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Not long ago, teaching a remedial pre-(very pre) Calculus sequence at a small liberal arts college, I encountered what has to be one of the more bizarre manifestations of math freak-out. An unusually articulate student, engaged and attentive throughout the first few weeks of the semester, soon appeared withdrawn and tense. Suddenly overcome with newfound nervous energy, she continuously played with her hair and seemed distracted and unfocused. Review of circular functions and periodic behavior apparently overloaded already sensitized math neurotransmitters upstairs ("why tangent repeats every π while sine and cosine do it every 2π just blows me away!"). In some weird dehydrated frenzy, she began to consume copious quantities of "grape juice" (later verified true: g.j. it was) from a large thermos brought to class with text and notes. This soon evolved into a well-defined ritual and (from my end) the visual fixture of a front-row student feverishly washing down blackboard notes with cold juice proved somewhat disarming. My curiosity quickly peaked and following one particularly, how should we put it, thirsty afternoon, I asked if there might be some physiological problem. "No," she mused almost wistfully. "It's just my way of coping. What you people like to call math anxiety, y'know? The, uhm, juice -- it calms me down."

This pronouncement of the situation - was it the resolution or resignation with which verdict and treatment were offered? - echoed for some time in my mind. The whole thing seemed so incredible. Still, dysfunctional stress disorders of any shape or form can be quite debilitating and often require serious attention. Obsessive-compulsive rituals are commonly maladaptive endpoints to sensory stress overload. Why, then, should a phobic reaction to mathematics, a learned behavior like any other, be different?

While the above true tale depicts (maybe) an extreme-value, if you will, of radical math trauma, it nonetheless motivates an important question. To what extent does such learned behavior influence and impair the process of learning the subject matter? Often we ascribe poor conceptual skills and low aptitude scores on exams to weakly rehearsed fundamentals and inferior mechanical training at the primary and secondary school level. To no uncertain degree this is a contituent part of the problem. But somewhere into this equation how do we factor the more intangible, not easily quantified, components of cognitive stress? Or of social norms, which inhibit (or at least do not actively recruit) positive expectations of success (eg., for women) in the quantitative sciences, mathematics in particular. Early on, a rehearsed pattern of failure becomes not only well established and familiar, but an acceptable, and ultimately relied upon, event.

The opportunity to examine this is greater detail surfaced unexpectedly within the traditional format of a first-year Calculus course I was teaching at Pitzer College. The majority of beginning Calc customers at Pitzer are primarily social science students with a fairly sparse backlog of mathematical sophistication and technique.

By the time we reached the Fundamental Thm. (circa Thanksgiving this happens) several students complained of crisis proportion difficulties and felt, in general, too "intimidated" to fathom what was going on. We threw around different ways of framing hard-to-get topics (selling Riemann Sums was like forcefeeding strychnine!), still nothing seemed to penetrate the psychic barrier they had created.

I had an idea: in an attempt to identify this psychological impasse or at least to gain some measureable insight into the freak-out factors that were exponentialy gaining ground, I hustled the group down to the campus bookstore. We proceeded to the "self-help" psych aisle and I issued the following instructions. Grab the title most applicable to the sense of dread presently experienced. These were the four editions selected:

1. Feel the Fear (And Do It Anyway) - Susan Jeffers, Ph.D.
2. Stress, Sanity and Survival - Robert Woolfolk, Ph.D., Frank Richardson, Ph.D.
3. The Relaxation Response - Herbert Benson, M.D.
4. On Death and Dying - Elisabeth Kubler-Ross

A common denominator? Interesting that the primary target or focus of each of the above centered on fear and fear syndromes, physiological stress responses and "anxiety feedback loops." Anxiety feedback loops?! Speak of this to your garden-variety, off-the-street mathematician and see what response this evokes! According to the above-listed lit, a simple 3-fold model describes the "fight-or-flight" response. An exogenous fear stimulus (environmental cue) triggers endogenous (visceral) stress. Stress hormones, inturn, instigate a sometimes alarming array of somatic symptoms (rapid pulse, acclerated cardio-pulmonary activity, etc.); a sense of panic and pervasive fear consumes the conscious mind in its attempt to label and interpret the state of physical dis-ease. This cognitive labeling or negative ideation of the somatic symptoms then becomes the necessary cue to promote rpetition of the cycle. And in the most chronic cases the above may become an infinite loop (unbounded?)!

The salient point here is that fear-anticipation and fear-reaction are essentially equivalent events as the cycle replicates. But this fact of life seems particularly germaine to the math-phobic's reality: the student subscribes to an inherent lack of ability, or lack of success solving problems. The acceptance of this failure becomes a rehearsed and expected event. Together, these perceptions become a self-propelling force, creating a familiar feed-back dynamic with which the student becomes alienated or disaffected and/or both.

Learned behavior can be unlearned; to disrupt this cycle of negativity one must orient and efffect an appropriate labeling of fear-cues and re-orient these signals towards positive expectation. Cognitive distortions must be recognized and disallowed. In the context of mathematical problem solving, this prescription points to a structured reinforcement of successful outcomes - seed positive results so that this, in effect, becomes the norm. After all, this certainly is the case with the most accelerated students. They are driven by the conifdence of repeated sucess many times over; and this formats the necessary creative mobility to tackle the more difficult, abstract situations.

One way of creating positive expectation and diminishing withdrawel and isolation, I have found, is by utilizing extra-curricular groups. Meeting outside of class, and optimally in as informal an environment as possible (coffee house, baseball field, Mt. Baldy!!), the trick is to encourage interactive problem solving and out-loud (to eachother) communication of the concepts and idea. The best model for this (that I know of) is the work-shop format agendized so successfully by Uri Treisman at Berkeley (initially set up for minority students taking Calculus, recently this has served as the blueprint many other institutions have adopted for math and other quantitative-science disciplines). Loosely simulating the structure I employed proctoring Treisman-planted workshops at Cal Poly Pomona, groups of students were assembled to tackle (at first) easy and (later on) more difficult problematic topics relating to concepts offered in lecture. Verbal discussion and exchange of ideas and solutions were the only components of operation. This give-and-take free-for-all of problem-solving technique was Marxist oriented: communal ex-change and <u>shared</u> perceptions were the ingredients demanded. Individual initiative was fostered and channeled as feedback to the rest of the group.

This symbiotic nature of idea-sharing was quickly infectious and virtually synergistic in scope. Insofar as promoting paths of solution-productive thought, the collective insight seemed to out-distance the sum of the constituent parts!

Eventually the best results were recruited with more challenging problems which permitted a greater degree of dis-cussion and verbal description of the underlying ideas involved. Here's an example: Sketch $y = x^n + \sin^m x$ (m=n=1 is usually a text-assigned homework exercise; so try m=n=2, what info does 1st and 2nd derivative relay? Now, who can generalize for different m and n, eg. m,n both even, both odd, etc). Another example: Compute the derivative of x raised to itself n times (if your idea of fun is logarithmic differentiation! -see below*).

Pushing through fear is less frightening than living with the underlying fear that comes from a feeling of helplessness," notes <u>Feel The Fear</u>'s Dr. Jeffers. Functionally this is the moral of the story. And it's a message that plays well with helpless-feeling students.

*: One person came up with a recursion formula,

$$d/dx\,(x{*}n) = (x{*}n)\,d/dx[x{*}(n-1)]\ln x + (x{*}n)[x{*}(n-1)]x^{-1}$$

where "x*n" indicates x raised to itself n times.

However the onus of trumping up silly problems incurs the responsibility of providing complete solutions:

$$d/dx\,(x{*}n) = \left[\prod_{i=1}^{n}(x{*}i)\right](\ln x)^n + \sum_{j=0}^{n-2}\left[\prod_{i=j}^{n}(x{*}i)(\ln x)^{n-(j+1)}x^{-1}\right] + (x{*}n)(x{*}(n-1))x^{-1}$$

<u>Then</u> came the question about $d^n/dx^n\,(x{*}n)$!!!!