

Elucidating the processes of children's development and change in mother-child interactions: A dynamic systems approach

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Purpose of study

This study aimed to establish a theoretical foundation for elucidating the development of social behavior by demonstrating that the dynamic systems approach (DSA) offers a comprehensive framework for understanding children's development. Second, it aimed to examine the empirical and methodological applicability of the DSA through two distinct investigative strands: (1) investigating the importance of individual differences and nonlinearity in children's development using longitudinal quality-of-life (QOL) data, and (2) evaluating the utility of this framework for analyzing dyadic socioemotional dynamics through a state space grid (SSG) analysis of parent-child interactions.

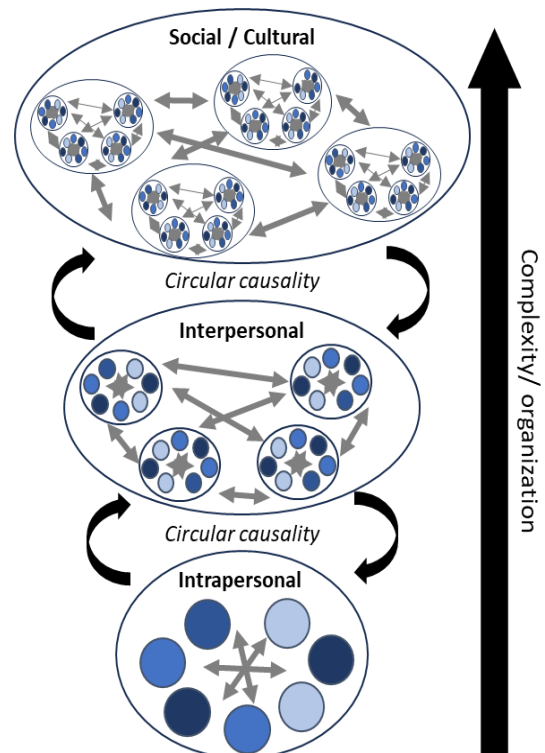
1. Theoretical foundation: The dynamic systems approach

This study positions the DSA as a highly effective theoretical framework for elucidating the processes of development and change in children's social behavior. Our examination involved a multifaceted integration of philosophical grounding, conceptual organization, and methodological implications.

The DSA is philosophically grounded in the process-relational worldview (Overton, 2015). This worldview departs distinctly from the mechanistic approach, which reduces development to individual parts and treats developmental phenomena as the sum of such parts. Instead, the process-relational worldview integrates organicism and contextualism, drawing its foundation from Whitehead's process philosophy. It operates on the ontological premise that coactions between elements and the processes

Figure 1

Hierarchically nested structure of dynamic systems (Based on Hollenstein, 2013).



themselves constitute reality. Thus, it seeks to understand self-organizing organisms within their historical and environmental contexts. This perspective allows us to grasp the processes of change and stabilization through interrelations, opening new possibilities for uncovering the underlying processes of development.

Serving as the theoretical foundation for this study, the DSA offers a metatheoretical framework—aligned with the worldview described above—for the study of stability and change in development (Witherington, 2007). The DSA has three key aspects: (a) it offers a systemic view; (b) it integrates multiple timescales; and (c) it emphasizes individual differences (Figure 1). First, the DSA perceives a dynamic system as a construct that develops (changes and stabilizes) over time through continuous interactions among a complex set of elements (a). The DSA presents a nested hierarchy of multiple timescales and varying levels of complexity, encompassing intrapersonal elements (e.g., biopsychological factors), interpersonal elements (e.g., parent-child relations, peer relations), and sociocultural systems (e.g., communities) (b). The levels within the system are dynamic and interdependent, characterized by circular causality; interactions at the micro-scale give rise to the emergence of macro-level order or new states, while macro-level order, in turn, constrains micro-level

interactions. In such a system of complex interactions, elements link and evolve in individualized and diverse ways, underscoring the importance of individual differences (c).

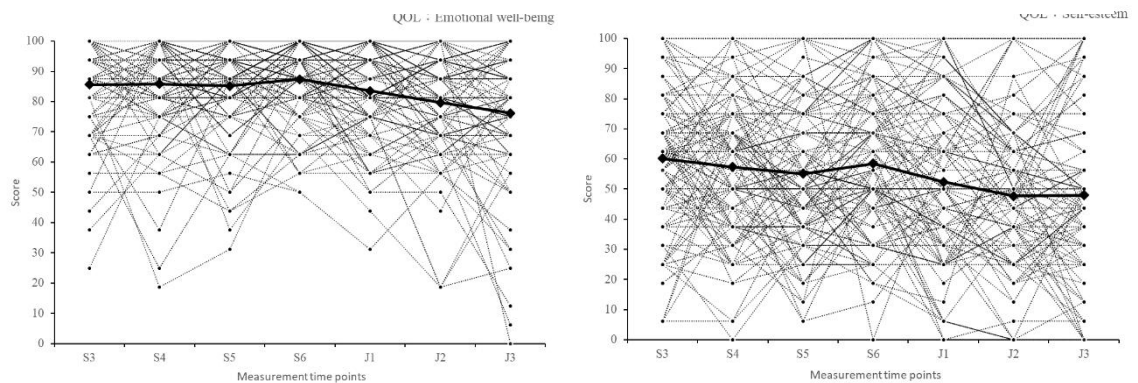
Traditional reductionist approaches have helped delineate factors related to normative development; however, they have failed to account for discontinuous change, individual differences, equifinality, or multifinality. Yet, a core part of development involves discontinuous and nonlinear emergent change and its underlying processes. By adopting the DSA and employing a methodological approach that prioritizes the measurement of multiple factors, longitudinal research design, and the analysis of nonlinearity and individual differences, it becomes possible to capture these developmental changes with greater precision. In conclusion, the DSA is an optimal theoretical framework for understanding the complexity of developmental change. Research related to these theoretical perspectives was presented at the International Society for Research in Child and Adolescent Psychopathology (Takeshima, Kawai, & Sato, 2025) and the Japanese Psychological Association (Takeshima, 2025).

2. Developmental trajectories of children's quality of life

Drawing upon the DSA, we analyzed nonlinear changes and individual differences in the trajectories of a key developmental outcome: children's quality of life (QOL).

Figure 2

Developmental trajectories of QOL (emotional well-being and self-esteem) from 3rd to 9th grade (adapted from Takeshima, Namba, & Kawai, 2023).



The study involved 126 children (64 boys and 62 girls) from the 2022 cohort of the Japan Children's Study (conducted by the Center for the Study of Child Development, Mukogawa Women's University). The children's QOL was measured annually from the third grade of elementary school (ages 8–9) through the third grade of junior high school (ages 14–15) (Figure 2). While the results showed a decline in the mean QOL score during junior high school, a quadratic growth model (representing an inverted U-shaped curve) demonstrated a good fit when estimated through latent growth curve modeling. We also observed significant individual differences in developmental trajectories, characterized by increasing inter-individual variability over time. These results are consistent with the theoretical

expectations of the DSA, which accounts for both nonlinearity and individual variation. These findings were published in the Research Report of the Mukogawa Women's University Institute for Education (Takeshima, Namba, & Kawai, 2023).

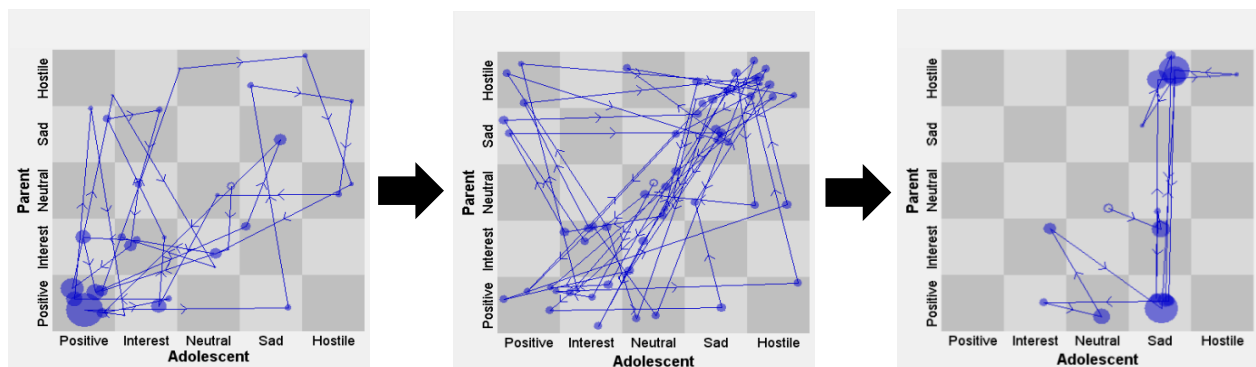
3. Applying the DSA to analyze parent-child dynamics

One of the primary research challenges within the DSA is to elucidate how real-time (moment-to-moment) interactions relate to changes that occur over developmental time. Although it is well established that socioemotional interactions with mothers play a crucial role in a child's long-term development, these processes have yet to be fully explored from the perspective of system dynamics. Therefore, it is essential to define mother-child dynamics from a DSA perspective and analyze them empirically. In this study, we conceptualize dyadic interaction as an irreducible system and examine the applicability of state space grid (SSG) analysis, which characterizes dynamic processes as trajectories that unfold across a state space over time.

The SSG analysis is a methodological framework developed based on the conceptual foundations of the DSA (Hollenstein, 2013). By utilizing observational data, the SSG analysis visually represents and describes real-time fluctuations in socioemotional dynamics as state changes within the parent-child system. The grid organizes these dynamics into theoretical categories—for instance, plotting child behavior on the x-axis and maternal behavior on the y-axis—thereby allowing dyadic interactions to be mapped as a time-series trajectory. This approach facilitates a

Figure 3

State Space Grid (SSG) analysis of parent-child interaction using hypothetical data.



quantitative assessment of the system through content metrics, such as duration and frequency within specific regions of the state space, to identify prevalent socioemotional states. Furthermore, structural metrics, including dispersion and transitions (movement frequency), are employed to characterize the system's organization, specifically its flexibility or rigidity. The SSG analysis can also be extended to larger timescales (e.g., monthly

observations) to capture the process of phase transitions, in which the system shifts from one stable state to another (Figure 3). From the DSA perspective, it is predicted that the system will undergo a period of temporary instability as it approaches a tipping point; a phenomenon that researchers are increasingly recognizing as an early warning signal (EWS) of qualitative systemic change.

A deeper understanding of these dynamics will help elucidate the processes underlying developmental changes in parent-child relationships, the emergence of maladaptive behaviors in children, and their respective EWSs. Furthermore, this approach has the potential to predict early signs of improvement and readiness for intervention. In a preliminary empirical analysis of parent-child dyads who participated in parent-child interaction therapy for behavioral problems, we demonstrated that a temporary increase in instability precedes the intervention-induced reorganization process of mother-child interactions. These findings were presented at the Japanese Society for Developmental Psychology (Takeshima, Niizawa, Shigemoto, & Hosokawa, 2026).

Moving forward, a crucial future direction is to empirically examine the processes through which children's socioemotional interactions influence the development of both adaptive and maladaptive behaviors. To achieve this,

we will advance an international collaborative research initiative with Queen's University in Canada, aiming to construct both a dynamic developmental model of maladaptive behavior and just-in-time preventive intervention models.

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