# Chapter 12
# Anger in Children's Tantrums: A New, Quantitative, Behaviorally Based Model

**Michael Potegal and Peihua Qiu**

**Abstract** Because excessive anger in early childhood can predict later psychopathology, quantifying its intensity and time course is clinically important. Anger consists of a set of experiential, physiological, and behavioral responses whose coherence is sufficient to justify the assumption of a common latent variable that can vary in intensity. The relationships between anger intensity and various anger-driven behaviors in children's tantrums are probabilistic, nonlinear, and different for each individual behavior. Although any one behavior can provide only a partial and indirect measure of anger intensity, the entire trajectory of anger across the tantrum may be reconstructed by combining the observed temporal distributions of the various behaviors. In particular, we observed that behaviors characteristic of lower intensities of anger tend to occur at both the beginning and the end of tantrums while behaviors linked to higher intensities of anger are distributed around a single early peak. Accordingly, our anger intensity-behavioral linkage function model reconstructs a single, common, latent anger intensity variable, MA($t$), whose rise and fall controls the momentary probability of eight angry tantrum behaviors through linkage functions that are unique to each behavior. We introduce the MA50 as a practical measure of the "characteristic" intensity of the eight angry behaviors and note how the model may inform study of the neural substrates of anger.

## 12.1 Introduction and Chapter Organization

This chapter is organized as follows: Section 12.2 reviews the behavioral phenomenology and clinical importance of childhood anger, the value of quantifying its intensity and time course, and some of the difficulties involved in doing so. We argue that anger consists of a set of experiential, physiological, and behavioral responses whose coherence is sufficient to justify the assumption of a common latent variable that can vary in intensity. We note that although behaviors (or "action tendencies") are particularly salient indicators of anger, the relationships between anger intensity and various behaviors are probabilistic (rather than deterministic), nonlinear (because different behaviors become most probable within different portions of the anger intensity range), and different for each individual behavior. Thus, each behavior can provide only a partial and indirect measure of

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anger intensity. However, the observation that different behaviors are characteristic of different portions of the anger intensity range implies that the entire trajectory of anger may be reconstructed by combining the temporal distributions of the various behaviors. The model presented in Section 12.3 accomplishes this through a single, common, latent anger intensity variable, MA($t$), whose rise and fall controls the momentary probability of eight angry tantrum behaviors through linkage functions that are unique to each behavior. This model is predicated upon two basic observations. First, anger is episodic and, within an episode, anger intensity rises and falls over time. Second, some behaviors are characteristic of lower intensities of anger while other behaviors are more closely linked to higher intensities of anger. From these two observations, it follows that “low anger” behaviors should be more likely toward the beginning and the end of an episode, when anger intensity is lower, while “high anger” behaviors are most likely to be distributed around a single point within the episode, when anger is peaking. The observation of just such unimodal distribution of high anger behaviors whose peak coincided with the trough in the bimodal distribution of low anger behaviors in children’s tantrums (Potegal, Kosorok, & Davidson, 2003, Fig. 12.3) was the inspiration for our model. Section 12.3 also introduces the MA50 as a practical measure of the “characteristic” intensity of the eight angry behaviors. Sections 12.4, 12.5, and 12.6 note current limitations and future directions for model development, describe extensions and applications to different measures and groups, and review applications to, and implications for, appraisal models of emotion and emotion display rules. Section 12.7 notes how the model may inform study of the neural substrates of anger.

## 12.2 Phenomenology and Importance of Childhood Anger

Episodes of anger are frequent in early childhood. Young children may express their anger first by grunting and growling; they may then escalate to shouting and screaming (Potegal & Davidson, 2003). Children may grab, push, or pull; becoming more angry, they hit and kick. Some run away (Eisenberg et al., 1999); others throw their heads back and become so rigid with tension that they suffer painful, involuntary muscle spasms of the fingers and toes. These responses are surprising in their diversity and can be striking in their intensity; the more extreme forms can be alarming to the parents who witness them. Beyond these dramatic displays, the reasons for focusing on anger in development include the observation that excessive anger at 2 years of age predicts increased risk of psychopathology at 5–6 (Radke-Yarrow & Kochanska, 1990). In turn, excessive anger at 4–6 years of age predicts socially inappropriate behavior in school (e.g., low social skills and excessive aggression), and behavior problems at home, through 8–10 years (Eisenberg et al., 1999). Anger is especially potent in exacerbating aggression in 7–13 year olds boys with behavior problems (Orobio de Castro, et al., 2005). Excessively intense and prolonged episodes of anger (“severe rages”) have been suggested as a diagnostic criterion for the “broad phenotype” of juvenile onset bipolar disorder (Leibenluft, Charney, Towbin, Bhangoo, & Pine, 2003, but see Potegal, Carlson et al., 2009). A reliable measure of anger is needed to answer questions such as Is a child’s anger and anger regulation (in) appropriate for her age? How, exactly, is anger related to risk of clinical impairment? How successful is a given treatment in fostering control and reducing or limiting anger?

### *12.2.1 Rationale for Quantifying Anger*

Progress in science depends upon quantification, but little is known about quantifying anger (e.g., Fridja et al., 1992). In the past, emotion research has sometimes focused more on words relating to anger rather than on behaviors associated with it. In this tradition, some authors have suggested that the term "anger" reflects a level of intensity intermediate between lower level "annoyance" and higher level "rage" (e.g., Plutchik, 1980). By having subjects rate their own individual experiences on 1–10 scales using different anger-related words, Fridja et al. (1992) verified the intuition that words in the English lexicon ranging from "irritated" or "annoyed" through "angry" to "furious" or "enraged" represent an internally consistent dimension of anger intensity. To the notion that anger intensity varies along continuum from annoyance and irritation up to rage and fury, Lewis (this book) adds that rage is distinguished from anger by behavior that is not goal directed and that is out of control.

### *12.2.2 Anger as a Coupled Response System*

There is a general consensus that anger, like other emotions, is a complex system of responses that are variably coupled (e.g., Gross, 1998). These responses include appraisal processes and cognitions, subjective feelings, physiological arousal, facial and vocal expressions, and certain acts and/or impulses to action (e.g., to hit or to hurt, depending on developmental level, Freud (1972), Feshbach, 1964). Each of these responses has some previous or potential use in quantifying anger intensity and all should eventually be included in a quantitative theory of anger. Up to now, subjective self-report and facial expressions have been the primary measures. However, there are theoretical and methodological issues with these measures, which we review briefly.

### *12.2.3 Current Measures of Anger Intensity*

Even today, in the twenty-first century, psychologists have had to rely upon subjective self-reports along arbitrary numerical scales to estimate anger (e.g., Hoeksma, Oosterlaan, & Schipper, 2004). Such reports have the virtue of being easy to elicit. However, establishing their reliability remains a challenge, especially for young children who are notoriously poor reporters of their own anger (e.g., Dearing et al., 2002; Denham & Couchoud, 1990; Levine, Stein, & Liwag, 1999).

As reviewed by Green et al. and Matsumoto et al., respectively (this book), vocal and facial expressions are among the most salient objective indicators of anger. Vocal anger in adults is characterized by increases in tempo and co-varying increases in loudness and pitch; these effects can be readily distinguished from those associated with, e.g., fear or sadness (Green et al., this book.) Although the recognition of affective state from voice samples is considerably better than chance and is as good as, or better than, from facial expression, the most extensively studied objective measures of anger are, indeed, facial expressions. These involve lowering of the brows, narrowing of the palpebral fissure, and increased tension around the mouth (e.g., Matsumoto et al., this book). Facial expressions have much to recommend them as a quantitative measure. The "universality" claim, that expressions of anger (like the other basic emotions) are similar across cultures, is still debated (e.g., Russell, 1997), but is supported by the most recent and rigorous cross-cultural studies (Chapter 8 by D. Matsumoto et al., this volume). Although anger-related facial action units (AU) were once thought to be more difficult to recognize or label (Ekman, 1994, c.f., Russell, 1995), expressions of anger were among the facial expression most consistently recognized cross-culturally, with correct identification in the 80–90% range (Haidt & Keltner, 1999). The total number of co-occurring AUs marks the level of self-reported anger (Alvarado & Jameson, 2002); thus, facial expression can be used to scale anger intensity. Methodologically, raters can estimate the intensity of facial anger reliably (e.g., Hess, Blairy, & Kleck, 1997; Matsumoto, 1989).

### *12.2.4 Coherence of Measures*

There are, however, limitations on facial expressions as a measure of anger. Facial displays of anger are actually relatively rare in adults, even in experimental situations designed to provoke anger. This discrepancy is one instance of a lack of agreement, or "coherence", among facial expressions of emotions, self-reported affect, and other measures. Such coherence is often assumed, and some experimental evidence supports it (e.g., Matsumoto, Nezlek, & Koopmann, 2007), but serious criticisms have been raised with regard to coherence, at least for some emotions (e.g., Fernandez-Dols, Sanchez, Carrera, & Ruiz-Belda, 1997). For anger, however, three of four studies have found substantial coherence of measures in adults, at least under some conditions. Significant correlations between facial expressions and reported feelings of anger were found in a posed expression task (Coan & Allen, 2003), in a more naturalistic interview study of conjugal bereavement when people were talking about the injustice of their spouse's death ($r = 0.44$, Bonano & Keltner, 2004), and when mothers interacted with their preschool daughters in an experimental frustration task ($0.42 \leq r \leq 0.57$, Cole, Teti, & Zahn-Waxler, 2003). Coherence of emotion measures is thought to be greater at higher intensities of emotion (e.g., Fridja et al., 1992; Davidson, 1992; Rosenberg & Ekman, 1994; Tassinanry & Cacioppo, 1992). However, although facial expressions of anger distinguished subjects in Stemmler's (1997) study who reported having been slightly angered by exposure to the mild variant of an insult manipulation from those who had been exposed to the moderate or "full" anger variants, facial expressions did not distinguish the moderately from the "fully" angered subjects. That is, facial expression failed to distinguish anger intensity at the upper end of the adult range.

Coherence may be stronger in children. This conclusion is suggested by three studies of 7–12 year olds who were confronted by an anger-provoking peer confederate, either live or on videotape. Children who lost a computer game and were taunted by the winner (Underwood & Bjornstad, 2001) had angry facial expressions that were mildly but significantly correlated with the children's report of being bothered by the winner's taunts ($r = 0.18$). There were some curious inversions of expected responses reported in this study, with mad feelings being associated with distress gestures (hanging the head, covering the face to cry, or crying) and sad feelings being associated with angry gestures (hostile stares and glares, flinching in exasperation, banging the keys in frustration, invading the other's personal space, and banging against the actor's chair). Greater coherence was found in responses to peer disapproval, e.g., self-reported anger was significantly associated with negative facial expressions including anger, contempt, disgust, fear, and sadness. These effects were particularly marked among girls and 12 year olds ($0.39 \leq r \leq 0.6$ Casey, 1993). Coherence was the greatest and most specific in children who lost a competitive game to a peer confederate who cheated (Dearing et al., 2002; Hubbard et al., 2004). There were significant correlations among six of the ten pairs of measures that included facial expression and self-report of expressed anger. Notably, angry behaviors (e.g., throwing or slamming down game pieces, swinging a fist or punching it into the opposite hand, hitting their own head) were correlated with the largest number of other measures including facial expressions, self-report, and skin conductance reactivity. These effects were progressively stronger for children judged to show low, average, or high-reactive aggression. In fact, these angry behaviors were the only measures that significantly predicted the child's judged aggressiveness and his/her social rejection in peer sociometric ratings.

Beyond the coherence issue, the theoretical basis for using facial expressions to measure anger is challenged by the functionalist caveat that facial expressions are a means of communication and/or social manipulation (e.g., Fridlund, 1997). From at least the age of 4 or 5, facial expressions of anger appear to be a mixed signal, influenced not only by the individual's internal state, but by her communication goals as well (see "Display rules," Section 5.4). Methodologically, studies that capture facial expressions on film or videotape are most often carried out under restricted laboratory conditions. The dynamic range of facial expressions in naturalistic situations is unknown, but they may not reliably reflect affect at its extremes. At the lower end of the intensity range, 15 month olds respond to brief, gentle arm restraint with a highly systematic progression of responses (Potegal et al., 2007). They first struggled against the restraint and then protested vocally. Angry facial expressions appeared last. This progression of behaviors was smooth and overlapping, i.e., the earlier behaviors continued even after the later behaviors began. Thus, this progression appeared to reflect a steadily increasing intensity of anger in which the lower intensities were not reflected in facial expressions. At the upper end of the range, Stemmler's (1997) results suggest that angry expressions do not become progressively more pronounced as anger rises from baseline all the way to its peak but that they saturate at some sub-maximal level. While facial expressions are surely valuable indicators within some range of anger intensities, it is unlikely that they are sensitive indicators throughout the full range.

### *12.2.5 Behavioral Measures of Anger Intensity*

In everyday life, we detect the anger of others by an array of behavioral and physiological cues: facial expression, loudness, pitch and tempo of voice, facial flushing, threatening or aggressive actions, and so forth. In both infants (Camras, Sullivan, & Michel, 1993) and adults (Wallbott, 1998), anger can be reliably differentiated from sadness (and some other emotions) by the greater amplitude and "jerkiness" of its associated body movements. Although some people's anger-associated behaviors may be subtle and/or idiosyncratic, we are often correct in gauging the intensity of children's anger by their behavior; a grimace and a grunt may indicate their irritation; a shout, their anger; a screaming, hitting and kicking attack, their rage. Accordingly, gestural expressions were the strongest or most general indicator of children's anger in at least two of the studies above (Underwood & Bjornstad, 2001; Hubbard et al., 2004). These observations further imply that each angry behavior may reflect a "characteristic" range of anger intensity. In keeping with these objective observations of behavior, an analysis of self-reports by adults suggests that emotions can be more readily distinguished from each other by their action tendencies then by their feeling states; the action tendencies reported for anger were yelling and hitting (Roseman, Wiest, & Swartz, 1994). Etymologically, the Greek (anchein) and Latin (angor) roots of the word anger refer to "strangling." Adults' propensity for angry actions tends to fall along a single, "Anger Out" scale which has been made psychometrically sound by Spielberger and colleagues within their frequently used *State-Trait Anger Expression Inventory* (Chapter 23 by C.D. Spielberger and E.C. Reheiser, this volume). In expanding the items on the Anger Out scale, Deffenbacher, Oetting, Lynch, and Morris (1996) identified two clusters of verbal anger expression (loud and argumentative, intimidating and threatening) and two clusters of physical anger expression (threatened or actual assault, property damage). Although separable, these clusters were correlated with each other and with trait anger, again suggesting that these overt behaviors all reflect the same or related underlying process(es). Furthermore, these behaviors are associated with the subjective experience of anger. In both hypothetical scenarios (Winstok, 2007) and recalled incidents of actual everyday emotion (Sonnemans & Frijda, 1994), the reported "drasticness" of action was one of the strongest predictors of overall intensity of felt anger (c.f., Shaver, Wu, & Schwartz, 1992). The continuity between feelings of anger and angry behavior, and their scalability, was shown in a three-item scale of increasing anger intensity (feeling annoyed, feeling angry, and yelling at someone) developed by Ross and colleagues (Mirowsky & Ross, 1995; Ross &

Van Willigen, 1996, Scheiman, this book.) This scale was found to have Guttman scale-like transitivity, i.e., across subjects, yelling represented higher intensity than feeling angry. In turn, feeling angry represented higher intensity than just feeling annoyed.

Quantifying the intensity of anger relative to a range of identifiable behaviors would be scientifically useful, not only in designing new studies, but in interpreting older ones. One costly, large scale, longitudinal study of children's anger in this context recorded "pushes and shoves" (Huesmann, Eron, Lefkowitz, & Walder, 1984); other such studies carefully document the emergence of "hits, kicks, and bites" (e.g., Nagin & Tremblay, 2001). Because there has been no way to scale the intensity of children's various angry behaviors to produce a rational estimate of their overall anger, these worthwhile studies are more difficult to compare.

### *12.2.6 The Time Course of Anger*

Like other emotions, anger rises, than falls in the course of a typical episode. As reviewed by Potegal (this book), the rise is typically rapid and the fall slower. Other than this, little is known about the trajectory of anger. Really interesting questions about anger dynamics remain to be asked: How do shorter and longer episodes of anger differ? Do these episodes begin similarly, but then differ because anger continues to increase to a higher level in what will become the longer events? If, on the other hand, shorter and longer events differ systematically from onset, is a more rapid rise of anger associated with a shorter or a longer event, a lower or higher peak?

### *12.2.7 Challenges and Opportunities for Behavioral Quantification of Anger*

While a rating scale for anger intensity based on observable behaviors has the obvious advantage that behaviors can be recorded and coded with great reliability, the behaviors themselves are topographically and physiologically diverse. For example, Eckhardt and Deffenbacher's (1995) list of nine categories of anger-related behaviors among adults includes sullen withdrawal and "icy stares"; refusal to cooperate with others; sarcasm, hostile humor, and cutting remarks; verbal threats; and various forms of physical aggression against property and people. The angry behaviors we commonly observe in others, and experience in ourselves, are not only highly diverse, they also appear discontinuous within episodes. Thus, when we adults are mildly angry, we may cross our arms and purse our lips. As we become more angry, we do not cross our arms more tightly harder or purse our lips harder. Instead, we may retract our lips in a grimace, grit our teeth, or wag a finger, and then move up to swearing and shouting and eventually, perhaps, to physical assault. That some behaviors are more probable at low anger intensity while others become more probable at higher intensities suggests the possibility that behaviors can be ordered or weighted by their "characteristic intensity" of anger. Furthermore, the common experience that the intensity of a person's anger at a given point in time can often be correctly inferred from his/her behaviors at that point implies that the set of these behaviors may together span the intensity range. In turn, this suggests the possibility of reconstructing both the overall trajectory of anger and the functions linking the probability of each behavior to anger from the observed distributions of these behaviors within anger episodes. However, we adults tend to mask emotions; our angry responses are also tempered by our status relative to the offender (Kuppens, Mechelen, & Van Meulders, 2004), by fear of retaliation (Winstok, 2007), and so forth. These concerns, as well as individual idiosyncrasies in adults' expression of anger, present a serious problem for modeling.

### *12.2.8 Temper Tantrums: A Solution to the Problem*

To define the trajectory of anger and find its links to individual angry behaviors from an observed distribution of behaviors, it is necessary to have a substantial database in which a relatively small number of stereotyped, easily classifiable angry behaviors appear with some frequency. Not having fully acquired social display rules, young children are less likely to mask their emotions than adults. In particular, temper tantrums are common in children between the ages of 18 and 60 months, many of whom have them up to once or twice per day (Potegal & Archer, 2004). Tantrums typically occur in the familiar home environment among people with whom children feel comfortable (Einon & Potegal, 1994), so emotional expression is likely to be uninhibited. Unlike the more idiosyncratic anger of adults, angry behaviors within tantrums are both similar and common enough across children to be amenable to study. Also unlike adults' naturalistic anger episodes that can involve two or more participants whose interactions are difficult to control, the role of parents in tantrums can, to some extent, be reduced and standardized.

It is a truism that there are no individual behaviors that are either necessary or sufficient for defining an episode of anger. In fact, each of the angry behaviors in a tantrum can occur by itself, although the base rates for such behaviors outside a tantrum are low (e.g., Snyder, Stoolmiller, Wilson, & Yamamoto, 2003). However, when several of them co-occur in a short period with obviously increased intensity, changed rhythm and forcefulness of vocalization and movement, in addition to physiological signs such as facial flushing (i.e., when all anger response systems are activated), there is little doubt that the child is angry. Conversely, it is also generally clear when a child is faking it.

## 12.3 Modeling Methods, Data, and Results

Here, we first describe two tantrum data sets collected with different techniques at different times and places, but whose intensity-related groupings of angry behaviors are similar, nonetheless. We then describe the anger intensity-behavioral linkage function model.

### *12.3.1 The Data*

The first data set consisted of retrospective written narratives collected in 1993–1995 from parents in Madison, WI area who described one of their child's tantrums in detail (Potegal & Davidson, 2003; Potegal, Kosorok, & Davidson, 2003). The current analysis includes a total of 127 of these tantrums had by those 3- and 4-year olds (65 boys, 62 girls) in which at least one angry behavior occurred. For details of data reduction, tantrum reconstruction, etc., see Potegal and Davidson (2003), Potegal et al. (2003). Children in the first and second sets were recruited largely from volunteer lists maintained by the University of Wisconsin's Waisman Center and the University of Minnesota's Institute of Child Development, respectively. Most were white and middle class. The second set of 119 in-home tantrums had by 59 of 3- and 4-year olds (41 boys, 18 girls) was collected in the Minneapolis, MN area in 2001–2003 (Potegal, 2003, 2005). Each child contributed up to three tantrums to this latter data set. A more rigorous methodology was used to collect these data. In brief, tantrum behaviors were recorded by parents on a user-friendly coding form with "anatomical" ordering of child behaviors into six rows to make them easy to find. For example, tears were noted in a top row with a "face" icon, a "voice" row for vocalizations was just below, and a row with a leg icon for kicking was near the bottom. Parents recorded behaviors in four consecutively labeled 30 s columns across each page with the help of a purpose-built coding timer (Advanced Research Corporation, Minneapolis, MN). The timer's timing circuit successively illuminated LEDs mounted above each of the coding columns on the form, thus directing parent's attention to the column to be used at the moment. The timer also contained an audiocassette recorder that recorded vocalizations directly; the timing circuit placed a marker signal on the tape at 30 s intervals for subsequent synchronization with parental observations. During a 2 h home visit, parents learned to use the timer by coding a videotape containing four "composite" tantrums (i.e., compiled and edited clips of real tantrums). Reliabilities for training tape coding were reasonable; mean kappas for parents' coding of behaviors classified as low, intermediate, and high anger and distress (Table 12.1) were 0.84, 0.91, 0.69, and 0.73, respectively. Using the timer also limited parent mobility, thereby tending to minimize physical intervention in the tantrum (parents were instructed to abandon coding of any tantrum that required extensive intervention).

In all cases, tantrums were reconstructed from the records taking the first recorded behavior as the start point of the tantrum. In the WI study, all behaviors were coded from the parent narratives. In the MN studies, physical behaviors were taken from the parental coding form while trained raters coded vocalizations (anger-related shouting and screaming and distress-related whining and crying) from the audiotape. For the latter coding, shout was defined as a loud vocalization, usually containing words; scream was defined as a higher pitched vocalization, usually without words. Inter-rater reliabilities (kappa coefficients) for screaming, shouting, whining, and crying were 0.74, 0.72, 0.65, and 0.83, respectively.

### *12.3.2 Principal Components Analyses*

Separate principal components analyses of log ($x$+1) transformed cumulative behavior durations in the two studies produced highly similar solutions. Each analysis yielded three components that appear to reflect different intensities of anger, and one component of distress. In both analyses, the order of eigenvalues was the same and the components together accounted for >50% of the variance. Furthermore, as shown by the main diagonal entries in Table 12.1, most behaviors load on the same components in both analyses. *Kick*, *scream,* and *arch* load on a principal component named "high anger", *throw* loads on "intermediate anger", and *stamp* loads on "low anger." *Hit* loads on both high and low anger in each analysis. Relatively minor differences between the two analyses include the shifts in *shout* and *push* to higher loadings on high and intermediate anger, respectively, and a shift of *run away* into intermediate anger. The major difference is that whine appears in distress in the WI data and in high anger in the MN data. This shift may be due to some co-variation across types of vocalization, i.e., whine, shout, and scream may tend to co-occur across children (Section 4.2.7)

In both data sets, the identification of the factors with different levels of anger intensity was supported by multiple regressions indicating that the high anger factor had higher correlations with tantrum duration, visible autonomic activation (e.g., tears, flushing), and parental judgment of overall tantrum severity than did the lower anger factors (Table 12.2). Thus, the fact that differences in the factor structure and behavior loadings are minor in the face of the major differences in sampling and data collection methodology speaks to the robust linkages between tantrum behaviors and anger intensity. Similar groupings of low vs. high intensity anger behaviors can be seen in Mascolo, Harkins, and Harakal (2000) clusters of "frustration" vs. "anger" related behaviors in preschoolers' social conflicts (e.g., *jump* and *throw* vs. *grab* and *scream*, respectively). Like these authors, we also

**Table 12.1** Comparison of behavior loadings on principal components in WI and MN tantrums

| | | Minnesota | | | | |
|---|---|---|---|---|---|---|
| Principal components | | High anger | Intermediate anger | Low anger | Distress | Eigen values |
| WISCONSIN | High anger | Kick *0.73*/**0.54** | Push *0.39*/**0.69** | | | *2.03* |
| | | Scream *0.63*/**0.56** | | | | |
| | | Arch *0.49*/**0.57** | | | | |
| | | Hit *0.50*/**0.40** | | | | |
| | Intermediate anger | Shout *0.66*/**0.83** | Throw *0.81*/**0.65** | | | *1.27* |
| | Low anger | | | Stamp *0.79*/**0.78** | | *1.15* |
| | | | | Flap *__/**0.68** | | |
| | | | | Hit *0.39*/**0.47** | | |
| | Distress | Whine *0.58*/**0.68** | | | Cry *0.67*/**0.58** | *1.46* |
| | | | | | Seek comfort *0.67*/**0.82** | |
| | Coping style | | Away–*0.75*/**0.61** | | Down *0.62*/**0.53** | *1.14* |
| | Eigen values | **3.6** | **1.32** | **1.22** | **1.47** | |

Loadings on respective *WI* and **MN** tantrum components are shown as: *italic* **/bold**. The *WI* results are from Potegal and Davidson (2003), Table 4.
*Not included in WI narratives. "Down" indicates lowering the body. "Away" indicates moving or running away from parent.

**Table 12.2** Regressions of WI and MN principal components on tantrum duration, autonomic activation and judged severity

| | Tantrum duration | | Visible autonomic activation | | Judged severity | |
|---|---|---|---|---|---|---|
| Factor | *WI* | **MN** | *WI* | **MN** | *WI* | **MN** |
| High anger | 0.39*** | 0.18*** | 0.31*** | 0.30** | 0.25*** | 0.26** |
| Intermediate anger | 0.26*** | 0.002 | 0.14** | −0.01 | 0.09 | 0.05 |
| Low anger | 0.03 | 0.09* | 0.07 | 0.07 | 0.02 | 0.14 |
| Distress | 0.50*** | 0.78*** | 0.17** | −0.001 | 0.28*** | 0.16 |

*$p$<0.02, **$p$<0.01, ***$p$<0.005 WI results from Potegal and Davidson (2003), Table 5.

found distress (sadness) to be a separate factor in both data sets. The generality of this factor structure is not limited to children under 5; very similar factors were found in the outbursts of 5–12 year old inpatients on a child psychiatry ward (Potegal, Carlson, Margulies, Gutkovitch, & Wall, 2009).

### *12.3.3 The Model*

The elements of the anger model are momentary anger [MA($t$)], a single, latent variable whose trajectory controls the overall time course of the various angry behaviors, and a set of linkage functions which express the probability of each behavior as unique functions of MA. The two-parameter beta function was chosen to represent MA($t$) because it can assume a variety of trajectories depending upon its parameters. Figure 12.1, which includes a monotonic rise, a monotonic fall, and also U and inverted U shapes with different skews, illustrates how the polymorphic flexibility of the beta allows the data to determine the trajectory of MA($t$). The behavioral aspects of emotion are often couched in terms of a probabilistic impulse to action or action tendency. Accordingly, a key feature of the model is that behavior is probabilistically (not deterministically) linked to MA($t$). If some particular behavior were a "true" indicator of MA in this model, its probability would increase linearly with MA throughout its entire functional range. The linkage function of this behavior would be a straight line with a positive slope. However, the preceding discussion suggests that there is no "true" indicator of MA and that different behaviors become most probable within different parts of the MA range. After examining a number of candidates for the linkage functions, including nonparametric approximations and negative exponentials, we chose a composite logit polynomial. The logit component handles binary variables appropriately; the polynomial terms provide the closest approximation to empirical observations while preserving the distinction between the linkage functions and the MA($t$) term which is embedded within them (i.e., parameters of the linkage functions and of MA($t$) can be estimated separately).

Estimation of model parameters required some complex and novel statistical manipulations because the observed behaviors are correlated (not independent), both at any particular moment in time and throughout the course of tantrum as well. For example, the occurrence of behavior $X$ at time $t_1$ is not independent of the occurrence of behavior $Y$ at $t_1$ or at any subsequent time. The steps and corresponding rationales in model estimation are outlined briefly as follows:

(1) Tantrum durations were normalized to a 0–1.0 scale, thus permitting tantrums of different durations to be combined on the same scale.

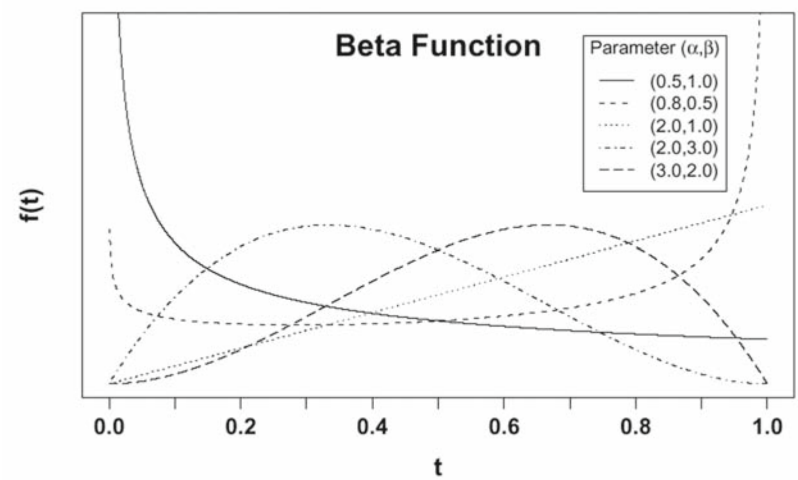



**Fig. 12.1** Parametric variations in the shape of the beta function

(2) The beta parameters $a$ and $b$ were reformulated as the exponential terms, exp($a$) and exp($b$). This reparameterization lifted the restriction that the parameters must remain positive (i.e., >0), thus permitting some of the required statistical manipulations. With these adjustments, MA($t$) assumes the following form:

$$\mathrm{MA}(t, a, b) = t^{\exp(a)-1}(1-t)^{\exp(b)-1}, \text{ for } a, b \in (-\infty, \infty) \tag{1}$$

(3) Initial modeling (Qiu, Yang, & Potegal, 2005) showed that the trajectory of MA($t$) shifted markedly with overall tantrum duration. In particular, the longer the tantrum, the more delayed was the peak of MA($t$). To accommodate such effects, the $a$ and $b$ parameters of MA($t$) are now formulated as a second-order polynomial of duration, $d$. Namely,

$$a = a_0 + a_1 d + a_2 d^2, \; b = b_0 + b_1 d + b_2 d^2 \tag{2}$$

where $a_0$, $a_1$, $a_2$, $b_0$, $b_1$, and $b_2$ are unknown coefficients.

(4) The probability of the $k$th angry behavior at each point throughout the normalized time of the tantrum is represented as $\pi_k(t)$ for $k = 1, 2, \ldots, 8$. Because logit functions with linear terms alone were found insufficient to capture the complex relationships between MA and behavior likelihood, second-order polynomials were used to link $\pi_k(t)$ with MA($t$), yielding the linkage function equation

$$\log\left[\pi_\kappa(t)/(1-\pi_\kappa(t))\right] = C_{0k} + C_{1k}\mathrm{MA}(t, a, b) + C_{2k}\mathrm{MA}(t, a, b)^2 \text{ for } k = 1, 2, \ldots 8 \tag{3}$$

(5) The parameters, $a_0$, $a_1$, $a_2$, $b_0$, $b_1$, $b_2$, $c_{0k}$, $c_{1k}$, and $c_{2k}$, were then estimated using the well-accepted Generalized Estimating Equations technique (GEE, e.g., Liang & Zeger, 1986), which

is a generalization of least squares regression when the regression model is nonlinear. The GEE was chosen for this analysis rather than the commonly used alternative, the Newton–Raphson algorithm, because the latter requires specification of the likelihood function which is difficult to formulate explicitly for longitudinal data when the observations over time are nested (e.g., within subjects) and are all correlated, as they are here. By contrast, the GEE requires only the specification of the mean and variance functions, which are not difficult to formulate even when inter-variable correlations exist. Model-checking plots (Cook & Weisberg, 1999) were used as graphic goodness-of-fit heuristics in determining, e.g., the order of the polynomials for MA($t$) and linkage functions. Mathematically inclined readers are referred to Qiu, Yang, and Potegal (2009) for a fuller exposition.

### *12.3.4 Comparison of Wisconsin and Minneapolis Data*

We used the eight behaviors that loaded on anger factors in both data sets. The model produced good fits to these data and met standard statistical criteria for stability. The iterative GEE algorithm converged to a solution reasonably rapidly and did so from a range of initial values (this was an improvement over results obtained with a simpler model of the WI data, Qiu et al., 2005). Notably, the MN data yielded a more stable solution than did the WI data. Because MA turns out to be a complex, joint function of time within the tantrum and overall tantrum duration, Fig. 12.2 compares MA($t$) for the MN (top row) and WI (bottom row) data as wire-frame time-duration surfaces. This figure shows the crucial result that the time-duration surfaces of the WI and MN data are reasonably similar. Their similarities include the following:

(1) Within tantrums, MA($t$) typically rises steeply and falls more slowly. This is entirely in keeping with expectations about the time course of anger derived from self-reports (Potegal, this book). By definition, MA($t$) = 0 at $t = 0$; the high initial value shown for MA($t$) on the graphs indicates that it rises to near-peak values by the end of the first time unit.
(2) The longer the tantrum, the more delayed is its peak.
(3) The peak height of anger varies as an inverted U-shaped function of tantrum duration. Tantrums lasting up to 9 min (in the WI data) or 15 min (in the MN data) show progressively higher peaks of MA. Tantrums which are longer than these respective durations (17% of the WI sample and 4% of the MN sample, respectively) have progressively lower peaks. There was good agreement in the coefficients of parameter $a$ of the MA beta function. The surfaces do differ in the extent to which the peak shifts toward the end in the longer tantrums; the more rigorous procedures for collecting the MN data and the faster convergence in their modeling suggest that the surface generated from these data is a better estimate of population characteristics. Figure 12.3 provides simpler views of the trajectories of MA($t$) for tantrums that are 3, 6, 9, and 24 min long. Note the very rapid rise of MA($t$) in shorter tantrums. The rising phase of MA($t$) appears similar for the three shorter tantrums; the principal difference is in peak height. Thus, as a first approximation, the answer to the question raised in Section 12.2 is that the difference in most tantrums is not in the rate at which anger climbs, but in the peak value it achieves. In contrast to this plausible result, the finding that tantrums longer than 9–15 min are systematically less angry comes as a surprise (despite a previous analysis of the WI data which suggested a slower rise for the longer tantrums, Potegal, Kosorok, & Davidson, 1996). We are unaware of any published findings to this effect and the result may not accord with intuition. Why has nobody noticed? We suggest that it would be very difficult to retain estimates of moment-to-moment anger while observing a long tantrum. Instead, observers are more likely to form an impression of overall or cumulative

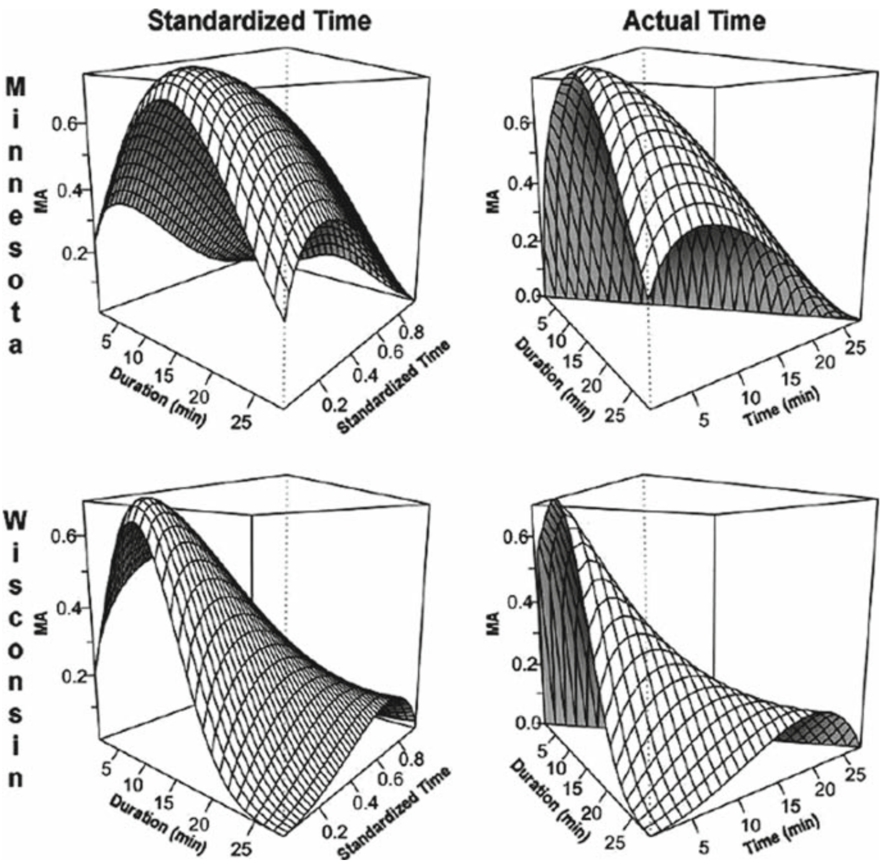
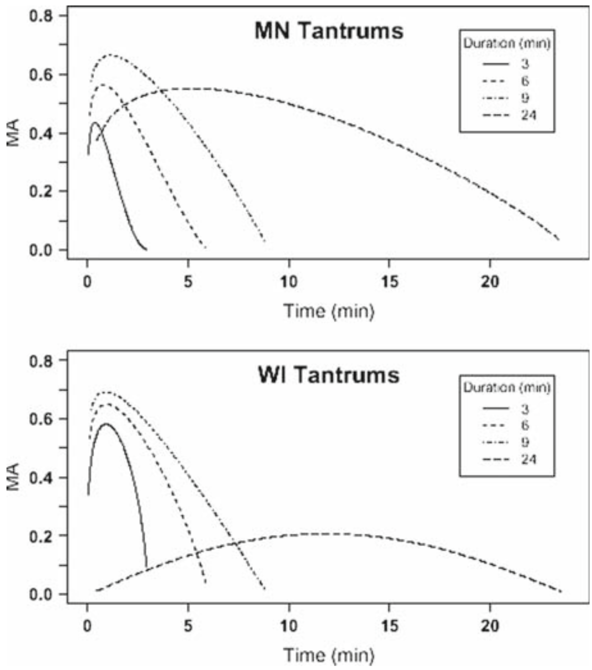



**Fig. 12.2** Time within the tantrum is represented along the *X*-axis, overall tantrum duration is represented along the *Y*-axis, and MA($t$) is represented on the *Z*-axis. For each value of duration on the *Y*-axis, the corresponding *X*–*Z* curve displays the trajectory of MA($t$) over time for the idealized tantrum of that duration. The *X*-axis in the left column is the standardized time (0–1.0) used in our calculations. The same results are displayed in the right column, but with real time on the *X*-axis. The real time graphs depict the trajectory of MA($t$) and the location of its peaks more realistically, but are somewhat more difficult to read because of the brevity of the shorter tantrums

anger. Accordingly, the plots of cumulative MA($t$) over time in Fig. 12.4 show that "total anger" increases up to 15 min for the WI data and up to 20 min in the MN data. This implies that less than 8% of the WI tantrums or 2% of MN tantrums would have shown a reduced level of cumulative anger relative to shorter tantrums. That is, tantrums long enough to show reduced levels of anger are relatively rare.

The panels of Fig. 12.5 display pairwise comparisons of the linkage functions derived from the two data sets. The overall probabilities of each of the respective behaviors are in close agreement (i.e., the mean heights of the pair of functions for each behavior are similar). Furthermore, the functions for most of the behaviors have qualitatively similar shapes. Pairwise, all parameters agree in sign (e.g., $a_0$ for stiffen is negative in both WI and MN data), meaning that the parameters have similar effects on the linkage functions. Finally, there is overlap in the respective 95% confidence intervals for each of the three parameters for six of the eight behaviors. The WI and MN linkage functions for scream differ in one parameter. The major discrepancy is in the parameters for

**Fig. 12.3** MA($t$) for the 3, 6, 9, and 24 min $X$–$Z$ duration planes of the real time (*right column*) plots of Fig. 12.2 are superimposed here on single graphs



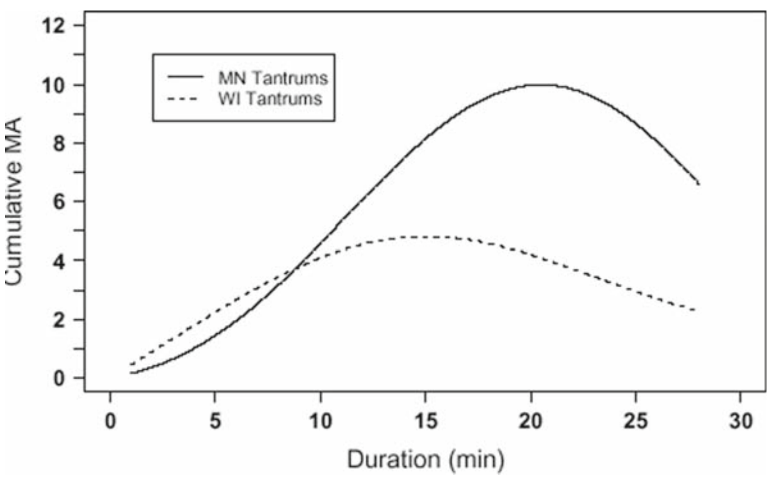




**Fig. 12.4** Comparison of cumulative MA as a function of tantrum duration

arch/stiffen. Where results do differ, the parameters derived from the MN data are again better estimators of population characteristics. Although a linear term was included in all the linkage functions, as expected, none of them are strictly linear. That is, there is no "true" behavioral indicator of MA. Most functions show a maximum somewhere along the range of MA, indicating the level of anger at which that behavior is most likely. The lower anger behaviors, e.g., arch and throw, differ from the

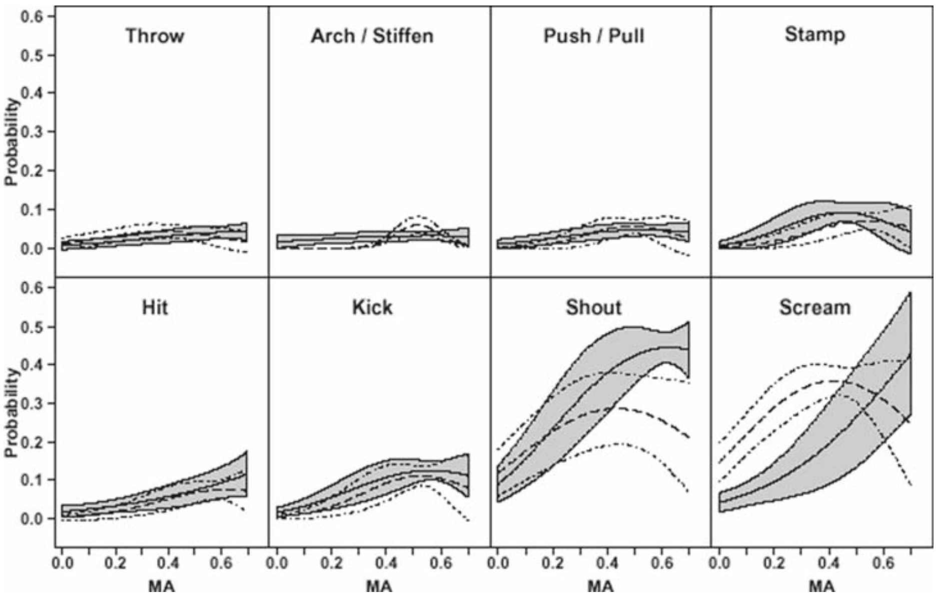



**Fig. 12.5** Comparison of MN and WI linkage functions. *Dashed lines* are WI linkage functions ±1 SD; *gray areas* are MN linkage functions ±1 SD

higher anger behaviors, e.g., scream, shout, and kick, in that the probability of lower anger behaviors increases only slightly along the range of MA and they reach their respective maxima (i.e., they become most probable) at lower values of MA. In contrast, the probability of higher anger behaviors increases strongly with MA and they become most probable at higher values of MA. These effects are expressed by shallow, inverted U-shaped linkage functions for the lower anger behavior and steeper, right-shifted linkage functions for the higher anger behaviors. This is exactly the expected outcome, quantitatively capturing the qualitative relationship between internal anger intensity and corresponding external behavior that was the impetus for this model.

#### 12.3.4.1 The MA50 as a Measure of the "Characteristic" Anger Intensity of Tantrum Behaviors

One major application is the estimation of anger intensity in particular events as expressed by the behaviors occurring in that event. Because the model calculations are complex, we offer a computational shortcut to anger estimation in the form of a set of anger "weights," termed the MA50. The MA50 of an individual behavior is derived from its linkage function and reflects its ranking on the MA scale. Specifically, the MA50 for a behavior is defined as that MA value at which the probability of the behavior is midway between its initial and peak probabilities. The MA50 is analogous to the standard effective dose (ED50) and lethal dose (LD50) measures in pharmacology, which compare drug potencies by the dose necessary to produce a given effect in half the subjects. In Fig. 12.5, e.g., stamp in the MN data reaches its peak value (i.e., is most probable) at MA = 0.45; its MA50 = 0.23. In contrast, the probability of scream increases all the way to the end of the calculated MA range, MA = 0.7; the MA50 of scream is 0.47. Table 12.3 provides provisional MA50 values calculated from the linkage functions of the MN data. Because the convention in psychology is that weights should be small, whole numbers, Table 12.3 also provides a list of suggested weights. These weights have been rounded up or down to increase consistency with the factor analytic results and to be conservative with regard to the magnitude of differences in characteristic intensity among behaviors. Overall anger intensity calculated with these weights can be correlated with other variables of interest (e.g., behavioral and/or autonomic arousal, judgments of the severity of anger, or risk of psychopathology) or used to differentiate among groups where differences in anger intensity are thought to be important, e.g., among children who are at low vs. high risk for externalizing disorder. Readers may wish to compare results obtained with unweighted vs. MA50 weighted scores or derive their own regression coefficients for the various behaviors and compare them to the listed values.

**Table 12.3** "Characteristic" anger intensities of tantrum behaviors

| Behavior | Provisional MA50 | Suggested weight |
|---|---|---|
| Scream | 0.47 | 4 |
| Hit | 0.47 | 4 |
| Throw | 0.32 | 3 |
| Kick | 0.26 | 3 |
| Shout | 0.25 | 3 |
| Push | 0.23 | 2 |
| Stamp | 0.23 | 2 |
| Arch/stiffen | 0.21 | 2 |

MA50 values are denoted as "provisional" because the current linkage functions, and the MA50 values calculated from them, are approximations to the "true" linkage functions (Section 3.2.2).

## 12.4 Current Experimental Limitations and Theoretical Assumptions

### *12.4.1 Methods*

*Data collection.* The detailed analysis of the rising phase of MA($t$) is limited by our use of (1) the first occurrence of a tantrum behavior, rather than the tantrum triggering event, as the start point and (2) 30 s observational units. Both limitations were imposed by our observational techniques and are being rectified in ongoing studies with new methodology.

### *12.4.2 Modeling Assumptions, Functions, and Interpretations*

*The beta function.* There is no a priori reason for the central nervous system to be in the business of generating beta functions. It was chosen for modeling MA($t$) because it can assume a variety of shapes, but it is only an approximation at best. We did obtain similar results with the lognormal and gamma functions. A particular limitation of the beta is that the rising and falling phases assume the sigmoid configuration typical of many biological growth functions only under a certain range of parameter values. However, modeling the rising phase of MA($t$) with a logistic function did not produce a better fit to the data.

*Linkage functions.* Because the rates at which various tantrum behaviors occur outside a tantrum are very low compared to their probability of occurrence within a tantrum, the initial values of the linkage functions shown in Fig. 12.5 should all be 0. That they are not is a consequence of using the first behavior to occur as the start point of the tantrum.

*Variability.* The MA($t$) time-duration surfaces indicate that, up to some duration, the longer the tantrum, the higher is its MA peak. However, there is considerable variability in our data sets, which certainly include some tantrums that are short, but contain many angry behaviors.

*Multiple peaks?* Recall of emotion experiences by adults as well as some observations of children's tantrums suggests that one or more secondary peaks may be superimposed on the primary rapid rise and slower fall of anger (Frijda, Mesquita, Sonnemans, & Van Goozen, 1991 Fig. 7.2, Parens, 1993, Fig 7.1). Pooling and normalizing data to a 0–1.0 time axis was necessary to develop the current model, but precluded the possibility of detecting anger cycles with a brief period.

*Other associations among angry behaviors.* The alert reader will have noticed that similarities among linkage functions, and the ordering of MA50s derived from them, correspond only partially to the grouping of behaviors into intensity-related factors in the factor analyses. This is not necessarily a contradiction in that the factor analyses involve the cumulative durations of behaviors within tantrums while the linkage functions derive from the temporal distributions of behaviors. A likely explanation for the differences is that behaviors may load on the same factor for reasons other than a common drive by MA. For example, highly vocal children may shout and scream when MA($t$) is high, but not necessarily hit or kick. These same children may also be more likely to whine. This differentiation would be consistent with clustering of verbal vs. physical anger patterns in adults (Deffenbacher et al., 1996).

*Alternative/future models of MA(*t*).* The attentive reader will have also noticed that time enters into our model directly in that MA is a straightforward function of time, but also indirectly in that the parameters of MA vary with overall tantrum duration. While the model provides a consistent fit to the data and new insight into the time course of anger, the effects of time would be more concisely represented in a single variable. Tantrums unfold over time depending upon initial conditions, the state and traits of the child, and on the interactions of these variables with events such as parental intervention. Overall duration in the current version of the model is presumably a stand-in for these collective effects. A future approach could involve dynamic equations, or numerical simulations, in which MA appears as an evolving function of time; time- and/or event-driven variation in the growth and decay parameters would capture the influence of relevant variables and processes. However, all these approaches require prior knowledge of the basic linkages between MA intensity and the behaviors that indicate anger. The current model provides this necessary knowledge.

*MA(*t*) vs. "anger."* How does MA($t$) fit with the coupled response systems of anger? Our basic assumption, that anger scales along a single dimension of intensity, implies that significant variance in behaviors can be captured by a single variable, MA($t$), whose value represents overall anger intensity. This assumption also precludes the idea of multiple types of anger or distinctions between lower intensity anger and higher intensity rage suggested in several other chapters in this book. Note our care in using the term MA($t$), not anger, in our discussion. At one extreme, MA($t$) may be a classic latent variable, a statistical construct which functions as a convenient envelope for the set of behaviors observed and which reflects no deeper psychological or physiological process. At the other extreme, MA($t$) may describe the time course of measurable neural process(es) which control behavioral response tendencies as well as autonomic responses, subjective experience and their coupling. As such, calculated MA might have stronger correlations with, and higher predictive value for, e.g., experimentally measured autonomic arousal, self and other judged intensity of anger, impact on family life, level of childhood psychopathology than do any individual behavior or combination of behaviors. For the moment, we regard MA($t$) as a global variable that describes the envelope of the action tendencies and acts which comprise one subsystem of anger.

## 12.5 Some Future Extensions and Applications of the Model

### *12.5.1 Facial, Vocal, and Autonomic Expression*

To this point, the model has addressed the probability of responses, but other response characteristics change in anger as well. The model should be extended to include increases in response "intensity" with anger (e.g., increments in amplitude and frequency of vocalizations and the speed, force, and repetition of physical acts). Even more importantly, the model should incorporate the traditional measures of facial, vocal, and autonomic anger expression. A strong form of the proposition that facial expressions are "gold standard" markers of emotions would be the claim that the linkage function for facial anger in our model would be linear over the full range of MA. Self-reported anger intensity is most closely related to the total number of co-occurring AUs (Alvarado & Jameson, 2002). However, although facial expressions of anger distinguished subjects in Stemmler's (1997) study who reported having been slightly angered by a mild variant of an insult manipulation from those who had been exposed to the moderate or "full" anger variants, facial expressions did not distinguish the moderately from the "fully" angered subjects. These results suggest that angry expressions do not become progressively more pronounced as MA rises from baseline to its peak but saturate at some submaximal level. Stemmler (1997) did find that the slight, moderate, or "fully" angry groups showed correspondingly graded increases in diastolic blood pressure (DBP). The model would become more general, and more integrated across levels, by inclusion of linkage functions for these measures, too.

### *12.5.2 Linkage Functions May Vary with Conditions*

The similarity between the linkage functions derived from the WI and MN data indicates their consistency across children. This does not mean that they are unchangeable. It is entirely plausible that linkage functions shift with stimulus conditions and/or experience. In the arm restraint study noted in Section 12.2, e.g., the finding that angry facial expression had the longest latency and lowest probability of the three responses suggests that its linkage function was displaced to the right. In this study, the child was seated on the parent's lap facing away from her, i.e., there was no visible social stimulus for eliciting a facial expression. Functionalist accounts of "audience effects" on facial expression (cf. Hess, 2001) suggest that if the child were to see the parent's face and visual communication were salient, facial expressions would become more probable. That is, the linkage function for facial anger might well shift up and/or left.

### *12.5.3 Life Span Change vs. Continuity*

We assume continuity of anger dynamics across the life span in order to develop the implications of the model; we justify this assumption on the grounds that the two basic phenomena, a rise-and-fall trajectory and a differential association of various behaviors with low and high intensity anger, remain true in adulthood. The observations that tantrums increase in duration up to age 5, at which time they approximate the lower end of the range of adult episodes of anger, and are then reported not to change with age in adulthood (Potegal, this book) suggest that some MA($t$) parameters may remain fairly stable from middle childhood on. Episode-wise, self-reported intensity of anger increases with the degree of perceived injustice (Mikula, Scherer, & Athenstaedt, 1998) and relative social status (Edwards, 1998); these findings may reflect not only how MA($t$) is governed by social circumstances but also how it is subjectively experienced by adults. Anger intensity is reported to drop across adulthood (Schieman, this book), suggesting a reduction in peak MA(*t*) with age.

Linkage functions may be, perhaps, even more prone to change with development. Effective parental discipline for specific behaviors, such as biting or hitting, might shift the linkage functions for these behaviors down and/or to the right. In fact, the socialization of children away from the physical expression of anger might be nicely captured by corresponding overall shifts in linkage functions. On the other hand, some ordering of linkage functions may be preserved through the life span. Some victims of partner abuse report being shoved and slapped both *before* and *after* the main physical assault (Dobash & Dobash, 1984). This observation finds a natural explanation in that shoving and slapping are behaviors that occur at lower levels of MA, i.e., at the beginning of its rise and the end of its fall.

### *12.5.4 Sex Differences*

Overall, many surveys indicate that the frequency and intensity of men's and women's experiences of anger do not differ (Fischer & Evers, this book). However, one notable sex difference is that women are much more likely to cry when angry (Vingerhoets & Scheirs, 2000). Reframing these findings in terms of the model, men and women may have similar MA(*t*) curves, but their linkage function for crying differs markedly. Campbell and Muncer's (1994) finding that men typically see the expression of anger as seizing control of the situation and exerting dominance while women more typically view the expression of anger as a loss of self-control has been replicated in England (Archer & Haigh, 1999), Spain (Ramirez, Andreu, & Fujihara, 2001) and France (Richardson & Huguet, 2001). One current hypothesis is that women are more reluctant to express anger and do so only at higher intensities, which is when they are more likely to feel they have lost control (e.g., Astin, Redston, & Campbell, 2003). This hypothesis is supported by a meta-analysis showing greater likelihood of male aggression at low or moderate levels of "emotional arousal" (i.e., anger), but much less difference at high arousal levels (Knight, Guthries, Page, & Fabes, 2002). In the laboratory, women's longer latency to respond to continuing provocation has been accordingly interpreted as indicating their higher anger "flashpoint" for overt aggression (Zeichner, Parrott, & Frey, 2003). This interpretation has a natural and empirically testable explanation as a right shift of behavioral linkage functions for women.

## 12.6 Implications of the Model for Theory and Research on Anger

### *12.6.1 Appraisal*

As argued by Potegal and Stemmler (this book), appraisal in some form is a necessary part of the neurological process of anger elicitation in adults. The same must be true of children. However, anger rises too quickly in the majority of tantrums for extensive appraisal to occur. Tantrums are well practiced and seemingly automatic. A child whose daily tantrums begin in earnest at 18 months will have had upwards of 500 tantrums by her third birthday. Such extensive practice probably contributes to tantrum automaticity and the rapid rise of MA(*t*). In meeting the challenge of reconstructing the appraisal process in children's anger, Stein, Trabasso, and Liwag (1993), Fig. 20.2 developed a richly detailed flow diagram of cognitions and plans. As thoughtful and detailed as such diagrams were, they could not reflect events in real time because the requisite real-time data were not available.

Before conjecturing about how appraisal may drive children's anger, the trajectory of that anger, and the time frame into which any such processing must fit, should be established.

### *12.6.2 Display Rules: Anger Regulation in Social Context*

Deliberate "minimization" and "maximization" of negative emotions can be seen by the second year of life (Saarni, 1993). These instances typically occur in a social context. The term "display rules" refers to socially learned rules that determine how much of felt emotion is shown, and to whom (e.g., Underwood, Coie, & Herbsman, 1992, Lemerise & Harper, this book). Restraining the expression of anger is more characteristic of girls than boys. As early as 4–5 years of age, girls receiving an unattractive gift express fewer negative emotions than do boys (e.g., Davis, 1995). In recalling their own experiences as well as in responding to vignettes, 7–12 year olds indicated that they modify their own emotion expression according to the age, sex, and social role of the person with whom they are interacting; girls report more anger suppression than boys (Underwood et al., 1992; Shipman, Zeman, Nesin, & Fitzgerald, 2003). Within the model, such display rules would naturally appear as a down shift or right shift of linkage functions. Thus, use of the linkage functions could help quantify these sex differences.

### *12.6.3 Caveats*

The foregoing discussion suggests shifts or differences in MA($t$) and/or linkage functions as potential explanations for some normal and psychopathological anger-related phenomena. With this in mind, we note the need for care in applying the model. For example, MAs calculated separately for different groups will be comparable in certain respects, but not in others. Thus, peak locations can be directly compared. In contrast, although MA is a ratio measure (e.g., an MA of 0.4 is a level of intensity twice as great as a MA of 0.2), equivalent MA peak heights in different groups do not necessarily represent equal occurrences of angry behaviors. Specifically, if MA($t$) values are to be compared among groups, their data must be entered into the model together. At this early stage in model development, determining what may be happening in particular cases is likely to require rigorous modeling of an extensive data set collected for that specific purpose. Qualitative explanations of phenomena in terms of MA($t$) and/or linkage functions without such rigorous modeling may be more facile than true.

## 12.7 The Anger Intensity-Behavioral Linkage Function Model and the Brain

As described by Potegal and Stemmler (this book), meta-analyses of neuroimaging studies highlight the lateral orbitofrontal cortex (OFC) as an area very consistently activated in anger. Hemispheric asymmetries in EEG activation have consistently implicated left frontal cortex as a region that becomes activated with anger (e.g., Harmon-Jones, Sigelman, Bohlig, & Harmon-Jones, 2003). How does the anger intensity-behavioral linkage function model fit with, or facilitate the analysis of, the neural bases of anger? It is possible, of course, that MA($t$) is a classic latent variable, a statistical construct with no necessary physiological substrate. Alternatively, the beta may be methodologically useful in the curve fitting of neural activity. If, however, activation in lateral OFC and associated regions is the basis for an increased probability of anger-related behaviors, then MA($t$) may turn out to be the envelope of that activation. Our model implies that the order of appearance of different angry behaviors is determined by their respective linkage functions, perhaps as successively higher thresholds along the MA axis. Here we note two precedents for how this process might be instantiated in the brain.

### 12.7.1 Spinal Motor Neurons

One physiological model for automatic escalation in the nervous system is the sequential recruitment of spinal motorneurons, in order of size, for a movement being executed, i.e., the well-established "size principle" (e.g., Cope & Pinter, 1995). Because the force that motor neurons elicit is an increasing monotonic function of their size, (i.e., the larger the unit, the more force it exerts), a consequence of the size principle is that force increases in a roughly linear fashion up to the requirements of the movement. The mechanism of the size principal is embedded in the neurophysiology of the spinal motor neuron pool. However, spinal circuitry operates in the millisecond range while the cerebral circuitry of anger functions in the second to minute range. Furthermore, because anger escalation involves cerebral rather than spinal circuitry, it may not function as rigidly as motor neuron recruitment. Thus, a more relevant model may be the neural control of fear responses.

### 12.7.2 The Temporal Organization of Anxiety and Fear

Fanselow (1994), Blanchard and Blanchard (2008), and others have shown that when an animal first detects a predator at a distance, it becomes immobile ("freezes"). If the predator comes closer it flees; if the predator closes in, the animal then counterattacks defensively. In McNaughton and Corr's (2004) generalized model of this hierarchy, an internalized perception of threat increases along a continuum (e.g., with increasing proximity of the predator); the behaviors in the hierarchy are triggered at successively higher levels of this continuum. These hierarchically triggered, but topographically distinct behaviors are generated by different neural circuits. Details of neuroanatomy and behavior may vary for species and individuals, but in exactly this sense, a recent neuroimaging study of humans being pursued by a "predator" in a virtual maze (but with real physical pain in the form of electric shock if the predator "catches" the avatar) demonstrated a very dramatic shift in the region of brain activation. Activation in orbitofrontal cortex and lateral amygdala associated with milder anxiety shifted to the periaqueductal gray and central amygdala as the predator closed in and fear intensified (Mobbs et al., 2007). We suggest that response shift with increasing MA($t$) may similarly involve sequential recruitment of different neuroanatomical systems in the brain.

Explosive growth in affective neuroscience is just beginning and the sophisticated physiological measures in use should be complemented by the most objective, behaviorally based measures of emotion available. We hope that the ideas for quantifying anger presented here will facilitate that growth.

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