A Model for Stream of Thought in Anxiety and Depression

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Abstract

Depression and anxiety are debilitating conditions that significantly reduce the quality of life for many people and their loved ones. Understanding the "internal world" of the sufferer is difficult for those who have not had direct experience. We examine the internal scripts that are a hallmark of these illnesses. Once triggered by external and internal events, what is the path, duration, and severity of resultant thoughts and emotions? These paths may be called thought streams. We are creating a simulator to better understand an abstracted version of these thought streams. Existing research has been done in modeling mental illness, for example connectionist or hybrid models of the neurobiological mechanism of illness. SAD (Stream of thought in Anxiety and Depression) is more closely related to earlier work on goal-oriented, normal day dreaming since it symbolically represents conscious aspects of thought. The difference is that SAD is intended to capture depressive or anxious thinking over time.

Depression and anxiety are debilitating conditions that significantly reduce the quality of life for many people and their loved ones. Much work has been done to understand and treat these debilitating and sometimes lethal illnesses. But understanding the "internal world" of the sufferer is difficult for those who have not had direct experience.

We examine the internal "scripts" that are a hallmark of these illnesses. In addition to major life events, like the death of a loved one, what triggers acute episodes? Once triggered by external and internal events, what are the path, duration, and severity of resultant thoughts and emotions? We call these paths "*thought streams*". William James wrote that "Consciousness… does not appear to itself chopped up in bits…a "river" or "stream" are the metaphors by which it is most naturally described" (James 1890).

In healthy, non-goal oriented thinking, the mind wanders from topic to topic, none of which generally leads to negative thought streams. Meditators sometimes refer to this as "monkey mind", an analogy to monkeys jumping amongst trees. A goal in meditation is to try to quiet the mind and reduce this mental activity since it can increase ones' stress level or lead to negative mental states. This mind-wandering is typically what we think of when someone asks "what are you thinking?" and you respond with "just wandering". It is non-productive day-dreaming. Innocuous as this is in people not suffering from anxiety or depression, any given thought can act as a trigger for those that do.

Our chosen method is to develop a software model that attempts to capture an abstracted form of these thought streams. We believe that finding a way to categorize the triggers and scripts into generalized patterns is more promising than attempting to focus on specific, individualized events. For example, receiving criticism at work is an abstraction of a number of detailed specific events that could occur. One of the challenges is to find the proper level of abstraction between the most specific experiences of an individual and ones so general to be of little value in understanding depression and anxiety.

The primary purpose of this work is to better understand dysfunctional thinking and to predict how it influences future mood. At this point, we are not attempting to treat depression or anxiety or to directly assist mental health professionals in diagnosis or treatment. Our hope is that at some point the work could be of benefit to new mental health professionals by helping elucidate the internal state of patients. Conversely, these professionals and the patients they treat will be invaluable sources for additional knowledge acquisition and validation of the system.

The Psychology of Depression and Anxiety

Cognitive models of negative emotion suggest that depression and anxiety are associated with different cognitive features. However, distinguishing anxious from depressive self-talk is difficult because of the overlap between anxiety and depression (Safren, et al. 2000).

Minds are busy. The unfortunate part is that many of these thoughts are repetitive, and of those, many are negative. Much of the time we are not doing useful reasoning like planning, problem solving, or decision making. Some spend significant time (1) ruminating about the past, replaying feelings of grief, shame, or remorse and (2) worrying about the future, often about things we cannot control, like rain or unlikely events like a major earthquake in Texas.

Why is it that in a healthy mind, we are able to "escape" these negative thoughts, rather than spiraling into repetition and increasingly negative thinking? Styron (1990) writes

"depression is a disorder of mood, so mysteriously painful and elusive in the way it comes known to the self…as to verge close to being beyond description". While the severely depressed individual might appear stuporous, turmoil of these negative thought spirals may be raging. The mind becomes obsessed with feelings of desperation. The desire to escape this torture leads some to attempt or complete suicide.

Types of daydreams are directly related to depression. Several measures, e.g. the Beck Depression Inventory, are used to measure depression level. Depressed subjects' daydreams included those that were "neurotic, anxious, dysphoric, and negative", including mental agitation and distractibility, indecisiveness, personal devaluation, and fear of failure (Giambra and Traynor 1978).

Cognitive Modeling of Mental Illness

Cognitive architectures are frameworks used to design systems that emulate human reasoning. Examples are SOAR, ACT, ICARUS, and CLARION[1]. These have been used to create artificial agents that can solve problems, either independently or in cooperation with humans. Increasingly, these architectures include support for modeling emotions.

Work in cognitive modeling often focuses on goal-directed behavior (Mueller 1990). What if there is no real goal from which to begin inference? Instead, the initial trigger may be an external sense perception or a thought, brought to awareness through what feels like a mystery.

Some work has been done in modeling mental illness. Of this work, the objective is often to assist mental health practitioners working with patients or to understand the neurobiological mechanism of illness through simulation. Webster and Banks (1989) use symbolic logic and chaotic dynamic systems theory to simulate manic-depressive illness. Most of the discussion focuses on Type II bipolar with its episodes of hypomania and mild to moderate depression. Their conclusions are "that manic-depression may represent a bifurcation from the chaotic dynamics of normal emotional lability to the pathological periodicity of affective illness". Sun, Wilson, and Mathews (2011) used the CLARION Cognitive Architecture to develop a simulation for addiction and Obsessive Compulsive Disorder (OCD). This system embeds models of these disorders within a comprehensive system that studies the interaction among cooperating sub-systems. It is largely based on Neural Networks and shows great promise for its intended purpose – better understanding the internal, hidden aspects of mind that lead to certain behaviors. Our work is more like the work on day dreaming (Mueller 1990) in the sense that we are trying to symbolically represent the evolution of *conscious* depressive and anxious thinking.

The SAD Model

We have developed a basic version of the SAD model for Anxiety and Depression which is an early attempt to capture the stream of thoughts that occur within individuals who are experiencing the commonly co-occurring illnesses of anxiety and depression. Thoughts, emotions, behaviors, and external events may cause individuals to become better or worse over time.

A few definitions are in order. First, a "thought stream" as described previously, is a general chain of thoughts, as one might have when day-dreaming. The second is a type of thought stream called a "thought spiral". This is a cyclic chain of frequently repetitive negative thoughts that have been established over time. These are somewhat like AI scripts in that they represent an expected sequence of thoughts. The third is a "thought trigger", or just trigger. This is a general category of events or thoughts that initiate thought streams. Fourth, a thought script is essentially an individual thought, like "I feel overwhelmed", which form the components of thought streams and spirals. However, a thought script may embed a brief, frequently occurring spiral, as shown later.

A rule-based prototype has been developed with CLIPS (Riley, 2005). Facts represent mood states, events, thought triggers, and related data. Rules represent thought scripts and spirals. A file of temporally-ordered events is used as a driver to the simulation. These events include (1) perceptions, including visual and auditory images (e.g., seeing a large stack of mail, hearing a ringing phone), (2) other actions such as waking up from sleep perhaps with vivid dream recall, and (3) internal experiences like intense memories that appear to come from nowhere (some PTSD sufferers call this "flashbulb thoughts"). These events offer some way to show how a thought stream is initiated. Particularly challenging is modeling how thought spirals "turn off". For now, this can occur from attending to some types of external stimuli or performing some action, e.g., falling asleep. In reality, avoidant behaviors may be the only way to stop the thought spirals. A simple example run is given in the Prototype Implementation section.

In the event simulation, external events do not necessarily occur in fixed time units. Several events may occur within an hour; other times events may be hours apart. When the individual is feeling well, events that affect the individual may be days apart. Rules often generate new events as the simulation progresses. Consider that two events e_x and e_{x+1} have been read from the input file. If a stream of thought produces another event between e_x and e_{x+1}, it is inserted. For example, if the individual is asleep when e_{x+1} would have occurred, then a new event e_{x+1} replaces the one from the input file. Otherwise, it is inserted between these two events. While this is an imperfect representation, the intent is to create a starting

[1] Wikipedia contributors, "Cognitive architecture," *Wikipedia, The Free Encyclopedia,* http://en.wikipedia.org/w/index.php?title=Cognitive_architecture&oldid=532671550 (accessed January 30, 2013).

point for the system. The last section suggests ways this model may be improved.

An example input for part of one day is shown in Table 1. This individual awakens in a depressed state. Triggers that generally lead to increased anxiety (noticing a stack of mail to be dealt with) and avoidance behavior lower the mood of the individual. Activities that can be considered accomplishments raise mood (e.g., taking a shower for a significantly depressed individual can be a significant accomplishment).

Table 1. Simplified Event Simulation Input.

Event/Trigger	*Time*	*ADVAL*
Wake	D1 3:00am	-4
Undesired Activity	D1 5:00am	-6
Shower	D1 2:00pm	-2
Distraction: TV	D1 6:00pm	-4

The ADVAL (Anxiety/Depression Value) is in the range of -10 to 0, where negative values represent anxious/depressed mood intensity and 0 represents a normal mood state. The first ADVAL value in Table 1 is the initial condition of the individual. This value changes as a result of executing the system or reading the next event from the input file.

Once a trigger has been activated, a thought script is selected dependent on the current mood state and its intensity for the individual. These can then lead to either the initiation of associated thought streams (via the assertion of facts in working memory) or to the expiration of the thoughts initiated by the trigger (as described by CMI later). A simplified example, in pseudo-code, is shown below. For a given mood state, the example shows alternative trigger effects, dependent on mood intensity. The SELECT DIVERSION ACTIVITY is an example of some action that stops the current thought stream temporarily. Most of these might be ineffective in stopping the thought stream, worsen it to become a thought spiral, or trigger new ones.

Abstracted versions of two script examples, "OVERWHELMED" and "I CAN'T" are shown below. These scripts are related depending on conditions. So, under certain conditions, the "I CAN'T" script may execute after the "OVERWHELMED" script.

Script Name: I CAN'T
Trigger: Overwhelmed script or new event trigger
Mood State: moderate depression/anxiety (ADVAL < −3)

Update CMI (due to this script being activated)

Thought stream:
I don't want to…
But you should…
(This may cycle to previous thought more than once)
But I have to…
I just can't… (repeats script)

Script Name: OVERWHELMED
Trigger: Unpleasant task <can also be initiated from other thought streams>
Examples: See a stack of mail, a task list, work items

Mood State: normal: ADVAL = 0
CMI unchanged
Actions (one of)
- Stop -- go on to unrelated activity/thought stream
- Healthy coping -- pick a task or break a big task into smaller pieces

Mood State: anxious/depressed state: ADVAL < 0
Update CMI based on chosen action
Actions (one of, dependent on intensity level)
- run I DON'T WANT TO SCRIPT
- run I CAN'T SCRIPT
- run WHAT'S THE POINT SCRIPT
- run I'M NOT GOOD ENOUGH SCRIPT
- run SELECT DIVERSION ACTIVITY
  (creates a state change until new trigger)
  - examples: television, anti-anxiety medications, drinking alcohol, sleeping

Collective Mood Intensity (CMI) is a numeric measure of the current strength, or intensity, of a mood state. For a given mood, it is a function of the number of the thought streams triggered within that mood state and the contribution of each triggered thought stream or action within the recent past.

$$\text{CMI} = \sum(mi_{ts} + mi_a) \quad \text{for } time=0 \text{ to } c$$

Each thought stream and action has an associated value for each mood state it affects. The higher the CMI value, the longer the mood stays active. For example the DIVERSION ACTIVITY reduces the CMI value for the mood state from which the activity was triggered. The value mi_{ts} is the mood intensity contribution of a single thought stream and mi_a is the contribution for an action. Once a CMI reaches nearly zero, its time is reset to 0. This is intended to represent the expiration of a thought stream. Similar CMIs are calculated for the other moods. At this point the next event and its associated ADVAL are read from the input file.

Prototype Implementation

We developed the SAD prototype using CLIPS, or C Language Integrated Production System. CLIPS is a domain-independent rule-based expert system shell originally developed by NASA. Rules are written as if-then statements, such that the antecedent ("if" portion") matches facts and the consequent ("then portion") performs actions, which may include adding or deleting facts to what is known as working memory. Rules may contain variables that match multiple facts. Working memory records the

current system state, i.e. what is currently true about the domain. The inference engine selects a rule and executes its actions. It then continues to select rules and execute their actions. This process continues until no applicable rules remain (Riley, 2013). A rule is shown below. The assert and retract statements alter working memory. Pattern matching is simple here in that it looks for specific facts in working memory. Other rules can match any number of facts that satisfy a general pattern. As an example we present an initial rule shown below; indeed more rules need to be added.

```
(defrule rainy-day-3 "low level anxiety"
   (thought-trigger rain)
   ?ms <- (moodstate anxious)
   ?msev <- (moodseverity low)
=>
   (printout t "Rain! I'm nervous about driving!")
   (retract ?msev)
   (assert (moodseverity high))
   (assert (phase show-current-state)))
```

A sample run of the prototype is shown in Figure 1. Comments in the output are produced to trace program execution. In the current prototype, ADVAL is an enumerated set of values {high, moderate, low, normal}. The thought triggers are concrete, e.g. I observe that it is raining. This is to make it easier to explore and evaluate scenarios. CMI as defined in the conceptual model is implemented as a simple counter of thought scripts executed (this is also used to prevent infinite loops in the event that rules keep firing). Event times are not currently implemented.

From the last output shown, the 'I CAN'T" script would execute. Consider one scenario. Given that the person is in a depressed, highly anxious mood, the spiral may end with an avoidance activity, e.g. not leaving the house. This reduces anxiety, but elevates depression and triggers a spiral down to the "I'M NOT GOOD ENOUGH" script. As time passes, this spiral "calms down" and expires. In CLIPS, no more rules are activated, so the next event trigger is read from the input file.

Note that in the prototype, mood is used to represent the current state of the individual, not their psychiatric (DSM-IV) diagnosis. Even a person experiencing a major depressive episode has times during which their depression is less.

The current system does not yet implement SACs ("short awful chains"). These short sequences of intensely negative thoughts are meant to represent situations in which the individual is experiencing a major episode of depression or anxiety. A panic attack is an example of the latter. Under these conditions, the threshold for escape is much higher than for other situations. In a major depression, it is unlikely that the individual will be capable of finding a diversion, other than perhaps sleep. Even this may require a heavy dose of medication. First thoughts that occur may still be significantly negative, e.g. "Why did I have to wake up"? Sleep, whether drug induced or not, may not produce any significant mood changes in severe depression. In the severest depressions, suicidal ideation SACs may be all-consuming and potentially lead to an attempt or completion.

```
CLIPS> (run)
_____________________________________

       Mood Model

_____________________________________

We follow a stream of thought
Get initial thought topic. Just rain
for now

STARTUP: with thought trigger <Fact-5>
====================
Moodstate is anxious
Mood severity is high
Thought trigger is rain

Rain! I can't drive. I AM AFRAID

From here we follow a thought spiral
(scripts)

Moodstate is depressed
Mood severity is low
Thought trigger is rain

Sad thought script (count is now 1)

Since we're sad already, this
continues (count++)
Moodstate is depressed
Mood severity is low
Thought trigger is I-can't-do-this

… <continue system execution>
CLIPS>
```

Figure 1. Sample run of the SAD prototype.

Conclusions and Future Work

Although the work to date is conceptual in nature, the prototype developed allows us to focus on the issues. Thoughts are not the only participant in one's experience. Thoughts, emotions, and memories are all part of the conscious experience of the individual. Lerner and Keltner, D. (2000), for example, discuss the interdependent relationship between thoughts and emotions. Memories, especially those associated with strong emotions, can form new associations with external triggers. Unhealthy coping mechanisms can result as one attempts to escape the "mental hell". Capturing this complex interaction will require significant prototype enhancements.

Exploration of additional or alternative representation and reasoning is an important area for exploration. Significant challenges include: (1) determining the proper level of abstraction for modeling thought streams, (2) improving state change modeling e.g., from dysthymia to major depression, (3) additional study of the interaction between anxious and depressive thoughts, and (4) exploring other knowledge representation and reasoning strategies. For the latter, Bayesian Belief networks allow for more sophisticated representations of influences between propositions (sequences of thought topics in our case). Markov Models stochastically represent the progression of states within a system. These however, do not capture the cyclic and cumulative features of the desired model. While human stream of thought appears sequential, multi-agent or blackboard models may provide insights into the non-focused, seemingly "jumpy" nature of our thoughts.

Validation has been from a small number of written retrospective reports and stream of thought diaries, and much more is needed. Yet more tests are required and therefore experimentation with the simulator's temporal modeling is also needed. For example, one does not generally move from dysthymia to a major depression episode over the course of a week. Additional sources of data may be useful for validation. The COGNO computer system (Wiemer-Hastings, et al. 2004) has been used to automatically classify dysfunctional thoughts. They found that for a subcategory of dysfunctional thoughts, the rule-based system classified most correctly. Sources like the Journal of Abnormal Psychology, in which researchers employed patient transcripts, diaries, oral histories, are available. Data mined from anxiety and depression web sources (e.g. Google Groups alt.suicide.holiday) may also provide a rich source of data.

Beyond the primary purpose of the work is the application in training of mental health counselors. Those counselors that have no personal experience with these mental illnesses could gain a better understanding of the internal mental states of the illness and its progression. In a humble reference to (Nagel 1974) "Consciousness has essential to it, a *subjective character*". Our simulation may help immerse counselors into aspects of the mental subjective experience of their patients. Even with the most empathetic and experienced therapist, following the wild ride of someone else's thoughts and emotions can give but snapshots of the experience.

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