

How Parenting Styles Shape Digital Immunity in Adolescents? A
Longitudinal Study of Resilience Development Across Physical and Virtual
Domains

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Abstract

As adolescents increasingly navigate fluid boundaries between physical and virtual domains, traditional frameworks of digital safety are evolving toward a more robust construct: Digital Immunity. This study investigates how multidimensional parenting styles and digital mediation shape the development of adolescent resilience across cognitive, emotional, behavioral, and social network domains. Utilizing longitudinal data from the Taiwan i-Generation Panel Study (TIGPS) 2025/2026 waves, we operationalized parenting and immunity indicators through Exploratory Factor Analysis (EFA) and introduced a methodological innovation by applying Heterogeneous Graph Neural Networks (GNN) to capture the non-linear, structural dependencies within student-parent dyads. To achieve explainable AI, we employed SHAP-based Integrated Gradient (IG) scores to rank the absolute importance of parental features. The GraphSAGE model demonstrated substantial predictive power, explaining significant variance in key outcomes such as virtual space idealization ($R^2 = 0.438$), virtual-real identity dissociation ($R^2 = 0.343$), and online addiction tendencies ($R^2 = 0.304$). Feature attribution analysis revealed that Parental Warmth and Support acts as a "protective anchor," narrowing the psychological gap between a student's offline self and their digital persona. Furthermore, the results distinguish between general parenting and specialized digital mediation, finding that maternal active direction is a primary driver of cognitive media literacy, while paternal conflictual monitoring is closely associated with behavioral risks. By integrating computational social science with developmental psychology, this research underscores that digital immunity is a socialized trait fostered by household relational health and proactive "connected parenting." Our findings provide a robust empirical foundation for policy interventions aimed at bridging adolescent resilience across virtual and physical boundaries.

Keywords: Digital Immunity, Heterogeneous Graph Neural Networks, Parenting Styles, Explainable AI, Adolescent Resilience, TIGPS