A Microgenetic Dynamic Systems Analysis of Temporal Relations Among Domains of Early Childhood Regulation

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Background

- Self regulation in childhood has cascading effects on social, academic, and emotional competence (e.g., Graziano, Keane, & Calkins, 2007).
- While an integrated view of self regulation acknowledges the contributions of physiology, emotion, and behavior to regulatory adjustment, investigations are just beginning to determine their interrelations (Bell & Deater-Deckard, 2007; Santucci, et al., 2008).
- Along with additive and interactive effects, a dynamic systems framework recognizes that these relations are self-organizing across time (Granic & Hollenstein, 2003). In this view, valuable information can be gained from system-level processes (e.g., stability, organization) beyond information about any individual domain (Gottlieb & Halpern, 2002). Further, the coherence of systems has emerged as an important adaptive construct across domains.
- This study used state space grid analysis (SSG) (Lewis, Lamey, & Douglas, 1999) to graphically model the regulatory *system* and elucidate its unique predictive value by mapping the simultaneous states of children's behavior, emotion, and physiology over 10 second intervals during a challenging task.

Method

- Participants were part of a longitudinal study following 250 ethnically diverse children (50% female), and their caregivers, annually from ages 4-8. Data in this report were collected at age 6 (N=215) and age 8 (N=95 [collection currently underway]).
- At age 6 children participated in a 2 minute delay of gratification task in which they had to wait their turn to play with an attractive remote control robot.

In every 10 second period:

- Behavior was coded on a 0-3 ordinal scale indicating degree of approach to the toy (none, ask, reach, touch).
- Expressed positive emotion was coded on a 0-3 ordinal scale (none, mild, moderate, extreme) (ICC = .870).
- Heart rate was measured using Biopac 7 acquisition software & wireless electrodes, and scored with Mindware software.

- Parent-reported adjustment on the Child Health Survey and child self report on the Behavioral Assessment System for Children (BASC-2) were collected at age 8.

Analytic Approach

- Figure 1 displays a state space grid for an individual participant, analyzed using Gridware v.1.15 software.
- The state of positive emotion is displayed on the horizontal axis, and behavior on the vertical. The state of physiology is indicated by color (low heart rate in yellow, moderate in blue, and high in red).
- The open circle indicates the beginning state (in this case, not displaying positive emotion, not behaving toward the robot, and a low heart rate). One can then follow the arrows to sequential states of the system.

- We can extract individual level variables from the SSG.
- **Dispersion** is a measure of the variability of the system.
- **Entropy** is a measure of the unpredictability or disorganization of the system.
- Figure 2a and 2b illustrate the difference. Both examples have high levels of dispersion (range), but figure 2a shows an individual who moves through states in a predictable, organized way (low entropy), and figure 2b shows a disorganized or unpredictable path. Figure 2c illustrates low dispersion and low entropy.

- Beyond individual measures, we can also examine sample level indices. Figure 3 represents trajectories for the entire sample overlaid on top of one another. From this view, we can begin to examine the characteristics of the system of self regulation at the group level.
- **Attractor states** represent areas in the grid where the system is more likely to settle. They are measured by calculating the average latency of the system to return to a given state (shorter times reflect stronger attractors).
- Additionally, once attractor states are identified, one can predict **transitions** toward and away from attractor states.

Figure 1.

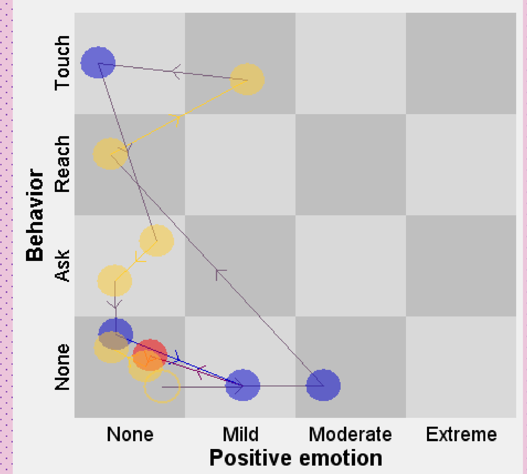


Figure 2a.

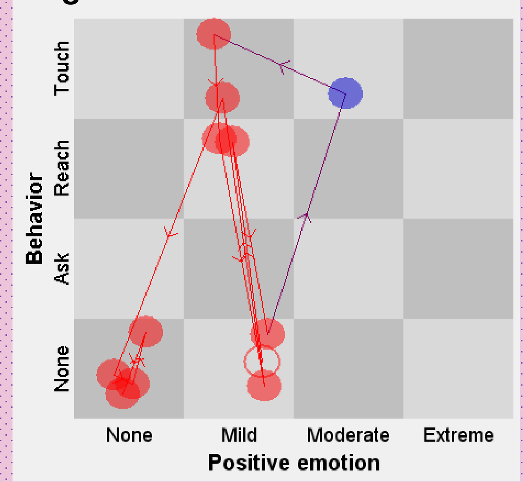


Figure 2b.

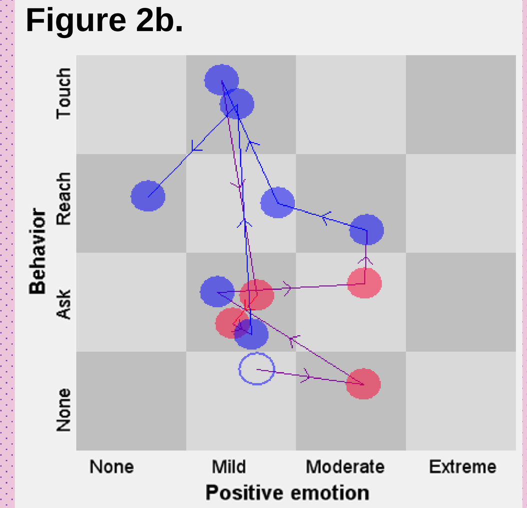
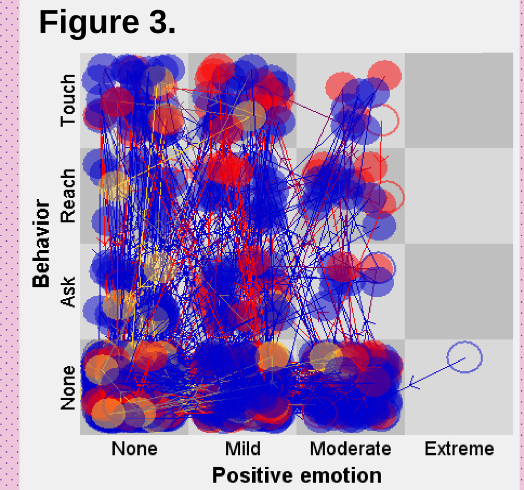


Figure 2c.

Figure 3.



Results

- Dispersion and entropy at age 6, across each pair of regulation domains, predicted adjustment at age 8 across spheres of functioning and reporters.
  - Within the **emotion/behavior** subsystem (Table 1a), entropy had relatively stronger predictive value than dispersion, indicating that the organization, and not simply the variability of responses, was a key determinant of system-level adaptation. Specifically, higher entropy (more disorganization) in the emotion/behavior subsystem at age 6 predicted worse self esteem, more attention problems, and a trend for more social stress, at age 8.
  - Alternatively, in the **emotion/physiology** subsystem (Table 1b), dispersion and entropy were equally good predictors. Higher levels of both dispersion and entropy predicted *better* adjustment across outcomes and reporters.
  - Overall, the **behavior/physiology** subsystem (Table 1c) was relatively less predictive of later adjustment.

- Finally, in examining group level variables, there were no attractor states identified in this system. Potentially, the variability of the trajectories across individuals may have precluded identifying specific cells that were relatively more populous across the entire sample. Because no attractor states were identified, it was not possible to probe transitions in the system.

Table 1a.
Correlations between **Emotion/Behavior** System Organization and Later Adjustment

Outcome	Dispersion	Entropy
Self Esteem[1]	-.200 #	-.228 *
Attention Problems[1]	.163	.226 *
Depression[1]	.088	.135
Social Stress[1]	.141	.201 #
Academic Performance[2]	-.256 *	-.251 *
Medical Disorders[2]	-.159	-.106

***p<.001, **p<.01, *p<.05, #p<.10
[1]Child Self Reported; [2]Parent Reported

Table 1b.
Correlations between **Emotion/Physiology** System Organization and Later Adjustment

Outcome	Dispersion	Entropy
Self Esteem[1]	.086	.143
Attention Problems[1]	-.145	-.183 #
Depression[1]	-.242 *	-.244 *
Social Stress[1]	-.205 *	-.216 *
Academic Performance[2]	.033	.039
Medical Disorders[2]	-.230 *	-.216 *

*p<.05, #p<.10
[1]Child Self Reported; [2]Parent Reported

Table 1c.
Correlations between **Behavior/Physiology** System Organization and Later Adjustment

Outcome	Dispersion	Entropy
Self Esteem[1]	.049	.039
Attention Problems[1]	-.010	.001
Depression[1]	-.197 #	-.162
Social Stress[1]	-.103	-.072
Academic Performance[2]	-.077	-.055
Medical Disorders[2]	-.201 #	-.181 #

#p<.10
[1]Child Self Reported; [2]Parent Reported

Discussion

- The pattern of results across self regulation subsystems suggests that system level analysis provides added value over analyzing individual components. Given that differing combinations of individual variables (emotion with behavior, emotion with physiology, and behavior with physiology) produced widely different relations to later adjustment (worse adjustment, better adjustment, and no prediction at all), it is not likely that individual components are driving the system level results.
- Given that disorganization is generally considered maladaptive, the finding that entropy was positive for adjustment in the emotion/physiology subsystem was surprising. One potential interpretation is that entropy in this particular system may index something akin to flexibility of responding. There may be something specifically adaptive about not being rigid in terms of emotion and physiology (for example, if heart rate is high, it may be better for emotion to vary, rather than to be consistently high as well). Furthermore, flexibility in physiology itself can be adaptive, in that one's heart rate should rise and fall in response to encountered challenges.
- Finally, these findings demonstrate that absolute levels may not be as important as the relation of constructs to each other. That is, it is possible to have stability in the system at the low or high ends. Similarly, variability of responses proved less influential than entropy, in several domains, highlighting the salience of systemic *organization* as a particularly crucial developmental influence.

Future Directions

- Applying this paradigm to other tasks with a greater variability of emotional responses will allow us to examine the interaction of behavior regulation with *negative* emotion regulation.
- Entropy is calculated as an average of probability functions of responses across the two utilized dimensions. Therefore determining a way to calculate these entropy parameters across all three domains of functioning is an area of potential future development for SSG techniques.
- Given that this technique is often applied to dyadic interactions, it would be interesting to examine dyadic regulation of parents and children in one or more of these domains.

References and Acknowledgements

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