Affective Agents: Sustaining Motivation to Learn Through Failure and a State of "Stuck"

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Abstract:

Since failure, over and over and over again, is a prerequisite to becoming an expert, so to is the ability to persevere and remain motivated through failure. Many researchers creating ITSs have taken the approach of manipulating the task in terms of difficulty, focus, and other parameters in an effort to sustain users' motivation. There are numerous circumstances where this approach is impractical, undesirable, or simply impossible. This task-manipulation approach misses the important opportunity to help users develop skills to deal with failure and frustration. We propose instead an approach that uses affective agents[1] to help users develop metacognitive skills such as affective self-awareness for dealing with failure and frustration. An important element of our approach is the use of one or more affective agents as peer learning companions to facilitate development of empathetic relationships with learners. This paper describes work in progress exploring how characteristics of affective agents can influence perseverance in the face of failure.

Introduction:

We choose to focus on motivation through failure because of its importance in the learning process. At Stanford's Department of Mechanical Engineering there is a saying that, "Spectacular failure is better than moderate success." (Faste, 1996) This is not an overtly masochistic agenda, rather the message is that if you do not strive for spectacular success you will never achieve it; if you achieve moderate success you have not strived far enough." Kay's version of this sentiment is that, "difficulty should be sought out, as a spur to delving more deeply into an interesting area. An education system that tries to make everything easy and pleasurable will prevent much important learning from happening." (Kay, 1991) In Csikszentmihalyi's words this would be the notion of matching adequate challenge with skill in service of Flow, or optimal experience (Csikszentmihalyi, 1990).

In this vein, in their chapter on *Motivation and Failure in Educational Systems Design* Roger Shank and Adam Neaman describe the utility of simulated Learning By Doing environments, to accelerate the pace of learning through exposure to difficult circumstances that may arise less frequently than in real world situations. This will inevitably accelerate the rate of failure and, if motivation is sustained, the rate of learning as, "novices are exposed to rare, but critical, experiences" (Schank, Neaman, 2001). Shank and Neaman acknowledge that fear of failure is a significant barrier to learning and believe this can be addressed in several ways: minimizing discouragement by lessening humiliation; developing the understanding that consequences of failure will be minimal; and providing motivation that outweighs or distracts the unpleasant aspects of failure. They show that they have been able to sustain the motivation of learners, who care about what they are doing, by providing them access to experts at the time of failure. Through questions, stories, anecdotes and additional experiences learners are given the opportunity to, "expend the effort to explain their failures". Learners are given the opportunity to achieve and become expert (Schank, Neaman, 2001). Many have taken the approach of tailoring the task to the individual user in an effort to maintain motivation, an affective state, Flow or optimal challenge (Malone, 1981; Monk, 2000, Hill et al., 2001). Hill et al. in their paper, Toward the Holodeck, discuss the merits of the creation of a Holodeck like setting in terms of its immersive, believable, and motivating qualities. This terminology is remarkably similar to descriptions of psychological Flow.

[1] Affective Agents can sense users' affect and respond with displays of their own affect .

Background:

While this task manipulation approach seems appropriate in some circumstances it runs the risk of missing an important opportunity for users to learn affective self-awareness and engage in related metacognative development. In other circumstances it is simply not possible. The task may not lend itself to modification or modularization, it may be unbounded, or its analysis and manipulation may be beyond the current capabilities. What we propose instead is an affective approach. Regardless of task state information or activity tailoring, it is possible to gather information about the user's affective state and to use this to guide affective interactions on behalf of the user. In many circumstances tasks are harder than anyone would like them to be. And, these tasks may not always tailor themselves to facilitate motivation. Considering these conditions, from a pedagogical perspective, it is important to take into account the phenomenon of "negative asymmetry"; that the staying power of negative affect tends to outweigh the more transient experience of positive affect (Giuseppe, Brass, 2003). Unfortunately for the purposes of sustaining learners' motivation negative asymmetry means that negative affect experienced from failure and repeated failure is likely to persist disproportionately to the positive affect experienced from success. A separate and compounding factor is that it is often easier for novices to see their failures than to realize their successes. One approach is for educators and innovators to try extra hard to create motivating learning environments which celebrate achievement and provide sustaining inquiry opportunity at times of failure, such as those advocated by Shank, Neaman, Lester, Moran, Monk, and Hill et al. Another is to provide tools and experiences that foster affective self-awareness, skills for dealing with failure, frustration, and other forms of negative affect, as well as skills for identifying and benefiting from incremental success. These would have the goal of developing within users a greater metacognitive ability to control their own motivational engagement with difficult tasks, in spite of recent failures and difficult tasks.

This strategy of pedagogical adaptation that is mindful of the learners' affective state has been pursued in the work of several researchers. In their work on interactive pedagogical drama for health interventions, Marsella and Johnson use affective elements of textual dialogue to inform and adapt their agents with the goal of altering user affective states through changes in their perspective rather than in the task (Marsella and Johnson 2003). Aimeur's provoking agents employ this strategy through cognitive dissidence: the agent companions serve as troublemakers to perturb the affective state of individuals. When a learner is comfortable with the status quo the troublemakers introduce problems that are aimed at generating pedagogically productive insights by the learners (Aimeur, Frasson and Dufort, 2000). Kort, Reilly and Picard propose a model of constructive learning that relates learning and emotion in an evolving cycle of learner affective states. Their proposed cyclic trajectory begins with anticipation, expectation, and exploration, a stage where intervention is to be discouraged. If the learner progresses to disappointment or discouragement and stays there too long, then intervention may be productive. They argue that this cycle, including its negative states, is natural to the learning process, and that learners can develop skills to keep moving through it, propelling themselves out of the failure mode and into a more hopeful state conducive to continued exploration and learning (Kort, Reilly and Picard, 2001).

It is interesting to compare elements of negative affective states with the elements of Flow: a feeling of being in control; concentration and highly focused attention; mental enjoyment of the activity for its own sake; a distorted sense of time; a match between the challenge at hand and one's skills. In direct contrast elements of negative affect include: a feeling of being out of control; a lack of concentration and inability to maintain focused attention; mental fatigue and distress caused by engagement with the activity; and a negative distorted sense of time, taking forever or never ending and taxing endurance. In short there may be a negative corollary to Flow, commonly called Stuck: or non-optimal experience (See Table 1.). While Flow and Stuck are frequently associated with positive and negative affect respectively these states do not require emotional components. The study of Flow includes findings that conscious awareness tends to diminish happiness and Flow (Csikszentmihalyi, 1990). This suggests that conscious awareness of frustration and Stuck states may diminish these states as well. If this is the case affective self-awareness should then assist users to mitigate the detrimental effects of Stuck on their learning. We expect this to be especially true when users encounter recurring failure that is often a prerequisite to the development of deeper understanding. The phenomena of negative asymmetry and the benefits of affective self-awareness described here illustrate several fundamental impacts to learning. In these descriptions motivation is intimately intertwined with failure, frustration, affect, awareness, and emotional intelligence. We are using the current understanding of these psychological effects to inform the development of affective agents that behave with appropriate interactions toward learners.

Flow: Optimal Experience	**Stuck: Non-Optimal Experience**
All encompassing	All encompassing
A feeling of being in control	A feeling of being out of control
Concentration and highly focused attention	A lack of concentration and inability to maintain focused attention
Mental enjoyment of the activity for its own sake	Mental fatigue and distress caused by engagement with the activity
A distorted sense of time	A negative distorted sense of time, taking forever or never ending and taxing endurance (Weybrew, 1984; Czerwinski et al., 2001).
A match between the challenge at hand and one's skills	A perceived miss-match between the challenge at hand and one's skill
Frequently associated with positive affect	Frequently associated with negative affect

Table 1. Elements of Flow: Optimal Experience and Stuck: Non-Optimal Experience.

Proposed work:

We are seeking to tease apart internal personal strategies and interpersonal social motivations. In this work we are making the distinction between, on the one hand, adjusting the environment to facilitate Flow, and on the other, empowering the user through self-awareness to participate in self-regulated motivational strategies. Rather than tailor the task we propose a learning companion that will not be an ITS agent that already knows the task domain, but rather, acts an affective partner, on the side of the learner – a collaborator to assist in affective self awareness. One approach we believe will be particularly fruitful is to present the affective agents as one or more peer-learning companions. (Chan and Baskin, 1990; Aimeur, Frasson and Dufort, 2000).

To gain a better understanding for the potential of the learning companions we are developing, the system configuration, and the utility of recognizing affect and engaging in interactions that promote affective self-awareness, let us imagine two scenarios involving twelve-year-old children Felix and Moira, engaged in the Towers of Hanoi task (Burleson et al., 2004). Through knowledge of the game state (progress, regression, rapidity and inaction) and affect sensing of these learners the learning companions will attempt to provide constructive interactions. These interactions are presented both in the non-verbal channels and in asymmetrical dialogue in which the character speaks with a synthesized affective voice (Cahn, 1989) and the learner uses the keyboard and mouse to select elements in the environment, select among text choices or enter text of their own. From all of these channels we are attempting to directly infer the user's affective state through a rich set of sensors including skin conductivity, facial expression analysis (eyebrow raise, head nod and shake, mouth smiles and fidgets, and blink rate), pressure mouse, and a seat posture sensor (Burleson et al, 2004) (See Figure 1.). Prior to the development of an affective inference engine, based on classification of clustered data from these sensors, we will use the sensors directly to make first order ad-hoc decisions to motivate agent interactions.

We will be paying particular attention to understanding the learners' progress and how information from the sensors changes with more objective measures of progress. We will use this to inform appropriate agent learner interactions and interventions. Making appropriate decisions based on progress is challenging particularly because progress in the context of learning is complex and multifaceted. Progress can take the form of experimentation, pursuing activities to increasing intrinsic motivation, developing task relevant understanding, subconscious awareness and mental models or analogies, or simply exposure, familiarity, and experience. At any given state of the Towers of Hanoi task an objective measure of progress can be obtained by calculating the remaining number of moves. But, progress in learning is not simply the quantifiable progress toward the objective goal of the particular task. We will focus our attention on the affective elements of progress. If, for example, the majority of sensors indicate that frustration is not present even when the user has not exhibited progress in terms of the task state our system will assume that curiosity, exploration, or familiarity are at play and the learning companion will allow the user to further explore the task without explicit intervention. If on the other hand there are lots of signs from the sensors believed to be associated with stress, the agent might intervene.

The risk of inappropriate interactions takes several forms. If an agent is overly excited about a learner's success the learner may feel awkward which may lessen their motivation for continued interactions with the agent and on the task. If an agent increases a user's affective self awareness when they are not Stuck, they may become more aware of small amounts of negative and this may do a disservice to the learner. The learner may enter Stuck more readily or they may benefit less from the productive frustrations or cognitive dissidences inherent in challenging tasks.

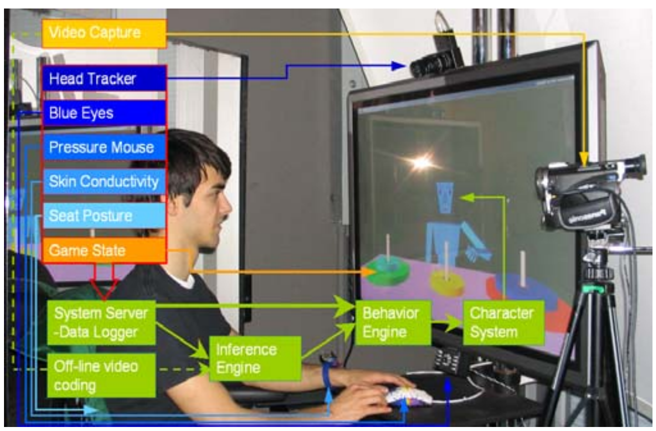

Figure 1: Learning Companion being developed with new affective agent platform.

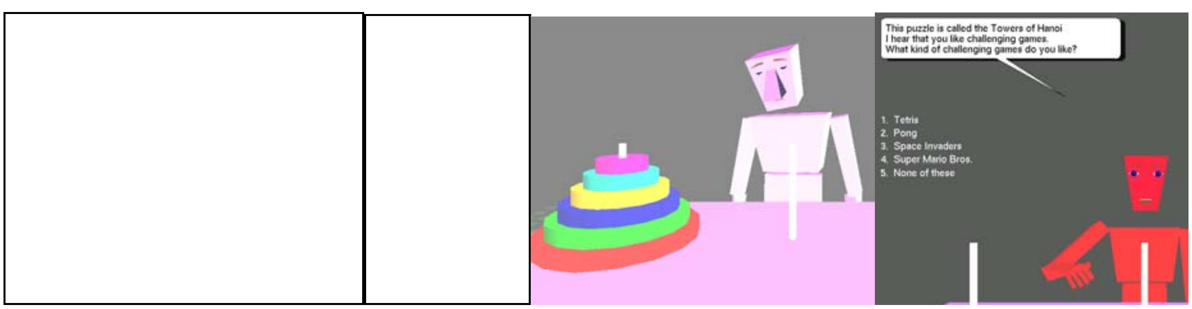

Figure 2. The agent is capable of a continuum of expressions and asymmetric dialogue.

Felix: Felix has been informed of the experiment and agreed to wear a wireless skin conductivity sensor. He sits in front of a large screen plasma display. The chair he sits on is instrumented with a posture sensor. The screen has a character that introduces itself as Casey. Casey was chosen as a gender-neutral name to facilitate increased affinity between the character and users of either gender. In the foreground there is a virtual Towers of Hanoi, with 4 disks. A group of two characters are playing with another puzzle in the background on one side and an independent character is playing with a third activity in the background on the left. Casey greets Felix by saying, "Hi, would you like me to tell you about this *activity?* The word *activity* is used as an unbiased word -- unlike *work*, *play*, or *puzzle*. Felix responds by selecting "Sure". To any human, Felix would appear interested but not enthusiastic, the system is not yet aware of this subtlety of Felix's affect. Casey proceeds to explain the rules of the activity and asks Felix if he understands. Felix clicks "Yes"; his postural state indicates moderate interest. During the introduction and the first several moves the system takes a baseline reading of the sensors and associates this with engagement typically present at the beginning of a new task. Casey explains the rules and gives him an opportunity to proceed with the puzzle. Felix lifts one of the disks off of the first pole and moves it to another pole. After moving the first several disks he discovers that he has run into a challenge where the disk he wanted to move cannot be moved. He starts to reverse some of the movements that he has made. Felix is not really aware that these are reversals since it is hard for a first timer to remember sequences with the disks but Casey is aware and after a while chooses to ask Felix the first of a series of Socratic questions, "Which pole are you trying to move the tower to?" This part of the intervention is not based on sensor information, but only on state information derived from the task interaction, as is typical in intelligent tutoring systems. Felix correctly clicks on the far pole. Casey says, "Ok, now imagine all the disks on that pole? Can you click on the disk that will be on the bottom?" Felix clicks on the largest disk. Casey says, "Click on all the disks that are in the way of moving that disk to the third pole now?" Felix clicks on the other three disks one by one. Casey says, "Ok, can you click on the pole that you want to move all of those disks too?" Felix clicks on the second pole and smiles as he realizes what to do next. He also releases some of the pressure being applied to the mouse. Sensing the smile and relaxed mouse pressure Casey chooses to defer further intervention and instead offers encouragement, "Why don't you try it?" If this had been a learning companion without affective recognition it would not be able to realize this affective subtlety at this point in the interaction and might continue with the sequence of questions longer than would be necessary. This would "rob the learner" of the opportunity of discovering the solution on his own.

Felix seems to be on a roll! The independent character comes over to watch and says, "Wow, you're doing well!" Felix appreciates the affirmation and continues to proceed. The independent character sticks around a bit but gets reabsorbed in its own puzzle and wanders off into the background. Under different circumstances this character might have offered instructive encouragement or empathy. Felix finishes the puzzle with ease and is pleased but not overly excited. Casey senses a marginal increase in skin conductivity and the presence of a brief smile. Casey therefore chooses to engage in an abbreviated and moderate celebratory interaction and then to continue with the presentation of the next activity, with 5 disks. An agent without affective sensors might have been overly enthusiastic which could have made Felix feel awkward or more detached from the agent. Felix proceeds with the puzzle occasionally looking up at Casey who gives moderate facial encouragement. When Felix shifts in the chair Casey shifts to mirror the intentional state. This behavior of postural matching is frequently seen in human-human interactions and is likely to increase the social connection between user and agent. It may also draw implicit reflective attention to the user's affect. Felix manages to get into a fairly lengthy series of reversals again. In this situation a character without affective sensing might chose to interact in an effort to retain Felix's attention. In this case skin conductivity has not increased, the mouse pressure remains low, and there is a reasonable level of postural movement (which has been shown to correlate to interest). Casey realizes that Felix is not displaying significant signs of frustration so continues with a strategy of implicitly mirroring Felix's affect in an effort to enhance his self-awareness. Felix emerges from the reversal and speedily finishes the last few steps. As the speed of the disk moves increase along with an increase in skin conductivity (indicating arousal) it becomes apparent that Felix is aware and excited by his proximity to the solution. Casey displays more excitement too! The independent character returns to watch and display excitement, too. Upon completion the characters celebrate with Felix, "Great job! We knew you could do it! This celebration continues until Felix shows signs (fewer smiles and lowering of skin conductivity) of decreasing excitement.

Moira: Moira is a gregarious and initially confident child who is easily overwhelmed; she falls into Dweck[2]'s *trait based* category with regards to her beliefs of intelligence. She proceeds excitedly until she too is perplexed by a series of reversals. Casey initiates Socratic questioning. Unlike Felix, and typical of *trait based* learners, she does not show excitement or interest when she answers. Her confidence has been shaken. Her rigid posture, increased mouse pressure, and rise in skin conductivity, the game state and the slowed motion of the disks collectively indicate this. Casey attempts to provide continued support for Moira. Instead of pausing after the identification of the role of the second disk in the solution Casey asks, "What is in the way of the second disk?" Moira selects a text option, "I don't know." Casey asks, "Is the 3rd disk in the way?" Moira clicks: "Yes." Casey: "If you want to move the second disk to pole 3 where do you want to move the 3rd disk?" Moira, by chance, correctly clicks on the middle pole. Through this series of questions Moira's mouse pressure and skin conductivity continues to increase. If Casey did not have affect recognition Casey might leave Moira at this critical point to make her own progress thinking that she had understood or that after moving disk 3 that she would figure out the next move. With affective recognition Casey might embark upon a different path altogether. Casey determines that Moira may be entering a state of Stuck. Casey can use this awareness to empathize with Moira. Casey looks frustrated and says, "Sometimes this activity makes me frustrated. Do you get frustrated?" Moira might welcome this shift of focus and click, "Yes". This would open the opportunity for a dialogue on affective-awareness. In this dialogue Casey can use a technique promoted by Dweck that uses an analogy that the brain is like a muscle and that exercising your brain makes it better at problems. Casey might say, "Most people find that if they realize they are frustrated it can help them realize that making mistakes is ok. Do you think that this would help you?" Moira might click,"yes", and Casey could respond "In fact making mistakes is part of learning how to do things better. Would you like to give this activity another shot? If we get frustrated we'll try to realize that we are frustrated, ok?" Moira is presented with 'yes' and 'no' options. If this dialogue had been initiated while things were going well it may have been an awkward interaction. If she answers 'yes' then the activity resumes, if on the other hand she answers 'no,' then taking a lesson gained from the researchers who manipulate task difficulty Casey would engage Moira in an alternative task that might be more fun for her. Casey's focus would still be on developing affective self-awareness and this new activity would give Casey the opportunity to continue to discuss the process or frustration, engagement, and self-awareness in a more relaxed setting. Casey's goal would still be to have Moira return to the task with these new perspectives. Casey might suggest, "Would you rather play a different game?" In selecting this response the words play and game are selected intentionally for their proven ability to increase intrinsic motivation. Moira might respond with interest or even enthusiasm to this. In which case Casey would get excited and says, "Oh, we can play my favorite game called numbelypoles! Here's how it goes. You and I will take turns, the rules are the same as in the first task but this time the goal is to make a tower on the blinking pole with the blinking disk as its base."

Some pilot experiments will need to be done but this game may be sufficiently more engaging to be of interest to students who have lost interest in the first game – alternatively more interesting yet still productive variants could be easily explored. This game is identical to the first but uses collaboration between the character and learner to explore the solution. After playing this game, reflecting on feelings of frustration and learning how to break down problems to develop solutions,

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[2] A closely related area that has yielded strong results addresses how an individuals' beliefs of their own intelligence effects their motivation, learning, and behavioral strategies in response to failure (Dweck, 1999). In her research on metacognitive beliefs she has found two predominant groups of individuals: those who believe their own intelligence can be enhanced, whom she calls *incrementalists,* and those who believe their intelligence is *trait based*. When *incrementalists* fail at a task they tend to increase their intrinsic motivation for the task, believing that if they try harder they will get better. When *trait based* individuals fail they exhibit avoidance and decreased intrinsic motivation for the task, believing instead that their previous performance defines their ability. They act on their desires to avoid further confirmation of what they perceive to be their "trait based" inability.

our hypothesis is that learners will be able to proceed with the primary activity more successfully. We expect that this will to be true even when they are *trait based* individuals, such as Moira, who have exhibited avoidance for the first task. After playing the collaborative game on a sub-set of the disks Moira should experience some increased ability at fluency, flexibility, an increased belief in her ability to succeed, some improvement in her affective state as measured by the sensors and some development of her affective self-awareness. This game could continue as long as needed and then end or if interest allows it can slowly transition back to the original game by asking Moira which disk and which pole should blink to achieve her successive goals. In this process her success is celebrated by Casey and other agents who become involved in the game. All of the agents become more and more confident of Moira's ability to succeed. Casey asks, "Do you think you can try the first activity again?" Moira is likely to be more interested and willing to try, even if she is not sure that she can succeed. Upon finishing, with or without further intervention her completion is celebrated, in accordance to the levels of excitement (smile and skin conductivity).

Discussion:

In these scenarios we have seen how Casey and other supportive agents nurtured the learning process. In Felix's scenario Casey's relationship is pretty typical. The learner meets a challenge and grows frustrated and is likely to quit without attention. If given supportive intervention coupled with the celebration of success, the learner is able to proceed with understanding and confidence. In Moira's scenario the frustration level is high which leads to a high risk of quitting. Casey detects this and shifts the discussion to the topic for frustration, ultimately invoking imaginative and collaborative play to reengage Moira in the activity, develop her affective self-awareness abilities and build her confidence.

We are implementing Casey with the ability to engage in scenarios such as the two described above. We intend to evaluate these strategies to discover if affective sensing can assist Casey to facilitate better perseverance through the state of "Stuck". This may help users develop metacognitive skills for dealing with failure and frustration. Initial studies will involve two conditions; Casey with and without affective sensing. After a set amount of interaction Casey will excuse itself and ask the learner to continue. We intend to measure the effects of the interaction in terms of perseverance on subsequent tasks and self-rated, sensed and judge-rated frustration encountered in a subsequent task (Weybrew, 1984; Czerwinski et al., 2001). We will also ask learners their perceptions in terms of liking and caring for and by Casey, using the Working Aliance Inventory (Bickmore and Picard, 2004, Paiva et al., 2004). This will be explored to see if there is an affective or relational effect beyond the motivation due to the persona effect.

There are obviously many other opportunities to be explored and understood, but these are our initial steps toward the development of a suit of prototypical scenarios. These prototypes strive be useful to a variety of learners. They also incorporate social pathways from one agent to another to allow Casey and the others the flexibility to adjust their approach and response to the interpretation of learners' conditions.

Conclusion:

Developing learning experiences that facilitate self-actualization and creativity is among the most important goals of our society in preparation for the future. To facilitate deep understanding of a new concept -- to facilitate learning -- learners must have the opportunity to develop multiple and flexible perspectives. The process of becoming an expert involves failure, understanding failure, and the motivation to move onward. Meta-cognitive awareness can play a role in developing an individual's ability to persevere through failure. We have presented a strategy for using affective agents to help sustain motivation through failure and a state of "Stuck." Many have taken the approach of manipulating the task; we take the approach of assisting users to modulate the effects of their own affective state. This strategy is likely to be particularly effective in assisting learners to pursue difficult and un-manipulated tasks that arise frequently in their everyday lives.

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