Appendix: The Mechanisms of Arousal in Problem Solving and Aesthetic Experience

Throughout this paper, I have been assuming that it is thrilling to solve a problem, be it an implicit one of childhood, an explicit one of adulthood, or an artistic one in aesthetic experience. My claim for the structural link between problem solving, aesthetic experience, and structural acquisition only requires that all these behaviors elicit something like an "aha" thrill. I could stop my argument there, as the text does, simply postulating that the "aha" insight experience is enjoyable and explains the consequent urge to solve problems. However, it turns out that the formal relation between the various behaviors and the abduction of motion may provide an explanation for the "aha" thrill itself. I now turn to an explanation of what causes the thrill, based on the formal analysis of the processes involved in interrelating mental representations. (I include this discussion as an appendix because it is even more speculative than the nature of the aesthetic principles in their role in learning, which I outlined in the text.)

AHA! Emotion Out of Abstract Motion and Loss of Control

Emotional theories fall into two classes—causal and interpretive. Causal theories seek to explain different emotions as a function of biological factors: on this view, particular emotions are the mental expression of particular physiological states. Interpretive theories emphasize the importance of belief systems in designating emotions. Such a view usually differentiates two processes—mechanisms of arousal and mechanisms of interpretation (Mandler 1975). It capitalizes on the independent fact that general arousal mechanisms exist and that their behavioral indices are associated with strong emotions.

Most complete theories of emotion include elements of both causal and

interpretive mechanisms. The modern tradition goes back to the James-Lange view that an emotion is the interpretation that we place on instinctual mechanisms: I impute fear to myself if I notice that I am withdrawing from some danger. On this view, the basic generator of the particular behavior is instinctive: the emotional interpretation merely symbolizes the behavior for the individual. A modern classic demonstration gives greater emphasis to the interpretive than the instinctive system: if a person is aroused (for example, by a chemical stimulant), he will both report and show signs of an emotion. Which emotion he feels is influenced strongly by his immediate context; if people around him are acting happy, so will he (Schacter and Singer 1962).

Emotions occur in broadly labeled categories, like "fear" and "happiness." What is at issue for this discussion is the arousal mechanism underlying momentary thrills that occur when we solve a problem. We can gain some insight into this by again considering the infant. Its first forms of interaction with the world are overwhelmingly physical: the infant is carried about, rocked to sleep, and so on. In all these cases, the world is interacting with the child by some manner of moving it: motion is a primary vehicle of social interaction. In fact, one of the earliest social achievements of the child is to get adults to pick it up.

Bodily motion controlled by others can be highly arousing—this may be directly caused, as by activity of the vestibular organs. It may also be independently magnified due to fear over temporary loss of control. We can see the importance of these concepts in one of the earliest occasions for smiling and laughing induced through social interaction. A fussing infant is picked up but continues to fuss. The adult jumps up and down slightly jiggling the child in a rapid motion, perhaps chanting some rhyme; the child quiets, looks at the adult, and smiles. Even more striking is the impact of picking up an infant rapidly and throwing it slightly in the air and catching it. The importance of brief loss of control is clearly strong in this case: only if the infant knows the adult, and is clearly aware of the game, does it enjoy the experience. Under those circumstances, the infant enjoys the game inordinately, as the adult increases the height of each toss.

It is tempting to wax poetic when discussing this kind of social and physical interaction. But, we can also subject it to an elementary formal analysis: on each cycle of the tossing game, the infant is in the adult's arms, then briefly flying, falling, then in the arms again. With repeated cycles, the exhilaration reaches a peak each time, just as the infant starts to fall. This experience seems paradigmatic of all thrills: they involve a brief moment of loss of control, bounded by safe havens. The safe surround creates a bridge of situational control across the moment of apparent danger, while basic somatic mechanisms are releasing strong emergency signals.

The conclusion is that the joy results from the release of instinctive emergency signals in a safe context. Why should the infant enjoy the discharge of emergency mechanisms, even it it is under controlled circumstances? The answer to this lies in a theory of emotions that is independent of the causal and interpretive theories (and therefore a theory that may be independently correct), the "opponent process" theory. (Solomon 1980). On this view, brief experiences of intense negative arousal due to extreme loss of control are followed by a long "recovery" period of mild positive affect. A paradigm case is the emotions of amateur parachute jumpers. Although they are terrified during their early jumps, they eventually accommodate to the terror and enjoy a prolonged recovery period after each jump in which they experience confidence and joy.

We can combine our analyses of problem solving and perception with the thrill of losing control to explain how the problem-solving thrill is engendered. Consider again the phenomenon of motion perception, which has received so much recent attention—the resolution of two static images presented in time is that of an object that moves from one to the other. This is described by practitioners of the associated experimental art as "the image of a motion"; such a designation is distinguished from "the motion of an image" in order to avoid the homuncularily reductive requirement of having an internal observer who watches the image in motion (Shepard 1984; Kubovy 1983; Podgorny and Shepard 1975). The implications of this simple reformulation are tremendous—it postulates that an elementary object of perception is an abstract mental "resonance" of a physically possible movement. The perception of pure motion emerges out of an abstract movement from one stable image to the next.

The research on mental imagery and movement is based on the study of physical objects that could move in real space. Yet, the imagined movement that is evoked is in fact between two *abstract mental representations* of those objects. This demonstrates that the mental system has the capacity to form an *image of motion* between pure mental representations. I have noted that problem solving involves the formation of distinct representations and then an integrative resolution among the representations—a "leap of imagination" that allows abstract movement from one representation to the other representation. This is one source of excitement when we experience the solution of a problem—we briefly move from one representation of it to the other, via the just-intuited integrating representation. Leaps are associated with momentary loss of control and an associated excitement. When we take a dive, shutting our eyes tight, we briefly give ourselves over to unmonitored forces; like the tossed infant, between the point of loss of control and regaining it, we experience a brief thrill.

As in the infant, there is a separate, perhaps more physiological source

of excitement that follows from the same basic principles. Consider, for a moment, the effect of perceived motion without the usual physically associated signals to our sense organs. It is just this that, in its extreme form, causes dizziness. The perception of motion induced by solving a problem, without proprioceptive or other cues, may elicit the same sort of disorientation, though to a much lesser degree.

This offers an explanation of why humans like to solve problems, even useless ones: we get a little thrill each time because the mechanisms of problem formation and resolution induce an inner percept of motion from one representation to another, with a momentary sensation of loss of control. It is a satisfying result of this proposal that the "aha" reaction to solving a problem occurs primarily just at the moment of initial intuition that one understands the solution. By hypothesis, it is at this point that one has arrived at an overarching representation that bridges the conflicting one. The image of motion from one representation to the other is emotionally effective until the structure of the integrating bridge becomes explicit—as one checks out the solution to the problem intuited in the resolving representation, the image of uncontrolled motion fades as the conflicting representations are explicitly integrated.

Coda—The Specific Emotions in Different Aesthetic Experiences

High art often elicits emotions of characteristic kinds. I suggested that problem solving is intrinsically thrilling because it evokes a feeling of inner motion on a freshly evoked dimension and a momentary loss of control. On this analysis, aesthetic experiences evoke the same mental mechanisms as problem solving and therefore the same emotional arousal. What remains is to explain the particular emotion that is felt—in problem solving, it is clear enough that we ultimately feel a mixture of pride and relief at having solved the problem. But what is the nature of the emotion evoked by aesthetic experiences, in which the "problem" exists only as a stimulus for the problem-solving activities themselves? That is, why do aesthetic experiences elicit emotions of particular kinds?

On the general theory of emotion, interpretive systems play a role in determining the emotion assigned to an aroused state. The everyday aesthetic objects shape the emotion as a function of their explicit or social content. Upon hearing the "shave and a haircut" tatoo, we experience a recognition that somebody wants our attention; the golden rectangle elicits a concept of "two-ness" and depth in a third dimension; "Happy Birthday" is a vehicle for saluting somebody else; "Goldilocks" tells an explicit story with the child's place in a family as the clear moral. Many high art works have even more explicit content: representational painting, literature, and theater use the interplay between structure and content to guide the audience's particular feelings.

Some kinds of art lack such content, yet evoke strong emotional responses. We can obtain the clearest picture of how the formal structure of aesthetic experience elicits and allows for the control of emotions by examining such cases. Art-music is a striking example, since it has almost no semantic structure and yet can release turbulent feelings. There are several other notable facts: the same piece of music evokes different emotions in different people, and it evokes different emotions in the same person at different times.

There are several sources of the emotional arousal in response to music. First, music can directly excite the somatic and autonomic nervous systems via orienting and startle responses; Haydn exposes this in the "surprise" symphony, with loud chords at (expected) unexpected points. A gong in the middle of a quiet passage has the same effect: the blood races, the mind blanks out while the "fight or flight" system reaccommodates. Second, there is a rhythmic alternation of outer attention and inner mental processing paced by the perceptual analysis of each musical "phrase" (see Tan, Aiello, and Bever 1981; Bever, Lasher, and Carroll, in press). Finally, an effective musical work is one that elicits representational forms that fulfill the aesthetic principles, thereby stimulating the abstract image of motion, as discussed above.

Music has these three powerful mechanisms that can increase arousal and mental movement. But we must also account for the fact that not just general excitement but particular emotions are often felt, emotions such as elation and deep sorrow. First, there are a few conventions that depend on cultural motives—a march with a snare drum indicates a military image, whereas parallel fifths continually convey an oriental aura. Some of the motivic conventions are understandably related to basic physiological mechanisms, for example, different tempos: the perceived tempo of a piece can itself directly recruit rhythmic activities in a listener, as reflected in a tapping foot or nodding head. Once the rhythm is induced, it can resonate with different classes of emotions; for example, a quick tempo is unlikely to be perceived as lethargic and sad, whereas a harmonically slow-moving piece is unlikely to be perceived as energetic and happy. In addition, minor changes in the rhythm of the variation in processing load and attention may mimic some formal properties of emotional states.

Beyond conventional and physiological determinants of the emotion, a listener has his own prior emotional states as well: a person who is already depressed may take almost any piece of music as an occasion for sorrow. The very fact that music only vaguely guides the emotional content may

account for its releasing power—the individual listener is free to attach his antecedently available emotions to the experience, thereby making it far more personally powerful than the usual response to an art work with explicit content.

This brief consideration of the sources of emotion in music outlines the kinds of factors which may play a role in other art forms, both high and low. Most important, it also highlights some emotional forces that can play a role outside of aesthetic experiences—most notably in problem solving and cognitive growth.