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INTEGRATING ABM & GIS TO MODEL TYPOLOGIES OF PLAYGROUP DYNAMICS IN PRESCHOOL CHILDREN

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ABSTRACT

We illustrate an objective, non-intrusive method that tracks the behavioral, temporal, and spatial data characterizing evolving group processes in children. This work establishes a methodology combining behavioral observational data, GIS, and agent-based modeling as an aggregate tool to give researchers the ability to establish group typologies according to the behavioral and geospatial distributions of its constituents. The proposed integration of behavioral coding with GIS, and the subsequent attempt to reproduce this aggregation with computational simulation has not been attempted before. As such, this work establishes an integrative protocol for measuring peer-to-peer processes and will serve to modify the research criteria in scientific fields using behavioral observation of humans.

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Integrating ABM & GIS to Model Typologies of Playgroup Dynamics in Preschool Children

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The current study is an attempt to further the amalgamation of a multi-disciplinary team that integrates human development, computer simulation, biology, and geography. We rely on emerging technologies and methods in agent-based modeling, social network analysis, and geographical information science to address questions of current interest to scientists studying the typology, ontology, and morphology of group dynamics. Our model systems consists of young children, with each involved discipline contributing towards answering a critical societal question, namely, how do children form relationships in the context of transitions and change? We propose that children's play partners are multiply determined by the combinatorial dynamics generated by a child's own characteristics with those of his or her peers and the geo-spatial characteristics unique to the environment. More specifically, we are proposing that four discrete, yet related, interpersonal dynamics underlie the formation and maintenance of group formation in preschool children. These four indices of behavioral and affective patterning are the foundation of our ability to track groups as they form. Each index provides unique, yet tractable, information about the groups as they arise, disband, or maintain levels of stability. In aggregate, these indices provide a quantitatively robust dataset that captures complex evolving processes. This aggregate -- a compilation of behavior, affect, and geo-spatial location residing in time -- is the basis for determining the validity of our computer simulation model. Our objective is to reproduce the observed pattern of grouping behavior.

Playgroup Morphology and Ontology: Interaction, Process, and Critical Components

Affect Tone. Children's affective expression can be viewed as a series of affect epochs. From these epochs, two aspects of each participant exchange are generated: (1) affect valence and (2) matching rate. That is, for each child, any social action with another child, provides an opportunity to generate moment statistics (i.e., mean) of affective valence (i.e., positive, neutral, negative), either for a specific episodic exchange or over an extended period of observation. In addition, by gathering affect on each play partner, it is possible to compare affective states between any two individuals at any given time during the observation period; in effect, this permits an estimate of affect matching rates within a dyad or group. Note that affect matching, a group level characteristic, provides very different information about emotion than does the individual's general propensity to be in a particular affective state. In combination these two features represent intra-individual and inter-individual affect signatures embedded in time, space, and context.

Bid Ratio. Within group (and within some general exchanges) behavior is generated by bid exchanges among its members. At the simplest level, what members do (i.e., the type of behavior (e.g., swing, play in the dirt)) is secondary to how a call to action is made .that is, the bid. Group cohesion is generated, not from the activity generated by the bid, but by the successes of the bidding process. Group maintenance is generated by successful bids; conversely, a series of unsuccessful bids jeopardizes the group. Obviously, it is not the ratio of successful to unsuccessful bids that inherently destabilizes a group but rather the inability of the group members to accurately gauge the social situation exhibited through this ratio .that reflects poor judgment, inadequate social skills, and so on. Moreover, within our construction and coding of the bid process, we will examine the intra-group bid structure. Specifically, as noted above, a bid can receive one of four responses: (1) accepted, (2) ignored, (3) rejected, or (4) counter-bid by other members of the group. Because of this potential response set, we expect each group and each member of the group to display an unique distribution of responses that have evolved from individual propensities combined with group level reinforcement histories.

Intra-Episode Variability. After forming a group, the characteristics of the group (i.e., group phenotype; see Fewell (2003) for discussion about group level phenotypes) are evident by their affective (e.g., affect matching) and behavioral probabilistic structure, or more precisely, the consistency of this structure across episodes of play. This consistency, however, does not imply the lack of either variability or drift. We should, for example, assume some adaptive variability over time; any complex, evolving system typically evidences moderate variability in response to fluctuations of endogenous components and exogenous influences (Auyang, 1998). For playgroups, such fluctuations would come from changes in the environment and the continuous entering and exiting of other children in the group. Furthermore, we expect to see a drift in the structure as the group matures. Again, this would be expected as group members learn to modify their intra-group behavior as a function of history; they would or should be able to telegraph bids (e.g., subtle behavioral cues .idiographic to the group .are enough to initiate or terminate an action or play sequence). We propose that this third feature can be captured using available mathematical tools that: (1) adequately capture and describe the relevant socio-affective and behavioral characteristics of the groups (see e.g., Griffin, 2000); and (2) parsimoniously elucidates intra-group, inter-episode changes .either by estimating changes in probabilistic structure (e.g., sequential analysis) or covariance change (e.g., Price’s Equation).

Time-Space. The set of factors that influence play likelihoods can be conceptualized as occupying an n-dimensional space along 4 primary axes: Affect Matching, Bid Ratios, Inter-Episode Variability, and time-space. Whereas the first three reflect intra-group behavior, the fourth dimension - time/space - represents the milieu of these groups. As noted above, play propensity between two or more children may be a function of who is available and where they are physically located relative to some feature of the playground (e.g., swing set); of course, we assume that these two aspects of play behavior are not independent. Time, within the conceptualization of play presented herein, has multiple facets. First, there is chronological time (e.g., 11:00 am). Second, there is calendar time (e.g., October). Third, there is episode frequency (e.g., 3rd time a particular group is seen playing together). And finally, there is episode duration. Groups are followed for an hour in the proposed index coding system. Although there is the possibly of left censoring, and to some extent, right censoring, the average duration of a play epoch(s) is within an hour. We think that the Time-Space axis can be incorporated into our conceptualization of playgroup dynamics via the GIS methodology described above.

These four indices of behavioral and affective patterning are the foundation of our ability to track groups as they form. Each index provides unique, yet tractable, information about the groups as they arise, disband, or maintain levels of stability. In aggregate, these indices provide a quantitatively robust dataset that captures complex evolving processes. This aggregate - a compilation of behavior, affect, and geo-spatial location residing in time - is the basis for determining the validity of our computer simulation model. Our objective is to reproduce the observed pattern of grouping behavior.

Observational Data Collection

Throughout the fall and spring, children's naturally-occurring free-play interactions are recorded. Observations are collected for 5 hours/day each weekday for the academic school year. The observations commence on the first day of classes, and each class has 3-4 coders collecting data each shift. Coders rotate throughout the classroom, remaining unobtrusive and uninvolved in children's activities. They record data using handheld computers, with the data automatically inserted into a database. Data from the handheld computers are downloaded into a desktop computer and converted into files that can be read directly into data management software. The advantage of using the handheld computers is that time-stamped data can be collected efficiently, entered quickly, and recorded with minimal error.

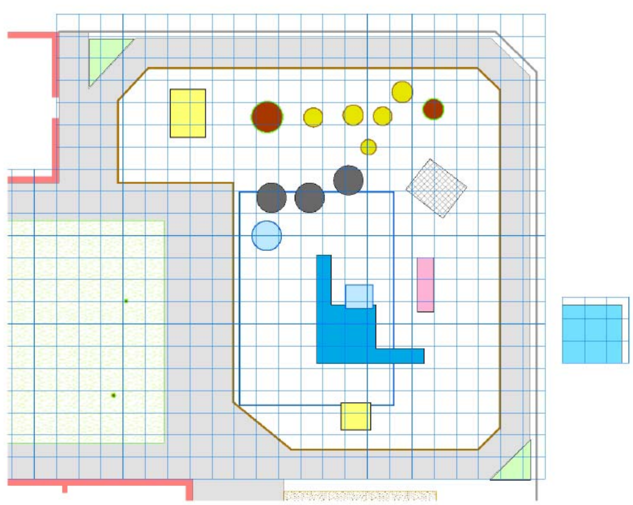

Figure 1. Map of the study site (e.g., outside area with a slide, climbers, playhouse, trees)

Interval Coding. Using a GUI interface, observers identify the first child in a randomized list and briefly (for 10 seconds) observe the child, record data, and then repeat the procedure for the next child on the random list. During the 10-second period, the observer codes several dimensions of the child and his/her context. For example, coders record whether the child is alone, with a teacher, or with other children. For solitary, teacher, and peer codes, the target is observed for activity (e.g., riding a bike, reading books, etc.), affect (i.e., positive, negative, neutral) and the presence of social peers (i.e., peers involved in direct interaction) and area peers (i.e., peers in the physical vicinity but not interacting with the target child). On a fine-grained grid that is digitized to a spatial location on the tablet PC screen, the start point (X,Y), stop point (X,Y), and farthest distance traveled (X,Y) are recorded (see e.g., Figure 1). Additionally, when a target is observed with a peer, we code who the child is playing with, the activity, the affective exchange between the group peers, and the physical location of the group. Such data are used to determine if the specific type of activity, affective proclivities, and physical location influences the degree to which children interact with others (e.g., we can compute separate models for distinct combinations of the three factors).

Group Coding. Each week, the scan data are analyzed to determine cohesive groups. Once a group is identified, a separate coder is assigned to follow each child within the group. Each day, four one hour blocks (2 in the am and 2 in the pm) are allotted for the group procedure. The coders first identify the location of the group members. In a calibrated database, each coder begins recording data into the tablet PCs on their respective child. In repeated 10 second intervals (for 30 minutes), the observer records the context of the event, who is present in the episode, the various affect and behavioral codes (e.g., bids, referencing, attending), and the physical location of the interval. Additionally, each child (whether group members or not) is randomly selected for 30 minute individual increments. The procedure used for the individual index coding is identical to the group observations; this method allows us to make comparisons using similar observational methods for children who form groups vs. those who do not.

Geographic Information Science and Tracking Playgroups

Once the field data are collected, they are transferred to a workstation GIS, where they are organized into a rich longitudinal database of children's movement behavior. These data are then coupled to the behavioral observations and aggregated and reconfigured as necessary to tease-out group movement, clustering, spatial segregation, and spatial polarization. This can be done on a one-to-one, one-to-many, and many-to-many basis for children. Additionally, it can be expressed geographically relative to notable features in the play environment: adjacency to sandboxes, distance from teachers, proximity to the outer limits of the play space, etc.

Applying this methodology has the added benefit of allowing us to query the database by spatial analysis and geovisualization. For example, using spatial analysis, we can run a suite of spatial statistics over the data to look for the formation of statistically-significant clusters of activity or conditions in the model. We can also test for the tendency of certain behaviors to co-locate in space, or identify group dynamics associated with patterns of spatial segregation. Using geovisualization, we can also build-up instance-level and aggregate surfaces of e.g., cooperation or disruptive behavior, and look at these clusters relative to the features of the playground. For example, we can visualize hotspots of collaborative activity, or coldspots where children's play tends to be isolated. The formation of databases of this form has the added benefit of providing a seed data-set for our agent-based model, as well as acting as a calibration and validation resource for our simulation.

We have developed a system for building time geography relationships that captures events in space and time in a robust GIS framework. This allows us to construct space-time paths and space-time prisms for individual, dyad, and group behavior (examples using synthetic data for two children are shown in Figure 2; this is an accurately scaled representation of the school). Doing so further allows us to build a map of activities in time and space, e.g., in what places do young children tend to spend the majority of their play time, how might this differ from other children, how does this vary by time-of-day, how does this alter when polarizing influences are absent, etc. These spatially explicit aspects provide a critical component to the scenario building implemented in our ABM.

Simulating Playgroups: PlayMate

Using dynamic child behaviors to modify the likelihood of interacting with another child, PlayMate provides a representation of postulated developmental shifts in playgroup formation for children ages three to five years. Framed around a state transition model, each child, represented as an agent, can be in one of four states: (1) playing with another child; (2) playing with an adult (a teacher); (3) playing alone after playing with another child; or (4) playing alone after playing with an adult. Play likelihood across the four states is modified through Play Propensity and Arousal (i.e., proxies of internal configurations), with accumulating values in each of the four states for each child (see Griffin et al., 2004, for a review).

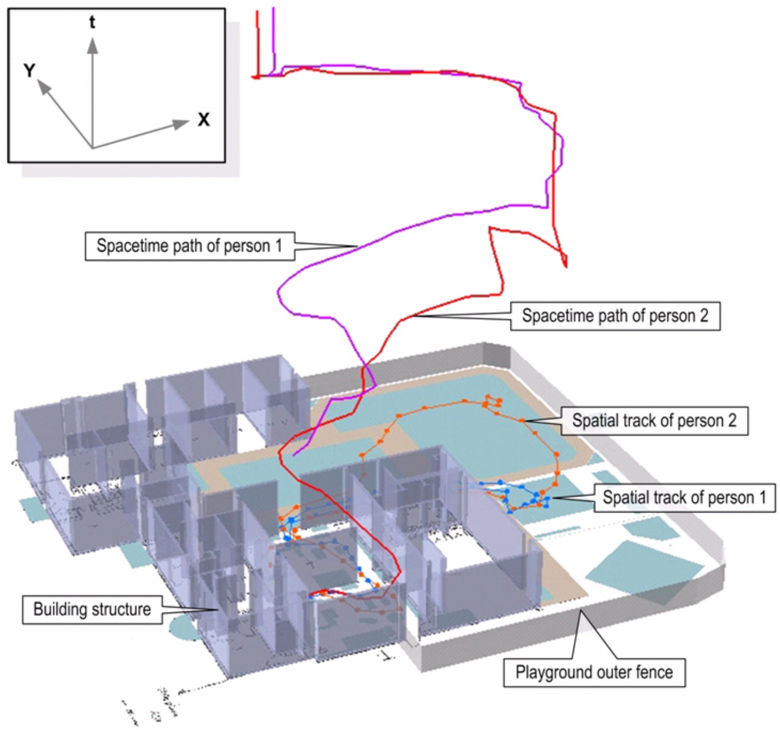

Figure 2. Illustrating the spatial (X,Y) and spacetime (X,Y,t) paths of two children.

To implement the simulation, a child is selected in round robin fashion to play with another child from the available pool (one is randomly removed to simulate a sick-day), and upon pairing, child i assesses child j on several dimensions determined by the investigator; minimally, these include gender and one relevant attribute (e.g., bidding behavior, affect, or a composite of both) being examined. The greater the homophily, as assessed by closeness on the variables in the model, the less likely the child is to exit the child-playing state and to continue playing with other children. Transition rules condition arousal level updates, and behavioral and affective exchanges as well as memory are updated through a summative value after each play episode. The summative values are entered into a tally matrix that, in turn, is converted to a child-to-child probability matrix. The tally and probability matrixes are then compared to similar matrixes extracted from the actual data. For model validation, PlayMate generates numerous quantitative indicators of the structure and composition differences between the simulated and real data; these include difference measures of Euclidian distance, Mean cell values, Entropy, Uncertainty reduction (a measure of mutual information), Solitary play, and row (i.e., child) signal-to-noise ratios. Each measure is assumed to provide slightly different information about the characteristics of the matrix structure. Our existing work validating PlayMate centered on simulating and replicating the peer interaction patterns obtained from coding individuals, with the incorporation of GIS and the Index coding procedure, we will be developing new validation indices. These will necessarily be complex, reflecting aggregate individual, group, and GIS data.

Data Simulation. Prior to running the simulations, each child receives a score based on
the three factors of gender, attribute level, and memory. For gender, each child receives a binary number (e.g., 0, 1), and rank orders for attribute scores are given based a predefined hypothesis (e.g., similarity in affect across all domains drives propensity for play). Finally, integers for memory rankings are based on a list of recent play pairings, with a current capacity of five possible pairings. Simulation runs typically consist of each child in the class playing 50 rounds in the round-robin fashion. Subsequently performing the routine 50 times allowed us to obtain approximately 120-200 play episodes, characteristic of the numbers obtained for each child in the real data within each time frame. State shift and play partner propensities are influenced by the three factors, with each variable weighted according to the theoretical justification that displayed affect and bidding behaviors are the strongest predictors of peer selection. Essentially, increased peer preferences are determined by the aggregate of the three factors, with attribute level difference modifying the likelihood of being in a child play state.

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