Formal Analysis of Self-Efficacy in Job Interviewee's Mental State Model

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Abstract. This paper presents a formal analysis approach for self-efficacy model of interviewee's mental state during a job interview session. Self-efficacy is a construct that has been hypothesised to combine with motivation and interviewee anxiety to define state influence of interviewees. The conceptual model was built based on psychological theories and models related to self-efficacy. A number of well-known relations between events and the course of self-efficacy are summarized from the literature and it is shown that the proposed model exhibits those patterns. In addition, this formal model has been mathematically analysed to find out which stable situations exist. Finally, it is pointed out how this model can be used in a software agent or robot-based platform. Such platform can provide an interview coaching approach where support to the user is provided based on their individual metal state during interview sessions.

1. Introduction
One of the significant issues faced by many countries of the world is the rising number of unemployed graduates. This issue has been worsened by the world's economic downturn. The high unemployment especially among fresh graduates has further been linked to certain socio-emotional and interaction skills deficiencies [1,2]. These personal behavioral inadequacies can be observed as results in low self-efficacy, anxiety disorder and low motivation. In addition these factors will impair individual's performance in job interview, a platform they need to convince their recruiter of their abilities for that job [3]. Thus, the inability of candidates to showcase their talents during interviews can prevent them the chance of getting hired regardless their talents or skills [4]. To overcome this, a number of technological innovations have been proposed to complement the conventional interview coaching methods, such as MACH [5], and TARDIS [6]. These digital coaching methods are solely focusing towards verbal and non-verbal approaches. However, there are a number of psychological factors which are said to influence performance, especially in a time bounded tasking event such as job interview. The levels of these behavioural constructs during an interview session are varied for each individual. Therefore, the right balance must be obtained to achieve an optimal performance during the process [7]. Thus, to build a software agent that provides support to individuals engaged in such tasking situation, it is imperative to understand and properly define the underpinning constructs as observed in cognitive psychology. In addition, it can serve as a foundation to design a digital artefact, equipped with the reasoning ability to understand the mental states of individuals in such demanding situation that require supports [8]. There are three fundamental constructs related to the mental state of

interviewee, namely 1) *self-efficacy*, 2) *motivation* and 3) *anxiety* [9]. In order to harness the interplay between these cognitive constructs and its relation towards interviewee's performance, an in-depth computational analysis of each of the constructs has been proposed. The paper is organized as follows; Section 2 describes several theoretical concepts of self-efficacy and interviewee. From this point of view, a formal model is designed (Section 3). Later in Section 4, a number of simulation traces are presented to illustrate how the proposed model satisfies the expected outcomes. In Section 5, a mathematical analysis is performed in order to identify possible equilibria in the model. Finally, Section 6 concludes the paper.

2. Theoretical Foundation of Self-Efficacy

Self-efficacy is one's judgment of his/her capability to organize and execute a cause of action required in a prospective situation [10]. The fundamental premise of self-efficacy theory is the people's belief in their own capability to perform a task in a given situation where they exert efforts and persevere in the face of difficulties and outweigh obstacles [11]. It can be described in the context of *social cognitive theory* – an approach to understanding human cognition, action, motivation, and emotion that assumes that we are active shapers rather than simply passive reactors to our environments [12,13]. It also forms part of an individual's self-belief system used to exert control over one's environment. Furthermore, it is a predictor of behavioural outcomes and well accepted in the domains of psychology, education, and cognitive science. These behavioural outcomes can be modeled through the interacted components using computational-based perspectives. The field of computational modeling of cognition has identified with this construct of self-efficacy as its feature prominently as internal factors in most human support models (e.g.[14]) or models of human behavioural change (e.g. [15]). In order to conceptualize the building process of self-efficacy in task-specific performance, psychologists developed a model of self-efficacy [16]. This model explains that prior to engage in any task, an individual possesses some level of self-efficacy derived as a function of personality, previous experience, and social support. In this case, *personality* is one's personal quality which is defined from values and attitudes and *prior experience* in the same or similar task has influenced both in the initial efficacy and on efficacy information. *Social support* is the type of support received from socializers such as parents, teacher, friends or a mentor.

Interview specific self-efficacy can therefore be seen as the confidence applicant has in her ability to perform well in an interview. There are a lot of factors that exhibit one's efficacy. Past experience, motivation, anxiety, cognitive ability, skills, social factors are few of the many factors that influence self-efficacy [16]. Interview self-efficacy on interviewee performance has been studied by identifying the mediating role it played on personality and biographical background [17]. The study also tested the moderating role of locust of causality attribution in defining the correlation between interview success and subsequent interview self-efficacy. In general, individuals engaged in activities are affected by *situational* and *personal influences* which can also affect their *initial ability beliefs*. Such personal factors are goal and efforts towards goal and situational issues are such as *feedback on goal* or effort. Self-efficacy affects the choice of activities, effort, persistence, and achievement [18]. Unlike the persons casting doubts on their capabilities, an efficacious person participates more ready, work harder (*effort*), persist longer when they encounter difficulties (*persistence*) and reach a higher level achievement (*task performance*). People acquire information to appraise self-efficacy from their prior performances (*mastery*), vicarious (*observational*) experiences, forms of persuasion, and physiological reactions. This efficacy information does not just affects final efficacy directly, but through a process that involves *appraisal*. *Personal goal* plays a central role in all achievement related models. It is the major determinant of actions as it contributes to appraisal; an effort committed to a task and directly affects final efficacy belief. *Effort* can be developed out of self-motivated individuals from high self-belief in ability (*self-efficacy*) and/or attribution to feed back. This explains the core explanation why an individual in a demanding situation exerts him/herself to get the job done. The level of *cognitive engagement* correlates with persistence but more persistence over time may not necessarily resulted in adequate engagement level as engagement may either remain constant or decline [19].

3. Formal Model of Self-Efficacy Belief

In order to formalize the model of self-efficacy belief in a time bounded task, five main phases were harnessed. These five factors are; 1) factor identification, 2) a conceptual model design from identified factors, 3) formalization in mathematical equations, 4) simulating the model, and 5) evaluation. Factors identification involves selection of endogenous or internal (local) and exogenous or external (non-local) properties of the construct under review from literature. These properties are mostly represented in the theoretical foundation and model explained in the previous section of this paper. Inputs to the model are sourced the environmental and social factors that influence person's beliefs (exogenous). As task progresses, people equally source for information to appraise efficacy from external factors (mastery, vicarious, persuasion and affective information). Internal factors, on the other hand, represent the psychology of the person during tasks. Mostly cognitive appraisal or behavioural tendencies that affect task specific achievements, e.g. cognitive appraisal and engagement.

The model conceptually shows how initial efficacy is built from environment factors and experience, the formulation of goal which drives commitment through efforts (as depicted in Figure 1). Efficacy is appraised by sourcing information from vicarious, persuasion, anxiety and mastery performance. Appraisal, persistence, and goal culminated with basic efficacy to produce the short-term efficacy which further accumulates to long-term (temporal) representations.
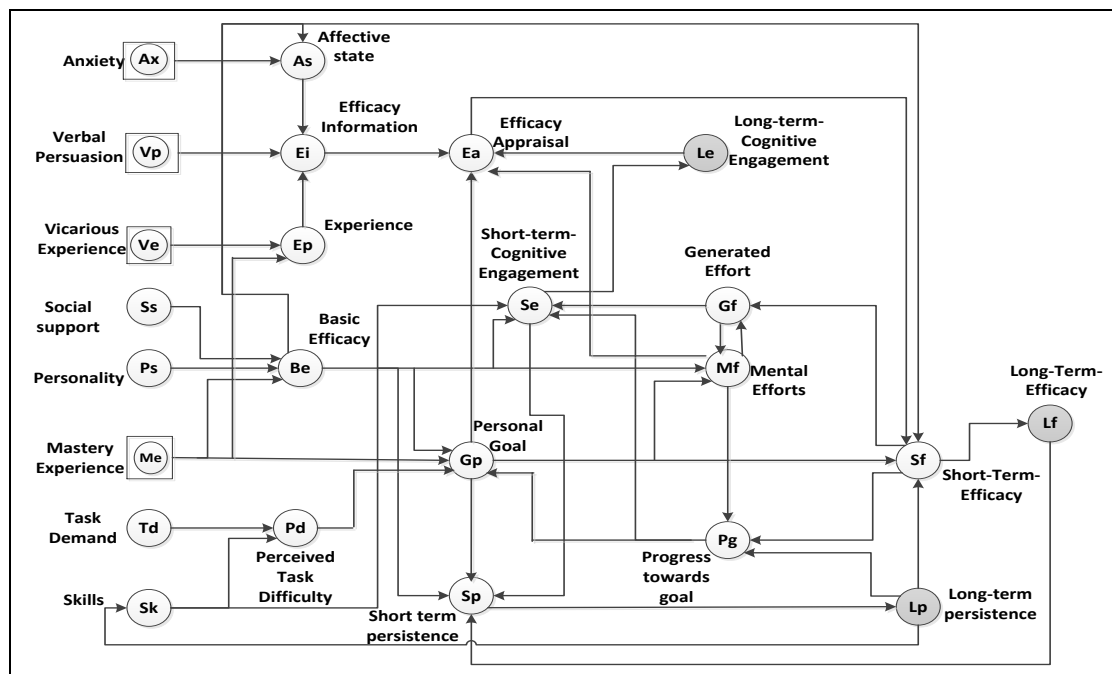

Figure 1. A Conceptual Representation of a Self-Efficacy Model

In formalizing the model, a set of differential equations has been constructed. These equations can be classified as *instantaneous* and *temporal* (as depicted in grey circles) representation (which will be dealt in greater details later). Once the structural relationships in the model have been determined, the model can be formalized. In the formalization, all nodes are designed in a way to have values ranging from 0 (low) to 1 (high).

3.1 Instantaneous Relationship

Affective State (As) which is derived by anxiety state (Ax) of the individual is influenced by the basic efficacy level (Be). Mastery experience (Me) and vicarious experience contribute to form the future general experience (Ep). Both of these levels (mastery experience and vicarious) can be positive or negative. Vicarious experience (Ve) is related to the expertise level, status and relationship within

individuals. In the case of efficacy information (*Ei*), it is casually positively affected by general experience, verbal persuasion (*Vp*), and contrary to affective state level.

$$As(t) = Ax(t) \cdot (1\text{-}Be(t)) \tag{1}$$
$$Ep(t) = \omega_{ep} \cdot Me(t) + (1\text{-}\omega_{ep}) \cdot Ve(t) \tag{2}$$
$$Ei(t) = [\alpha_{ei} \cdot Ep(t) + (1\text{-}\alpha_{ei}) \cdot Vp(t)] \cdot (1 - As(t)) \tag{3}$$

Basic efficacy (*Be*) is influenced through the contributions of social support (*Ss*), mastery experience, and personality (*Ps*). While skill (*Sk*) is computed through the regulation of normal individual skills and long-term persistence skills (*Lp*). Perceived task difficulty (*Pd*) is governed by the high task demand (*Td*) but react negatively with skills.

$$Be(t) = [\beta_{be} \cdot Ss(t) + (1\text{-}\beta_{be}) \cdot Me(t)] \cdot Ps(t) \tag{4}$$
$$Sk(t) = \gamma_{sk} \cdot Sk_{norm}(t) + (1\text{-}\gamma_{sk}) \cdot Lp(t) \tag{5}$$
$$Pd(t) = Td(t) \cdot (1\text{-}Sk(t)) \tag{6}$$

The impact of personal goal (*Gp*) is contributed on the interplays between basic efficacy, mastery experience and perceived task difficulty. However, it also can be regulated by progress towards the goal (*Pg*). Proportional contribution of basic efficacy, short-term cognitive engagement (*Se*), personal goal, and long-term efficacy (*Lf*) are contributing towards the formation of short term persistence (*Sp*).

$$Gp(t) = \varphi_{gp} \cdot [(\rho_{gp} \cdot Be(t) + (1\text{-}\rho_{gp}) \cdot Me(t)) \cdot (1\text{-}Pd(t))] + (1\text{-}\varphi_{gp}) \cdot Pg(t) \tag{7}$$
$$Sp(t) = \omega_{sp1} \cdot Be(t) + \omega_{sp2} \cdot Se(t) + \omega_{sp3} \cdot Gp(t) + \omega_{sp4} \cdot Lf(t) \tag{8}$$

Short-term cognitive engagement (*Se*) is proportional to basic efficacy, skill, progress towards goal and generated effort (*Gf*). The impact on efficacy appraisal (*Ea*) is an aggregation of basic efficacy, personal goal, Long-term efficacy (*Le*) and mental effort (*Mf*).

$$Se(t) = \beta_{se} \cdot [\omega_{se1} \cdot Be(t) + (1\text{-}\omega_{se1}) \cdot Sk(t)] + (1\text{-}\beta_{se}) \cdot [\omega_{se2} \cdot Pg(t) + (1\text{-}\omega_{se2}) \cdot Gf(t)] \tag{9}$$
$$Ea(t) = \alpha_{ea} \cdot [\omega_{ea1} \cdot Ei(t) + (1\text{-}\omega_{ea1}) \cdot Gp(t)] + (1\text{-}\alpha_{ea}) \cdot [\omega_{ea2} \cdot Le(t) + (1\text{-}\omega_{ea2}) \cdot Mf(t)] \tag{10}$$

Mental Effort (*Mf*) is formulated from a proportional combination of personal goal, generated effort and basic efficacy. The variations of mental effort and short-term efficacy (*Sf*) define the quantity of generated effort (*Gf*).

$$Mf(t) = \gamma_{mf} \cdot [\psi_{mf} \cdot Gp(t) + (1\text{-}\psi_{mf}) \cdot Gf(t)] + (1\text{-}\gamma_{mf}) \cdot Be(t) \tag{11}$$
$$Gf(t) = \omega_{gf} \cdot Mf(t) + (1\text{-}\omega_{gf}) \cdot Sf(t) \tag{12}$$

The weights, ω_{pg} for *Sf, Lp*, and *Mf* are proportionally varied to define the progress towards the goal (*Pg*). Short-term efficacy (*Sf*) is described through the proportional contribution of basic efficacy, efficacy appraisal, long-term persistence, and personal goal.

$$Pg(t) = \omega_{pg1} \cdot Sf(t) + \omega_{pg2} \cdot Lp(t) + \omega_{pg3} \cdot Mf(t)) \tag{13}$$
$$Sf(t) = \lambda_{sf} \cdot [\omega_{sf1} \cdot Gp(t) + \omega_{sf2} \cdot Ea(t) + \omega_{sf3} \cdot Lp(t)] + (1\text{-}\lambda_{sf}) \cdot Be(t) \tag{14}$$

3.2 Temporal Relationship

Long-term cognitive engagement (*Le*) is primarily contributed the accumulation exposure towards short-term cognitive engagement (*Se*), while the accumulated short-term persistence (*Sp*) produces long-term persistence (*Lp*). The formation of long-term efficacy is modeled using the accumulated presence of short-term efficacy (*Sf*).

$$Le(t+\Delta t)= Le(t) + \beta_{le}.[Sf(t)-Le(t)].(1-Le(t)).Le(t).\Delta t \tag{15}$$
$$Lp(t+\Delta t) = Lp(t) + \alpha_{lp}.[Sp(t) - Lp(t)]. Lp(t).(1-Lp(t)).\Delta t \tag{16}$$
$$Lf(t+\Delta t) = Lf(t) + \gamma_{lf}.[(Sf(t)-Lf(t)).(1-Lf(t)).Lf(t))] . \Delta t \tag{17}$$

In addition to all this, the rate of change for all temporal specifications (flexibility rates) is determined by flexibility rates β_{le}, α_{lp}, and γ_{lf}. Using all defined formulas, a simulator was developed for experimentation purposes; specifically to explore interesting patterns and traces that explains the behaviour of the interviewee efficacy level.

4.0 Simulation Results

In this section, the model was developed using a numerical programming platform to simulate a large number of conditions of fictional individuals. With variation of these conditions, some interesting patterns can be obtained, as previously defined in the earlier section. Three different scenarios were simulated and observed for analysis. The conditions for the scenarios are defined and the simulated results presented respectively in the following figures.

Scenario #1: Three different individuals with conditions to define a high level of efficacy, low-level efficacy and an average efficacious case. The values of the inputs to the agents are in table 1 and the simulation behavior in Figure 2.

Table 1. Initial Conditions for Fictional Individuals (A,B,C)

Factors	A	B	C
Ss	1	0	0.5
Ps	1	0	0.5
Me	1	0	0.5
Ax	0	1	0.5
Vp	1	0	0.5
Ve	1	0	0.5
Td	0	1	0.5
Sk$_b$	1	0	0.5

In addition to this, there are several parameters that can be varied to simulate different characteristics. However, in this simulation, we used the following settings: $t_{max} = 500$, $\Delta t = 0.3$, regulatory rates = 0.5 and flexibility rates = 0.2. These settings were obtained from several experiments to determine the most suitable parameter values for the model as consequences to be matched with the literature. For instance, while we change some parameters, we preserve some parts of the other paramaters to evaluate the conditions until we find it suffices to explain the simulated phenomena [20].
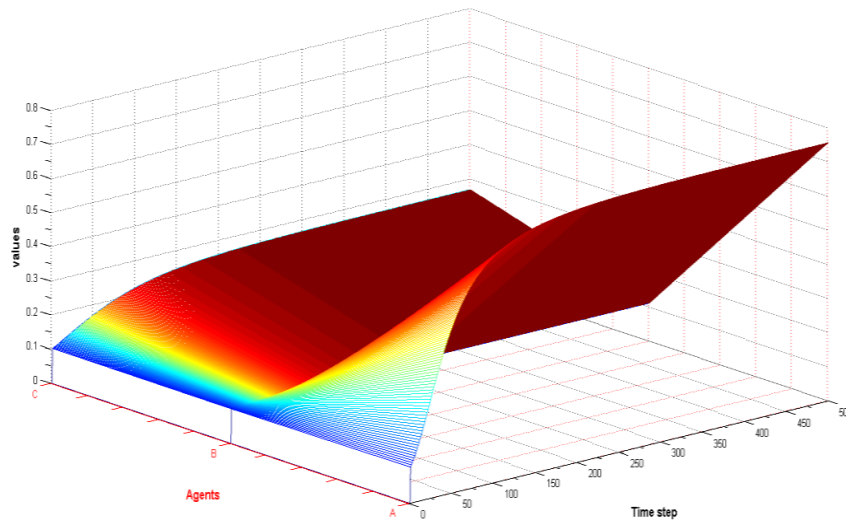
Figure 2: Simulation Results of Self-efficacy for Different Initial Inputs

This figure shows a high level of self-efficacy (long-term) for the first individual due to the favourable inputs from high exogenous levels of social support, mastery experience, skill with appreciable efficacy information (e.g.; low anxiety state, positive vicarious, and verbal persuasion). Individual *B* experiences a worst case scenario where all exogenous inputs are unfavorable (*low personality, low social support, negative or lack of task experience,* and *low efficacy information*). However, the third individual attained an average efficacy level due to the average effects as a result from the inputs that are set not to the extreme positions [19].

Scenario #2: In this case, four different fictional individuals with a number of diverse conditions are used to explain the effect of basic efficacy and efficacy information on long-term efficacy. The values of the inputs to these individuals are summarized in Table 2. The simulation results for this case are depicted in Figure 3.

Table 2. Initial Inputs for Different Variations of Individuals

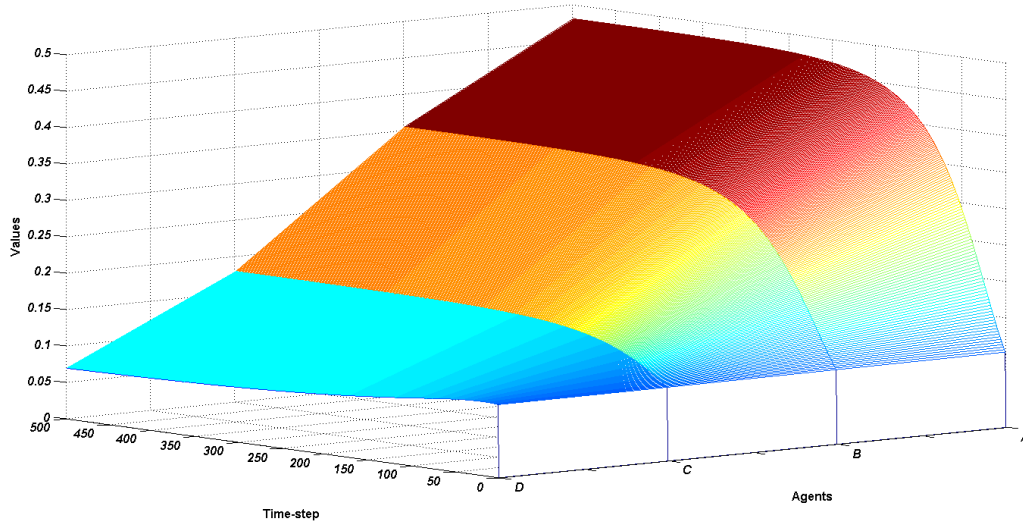| Factors	A	B	C	D
Ss	0.8	0.8	0.1	0.1
Ps	0.7	0.7	0.1	0.1
Me	0.9	0.5	0.5	0.1
Ax	0.2	0.8	0.2	0.8
Vp	0.7	0.1	0.7	0.1
Ve	0.7	0.1	0.7	0.1
Td	0.5	0.5	0.5	0.5
Sk_b	0.6	0.6	0.6	0.6

Figure 3: The Effect of Basic Efficacy and Efficacy Information on Long-Term Self-Efficacy

Figure 3 shows the influencing role of basic efficacy and efficacy information on long-term self-efficacy. In this case, persons *A* and *B* have high basic efficacy but while individual *A* receives favourable information during task engagement individual *B* does not. Individual *C* and *D* on the other hand have lower basic efficacy and while *C* receives information during task *D* does not. The impacts on the long-term efficacy shown on the figure support the fact that basic efficacy is very significant to obtaining appreciable efficacy beliefs in any task irrespective of efficacy information that may be received during the task engagement. However, the figure equally proves the strength of efficacy information as individuals that receives it appreciates on their efficacy level at the long-term.

Scenario #3: Analysis of Long-term Efficacy, Long-term Persistence and Long-term Cognitive Engagement through Temporal Parameters Variations.
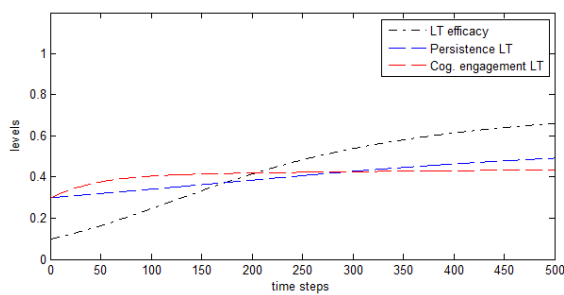

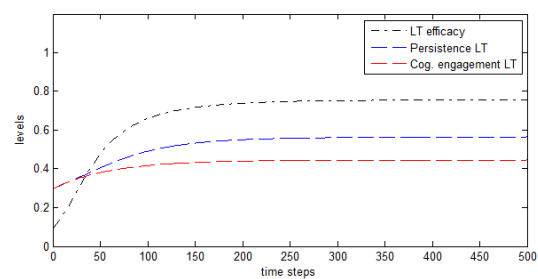**Figure 4:** Parameter Variations where β_{le}=0.1, α_{lp}=0.1 and γ_{lf}=0.1

Figure 5: Parameter Variations where β_{le}=0.5, α_{lp}=0.5 and γ_{lf}=0.5
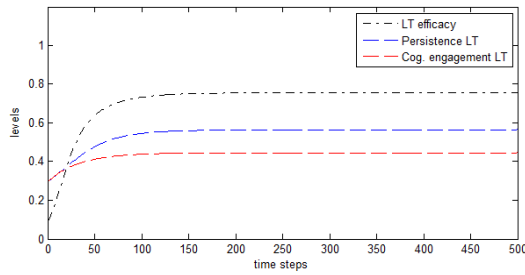
Figure 6: Parameter variations where β_{le}=0.9,
α_{lp}=0.9 and γ_{lf}=0.9

Figures 4, 5 and 6 show the analysis of the experiments results by varying the parameters' values related to the temporal equations. For example, Scenario 1 evaluates the effects of varying the external inputs on individual's long-term efficacy and shows the positive correlation, while Scenario 2 visualizes the strength of basic efficacy and efficacy information. These experimental results are consistent to the findings obtained from the literature (e.g., basic efficacy and efficacy information acquired during task affects one's self-efficacy beliefs) [16]. Finally, the last scenario (Scenario 3) varied temporal parameters to simulate fundamental characteristics of the temporal relations.

5. Mathematical Analysis
The main intention of evaluating a computational model is to ensure the correctness of the conceptual descriptions and the solutions of the model. In another words, evaluation step is a process to confirm the model is developed and implemented appropriately. In this section, the possible equilibria points are analyzed. One important assumption should be made; all exogenous variables are having a constant value. Assuming all parameters are non-zero, this leads to the following equations where an equilibrium state is characterized by:

$$dLe(t)/dt = \beta_{le}.[Sf-Le].(1-Le).Le$$
$$dLp(t)/dt = \alpha_{lp}.[Sp - Lp].Lp.(1-Lp)$$
$$dLf(t)/dt = \gamma_{lf}.[(Sf-Lf)].(1-Lf).Lf$$

Next, the equations are identified as,

$$dLe(t)/dt = 0$$
$$dLp(t)/dt = 0$$
$$dLf(t)/dt = 0$$

Assuming all temporal parameters are equal to 1, therefore these equations can be re-written as,

$$(Sf=Le) \vee (Le =1) \vee (Le = 0)$$
$$(Sp=Lp) \vee (Lp =1) \vee (Lp = 0)$$
$$(Sf=Lf) \vee (Lf =1) \vee (Lf = 0)$$

Therefore, the first conclusion can be identified where the equilibria points can only occur when *Sf=Le* or *Le=1* or *Le=0*. The next step is to combine these three conditions into a new set of relationship, as in $(A \vee B \vee C) \wedge (D \vee E \vee F)$ expression.

$$(Sf=Le \vee Le =1 \vee Le = 0) \wedge (Sp=Lp \vee Lp =1 \vee Lp = 0) \wedge$$
$$(Sf=Lf \vee Lf =1 \vee Lf = 0)$$

This expression can be elaborated using *Law of Distributivity* as $(A \wedge D) \vee (A \wedge E) \vee (A \wedge F) \vee, \ldots, \vee (C \wedge F)$ and this will result

$$(Sf=Le \; \wedge \; Sp=Lp \; \wedge \; Sf = Lf) \vee ,……., \vee \; (Le= 0 \wedge \; Lp=0 \wedge Lf=0)$$

These equations later provide possible combinations of equilibria points to be further analysis. However, due to the large number of existed combinations, (in this case $3^3 =27$ probabilities), it makes hard to provide a full analysis of complete equilibria cases. In this paper, only four equilibria cases are discussed. Note that the combination of $(Sf=Le \; \wedge \; Sp=Lp \; \wedge \; Sf = Lf)$ will be eliminated due to the conflict in logical reasoning.

Case #1: $Lf = 0$
In this case, from equation (8), this case is equivalent to:
$$Sp = \omega_{sp1}.Be +\omega_{sp2}.Se +\omega_{sp3}.Gp$$
If all weights were equally distributed, therefore this case is equal to
$$Sp = \omega[Be +Se +Gp], \text{ where } \; \omega \approx 0.33, \text{ and } \Sigma \; \omega \approx 1$$

Case #2: $Le=1 \wedge Lf = 1 \wedge Lp=1$
For this case, equations (5, 8, 10 and 13) provide a set of equilibria points through;
$$Sk= \gamma_{sk}.Sk_{norm} + (1- \gamma_{sk})$$
$$Sp = \omega_{sp1}.Be +\omega_{sp2}.Se +\omega_{sp3}.Gp + \omega_{sp4}$$
and if all weights were assigned 0.25 respectively, therefore,
$$Sp = 0.25.(Be +Se +.Gp + 1)$$
From equation 10 and 13, this case equivalent to;
$$Ea = \alpha_{ea}.[\omega_{ea1}.Ei + (1-\omega_{ea1}).Gp]+(1- \alpha_{ea}).[\omega_{ea2} +(1-\omega_{ea2}).Mf]$$
$$Pg = \omega_{pg1}.Sf + \omega_{pg2} + \omega_{pg3}.Mf$$

Case #3: $Se=Le$
Consider equation (10), the equilibria point is
$$Ea = \alpha_{ea}.[\omega_{ea1}.Ei + (1-\omega_{ea1}).Gp]+(1- \alpha_{ea}).[\omega_{ea2}.Se+(1-\omega_{ea2}).Mf$$
Assuming $\omega_{ea1} = 1$, this case equivalent to:
$$Ei = (Ea -(1- \alpha_{ea}).[\omega_{ea2}.Se+(1-\omega_{ea2}).Mf)/ \alpha_{ea}$$
From this, if $\alpha_{ea} = 1$, thus
$$Ei = Ea$$

Case #4: $Lp = 0$
Equation (5) provides an equilibria point of;
$$Sk= \gamma_{sk}.Sk_{norm}$$
Assuming $\gamma_{sk} =1$, thus $Sk= Sk_{norm}$
Another equilibria point (from equation 14), the effect of the stability point can be summarized as;
$$Sf= \lambda_{sf}.[\omega_{sf1}.Gp + \omega_{sf2}.Ea]+(1- \lambda_{sf}).Be$$
If $\lambda_{sf} = 0$, for that reason, $Sf=Be$

6. Conclusion
This paper presented a proposed formal analysis of an interviewee's efficacy model. The proposed model is heavily inspired by a number of theories in cognitive science and psychology. The concept of self-efficacy which is the main construct that the model tends to explain is routed in believe in one's capability to withstand and succeed in a given task. The simulated model agrees with the theoretical foundation of self-efficacy. The presented results show that the basic self-efficacy which one possesses at the start of any task such as job interview greatly influences the final efficacy and indeed the task performance. It also proves the important contribution of mastery experience and personality both to the basic self-efficacy and final self-efficacy beliefs. This is in line with several studies of self-efficacy

construct. The analysis of the formal model proves several equilibrium points to define the stability of the model. In order to design an intelligent software agent that can understand and predict human psychological state and provide support especially in a time bounded tasking situation like employment interview, it is important to formalize the underlining constructs which can then be incorporated into such software. This type of software can be integrated into a robot or any virtual agents that provide support during interview training or coaching session.

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