal networks, when combined, can be expressed as a set of differential equations as follows:

$$\frac{dLRa(t)}{dt} = \frac{dLFa(t)}{dt} = \frac{dLHa(t)}{dt} = \frac{dLTo(t)}{dt} = 0 \qquad (22)$$

Each stable-state temporal equation's resulting combinations can be rewritten as:

$$\begin{gathered}(LRa = SRa \lor LRa = 0 \lor LRa = 1) \land \\ (LFa = SFa \lor LFa = 0 \lor LFa = 1) \land \\ (LHa = SRa \lor LHa = 0 \lor LHa = 1) \land \\ (LTo = STo \lor LTo = 0 \lor LTo = 1)\end{gathered} \qquad (23)$$

Applying the law of distributivity, it can be re-created into a set of relationships by combining three logical conditions:

$$\begin{aligned}&(LRa = SRa \land LFa = SFa) \\ &\lor (LRa = SRa \land LFa = 0) \\ &\lor (LRa = SRa \land LFa = 1) \\ &\lor (LRa = SRa \land LHa = SHa) \\ &\lor (LRa = SRa \land LHa = 0) \\ &\lor (LRa = SRa \land LHa = 1) \lor \\ &\dots\dots \\ &(LTo = 1 \land LHa = SRa) \lor (LTo = 1 \land LHa = 0) \lor (LTo = 1 \land LHa = 1)\end{aligned} \qquad (24)$$

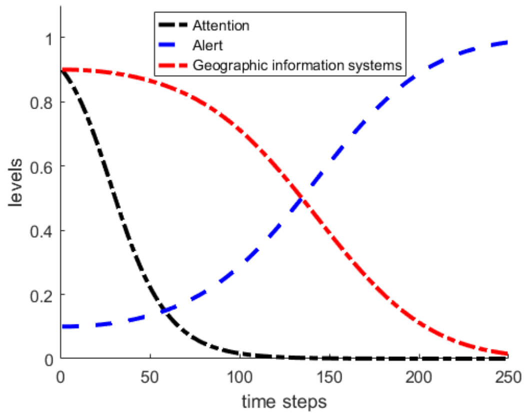

Figure. 7 Simulation results of worker's attention

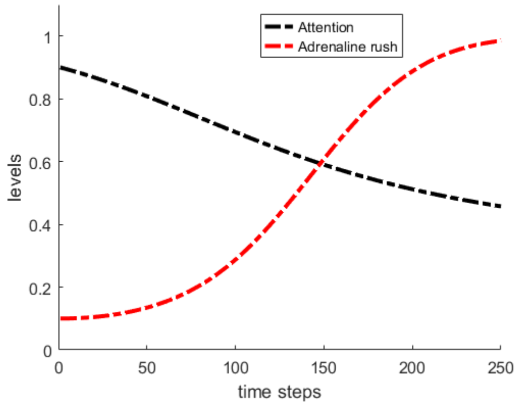

Figure. 8 Simulation results of worker's attention

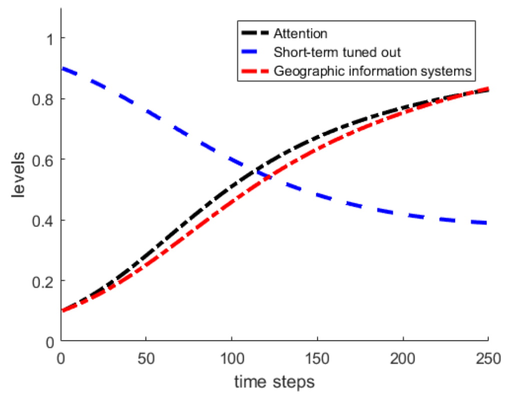

Figure. 9 Simulation results of worker's attention

Note that utilizing the other non-dynamic equations, more evidence concerning the equilibrium conditions of other variables can be uncovered for each of the selected examples and linked to literature. Some possibilities, such as high relaxed awareness and alertness at the same time, are not possible for workers $LRa = 1 \wedge LHa = 1$. In this scenario, we disregard the impossibilities.

Case #1: $(LFa = 1 \wedge LHa = 1)$

When a worker is both long term focused and alert, according to the equation of focused awareness Eq. (16), the worker's attention is determined by his or her alertness and the geographic information systems specification as follows:

$$\vartheta_{SFa}.(\omega_{SFa}.At + \omega_{SFa}.Gis + \omega_{SFa}.1) + (1 - \vartheta_{SFa}).SHa = 0 \quad (25)$$

Hence,

$$At = -\frac{(1 - \vartheta_{SFa}).SHa}{\vartheta_{SFa}.\omega_{SFa}} - 1 - Gis \quad (26)$$

Where $\vartheta_{SFa} \neq 0$ and $\omega_{SFa} \neq 0$

The simulation trace is shown in Fig. 7 shows the worker's attention is controlled by the worker's alertness and complex adaptive systems around him/her as well as it is recent finding [40]. Thus, by taking $LHa = 1$, the worker's attention is solely based on alertness. (kind of inattention is called attention deficit hyperactivity disorder [50]) as show in Fig. 8, and from equations of alertness Eq. (11) as follows:

$$\gamma_{SHa}.\left((1 - \sigma_{SHa}).At + \sigma_{SHa}.Ar\right) + (1 - \gamma_{SHa}).1 = 0 \quad (27)$$

Hence,

$$At = -\frac{1}{\gamma_{SHa}.(1 - \sigma_{SHa})} + \frac{1 - \sigma_{SHa}.Ar}{1 - \sigma_{SHa}} \quad (28)$$

Where $\gamma_{SHa} \neq 0$ *and* $\sigma_{SHa} \neq 1$

Case #2: $(LTo = STo \wedge LHa = 1)$

When a worker is on high alert for a lengthy period of time at the same time, he or she is tuned out in the short term, according to the equation of tuned out Eq. (17), the attention of the worker is based on tuned out and the adaptive systems that surround them [51]. The simulation trace is shown in Fig. 9 as follows:

$$\gamma_{STo}.(Gis.(1 - At) + (1 - \gamma_{STo}).STo = 0 \quad (29)$$

Hence,

$$At = \frac{(1 - \gamma_{STo}).STo}{\gamma_{STo}.Gis} + 1 \quad (30)$$

Where $\gamma_{STo} \neq 0$

The validity of the proposed agent-based modeling of situational awareness is tested via automated analysis. The automated analysis evaluates simulated behaviors to the developed model's internal validity because numerical data to characterize the agent's dynamic causal behaviors is difficult to come by some behaviors or patterns may be found in the literature based on empirical study. The temporal trace language is an appropriate formal language for describing agent-based modeling of complicated sociotechnical systems. The temporal trace language is a logic-based language that may be used to explicitly characterize the dynamic features of systems and to formalize agent-based modeling [52]. Using boolean connectives, the set of well-formed temporal trace language formulae is inductively stated in a formal fashion (such as $\neg, \forall, \exists, \equiv, \wedge, \vee, \Longrightarrow$). The first state property (P1) is completely alert while maintaining a high level of focused awareness [35, 53].

$P1 \equiv \; \forall\theta{:}TRACE, \forall t1, t2{:}TIME,$
$\forall\, f1, f2, h1, h2{:}REAL$
$[state(\theta, h1)| = alertness\_value(\theta, t1)$ &
$state(\theta, h2)| = alertness\_value(\theta, t2)$ &
$state(\theta, f1)| = focused\_value(\theta, t1)$ &
$state(\theta, f2)| = focused\_value(\theta, t2)$ &
$f2 \geq f1$ & $t1 \leq \; t2]$
$\Rightarrow \; h2 \geq h1$

The second state property (P2) is that a highly skilled individual with little environmental difficulty will lead to a relaxing situation [54].

$P2 \equiv \; \forall\gamma{:}TRACE, \forall t1, t2{:}TIME,$
$\forall\, r1, r2, s1, s2, c1, c2{:}REAL$
$[state(\gamma, t1)| = skill\_value(\gamma, s1)$ &
$state(\gamma, t1)| = challenge\_value(\gamma, c1)$ &
$state(\gamma, t2)| = skill\_value(\gamma, s2)$ &
$state(\gamma, t2)| = challenge\_value(\gamma, c2)$ &
$state(\gamma, t1)| = relaxing\_value(\gamma, r1)$ &
$state(\gamma, t2)| = relaxing\_value(\gamma, r2)$ &
$t1 \leq t2$ & $s1 > 0.7$ & $s2 > 0.7$ & $c1 < 0.3$ &
$c2 < 0.3$ & $c1 > c2$ & $s1 < s2$]
$\Rightarrow \; r1 < r2$

The third state property (P3) is that while we are concentrated (attention) on anything else (complex adaptive systems such as playing game), we frequently overlook important occurrences in our environment (tuned out) [55].

$P3 \equiv \; \forall\mu{:}TRACE, \forall t1, t2{:}TIME,$
$\forall\, o1, o2, a1, a2, s1, s2{:}REAL$
$[state(\mu, t1)| = attention\_value(\mu, a1)$ &
$state(\mu, t1)| = adaptive\_systems(\mu, s1)$ &
$state(\mu, t2)| = attention\_value(\mu, a2)$ &
$state(\mu, t2)| = adaptive\_systems(\mu, s2)$ &
$state(\mu, t1)| = tuned\_out\_value(\mu, o1)$ &
$state(\mu, t2)| = tuned\_out\_value(\mu, o2)$ &
$t1 \leq t2$ & $a1 > 0.7$ & $a2 > 0.7$ & $s1 > 0.7$ &
$s2 > 0.7$ & $a1 > a2$ & $s1 > s2$]
$\Rightarrow \; o1 < o2$

P1, P2, and P3 may all be used to see if the simulation traces are true, implying that the model's created patterns are consistent with the literature.

6. Conclusion

The construction of a computational model to understand situational awareness at work is described in this research. From the literature, a number of underlying concepts in situational awareness and their causal interplays were found and linked to create the model. Furthermore, differential equations were used to formalize the model and provide an executable model for simulation. The suggested model was evaluated in a number of scenarios that related to distinct personality attributes and environmental variables to examine how well it corresponds with the underlying ideas of workplace situational awareness. To examine feasible equilibrium conditions and compatible cases in the literature, mathematical analysis was used. Furthermore, the model's validity was checked using automated logical verification utilizing temporal trace language. The proposed model limitations were focused on four basic levels of situational awareness: relaxed awareness, focused awareness, high alertness, and tuned-out.

Other underlying theories in self-awareness emotional intelligence symptoms at the workplace will be re-modeled in future work using the self-modeling networks approach [49]. In addition, the integration of the proposed dynamical model into the internet of things will be one of our future projects.

Conflicts of interest

There are no ethical concerns with this study.

Author contributions

The first author constructed the theoretical framework and performed the analytic calculations and numerical simulations. The literature review was completed by the second author. The literature review was analyzed by the third author. A detailed examination was carried out by the fourth author.

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