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PAPER

A new dynamic systems method for the analysis of early socioemotional development

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Abstract

This study reports on a new dynamic systems method for studying infant socioemotional development, using conventional statistical techniques to portray dynamic systems constructs. State space grids were constructed from two ordinal variables, distress intensity and attention to mother, and hypothetical attractors were identified as grid cells with high cumulative duration of behavior. Attractor and state space characteristics were operationalized and tested, first to assess the utility of the method and second to reconceptualize and extend conventional developmental hypotheses. The basin strength and relaxation time of hypothetical attractors demonstrated their 'attractiveness' and predicted consistency in attractor location across sessions. Developmental changes and individual continuities in the organization of behavior were also revealed, in ways that would be inaccessible to conventional research methods.

Dynamic systems (DS) approaches to development have generated a good deal of attention and controversy in the last few years. Following trends in the biological and physical sciences, these approaches assume that developing minds, like all complex systems, have particular properties: nonlinear interactions among system components, phases of sensitivity and insensitivity to outside influences, and rapid transitions between stable states. According to the DS view, orderliness emerges in development through recursive interactions among organismic and environmental elements, and this orderliness progressively constrains the path of subsequent growth. Developing minds are thus self-organizing systems, accruing order through the spontaneous coordination of their constituents.

To date, motor development (Thelen & Ulrich, 1991), cognitive development (van Geert, 1991; van der Maas & Molenaar, 1992; Smith, 1995) and communicative development (Fogel, 1990, 1993) have been studied using DS methods. However, research on emotional development remains almost untouched by this wave. This is true despite considerable theoretical interest in self-organizing processes in emotional and personality development (Camras, 1992; Fogel *et al.*, 1992; Lewis, 1995, 1997; Magai & Nusbaum, 1996) and despite the call for DS applications by leaders in the field (Campos, Campos & Barrett, 1989; Goldsmith, 1993; Izard, 1995; Sroufe, 1995).

One reason for this gap may be that available DS methods are not well suited to the study of emotional development. In cognitive and motor development, some ability, skill or level of performance increases or decreases over time, and this change can be quantified for DS modeling (e.g. van Geert, 1994). In emotional development, graded change is not usually the issue. Rather, attention is given to the content, patterning and coherence of emerging adaptations (Thompson, 1993; Sroufe, 1995). Moreover, DS approaches have mostly been applied to normative development (e.g. syntax, semantics, conservation, locomotion). Emotional development is as much concerned with individual differences (e.g. in temperament and personality) as with normative change, and appropriate DS methods would have to be sensitive to both. Finally, DS researchers have studied the organization of discrete cognitive and motor skills by manipulating them directly. Emotional organization cannot be broken down into discrete skills that are manipulated independently. Thus, the most appro-

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priate DS methods may be naturalistic and observational.

The study of emotional development thus poses unique challenges for the DS approach and highlights the need for new methods. But new DS methods are necessary regardless. DS theorists agree on the value of small-sample, fine-grained designs, but disagree sharply on the analysis and presentation of data. European developmentalists have relied primarily on mathematical solutions, whereby iterative equations are used to model developmental profiles (van Geert, 1991, 1998; van der Maas & Molenaar, 1992). These solutions are elegant and informative, but many developmentalists find them too abstract or their terms too arbitrary to adapt to their own research concerns. North American theorists, on the other hand, have generally portrayed actual behavioral data using descriptive portraits (e.g. distance plots, probability regions) and descriptive statistics (Smith & Sera, 1992; Fogel, 1993; Thelen & Smith, 1994). These techniques are more accessible to mainstream developmentalists, yet they have been criticized for being too qualitative and for their 'metaphoric' use of dynamic systems constructs (van der Maas, 1995; van Geert, 1996; see Lewis & Granic, 1999b, for a review).

In the present paper, we report on a new DS methodology for analyzing the socioemotional behavior of developing infants. This method responds to the core concerns of emotional development by focusing on the content, coherence and stability of individual adaptations that change with age. At the same time, it is intended to cut a middle path between the mathematical and descriptive approaches, remaining descriptively 'real' yet quantitatively faithful to DS principles. Thus, our objective was twofold: to provide a novel perspective on emotional development by casting it in a DS frame, and to contribute to the repertoire of DS techniques available for developmental research.

DS principles for psychological development

Psychological systems, like other complex systems, are composed of many elements (e.g., perceptions, associations, emotions, expectancies, motor plans) that interact with one another reciprocally and repeatedly over time. In many (perhaps all) contexts, these interacting elements spontaneously become coordinated or coupled, producing a coherent (lower-dimensional) pattern that perpetuates itself over time. In DS terminology, such temporarily stable states are called *attractors* in the *state space* of the system. All the potential states of a given system comprise its state space, and states which are highly coordinated or coherent 'attract' the system from other, nearby states. Perceptual categories (Thelen & Smith, 1994), linguistic categories (Smith, 1995), motor coordinations (Hopkins & Butterworth, 1997), cognitive skills (van Geert, 1994), memories (Abraham, 1995), belief systems (Goertzel, 1995), personality traits (Lewis, 1995, 1997), emotional states (Wolff, 1993), and communicative frames (Fogel, 1993) have all been described as attractors in the psychological literature.

The 'attractiveness' of attractors can be characterized in two ways, both of which are central to the present investigation (see Figure 1). First, the range of other states (including S2 and S4 in the figure) that lead to an attractor is called the *basin of attraction*, and it provides a measure of the attractor's influence over the behavioral field at large. For example, states of hunger, frustration, fatigue and maternal absence may all be included in the basin of a distress attractor for the young infant. For the school-age child, the basin would be smaller or more limited. Second, the speed with which the system returns to the attractor, following a small perturbation (e.g. from S3 to S4 and back to S3 in the figure), is called the *local relaxation time* and is a measure of the attractor's resilience or stability. The faster the relaxation time, the more stable the attractor. For example, when a young child rapidly resumes a temper tantrum after being comforted, it suggests a highly stable tantrum state. A slower relaxation time means the tantrum is less cohesive.

Psychological self-organization can be observed on at least two time scales. The spontaneous assembly of order, as behavior converges to an attractor, is self-organization in *real time*, a scale of seconds or minutes. Yet, attractors themselves emerge and self-organize over *developmental time*, a scale of months and years (Thelen

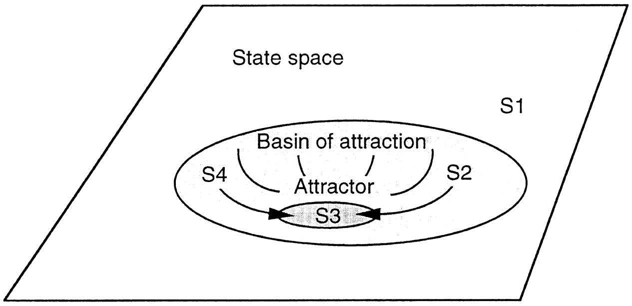


Figure 1 *Topographical depiction of a state space. The attractor (S3) is shown as a well at the bottom of a bowl-like basin. State S1 remains outside the attractor's influence, whereas states S2 and S4 move toward the attractor.*

& Ulrich, 1991). Studying emotional development in real time, we witness socioemotional behavior converging to attractors in seconds, as children fall into one of the emotional habits in their present repertoire (e.g. whining, gaze aversion or hand sucking for a toddler). Over developmental time, we witness some habits emerging and consolidating while others fade or disappear, as individual adaptations self-organize with age.

Thus, a DS interpretation of psychological processes relies on notions of attractors on a state space and self-organization at different time scales. But the means for portraying these ideas, simply and accessibly, are not at all obvious. In the present study, we asked how attractors could be identified in socioemotional data, how they could be graphically (and simply) represented on a behavioral state space, and how they could be evaluated and tested using familiar statistical techniques. We also asked how this would enhance our present perspective on emotional development. The idea of attractors adds little to traditional conceptions of normative skills and individual differences unless it reframes how we think about psychological *organization*. We hoped that a state space depiction would highlight the form (e.g., coherence, consistency) as well as the content of psychological organization in normative and individual development.

Research questions

Four questions guided our translation of DS constructs into research strategies. The first two questions were hypothesis driven and the second two were partly exploratory. (1) According to DS principles, infant socioemotional behavior and the psychological states underlying it should self-organize in interpersonal situations, converging to one or more attractors on the state space. We therefore predicted that infants' emotional behavior toward their mothers would converge to a small region of their state space, suggesting attractors, and that these hypothetical attractors would show evidence of 'attractiveness' (i.e. basins of attraction and quick relaxation time). (2) Attractors, by any reasonably strong definition, are expected to reappear across occasions under similar conditions. If our measures of attractiveness were legitimate, then hypothetical attractors with higher scores on these measures should recur over sessions more often.

Even if our methodology captured DS principles successfully, what would it suggest about early development that is not already known? The next two research questions took up this challenge by asking how conventional assumptions about early emotional development might be reinterpreted and extended through a state space analysis.

(3) Many theorists view emotional development as moving through stages of increasing organization, with some sort of qualitative transition from one stage to the next (e.g. Emde, Gaensbauer & Harmon, 1976; Sroufe, 1979; Case, 1988; Fischer & Ayoub, 1996). To investigate stages, we asked whether attractor consistency was greater within age than across age and whether attractor locations were qualitatively different before and after a hypothesized transition at 4 months (Fischer, 1980; Case, 1985). To investigate increasing organization, we looked for evidence that attractors and other state space features became more tightly organized with age (cf. Sroufe, 1995). (4) Other theorists highlight individual differences in early emotional development, including emotional dispositions that are continuous with age (Rothbart & Derryberry, 1981; Fox, 1989) and personality differences that crystallize with development (Tronick, Ricks & Cohn, 1982; Demos, 1986). Through a DS lens, such differences may be viewed as tendencies for the coupling of attentional and emotional elements which constrain later patterns of coupling without necessarily predicting the behavioral forms to which they give rise (Lewis, 1997; Lewis & Douglas, 1998). Thus, our fourth research question examined individual differences in attractors and other state space features within age periods and their continuity or influence from one period to the next.

Derivation of methodology

In order to operationalize attractors and other state space characteristics, and to use them to model normative and individual development, we re-analyzed videotape data from a conventional study by means of a new DS methodology. The previous large-N study investigated emotional predictors of cognitive competency across the first year. The data included video recordings of infants' emotional responses to maternal separation and reunion, collected on three consecutive weeks at $2\frac{1}{2}$ months and then again at 6 months (Lewis, Koroshegyi, Douglas & Kampe, 1997). For the present study, a subset of these videotapes was re-analyzed according to the following strategy.

A state space model requires at least two variables, one for each dimension being represented. The infant's facial expressions and gaze changes, visible close up on the videotapes, suggested two suitable candidates: emotional state and attention allocation. The relation between emotion and attention is of central importance in early emotional development, capturing both developmental and individual differences in emotional functioning in general and emotion regulation in particular (Kopp, 1989; Johnson, Posner & Rothbart, 1991; Thompson, 1994). Recurrent attentional–emotional habits may tap the development of affective-cognitive structures, assumed by emotion theorists to be the basic constituents of personality (Izard, 1984; Tomkins, 1984; Malatesta & Wilson, 1988). The development of these structures has been modeled in terms of self-organizing patterns of emotion–cognition coupling that recur across occasions and crystallize with age (Lewis, 1995; Lewis & Granic, 1999a).

The greatest variation in emotion and attention was apparent during reunion episodes. Emotion in reunion ranged from pleasure to extreme distress, with some degree of distress evident in nearly all sessions. Reunion distress has been found to be a rich measure of individual response styles as well as normative age differences in emotional development (Thompson & Lamb, 1984; Thompson & Limber, 1990). Thus, we decided to code the intensity of reunion distress for our measure of emotional state. Also during reunion episodes, attention ranged from on-face gaze at mother to full gaze aversion. Infants' gaze has been used to index their goals and expectancies in interpersonal situations and their individual styles of emotion regulation (Tronick *et al.*, 1982). Beebe and Stern (1977) demonstrated that young infants' gaze angle falls into a number of distinct categories (e.g. on face, peripheral, averted), each serving a different function in attentional and emotional self-regulation. We therefore decided to code gaze angle as our measure of attention allocation.

Next, fine-grained portraits of real-time behavior were constructed to model the socioemotional state space and identify its attractors. To construct these portraits, we plotted the consecutive values of our two variables, distress and gaze, as x–y coordinates which changed together in time. Trajectories in a state space can be depicted precisely using continuous variables, with very small increments of change plotted over very brief units of time. Whereas physiological measures can be coded continuously, behavioral measures are usually coded categorically, and this has been true in DS approaches as well (Fogel, 1990; Smith & Sera, 1992; Thelen & Smith, 1994). Yet distances on a state space cannot be quantified using categorical variables. Our compromise was to analyze emotional expression and gaze direction as ordinal variables, to capture a continuum of values which could still be reliably differentiated by observers. The result was a *state space grid* representing all possible coordinates as a matrix of cells, and showing a time line that moved from cell to cell depicting the sequence and duration of events (see Figures 3–6).

Attractors were identified and analyzed in three phases, using simple statistical techniques. First, to identify attractors, occupied grid cells were compared to determine which cells contained the greatest durations of behavior. Cells with greatest total durations, whether by virtue of repeated events or long-lasting events, were considered the best candidates for attractors, because they represented recurring and/or enduring states. Yet, there was no *a priori* criterion for determining how many cells, or what size region of adjacent cells, should be considered attractors. Thus, we developed a method of 'winnowing' the number of candidate cells until we arrived at a small number of densely occupied cells which were relatively homogeneous in duration. In the second phase of analysis, we measured the 'attractiveness' of these hypothetical attractors in two ways. The first involved operationalizing the basin of attraction or *influence* of the attractor. As shown in Figure 1, the basin of attraction is the region of state space from which trajectories proceed to the attractor. However, because our state space was not mathematically defined, we operationalized the basin rather simplistically as the probability that behavior in any grid cell would move to the attractor in the next step. The second measure of attractiveness operationalized local relaxation time, which we will henceforth call *return time* or *stability*. Real systems are constantly fluctuating due to stochastic forces, and these fluctuations can be used to estimate the stability of attractors (Kelso, 1995). We treated temporary exits from attractor cells as small fluctuations, and calculated return time as the time it took for behavior to return to the attractor each time it left. Rapid return times indicated stable attractors. In the third phase of analysis, we examined the assumption that behavior 'converged' to attractors in real-time self-organization by comparing time-in-attractors in the first few seconds with time-in-attractors for the remaining seconds of each episode. If organized behavior took time to converge or settle following mother's return, then behavior should occupy attractors less in the first few seconds.

Once attractors were identified and analyzed, the second part of the study set out to examine normative and individual development in state space terms. We continued to use all identified hypothetical attractors for this phase of analysis. Whereas the two tests of attractiveness, influence and stability, proved highly useful for comparing between hypothetical attractors, they were not conclusive enough as exclusion criteria to warrant omitting potentially useful data.

Method

Participants

Eight infants were selected from a large-*N* study for inclusion in this analysis. The original study recruited 42 mother–infant dyads through announcements, flyers, physicians' letters and advertisements. Three dyads were lost to attrition, and the remaining 39 were roughly even as to gender. All infants were born to term without serious complications, and mother was the primary caretaker, remaining at home at least part-time throughout the first year. Families were nearly all Caucasian and 82% were middle class. Selection for the present study was intended to maximize the socioemotional diversity of the eight subjects. To accomplish this, we chose two socioemotional measures taken at ten months, engagement with mother and distress intensity, each scored globally for each reunion episode and then averaged by subject (see Lewis *et al.*, 1997). We 'eyeballed' the scatterplot of these scores and chose points which were distributed most widely over the plot. For points close together, priority was given to those with no missing sessions at the 2- and 6-month waves.

Videotaping procedure

For the present analysis we used data from two waves of socioemotional measures, collected in the home by a single examiner. Separation–reunion sequences were videotaped by remote control for three consecutive weeks in each of two waves (six in all), at 10–12 weeks (2.3–2.8 months) and 26–28 weeks (6–6.5 months). The infant was seated in an infant seat, and the camera was focused on the face and upper body while mother sat or kneeled on the floor about 1 m away, just out of the camera line. Mothers were instructed to talk to the baby in a normal fashion but avoid physical touch. Mothers were then signalled to leave the room after a 30 s baseline and then to return on a second signal when the infant had exhibited 5 s of vocal distress. Mean separation durations (until the distress criterion was reached) were 5.24 min at 2 months and 4.65 min at 6 months. For the reunion, mother returned to her previous position and resumed the same vocal interaction. Reunions lasted for 30 s at 2 months and 45 s at 6 months, due to infants' increasing capacity for distress regulation. Details of this procedure are available elsewhere (Lewis *et al.*, 1997).

Coding procedures and grid construction

For each reunion episode, starting with the moment mother resumed her position, we coded angle of gaze and intensity of distress on two five-point ordinal scales. These variables were coded separately, second by second, in two consecutive runs through the tape, by a rater blind to the predictions. Distress codes ranged from neutral (including positive affect) to full distress, and they were based on judgments of intensity which included the number of regions of the face (Izard, 1979) involved in the emotion expression. The angle of gaze ranged from full-frontal gaze to full gaze aversion, representing gradations of engagement–disengagement similar to those suggested by Beebe and Stern (1977). Behavioral criteria for both scales are displayed in Table 1.

To code angle of gaze, the rater first observed the whole session in real time while noting the movement of the infant's face toward and away from the location where mother's face (just off camera) was presumed to be. Alert expressions, brow-flashes and smiles helped to pinpoint the angle of direct eye contact. Once this on-face angle was determined, the tape was rewound and then advanced second by second. The last frame of each second was rated. On a second run, the same frames were rated for distress, based solely on facial expressions (with the sound turned off). A second rater was trained fully by the first and then coded randomly selected sessions. Inter-rater reliability was computed on eight sessions (17.4%), using second-by-second codes. Cohen's kappas were 0.78 (Pearson's $r = 0.91$) for gaze, and 0.78 (Pearson's $r = 0.96$) for distress. This high level of reliability suggested that gaze direction could be

Table 1 *Scales for assessing distress intensity and angle of gaze*

Intensity of distress
(0) Contentment (happiness, interest or puzzlement)
(1) Mild distress (troubled, uncomfortable or mildly anxious expression involving only one or two regions of the face, as defined by AFFEX)
(2) Low–moderate distress (involving at least two regions of the face, i.e. eyebrows and eyes, or eyebrows and mouth)
(3) Moderate distress (fully articulated negative expression, i.e. in all three regions)
(4) Intense distress (cry-face)

Angle of gaze (note: mother was positioned 45° from infant's midline)
(1) On-face (focal gaze at mother's face)
(2) Peripheral engagement (within 15° of on-face, including mother's hair, body or clothes)
(3) Neutral (gaze at midline, plus or minus 30°, playing with own hands, clothing etc.)
(4) Gaze aversion (gaze 30°–60° beyond midline)
(5) Cut-off (gaze 60°–90° beyond midline)

ascertained with confidence despite the absence of the mother's face from the picture.

A state space grid was constructed for each reunion session for each of the eight subjects (three at each of two waves = 48 grids, minus two due to missed sessions = 46). First, the values of the two variables were recorded for each behavior event (i.e. each distress–gaze co-occurrence), along with the duration of that event. Most events (53%) lasted only 1 s, and 95% of all events were 1–5 s in duration. The longest recorded event was 36 s, and the next longest was 20 s. Next, a five-by-five grid, representing the 25 possible values of the pair of variables, was constructed (see Figures 3–6). Each event was recorded in its appropriate grid cell by means of a circle whose area was numerically proportional to the duration of that event (using the bubble graph feature of Microsoft Excel 97). For display purposes, a small random number was added to/subtracted from each pair of values, so that circles did not stack up on top of each other in the grid cells. To show the sequence of events, a second scatter plot was created with the points connected by a line. The placement of the points was further adjusted, when necessary, to minimize the criss-crossing of lines, by 'dragging' them individually by mouse, an additional feature of Microsoft Excel 97. Next, the bubble graph and line graph were superimposed using Corel Draw.

Data analysis and results

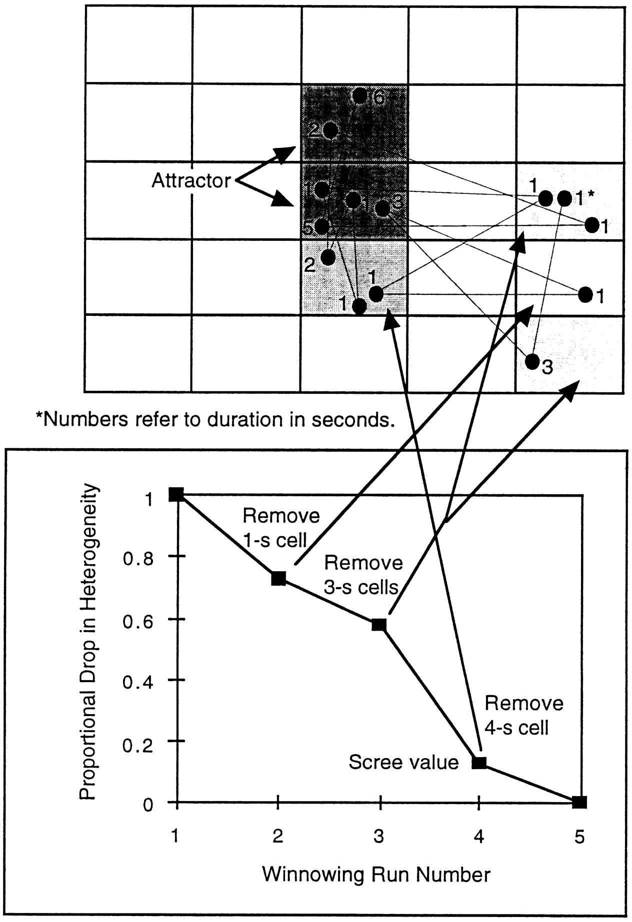
Identification of attractors: winnowing procedure

On a first pass, we scanned the grids visually and picked out likely candidates for attractors. Behavior appeared to cluster in one or more cells on nearly all grids. We then proceeded with statistical techniques to delineate and test these clusters more formally.

The first step was to identify hypothetical attractors on the basis of total cell duration. Total (cumulative) duration was calculated for each occupied cell (such that a single event of long duration could contribute as much as a number of shorter events). The spread of duration values was usually quite heterogeneous over the occupied cells, as one would expect. The next step was to 'winnow' the cells by successive runs until a small set (possibly only one) of cells with relatively high duration was reached. These cells were considered the hypothetical attractor (s).

Winnowing consisted of a series of runs, starting with all occupied cells and shifting to a smaller set of cells each time. For each run, expected values for cell duration were computed as total duration divided by number of cells. Then actual cell duration values were compared with expected values, and the squared deviations were divided by expected values, in the manner of a χ^2 statistic. (However, because seconds accumulating in each cell were not independent measures, no comparison with a χ^2 distribution was possible.) The sum of squared deviations was then divided by the number of cells in the analysis, providing a mean-square *heterogeneity* value for the whole set of cells. We then excluded the cells with the lowest duration value, one value at a time, and repeated the procedure on the next subgroup of cells. As shown in Figure 2, the mean square for heterogeneity dropped from run to run as the subgroup of cells got smaller.

Next, the whole series of heterogeneity values was examined for large drops or 'scree'. (It should be noted



*Numbers refer to duration in seconds.

Figure 2 *Identifying attractors by the winnowing procedure. Each winnowing run denotes grid cells of greater duration (successively darker shades of grey) whose removal decreases the heterogeneity of the set. After the steepest drop in heterogeneity (scree value), the remaining cell or cells (dark grey) comprise the hypothetical attractor.*

that the time units used for the heterogeneity analysis were necessarily arbitrary. Whether durations were measured in seconds or milliseconds would affect the magnitude of the mean squares but not their scree profile.) Following the largest drop in heterogeneity – the scree value – the cells remaining in the analysis were considered homogeneous (i.e. of equivalent duration). These cells were of high duration compared to the previous set, and no further subdivisions could be as distinctive. Thus, as shown in Figure 2, we used this set to identify our hypothetical attractors. If adjacent, these cells suggested a single multicell attractor. If not adjacent, they indicated separate attractors. (We did not bother to analyze higher order attractor configurations, such as periodic attractors, because of insufficient data points.) In fine tuning this procedure, we found that a drop in heterogeneity of less than 50% was not convincing compared with the heterogeneity remaining in the set. Thus, if no drop of greater than 50% occurred, we identified the final drop (at which heterogeneity went to zero) as the scree value, defining the one remaining cell as the attractor. The only exception to the procedure was when the initial heterogeneity value (at the start of the winnowing) was less than 1. This criterion indicated that the entire state space was relatively homogeneous, and no attractor was identified.

Finally, after attractors were identified on the first winnowing series, we often found considerable heterogeneity among cells that had been discarded; i.e. some had much higher durations than others. These long-duration cells were reasonable candidates for secondary, less powerful attractors. Whenever this appeared possible, we removed the identified attractors from the analysis (i.e. set them to zero) and repeated the winnowing procedure to test for other attractors. However, to guard against type I error, we proceeded, as above, only when the heterogeneity value at the start of a series was greater than 1.

Before going on, we should emphasize that the statistical approach used for identifying attractors was developed as a potentially useful alternative to more conventional approaches. We considered the use of sequential analysis techniques, but these were not appropriate. We were interested in the pooling of behavior on a heterogeneous state space, not the sequential path by which some events led to others. Moreover, sequentiality may be unimportant when looking at the tendency for behavior to move from *any* given state to particular target states. We also considered cluster analysis, but meaningful cluster boundaries are difficult to identify with ordinal data, since many points may have the same value. The small number of observations in each session also constrained our choice of methods. Our goal was not to reinvent the wheel, but to discover statistical methods that were particularly suited to identifying attractors on a two-dimensional grid map – attractors that would be reasonably obvious upon visual inspection alone. Like the techniques reported by Thelen and Smith (1994) and Smith (1995), this was an exploratory approach geared toward new ways of conceptualizing behavioral variation in real time.

Results

As shown in Figures 3–6, identified attractors were marked as shaded cells on each of the 46 state space grids. All grids but one showed apparent attractors. One attractor only was present in 27 grids (59%), two were present in 16 grids (35%), three were present in two grids, and one grid showed no attractors. Most attractors (77%) were constituted by single cells, but multicell attractors were also plentiful, consisting either of two cells (20%), three cells (once) or four cells (once). We checked attractor locations against our initial eye-balling of the grids, and found a high degree of agreement: 91% of the attractors we had picked out visually were confirmed by the analysis. However, 43% of these had a different cell configuration than we had estimated (e.g. visually identified two-cell attractors turned out to be one-cell attractors using the winnowing procedure).

Measures of attractor status and consistency

Influence

Once hypothetical attractors were identified, we proceeded to analyze their 'attractiveness', first in terms of influence and second in terms of return time or stability. To measure influence, we operationalized the basin of attraction as the probability that events in grid cells outside the attractor would move to the attractor cell (s) on the next event. This probability was determined by the ratio of 'hits' to 'misses', compared to an expected value based on the null hypothesis that movement to any cell was equally probable.

All movements on the grid were designated as either entering the attractor ('hits') or not ('misses'), with several exceptions. We excluded movements that (1) remained within the attractor, (2) remained within other attractors, (3) exited the attractor being evaluated (and therefore could not enter it on the same turn), and (4) entered other attractors (and thus were evaluated separately). Total hits and misses were compared with

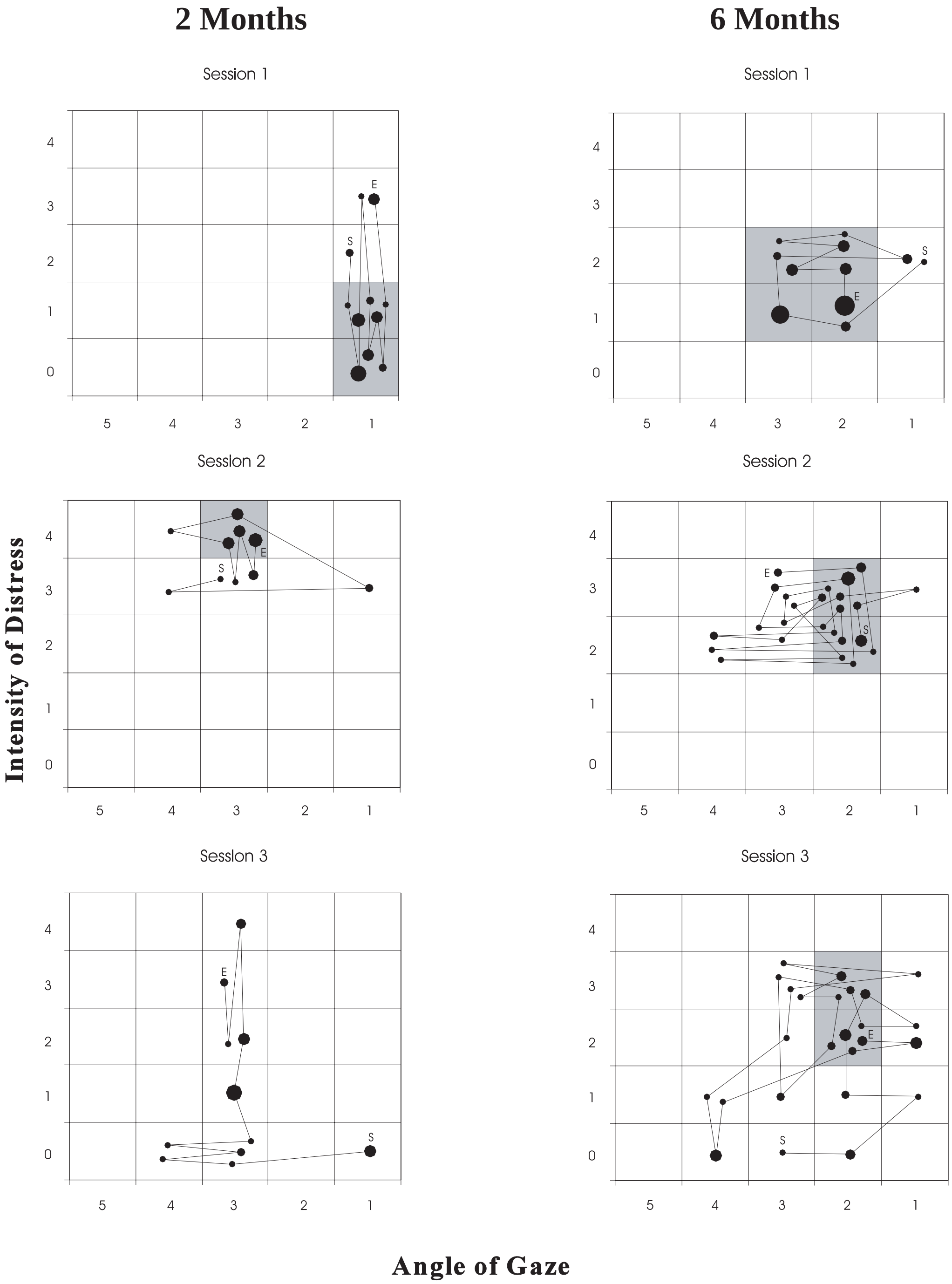


Figure 3 *All three sessions at both ages for one infant. Within-age consistency in attractor locations is evident at 6 months but not 2 months. High stability of attractors can be seen at both ages.*

expected values – the expected frequency of hitting *any* cell. Expected values were computed in two ways, reflecting two versions of the null hypothesis. First, only those cells visited by an infant within a particular age period (2 or 6 months) were considered possible destinations for behavior. This null hypothesis provided a reasonable test that attractors had influence values greater than chance, and χ^2 values computed on this basis were evaluated for significance at the 0.05 cut-off. However, this test was not appropriate for comparing across attractors, because the number of cells occupied could not be disentangled from differences in attractor influence. Attractors with more influence might 'pull in' the cell count, thus leaving fewer cells for computing the expected value (i.e. inflating it). Therefore, a second version of the null hypothesis considered all cells in the grid as possible destinations for each movement. Because all organisms 'specialize' in a limited range of behavioral states, this was not a very realistic assumption, leading to inflated χ^2 values. Therefore, χ^2 values computed on this basis were used only to rate attractors comparatively, not to determine statistical significance.

Stability

The second measure of attractiveness was stability, or mean return time. We operationalized return time as the number of events it took for behavior to return to an attractor once it had exited, with faster returns indicating higher stability. As with influence, return times were analyzed in two ways: first to see if they differed from chance and second to rate attractors for subsequent analyses.

To determine whether return times were shorter than chance, we compared them with the return times of cells not designated as attractors, using a *t* test procedure. For this test, all single-cell attractors were matched with 'nonattractor' cells based on number of events per cell (no comparison set was available for multicell attractors). This controlled for any artifactual relation between higher event numbers and faster return times. The 48 single-cell attractors ranged from two to seven events, and we were able to match 36 of them with nonattractors ranging from two to six events. Matching was performed by randomly assigning priority values to all nonattractors, and then selecting them (according to event numbers) in priority sequence until all possible matches were made. Note that this test was considered provisional due to conceptual ambiguities with the use of 'nonattractors'. First, these cells already showed some properties of 'attractiveness' in that behavior returned to them several times. Second, return times were always a product of the total state space configuration, and attractors may have influenced that configuration differently from nonattractors. Third, what differentiated attractors and nonattractors with similar numbers of events could only be total duration, and long-duration attractors might 'use up' the time available for returns, making them shorter artifactually. Nevertheless, attractor duration and return time were only weakly correlated ($r = -0.12$), so this effect could not have been great.

Return times were also examined in terms of *relative* magnitude. All attractors were compared, including multicell attractors. This larger *N* allowed us to refine the method of computing return time, to increase sensitivity without loss of statistical power. The following criteria were applied:

(1) The longer the return time, the more it was influenced by other events, so trajectories that stayed outside an attractor for 10 s or more were excluded from the calculation of the mean.
(2) Trajectories that entered a second attractor, left it, and then returned to that attractor, before coming back to the target attractor, were also excluded from the calculation of the mean. Such trajectories had clearly fallen under the influence of the second attractor, and their relevance during that time was difficult to interpret.
(3) Attractors with only one valid return time were excluded from the analysis, because estimates based on one observation were least reliable.

Consistency

In order to look at the recurrence of attractors within and across age, each attractor was assigned a consistency value of one or zero depending on whether it recurred in another session. Consistency was scored 'one' if a single-cell or two-cell attractor recurred in precisely the same location or if a single-cell attractor overlapped with one cell of a two-cell attractor. Within-age consistency (see Figures 3 and 4) and cross-age consistency (see Figure 5) were scored separately. Finally, associations between within-age consistency scores and influence and stability scores were examined using logistic regression, in order to answer the second research question.

Results

To assess influence using a significance cut-off, χ^2 values based on the more conservative null hypothesis were used. At 1 degree of freedom (df), a χ^2 of 3.84 is significant at the 0.05 level. We found that 46 out of 65

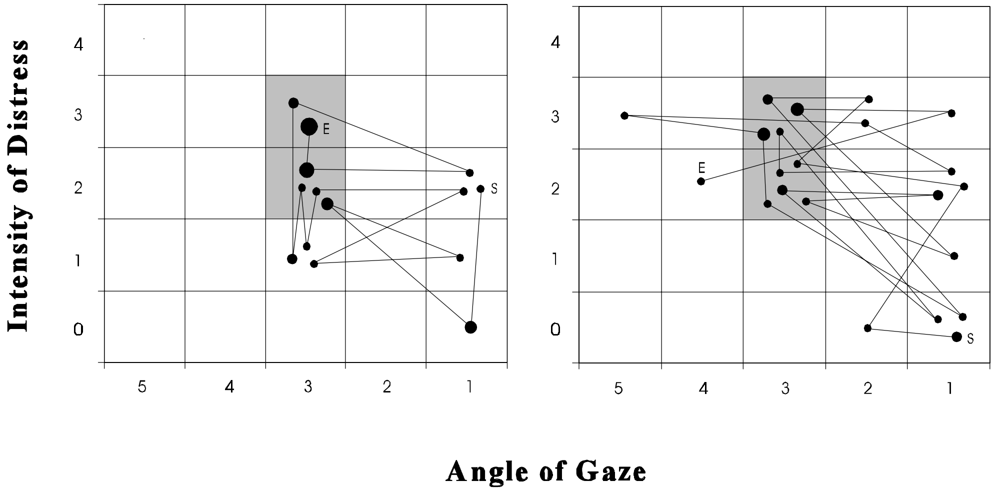


Figure 4 *Two 2 month sessions for one infant. Attractor consistency, rapid return time (high stability) and moderate influence are evident in both.*

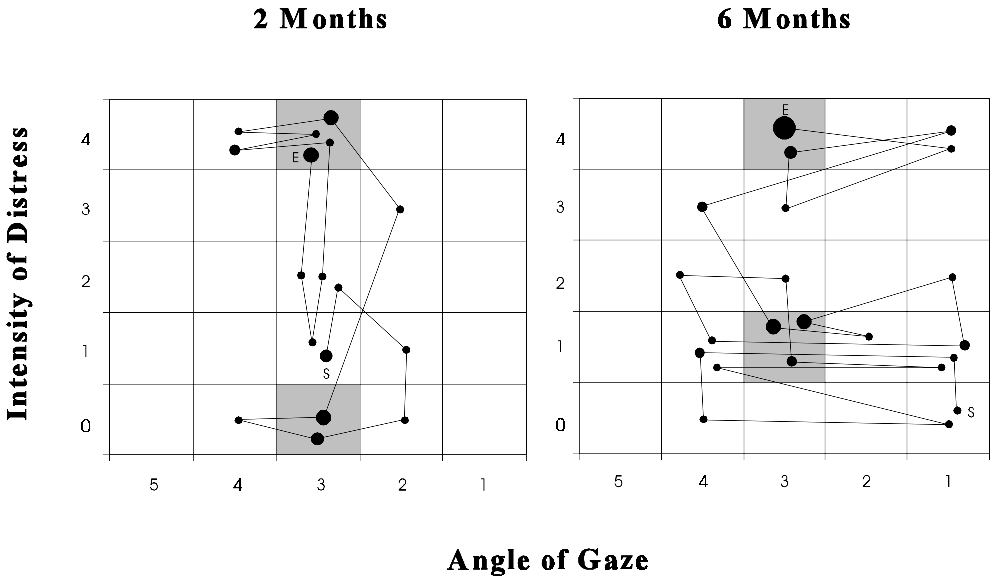


Figure 5 *Two sessions, one at each age, for one infant. Cross-age attractor consistency can be seen for one attractor. The 6 month grid also demonstrates low influence for both attractors and slow return time (low stability) for the bottom attractor in particular.*

identified attractors, or 70.8%, had influence values exceeding this cut-off. Thus, most identified attractors influenced behavior by pulling it away from other cells more often than by chance.

Next, the stability (return time) of identified attractors and matched nonattractor cells was compared. As predicted, return times for attractors were shorter, indicating higher stability, $M = 2.34$ versus $M = 3.80$, independent samples $t(59.11) = 3.50$, $p < 0.001$. Thus, behavior returned more rapidly to attractors than to other comparable cells.

Finally, attractor consistency was regressed on influence and stability in a logistic regression procedure. Because the distribution of influence was skewed (skewness = 1.43), three high outliers were replaced by values two standard deviations from the mean. With both predictors entered together, the model was significant ($\chi^2 = 6.03$, $p < 0.05$, accounting for 66.2% of variance in consistency). Thus, as expected, influence and stability both predicted the recurrence of attractors across sessions within the same age period. With the predictors entered separately, each made a significant contribution when entered first (for influence, $\chi^2 = 4.53$, $p = 0.03$, accounting for 63.1%; for stability, $\chi^2 = 3.74$, $p = 0.05$, accounting for 62.8%) but neither contributed significantly when entered second. The lack of independence between influence and stability was confirmed by a significant positive correlation between these variables (Pearson's $r = 0.49$, $p < 0.001$, $N = 43$).

Analysis of real-time convergence

We examined the assumption that behavior *converged* (i.e. self-organized) to attractors in real time by comparing the time spent in attractors in the first part of each session with that in the remainder of the session. On the assumption that infant emotional behavior converges quite rapidly, we compared the proportion of time in attractors in the first 5 s with that in the remainder (approximately 25 s at 2 months and 40 s at 6 months). These proportions were computed by dividing the total time spent in attractors by the duration of the segment. If infant behavior went immediately to attractors when mother re-entered the room, no differences would be expected. However, if convergence to attractors took several seconds, then these proportions should be statistically different.

Results

Mean time-in-attractors was 0.45 in the first 5 s and 0.62 thereafter, thus differing in the predicted direction, paired comparison $t(44) = 2.99$, $p = 0.003$. This difference in means, although significant, was actually less than anticipated. We did a binomial test of the direction of change, asking how often time-in-attractors increased or decreased after the first 5 s. Results showed increases in 69% of grids and decreases in 29% (one session showed no change). This difference was in the predicted direction nearly $2\frac{1}{2}$ times more often than not (binomial $p = 0.01$). Interestingly, the effect was stronger at 2 months (74% in the predicted direction, binomial $p = 0.02$) than at 6 months (64% in the predicted direction, binomial $p > 0.10$).

Age differences

The next set of analyses examined the notion of progressive stages of development in state space terms. We investigated the consistency of attractors within versus across age, qualitative differences in attractor locations across age, and changes in state space organization across age.

Consistency analysis

Within-age and cross-age recurrences of attractors were compared descriptively first. Then, for the quantitative analysis, we controlled for the number of grids sampled for each type of consistency. Within- and cross-age consistency scores were both summed for each infant at each age, yielding 16 aggregate values for each variable. These scores were divided by the number of grids sampled for each comparison – two for comparing within age and three comparing across age. The corrected aggregate values were then averaged and compared.

Content analysis

Next, age differences in the content (i.e. location) of attractors were examined descriptively. The grid was divided into four roughly equal quadrants: distressed/disengaged (upper left), distressed/engaged (upper right), nondistressed/disengaged (lower left), and nondistressed/engaged (lower right). The relative frequencies of attractors in these quadrants were then compared across the two age levels.

Age differences in organization

Finally, three measures of attractor characteristics and two measures of state space organization were computed at each age and compared across age. Measures of attractor status – influence and stability – were examined first, along with an additional measure, attractor duration. Attractor duration was computed as total time spent in each attractor divided by session length to arrive at a proportion. Correlations of attractor duration with influence and stability were low ($r = 0.26$ and $r = 0.12$, respectively), indicating a good deal of independence between these measures. All three measures were assumed to tap the coherence or resilience of attractors in different ways. Age differences in state space organization were examined next. Two variables were coded for each grid: number of behavioral events or cell movements (proportional to session length) and total number of cells occupied. Both variables were assumed to measure state space organization in different ways, with higher scores indicating greater variability or less cohesiveness.

Results

Most infants had one attractor that recurred at least once within each age period ($M = 0.88$ at 2 months, $M = 1$ at 6 months) and one attractor that recurred across age ($M = 1.13$), as shown in Figures 4 and 5, respectively. However, when correcting for sampling differences, attractor consistency was about twice as likely within age as across age, $M = 1.06$ versus 0.58, paired comparison $t(15) = 3.71$, $p = 0.001$.

Next came a descriptive analysis of age differences in attractor content (i.e. cell location). Attractors appeared in all regions at both ages, except for the mid-to-high left-hand region denoting distressed gaze aversion. Yet some age differences were evident in grid quadrants. Comparing the top two (distressed) quadrants with the bottom two (nondistressed), 47% of attractors at 2 months were in the distress region, compared with 31% at 6 months. Comparing the right two (engaged) quadrants with the left two (disengaged) quadrants, no age differences were found. Individual quadrants were examined next. At 2 months, the quadrant most populated by attractors was nondistressed/engaged (36%) and that with fewest attractors was non-distressed/disengaged (17%). At 6 months, non-distressed/engaged was still frequent (31%), but nondistressed/disengaged more than doubled (now 38%), changing from most rare to most frequent (see Figure 6). No other age trends in content were evident.

Finally, age differences in behavioral organization are presented in Table 2. As can be seen, influence scores were higher at 6 months, suggesting deeper or more extensive attractor basins at the later age. Attractor durations increased as well, indicating greater resilience in the attractors of older infants. However, stability did not change. Also as shown in Table 2, the number of events per second decreased with age, suggesting increased state space cohesiveness. However, the number of cells occupied did not change.

Analysis of individual differences

First, individual differences in the content of attractors, the regions of the grid most frequented, and grid movement patterns were each examined descriptively. Next, in order to assess the continuity of attractors over age, cross-age consistency scores were examined, first in relation to grid location, then in relation to influence and stability scores, and finally as a function of within-

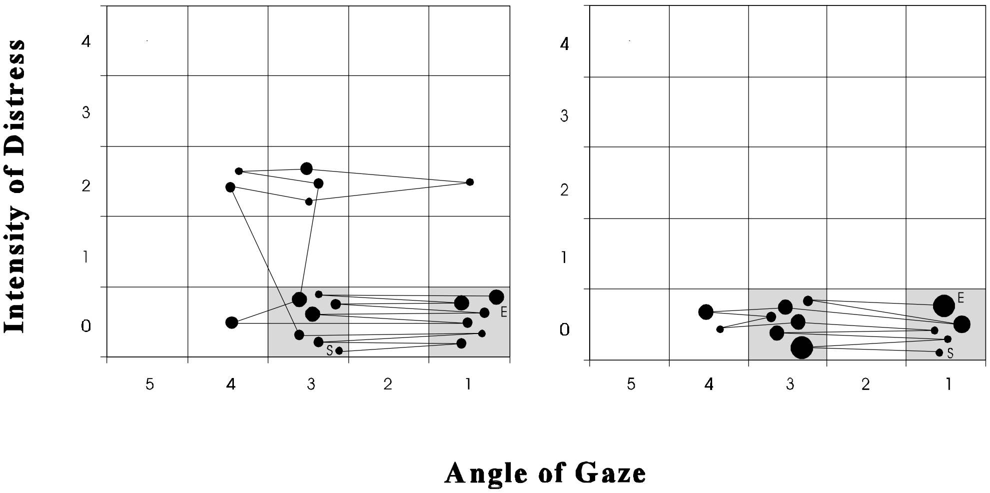


Figure 6 *One 6 month session for each of two infants. Both grids demonstrate the two attractors visited most frequently at 6 months.*

Table 2 *Age differences in attractor and state space characteristics*

Measures	2 month *M*	6 month *M*	*t* value	df	*p* value
Attractor characteristics					
Influence	23.8	37.4	2.25	49.9	0.01
Stability (return time)	1.9	1.7	0.73	41	ns
Duration	37%	46%	2.03	63	0.02
State space characteristics					
Cells occupied	7.6	7.5	0.10	36.9	ns
No. of events per second	0.50	0.41	2.34	44	0.01

age consistency. Logistic regression procedures were used to predict cross-age consistency from influence and stability scores (as had already been done for within-age consistency), and predictions from within-age to cross-age consistency were tested by means of a contingency table analysis. Finally, to test for continuities in the organization of individual behavior, the five variables measuring state space and attractor characteristics were aggregated by subject at each age. A correlation matrix was then constructed between the 2 month and 6 month measures, and significant *r* values were examined in greater detail, using scatterplots and partial correlations.

Results

Individual differences in the content (i.e. grid location) of attractor patterns were examined first. Attractor patterns varied widely at both ages. For example, at 2 months, three infants had attractors in the distressed/engaged quadrant on more than one session, while four had no attractors in this quadrant. Also at 2 months, three infants had attractors in the distressed/disengaged quadrant on more than one occasion (e.g. Figure 4), while two infants had no attractors there. At 6 months, one infant had attractors in a unique region of peripheral engagement/moderate distress on all three sessions, as shown in Figure 3. Only one other infant had even one attractor in this region, and that was at 2 months. Conversely, the nondistressed/disengaged quadrant was the most frequented at 6 months, with five infants showing repeated attractors there (e.g. see Figures 5 and 6). Yet two of the three remaining infants had no attractors in this quadrant.

Individual differences in global grid patterns were evident as well. One difference, of potential interest in future research, was the prominent *direction* of grid movement within sessions and sometimes across sessions. For example, some grids showed prominent vertical trajectories, remaining steady in gaze direction but shifting in distress (see Figures 3 and 5). Others showed prominent horizontal trajectories, shifting in gaze without changing distress (see Figure 6). These patterns of movement may reveal important individual or developmental differences in the style or efficacy of emotion regulation.

Continuity in individual differences was examined in several ways. First, we looked for evidence of strict continuity in attractor locations across age, as reflected by cross-age consistency scores. Of the 65 attractors identified, 28 (43%) showed cross-age consistency. But which attractors were they? Cross-age consistency did not show up more frequently in any of the four grid quadrants. Thus, attractor continuity was not related to content. Our next question was whether attractors with greater influence or stability were more likely to recur over age (as they had within age). Logistic regressions for the sample as a whole, and for 2 and 6 months independently, revealed no significant predictions ($\chi^2 = 2.97$, 0.17 and 2.33 respectively). Finally, we asked whether attractors that recurred within age were more likely to recur across age. Indeed, within- and cross-age consistency were significantly related, $\chi^2 = 4.77$, $p = 0.03$. χ^2 values were then computed separately for each age. No relationship was evident at 2 months ($\chi^2 = 0.73$, $p = 0.39$), but a significant association was found at 6 months ($\chi^2 = 4.24$, $p = 0.04$). Thus, within-age consistency at 2 months did not predict cross-age continuity, but continuity predicted within-age consistency at 6 months. In other words, entrenched behavioral habits at 2 months often disappeared, but habits that endured over age became entrenched at 6 months.

Finally, having examined continuities in attractors, we now looked for continuities in the organization of behavior for the subjects themselves, using both attractor characteristics and global state space characteristics as our measures. As shown in Table 3, substantial correlations between 2 month and 6 month variables were plentiful, many of these were significant or trends despite the very low *N*, and all significant correlations and trends were in the direction (positive or negative) which indicated developmental continuity. These findings suggest a good deal of developmental continuity in the tightness or flexibility of state space organization. In particular, 6 month attractor characteristics were predicted by 2 month state space *and* attractor characteristics. Interestingly, number of cells occupied and attractor influence both predicted 6 month stability, but 2 month stability predicted duration, not stability, at 6 months.

Given the very low *N*, we asked whether these correlations were overly affected by extreme values. Scatterplots for the four significant *r* values are shown in Figure 7. As can be seen, the cross-age correlation in attractor duration is highly questionable, but the other three correlations appear valid. Next, we computed two sets of partial correlations to remove the effects of related variables. To assess the influence of behavioral content, we controlled for gaze and distress means at each age in two separate analyses. It would be reasonable to expect, for example, that fussy infants had more rigid behavioral organization at both age periods, indicating that distress was responsible for the observed continuity. Partialing out distress would then lower the correlations. (A similar argument could be made for attentional style.) Instead, for the three correlations of

Table 3 *Correlations between 2 and 6 month scores for attractor and state space characteristics, aggregated by subject*

	6 month measures				
	State space characteristics		Attractor characteristics		
2 month measures	Cells occupied	No. of events	Influence	Stability	Duration
State space characteristics					
Cells occupied	−0.14	−0.49	0.02	-0.76^{*}	−0.46
No. of events	−0.23	−0.35	0.02	-0.52^{+}	-0.56^{+}
Attractor characteristics					
Influence	−0.22	0.31	−0.09	0.73^{*}	0.22
Stability	−0.47	-0.54^{+}	0.10	0.27	0.84^{**}
Duration	0.01	0.06	−0.34	0.40	0.66^{*}

Notes: $^{+}p < 0.10$.
$^{*}p < 0.05$.
$^{**}p < 0.01$.

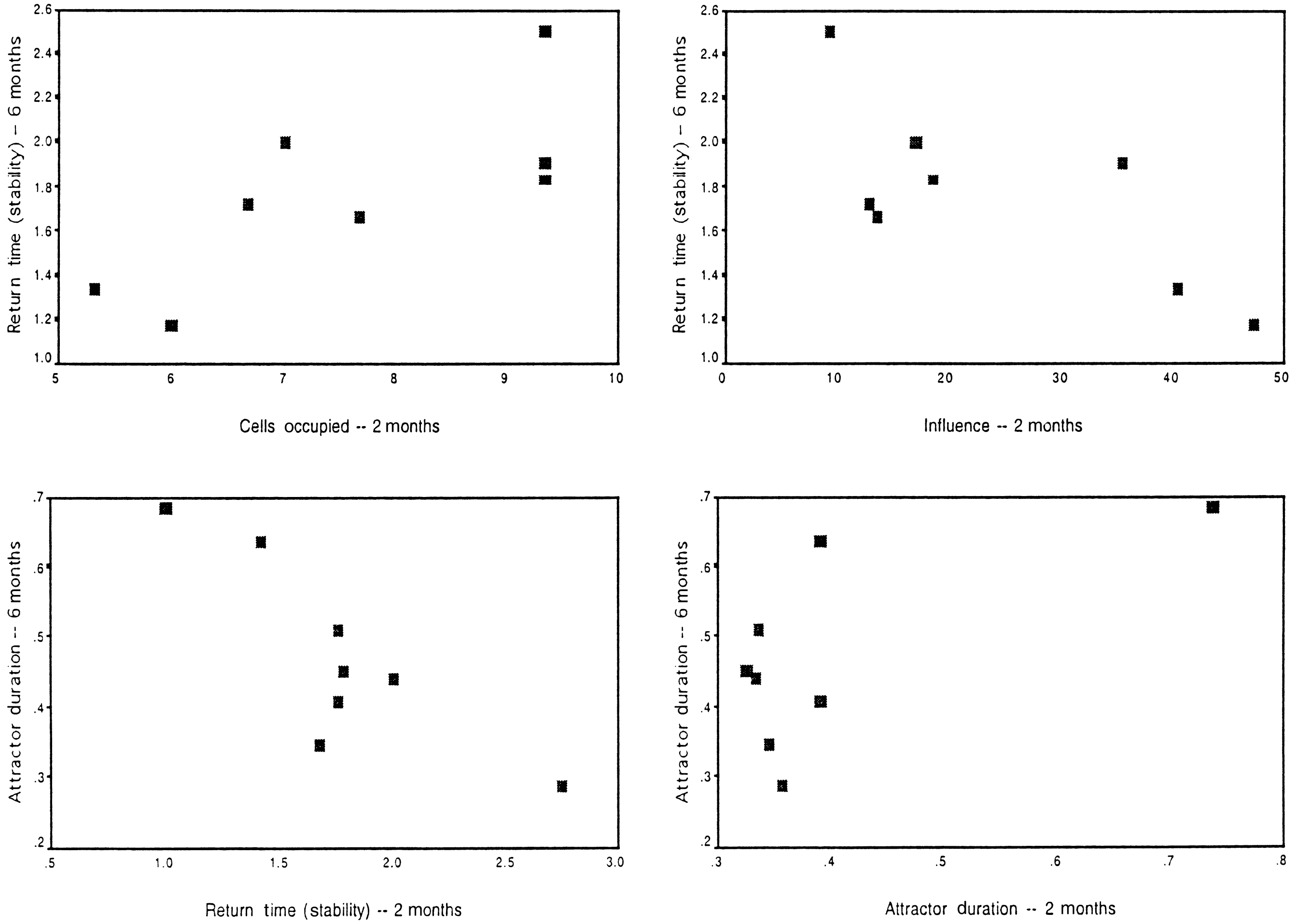


Figure 7 *Scatterplots depicting the four significant correlations between 2 and 6 month measures of attractor and state space characteristics. Except for 2–6 month attractor duration, all correlations appear valid.*

interest, *r* values changed only slightly, rising as often as falling (partial *r* values ranging from 0.67 to 0.87). Finally, we controlled for the mean number of attractors per infant per age, a variable highly correlated with attractor duration. Two *r* values rose rather than fell, and the third dropped slightly (from −0.76 to −0.70). Thus, we felt safe in concluding that the organizational features of behavior at 2 months predicted 6 month organizational features and did so independently of behavioral content.

Discussion

This study applied a new DS methodology to the analysis of early emotional development. In evaluating the results, we asked two questions: (1) how well did our methodology express DS principles using ordinal data and simple statistical techniques, and (2) what added perspective on emotional development was achieved by this analysis?

State space grids and DS principles

The winnowing procedure provided a quantitative tool for identifying potential attractors on ordinal state space grids. However, this method relied entirely on the cumulative duration of particular behavioral states. While duration is a necessary characteristic of an attractor, it remains a trivial characteristic without additional defining criteria. The value of the attractor concept is that it captures movement as well as stasis, specifically movement to a small range of 'preferred' states from a large range of available states. The analysis of influence showed that, indeed, behavior moved to identified attractors from other grid cells at a frequency greater than chance on most occasions. Given the low correlation between attractor duration and influence, this finding provides partially independent support for the 'attractiveness' of our attractors. The analysis of stability demonstrated that behavior returned to identified attractors more rapidly than to other behavioral states visited the same number of times. Given the low correlation between stability and attractor duration, our attractors showed a second index of 'attractiveness' that could not be explained by duration alone.

Influence and stability values were not only greater than chance, they also predicted a third characteristic of attractors – consistency across sessions within age. This finding was particularly interesting because consistency, measured on a scale of weeks, was conceptually and empirically very different from the two variables computed within sessions, influence and stability, both measured on a scale of seconds. A stable state arising on a single occasion may be considered temporarily 'attractive', as with the 'transient region of attraction' referred to by Thelen and Smith (1994, p. 179). However, such states are not attractors in the strong sense of the term. Moreover, the distinction between transient and recurring attractors has not been empirically examined by DS developmentalists, fueling criticisms that nonmathematical treatments are necessarily metaphorical (van der Maas, 1995). In physical systems such as lasers (Haken, 1987), or biological systems such as developing embryos (Goodwin, 1993), attractors refer to stabilities that greatly exceed the scale of single occasions and reflect lasting properties of system organization. Thus, predictions from real-time stability to long-term stability resonate well with DS principles common to the natural sciences.

The analysis of real-time convergence provided a final indication that our grids expressed DS principles in a meaningful way. Time spent in attractors increased after the first 5 s of the session. Rather than static, all-or-none conditions, attractors represent end-states for self-organization in real time. Thus, even in the study of such stable states as walking (Thelen & Ulrich, 1991) or smiling (Messinger, Fogel & Dickson, 1997), DS theorists assume that behavior converges or crystallizes within occasions; it is not just switched on like a neural program. The real-time lag in the appearance of attractors met this expectation. The fact that attractors stabilized more quickly at 6 months than 2 months is also intriguing, and may be suggestive of self-organization at a *developmental* scale: the more organized behavioral habits of older infants may be quicker to converge in real time. However, fine-grained longitudinal research is necessary to examine this possibility more thoroughly.

A different perspective on developmental and individual differences?

Despite the excitement generated by DS applications in developmental psychology, their ultimate utility has not been easy to determine (Bogartz, 1994; Izard, Ackerman, Schoff & Fine, in press). In the present study, we addressed this issue by revisiting conventional expectations about early emotional development from the novel perspective of state space modeling. Would our results agree with conventional assumptions and, more importantly, would they point in directions that could extend or revise those assumptions?

Attractor consistency was greater within age than across age, as expected. This finding conformed to the assumption of a stage shift at roughly 4 months (Sroufe, 1979; Case, 1988; Lewis *et al.*, 1997), but it provided no solid evidence for this shift. The ratio of within- to cross-age consistency was only 2 : 1, and measurements taken a few weeks apart should be more consistent than measures separated by several months, regardless of any developmental shift. As far as age differences in content, attractors in the distress region decreased and those depicting disengagement increased with age. These results parallel conventional research findings (e.g. Emde *et al.*, 1976; Kaye & Fogel, 1980), but they add little to what is already known and they fail to demonstrate *qualitative* change. In contrast, other DS research has demonstrated stage changes convincingly, at least within particular task domains, using growth curves and catastrophe theory to model developmental transitions (van der Maas & Molenaar, 1996; Ruhland & van Geert, 1998). These approaches rely on developmental time series data, tested for sudden jumps rather than global age differences. Thus, the current design, not the DS perspective in general, seems unsuited to measuring qualitative shifts.

More encouraging results came from the analysis of age differences in state space organization. The influence and duration of attractors increased with age and the number of state space movements decreased. Thus, behavioral organization became more coherent and cohesive with development. These results are consistent with conventional theory and research showing that emotion and attention regulation – and emotional functioning on the whole – become better organized over the first half year (Gianino & Tronick, 1988; Kopp, 1989; Johnson *et al.*, 1991; Thompson, 1994). However, they also extend these findings by suggesting a formal, content-free metric for 'organization'. Increased influence and duration mean that attractors were stronger and more resilient at 6 months than 2 months, whatever their content. The drop in the number of state space movements seemed to reflect the same increase in behavioral cohesiveness. Thus, coherent socioemotional states pulled in more variability and lasted longer at 6 months, whether they were states of frustration, engagement, exploration or avoidance. These results are consistent with Thelen and Smith's (1994) proposition that increasing attractor strength is the essence of skill development. The theme of increasing coherence, integration and predictability is fundamental to an organizational view of emotional development (Sroufe, 1995), but psychologists have lacked the tools to study the system components being organized. A DS analysis can look beyond the macroscopic forms of behavior, visible to conventional research methods, and focus on the microscopic interactions which constitute them (Tschacher & Scheier, 1997).

Individual differences in attractor locations were highly pronounced, and many of these were consistent over age. However, attractor continuity did not appear to be related to the content of behavior (e.g. presence or absence of distress, gaze preference) in any systematic way. The lack of content-related continuity in emotional functioning is not surprising in the first half-year of life, when the stability of temperament is overshadowed by rapid developmental change (Buss & Plomin, 1975; Rothbart & Derryberry, 1981; Kagan, 1984). For this reason, we were particularly interested in formal or content-free features of continuity.

At the level of individual attractors, influence, stability and consistency all failed to predict continuity, but continuity from 2 to 6 months predicted attractor consistency across sessions at 6 months. These findings suggest that strong behavioral habits are no more likely to persevere than weak ones during early infancy, supporting Kagan's (1984) contention that new behavioral forms replace older ones at times of developmental change. But they also suggest that the behavioral forms that do persevere become stronger, proliferating across situations as they mature. This picture of crystallization in individual development is intriguing, and it expresses the notion of branching pathways familiar to both developmentalists (e.g. Sroufe & Jacobvitz, 1989; Magai & Hunziker, 1993) and evolutionary biologists. However, this finding was not specifically predicted, and it must be treated as suggestive.

At the level of individual subjects, continuity was much more obvious. The rigidity or flexibility of state space organization, including attractor organization, was continuous over age, and this continuity was independent of both distress and attentional focus. This finding suggests a stable characteristic of attentional or regulatory style that is content-free. Given the early age of observation, this content-free characteristic may precede the reliable measurement of temperament. One possible candidate for such a characteristic is Guilford's adaptive flexibility, interpreted by Pascual-Leone (1989) as a content-free cognitive style variable.

Six month measures of attractor resilience and endurance, but not overall influence or cohesiveness, were predicted by state space and attractor characteristics at 2 months. Yet these characteristics were not themselves continuous. One explanation for this 'causal continuity' (Rutter, 1987) is that 6-month-olds can voluntarily shift their attention allocation and, to a degree, their emotion regulation. This normative capability could override individual differences in global organizational characteristics such as basin strength. Thus, early differences might predict the rigidity of temporary behavioral states but not the overall cohesiveness of behavioral episodes later in the first year.

These results are particularly intriguing because of the strength of the correlations. Temperament correlations across the same age span tend to be considerably lower, with the best predictions in the range of 0.40 to 0.60 (Rothbart, 1986). Of course, our *N* was extremely low, as is typical of DS research, and individual continuity in organizational rigidity was not specifically predicted. Thus, despite our precautions, both the findings and their interpretations must be treated as suggestive.

If these findings are replicated, what are their implications for individual development? Rigid behavioral organizations seem to indicate more tightly coupled constituents with less opportunity to assemble in new ways or couple with alternative constituents. These organizations should thus resist adjusting to change or novelty within or across occasions. If these organizational tendencies are indeed continuous over age, they may underpin lasting individual differences in children's interpersonal flexibility and the ease with which they adapt to a changing world. More rigid children may have a more difficult time tolerating novelty and ambiguity and switching between alternative strategies in stressful situations. These suggestions can only be raised tentatively on the basis of the present findings, but they embody a novel perspective on early individual differences. By permitting analysis of the organization as well as the content of behavior, a DS approach encourages new ways of looking at developing individuals.

Taken together, these results parallel some conventional assumptions and research findings concerning early emotional development. However, they also point to developmental phenomena that could not have been glimpsed through a more traditional lens. With respect to both normative development and individual differences, they add little to what developmentalists already know about the *content* of behavioral forms. However, they provide new insights and new findings concerning the *organization* of behavior, in terms of both developmental change and individual continuities. It seems appropriate that a DS method should have more to say about the form than the content of developing systems. Further extension and refinement of DS research strategies will show where this path leads.

Acknowledgement

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