Studying Emotions at Work Using Agent-Based Modeling and Simulation

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Abstract. Emotions in workplace is a topic that has increasingly attracted attention of both organizational practitioners and academics. This is due to the fundamental role emotions play in shaping human resources behaviors, performance, productivity, interpersonal relationships and engagement at work. In the current research, a computational social simulation approach is adopted to replicate and study the emotional experiences of employees in organizations. More specifically, an emotional agent-based model of an employee at work is proposed. The developed model is used in a computer simulator WEMOS (Workers EMotions in Organizations Simulator) to conduct certain analyzes in relation to the most likely emotions-evoking stimuli as well as the emotional content of several work-related stimuli. Simulation results can be employed to gain deeper understanding about emotions in the work life.

Keywords: Social simulation · Agent-based modeling · Emotional agents · Organization psychology · Workplace.

1   Introduction

Researches that deal with emotions in the workplace have recently received extensive attentions after a long period of neglect. This is due to the increasing awareness of organizational both theorists and practitioners during the last years of the crucial role that emotions play in the worklife. In fact, emotions shape employees behaviours, alter their well-being, their job-satisfaction, their motivation and their organizational commitment; they also impact their social relationships and their performance at work. Moreover, built upon findings from neuroscience, psychology and cognitive science, emotions have critical impacts on cognitive tasks that human resources practice during their daily work activities. These include decision-making, attention, memory, perception and learning. Consequently, new sub-domains related to organizational researches such as organizational psychology and organizational behaviour start to account for emotions, to explore and try to understand their nature, their causes and their roles in shaping human behavior within the organizational environment. Nevertheless, researches in these fields face some challenges due to the complex nature of emotions, to their unpredictability and to the difficult task to measure them. Almost of these researches use either self-reports or physiological indicators in

order to identify emotions. While the former method provides data that can be biased due to the subjective nature of emotions and to their ephemeral occurrence, the latter is, generally, expensive and data are altered by the 'unusual' environment participants are placed in. In this context, social computer simulation can represent a reliable alternative tool to study and explore the emotional experiences of employees in the workplace. According to [1], this type of simulation uses computers to study social systems behaviours. It can be useful when we try to study phenomena on which conducting real life experiments is impossible or phenomena which are difficult to get access to or to observe directly. In particular, the agent-based approach of social simulation is suitable to model and explore the human resources behaviour and specifically emotion dynamics at work. It offers a platform to conduct deep bottom-up understanding of the organization psychology from individual-level characteristics of its entities. In this way, researchers can capture and gain more insights about the complexity of the worklife and the human behaviour in organizational settings without going to the trouble of carrying out real life experiments. It is also worth to highlight that agent-based social simulation and modelling have been successfully used to model a large variety of complex systems in different fields such as social science, economics, ecology and political sciences.

The structure of the paper is organized into five main parts as follows. First, a literature review in relation to emotional agent-based models of human behavior in the workplace is exposed. Second, a presentation of the agent-based model of the emotional experiences of employees in the workplace is carried out. Third, an agent-based simulator WEMOS (Workers EMotions in Organization Simulator) is introduced. It simulates a workplace environment in which employees are subject to emotions-evoking stimuli. The simulation generates several results that are exposed. Finally, a discussion is elaborated about the simulation results and the different findings they highlight and a conclusion is also presented.

2   Emotional agent-based models of human behavior in the workplace

A wide range of agent-based models have been proposed in relation to the workplace context. They have been used to model, simulate and shed the light on several aspects underlying the behavior of employees in the workplace (e.g. [2] and [3]). However, using this paradigm to explore the emotional experience of employees in the workplace has not been given great attention. That is, few publications that discuss the issue of using emotional agent-based modeling and simulation in the organizational context can be available in the literature. Moreover, even the works that can be found represent major limitations that are discussed below.

In the context of underground coalmine environment, an integrative behavior framework for mine workers is presented in [4]. To create more believable and realistic behaviors of mine workers, physiological and psychological attributes such as emotion, personality and motivation are taken into consideration. An-

other work that is related to health care environments, can also be found in
[5]. Agent-based emotional models of patients and nurses in a simulated hospital environment have been developed. The simulated system aims to examine
the effects of negative emotional stress on the reasoning process of the nurses
while performing patient medication administration tasks. Additionally, and in
the military context, an emotion enabled architecture for situated agents DETT
(Disposition, Emotion, Trigger, Tendency) has been presented [6]. Emotions do
influence the way the agent intention tendency is directed. The proposed model
was used to simulate combat scenarios in the warfare.

   The main problem of the aforementioned models is their restriction to specific
organizational environments (e.g. underground coalmines, hospitals and military
contexts). This may limit their genericity. In this context, other emotional agent-
based models of employees in the workplace have been proposed independently of
any specific organizational context. In [7], authors propose an agent-based sim-
ulator as a decision support tool used by managers in the workplace. Managers
tune the settings of a team configuration system to optimize the team perfor-
mance. Emotions are used, with other parameters, to determine every worker
agent performance. In this work, the focus is set on only four emotions which are
desire, interest, disgust and anxiety. In [8], an emotional engine has been injected
into a framework devoted to study social organizations. The aim is to provide
a deeper understanding of the functioning of organizations. In fact, using the
simulated system, actors within organizations are able to capture the elicited
emotions and to cope appropriately with the emotional dimension of their be-
haviors. In this work, only social emotions of the actors, such as pride, gloating
and guilt, are considered. In [9], an agent-based model of emotions at work is pre-
sented. The research adopts a cross-disciplinary approach and takes advantage
of theoretical foundations from organization behavior and organization psychol-
ogy to elaborate upon the emotion generation process. The simulation model
remains very limited as it addresses only joy emotion.

3   Agent-based model of employees emotions

The proposed agent model corresponds to an employee in the workplace with his
associated emotion generation mechanism (Figure 1). The latter is based on the
OCC model [10] that represents a computation-oriented psychological theory of
emotions.

   Based on the OCC model, emotions are the result of appraisal of one of the
three main facets of the world: events, actions of agents, or aspects of objects.
This is regarding to the goals, standards, and attitudes of the agent [45, 58].
The appraisal of events by respect to the agent goals leads to *events-related
emotions* that include: *well-being emotions* (i.e. joy and distress), *prospect-based
emotions* (i.e. hope, fear, satisfaction, fear-confirmed, relief and disappointment)
and *fortune of others emotions* (i.e. happy-for, resentment, gloating and pity).
The appraisal of actions of agents (oneself and others) by respect to the agent
standards gives rise to *actions-related emotions* (also called *attribution emo-*
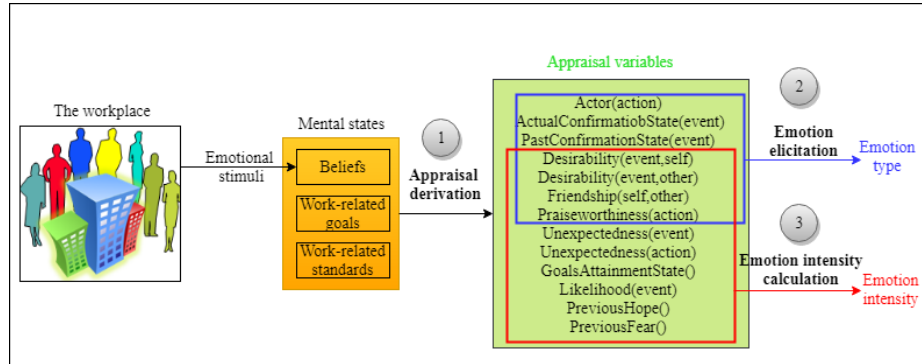
Fig. 1. Emotional agent model of employee emotions generation in the workplace

tions) that incorporate pride, shame, admiration and reproach. In some cases, an action of agent is also considered as an event that impacts the agent goals and his standards. The appraisal of such situation elicits *compound emotions* that contain gratification, remorse, gratitude and anger. Finally, the appraisal of aspects of objects by respect to the agent attitudes triggers *objects-related emotions* that unfold love and hate emotions. In this research work, we deal only with twenty over twenty two emotions of the OCC model as we take into consideration *events-related emotions*, *actions-related emotions* and *compound emotions*.

Following the presented OCC model structural components of emotions, it is necessary to identify the list of agent perceived events and actions of agents as well as his work-related goals and standards. This list is referred in the emotional agent model (Figure 1) as the agent mental states. It is also necessary to explain how the agent mental states correlate and how their corresponding relationships can be presented computationally. Furthermore, it is required to highlight how the emotion elicitation process with its sub-processes operate and use these identified OCC model-related components to generate emotions.

3.1   Agent mental states

In this work, mental states of the employee agent refer to its sets of beliefs, work-related goals and work-related standards.

Beliefs An employee agent is continuously perceiving its environment and the various happenings that may occur in the workplace. These input information are used to update the agent beliefs that correspond to its view about its external environment. In the current work, the agent set of beliefs is related to various emotional circumstances that may take place at work and may have implications on the agent emotional experiences. They include a range of emotions-inducing stimuli that can be of positive or negative valence. They refer to either emotional

events or emotional actions of agents that may occur in the organizational context. These stimuli have impacts on the emotional states of employees agents.

To identify the various emotions-inducing stimuli that may occur in the organizational context, an investigation in organizational behavior and organizational psychology literature is carried out. The investigation focuses on works that deal with work-related emotional experiences. A relevant work in the area, that is proposed by Ohly and Schmitt (2015) in [11], has been the source to inspire the current work. It introduces a taxonomy that was built upon diary studies sampled from 218 full-time employees of different industries and professions in Germany. This taxonomy is used to identify the list of the affective events and the agent actions that employees experience at work. Examples of emotions-inducing stimuli that can be retrieved from the taxonomy are *"got a new job offer"* which is an event and *"my supervisor thanked me"* which is rather an agent action.

Work-related goals and standards In the work settings, every employee has a set of goals that he tries to achieve and a set of standards that are applied to its conduct. Following the guidelines of the OCC model, when impacted by certain stimuli, these goals and standards engender emotions generation.

Accordingly, to conduct a study that deals with emotions in the workplace, we need to define the list of the employee work-related goals and his work-related standards. While the former are coupled with *Events-related emotions*, the latter are coupled with actions of agents to generate *Actions-related emotions*.

In this work, we are mainly inspired by [12] and [13] in order to identify this list. These two works from the organization psychology field provide a list of work-related values which can be used to find out the worker goals and his standards. Indeed, person values can be classified into two sets. The first is called terminal and they refer to the desirable end-states and goals that a person would like to achieve. The second set is called instrumental values and they refer to the preferable behaviors and the acceptable modes of conduct [14]. One example of work-related goals that are considered in the model is *"Advancement and promotion"*. According to work-related standards, *"Fairness"* is one example of this list.

3.2 Computational representation of the OCC model components and their corresponding relationships

As earlier specified, emotions are generated by respect to the OCC model. That is, they are the result of an appraisal of events and agents actions regarding to its goals and standards. In this vein, it is important to map the emotions-evoking events that occur in the workplace to the employee agent work-related goals. This is to generate *events-related emotions*. Likewise, it is necessary to map the emotions-evoking actions of agents to the employee agent work-related standards. This is required to generate *actions-related emotions*. For *compound emotions*, the mapping can be implicitly deducted from the relationships that

map certain stimuli (i.e. agent actions which are also considered as events) to both of the agent work-related goals and its standards.

To represent computationally the various aforementioned kinds of mappings, Fuzzy Cognitive Maps (FCM) are used. In brief, this technique is used to represent the fuzzy causal reasoning between concepts and to measure the strength of the impact among them. Thus, FCM can be employed to model the causal relationships that link events occurring in the organization environment to work-related goals of employee agents and their actions to their work-related standards. Moreover, FCM is also used to measure the strength of impact among these various concepts as well as to present the qualitative description of their presence degrees. These information are essential to elaborate on the emotions generation process as explained later. Figure 2 represents one example of fuzzy cognitive maps that are used in the current work. It shows the relationships between the work-related goal *Achievement* and its associated impacting events that can occur in the workplace.
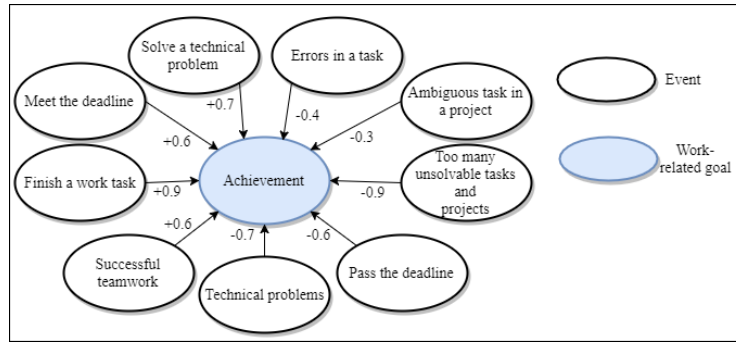

Fig. 2. Fuzzy cognitive map of Achievement goal and its impacting emotional events

Notably, to define the causal relationships among the FCM concepts as well as the weights of their interconnections, experts from organizational psychology are asked to participate in this task. Experts generated individual FCMs, with the same nodes but different concepts interconnections or/and different weights. Then, to get the final FCM, a combination algorithm that takes into account the credibility weight of each expert was applied from [15].

3.3 Emotion generation process

The emotion generation process of the employee agent is centered around three main components, namely appraisal derivation, emotion elicitation and emotion intensity calculation (Figure1).

Appraisal derivation It is used to evaluate the relevance of stimuli (i.e. events or agent actions) to the agent and to determine the values of appraisal variables.

These latter are dimensions which are used to assess the situation. They describe the individual subjective relevance that is attributed to the emotions-evoking stimuli. Following the OCC model [10] and inspired by the computational model of emotions that is proposed in [16], several appraisal variables are involved in the emotion generation process of the employee agent. These appraisal variables are used later either to derive the emotion type (i.e. the emotion label such as joy) by the emotion elicitation model, to calculate the emotion intensity (i.e. the strength of the emotional response), or to perform both of them (Figure 1).

The FCM that is presented above is used by the appraisal derivation component. In fact, the two central appraisal variables (i.e. desirability of events and praiseworthiness of agent actions) are used to appraise triggered stimuli. These two appraisal variables are evaluated based on the FCM parameters. More specifically, fuzzy values of events occurrences and the weights that are associated between events and agents goals are used to calculate the desirability of events. Likewise, fuzzy values of actions occurrences and the weights that are associated between actions and agents standards are used to calculate the praiseworthiness of actions.

Emotion elicitation and emotion intensity calculation After appraisal derivation, the appraisal variables are used to elicit emotions and to calculate their intensities. The emotion elicitation (Figure 1) defines a list of rules that specify the conditions under which each emotion type is triggered and map each situation to the corresponding elicited emotion label. In this work, in order to define these elicitation rules and to identify the list of appraisal variables to account for, the OCC model has been used. According to the emotion intensities calculation (Figure 1), it is used to determine the strength level of the elicited emotion. A sub-set of the appraisal variables, as proposed in the OCC model, were employed to calculate the emotions intensities. Moreover, the methods of their calculations were based on a computational model of emotions that can be found in [16].

4　Simulation and results analysis

During the simulation runs, different types of events and actions of agents take place in the organization environment and corresponding emotions are generated. These stimuli are triggered in line with a taxonomy that associates for each cluster of workplace events or actions a certain frequency [11]. The taxonomy data are built upon diary studies that are sampled from 218 employees of different sectors in Germany in 2015. In addition, several random variables are included in the simulation such as the fuzzy degrees of events occurrences as well as the degree of friendship between each pair of employee agents.

As the main objective of the current research is to gain deeper insights about emotions in the workplace, the developed simulator WEMOS provides several analyzes in relation to the emotions-evoking stimuli as well as the emotional content of these work-related stimuli. While the former aims to identify the

most likely stimuli that are the causes of a specific emotion, the latter seeks to explore the most likely emotions that are the consequences of a given stimulus. WEMOS takes as input the mapping among triggered events and performed actions of agents on the one hand and the generated emotions on the other hand in order to produce these insights.

4.1   Emotions-evoking stimuli

This part of analyzes concerns the most likely stimuli that are the causes of a given emotion in the organizational context.

Events-related emotions-evoking events Employee agents may perceive several emotions-evoking events such as *receive promotion* or *got good pay raise*.

Figure 3 shows a representative repartition example of events-related emotions-evoking events. This repartition concerns the most likely events that may trigger *well-being emotions* (i.e. joy and distress) in the workplace. Results reveal that *was-given freedom to make a decision* and *got good pay raise* are the most likely events that are responsible of *joy* emotion. They also show that *technical problem* is the most likely event to produce *distress* emotion.
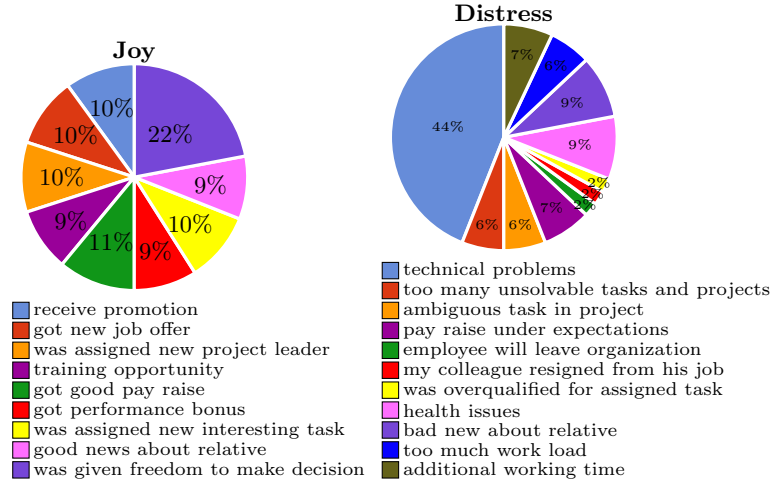

Fig. 3. Well-being emotions-evoking events

Attribution emotions-evoking actions of agents Appraisal of the employee agent own actions or the actions of its co-workers by respect to its standards generates *Attribution emotions*. Examples of emotional stimuli that trigger *Attribution emotions* may include *assisted my supervisor and felt competent* and *receive thanks from my supervisor*.

Running the simulation produced results that indicate that both of *receive a praise* and *receive thanks from my supervisor* are the most likely agent actions that invoke emotions of *Pride* and *Admiration* in the workplace (Figure 4). In addition, *negative discussion with a co-worker*, *conflict with a co-worker* and *unjustified reproach* are the main causes of *Reproach* and *Shame* emotions.
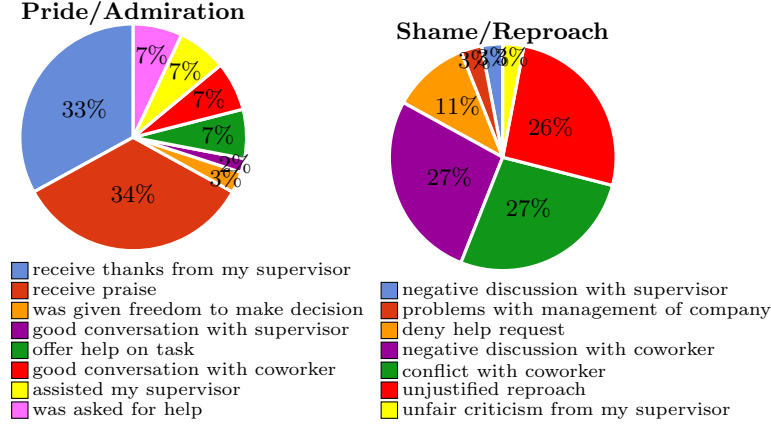

Fig. 4. Attribution emotions-evoking events

Compound emotions-evoking stimuli Some happenings in the organization are recognized as events and actions of agents that are impacting simultaneously the agent goals and its standards. They generate *Compound emotions*. The simulation shows that *meet the deadline*, *solve a technical problem* and *finish a work task* are the most common sources of *Gratification* and *Gratitude* emotions (Figure 5). Results also highlight that *had a phone call with a short-tempered customer* is the principle cause of *Anger* and *Remorse* emotions.

4.2 Stimuli emotional content

In this class of analyzes, the simulation reveals the most likely emotions that are generated as a consequence of a certain stimulus occurrence. In other words, more insights can be gained in terms of the emotional content of a given workplace happening. Figure 6 is a representative example of results that are produced by the simulation. It represents the repartition of the most common emotions that are generated when an event that belongs to the cluster *Managerial and internal problems, organizational climate* takes place. *Was overqualified for an assigned task* is an event that belongs to this mentioned cluster. Results demonstrate that *Shame*, *Reproach*, *Remorse* and *Anger* are the most likely emotions that are triggered following a stimulus that is included in the cluster *Managerial and internal problems, organizational climate* occurs.
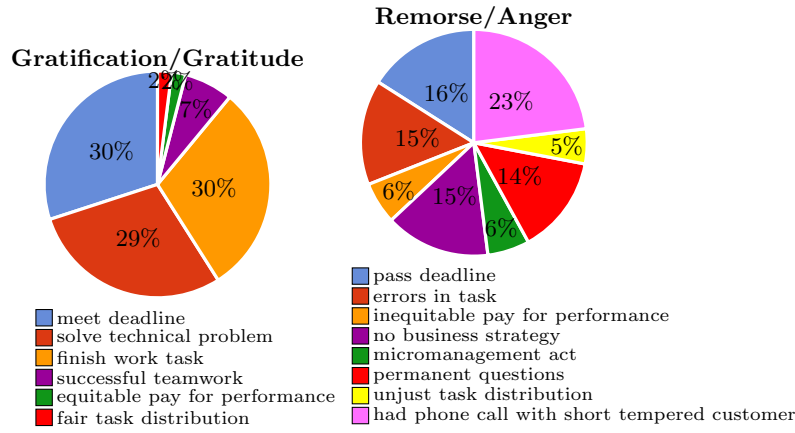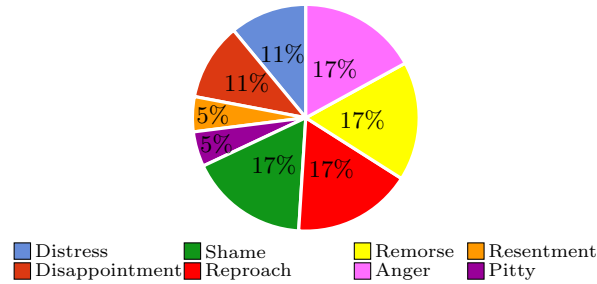
Gratification/Gratitude

Remorse/Anger

meet deadline
solve technical problem
finish work task
successful teamwork
equitable pay for performance
fair task distribution

pass deadline
errors in task
inequitable pay for performance
no business strategy
micromanagement act
permanent questions
unjust task distribution
had phone call with short tempered customer

Fig. 5. Compound emotions-evoking events

Distress   Shame   Remorse   Resentment
Disappointment   Reproach   Anger   Pitty

Fig. 6. The emotional content of stimuli belonging to the cluster *Managerial and internal problems, organizational climate*

5   Discussion and conclusion

Simulation results that are related to emotions-evoking stimuli are of great importance for managers and supervisors. Indeed, through the insights they provide, strategy-makers in organizations can act appropriately to prevent or foster the occurrence of specific emotions. For instance, simulation results reveal that, while traditional financial-oriented rewards and recognition that are based on promotion and good pay and benefits are important, they are not more frequent and more related to positive emotional experiences (e.g. Joy, Hope and Satisfaction) than psychological-oriented rewards such as giving subordinates the freedom to make decisions and involving them in problem solving. In fact, according to the simulation results, the emotion-evoking event *was given freedom to make decision* is more likely to produce Joy emotion than *got good pay raise* or *receive promotion*. Moreover, results also highlight the relevance of recognition and giving thanks to subordinates in order to induce Pride and Admiration

emotions. As such, a supervisor must find time to thank his team members for each job well done. This may make them feel valuated, boost their motivation and inspire them to do their best.

Notably, the simulation results that are linked to the stimuli emotional content are in line with other empirical studies that were conducted in other disciplines especially in organizational psychology and management. Indeed, a relevant research study that was published in [17] and was cited by 346 research papers is able to establish this agreement. In this work, authors found that *Interpersonal mistreatment from customers* is the most frequent source of Anger and *Recognition from supervisors for work performance* is the principle cause of Pride. These findings are in accordance with WEMOS simulation results. Indeed, according to the statistical insights it provides, Anger is most often to be felt when *had a phone call with a short-tempered customer*, which is a representative example of the cluster *Problems in interactions with clients or patients*, occurs. In addition, Pride is most likely to be generated as a consequence of *receive a praise* or *receive thanks from my supervisor*

Another correspondence between the current work findings and other relevant work in organization psychology [18] was also recognized. The research that is proposed in [18] is among the few research papers that have investigated the mapping between work-related emotional events and the most likely associated experienced emotions. It is cited by 368 research papers. According to the authors, *negative acts of management* lead to *Anger* emotions in 16% of cases. In this work, 17% of cases *Anger* are experienced following the occurrence of an event that belongs to the cluster *Managerial and internal problems, organizational climate*. In addition, in [18], *personal problems* engender *Sadness* emotion in 100% of cases. In the current study, *Health problems and private issues* lead to *Sadness* (i.e. *Distress*), *Fear* and *Pity* emotions. While the two works are congruent in relation to *Sadness* emotion, they differ in *Fear* and *Pity*. This is due to the fact that the current work deals with social emotions such as *Pity* and *Happy-for* which are not considered in [18]. Besides, we also take into consideration the occurrence of some unconfirmed events that are related to *Health problems and private issues*. This triggers emotions such as *Fear*.

To conclude, an agent-based simulator WEMOS of employees emotions in the workplace is developed. This social simulator provides analyzes that explore the experience of emotions in organizations. Based on the above discussion, WEMOS offers several results that can help underpin our understanding about emotions at work. In particular, managers, supervisors and strategy makers can take advantage of WEMOS to foster their awareness in relation to the most-likely events that may engender specific emotion and the most-likely emotion that can be generated given a certain circumstance. They can consequently operate in descriptive and predictive modes in organizations. Finally, WEMOS can be extended by considering the emotional contagion mechanism that is able to spread an integrative positive or negative emotional climate among co-workers. It is also possible to incorporate mood and personality that have significant impact on human behavior in the workplace.

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