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Dynamic systems, catastrophe models, and performance

Tim Woodman and Lew Hardy
Bangor University, Bangor, UK

Correspondence concerning this article should be addressed to: Tim Woodman, School of Sport, Health, and Exercise Sciences, University of Wales Bangor, Gwynedd LL57 2DG, UK. Tel: +44 (0) 1248 382756. Fax: +44 (0) 1248 371053. e-mail: t.woodman@bangor.ac.uk

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The Cusp Catastrophe Model of Anxiety and Performance

Following the original work of Thom (1975) and Zeeman (1976), Hardy and colleagues proposed a cusp catastrophe model of anxiety and performance. The cusp catastrophe model of anxiety and performance proposes that cognitive anxiety and physiological arousal affect performance in an interactive fashion (see Figure 1; see also Hardy, 1996, for details), whereby cognitive anxiety determines whether the effect of physiological arousal upon performance will be small and smooth (see back face of Figure 1), large and catastrophic (see front face of Figure 1), or somewhere between these two extremes.

Research testing the central features of the cusp catastrophe model has been fairly supportive of its predictions. For example, many studies have provided some quite conclusive evidence of interactive effects between cognitive anxiety and somatic anxiety/ physiological arousal (Deffenbacher, 1977; Edwards & Hardy, 1996; Hardy et al., 2004; Woodman et al., 1997) although the details of the interaction have not always been completely consistent with the cusp catastrophe model. Perhaps the strongest support for catastrophe models is from those studies that have tested the hysteresis hypothesis (e.g., Hardy & Parfitt, 1991; Hardy et al., 1994). The hysteresis hypothesis postulates that, under high cognitive anxiety, the path that performance follows will be different depending on whether physiological arousal is increasing or decreasing. More specifically, as physiological arousal increases so too does performance up to a certain point. Beyond this point further increases in physiological arousal result in a dramatic (catastrophic) drop in performance (see front face of Figure 1). In order for an individual to regain the upper performance surface, physiological arousal must decrease to a level below that at which the initial dramatic drop in performance took place. Consistent with cusp catastrophe model predictions, these studies revealed a hysteresis effect under conditions of high cognitive anxiety, but not under conditions of low cognitive anxiety.

Given the empirical support for a number of its central features, the cusp catastrophe model appears useful for modeling the complex relationship between anxiety and performance. At the very least, the model has forced researchers to think beyond simplistic conceptualizations of complex relationships. However, the catastrophe model is not a theory; it does not explain *why* anxiety and performance might be related in this complex multidimensional fashion. Also, the support for the hysteresis hypothesis can be criticized for using exercise-induced physiological arousal rather than anxiety-induced physiological arousal. Hardy (1996) suggested that the asymmetry factor (i.e., physiological arousal) in the cusp catastrophe model might be better re-labeled "effort required" as reflected by this exercise-induced physiological arousal, and recent research using effort required (Hardy et al., 2006) has also found support for the hysteresis hypothesis. This leaves two obvious possibilities: the asymmetry factor should be changed from physiological arousal to "effort required"; or there is more than one catastrophe model of anxiety and performance with both physiological arousal and effort required (and potentially others) as valid asymmetry factors.

Effort is central to Eysenck's (1982) Processing Efficiency theory. This theory postulates that worry (cognitive anxiety) serves two functions. First, it uses up some of the cognitive capacity available to the individual. Second, the worry signals to the individual the importance of the task at hand and thus serves a motivational function such that individuals invest more effort if they perceive they have at least a moderate chance of success. In this way, anxiety has both a debilitative effect and a facilitative effect. Take "effort required" as the asymmetry factor. If effort required to perform a task is not very high then anxious performers should perform well. However, when effort required reaches a certain threshold anxious performers will likely perceive the task as too demanding and withdraw effort. In this way, "effort required" as an asymmetry factor would help strengthen the theoretical underpinning to the catastrophe model.

Dynamic Systems: Theory or Model?

Dynamic Systems theory derives directly from Chaos theory, which itself is from the same family as Catastrophe models. All approaches have some common attributes. In particular, dual attractor states are integral to each approach. Dynamic Systems theory as outlined by Ninot and Fortes offers an interesting method for observing important intra-individual differences. However, contrary to Ninot and Fortes, we do not subscribe to the belief that any one method is superior to others. Further, the example given by Ninot and Fortes is a descriptive account of the individual; it is not theoretically driven. In our opinion, the more interesting question is: *why* does an individual's self-esteem change over time? As this is not the principal concern within dynamic systems theory as outlined by Ninot and Fortes, we believe that dynamic systems theory is a misnomer and should probably be called dynamic systems model. Such descriptive approaches are evident throughout much of the motor control literature. A classic example is the gait of the horse. When a horse accelerates, it changes from a canter to a gallop. The increase in the horse's speed leads to a sudden change in gait. Although such observations are interesting, it is more interesting to understand why such changes in gait seem necessary. In relation to Ninot and Fortes' example, although it is interesting and important to note sudden changes in the young girl's self-esteem, it is more interesting and theoretically fruitful to understand *why* such changes occur.

One explanation of anxiety effects that has received increasing attention over the last 10 years is the regression hypothesis. According to this hypothesis, expert performers, when highly anxious, regress from a skilled fluid performance to a more erratic novice-like performance, as they are attempting to control parameters of their performance that they normally execute automatically. For example, an anxious golfer might attempt to consciously control the angles in her wrist, elbow, shoulder, etc., rather than simply "just doing it", as she would normally when not under stress. This equates to a freezing up of the degrees of freedom that is characteristic of earlier stages of learning. Interestingly, when examining a cognitive explanation of anxiety effects, Hardy and

Mullen (2000) reported some data that support such freezing of degrees of freedom (“stiff wristing”) in golf putters under stress, which supports early dynamic systems theorists’ view that people learn new skills by first freezing degrees of freedom to control movements before gradually freeing them up as the skill becomes more automatic (see, for example, Newell & Van Emmerik, 1989; Vereijken et al., 1992). As such, the regression hypothesis might prove a fruitful avenue for dynamic systems researchers interested in unearthing the mechanisms via which anxiety affects performance.

In summary, catastrophe models and dynamic systems have much in common and provide useful information but the more interesting questions belong to future researchers who attempt to unearth the mechanisms that underpin these models.

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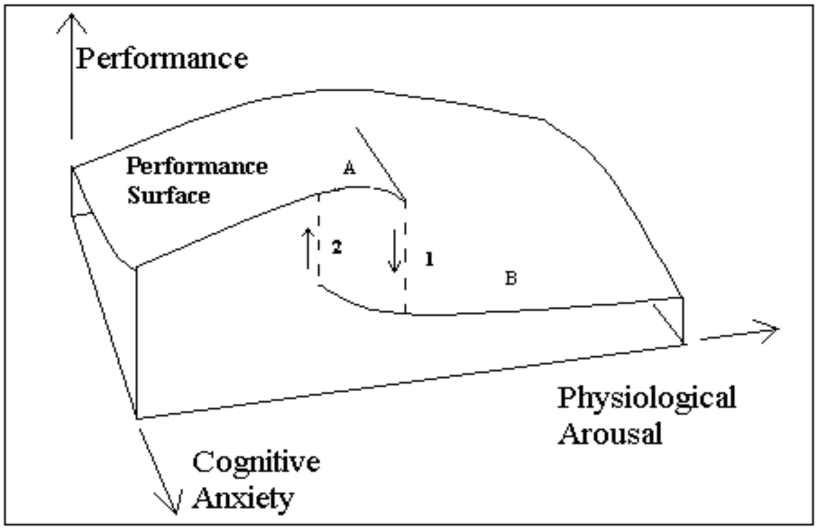
Figure 1. The cusp catastrophe model of anxiety and performance.


Performance
Performance Surface
A
2
1
B
Physiological Arousal
Cognitive Anxiety