

Original Article

Assessment of interactions at children playgrounds using network measures: An exploratory study based on graph theory

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Abstract

This study has used network measures to classify the children interactions in playground. The variance of network processes between genders was tested. Five girls and boys ($n = 10$; 4.6 ± 0.6 years old) were observed. Statistical procedures has revealed significant differences between genders in IDC ($p = 0.027$; $ES = 0.476$; moderate effect) and BC ($p = 0.011$; $ES = 0.576$; moderate effect). Results revealed a greater cooperation process between boys.

Keywords: Applied mathematics; graph theory; network analysis; children; interaction.

Introduction

The break time between classes may be an important period of time to study the development and maintenance of children's peer relationships (Boulton, 1995). In the playground can be possible to observe the social interactions between children and verify which kind of play are made (Boulton, 1999). These interactions may have an important impact in the children development in short and long term (Ladd, 2005). Social, psychological and physical skills may be influenced by the peer-relationships during open activities and for that reason it is an important area of study (Smyth & Anderson, 2000).

The variability of relationships is complex and dynamic and depends from many different constraints such as the context (e.g., playground, classrooms, home), gender, number of children in the group, the individual characteristics (e.g., psychological and physical skills, social environment) and even the mood (Veiga et al., 2016).

Usually, two methods have been used to analyse the interactions between childrens: i) surveys; and ii) systematic observation. Nevertheless, such methodological methods may limit the data acquisition. Surveys and systematic observations tend to be more qualitative than quantitative and for that reason the reproduction of the methods may be more difficult.

Nevertheless, new mathematical approaches may help to increase the quantification during the observational process. The social network analysis is based on graph theory and the investment of many researchers have been allowing to develop different measures that help to characterize a relationship in micro and macro-communities (Burt, Kilduff, & Tasselli, 2013; Hanneman & Riddle, 2005). General measures to characterize the structure of the groups and also centrality measures to classify the prominence level of each person in the group are extremely useful and allow to classify the network structures that occurs in micro, meso and macro levels (Barnes & Harary, 1983; Knoke & Yang, 2008).

Considering the lack of quantification and mathematical applications in the study of interactions in playground, our motivation was to analyse the interaction process between children in playground. For that reason, the aim our study was to measure general properties of children's group in playground and analyse the centrality tendencies inside the group.

Methods

Participants

The study was conducted with 5 boy and 5 girls ($n = 10$; 4.6 ± 0.6 years old) from a pre-school institution. The methodological procedures were firstly described to the parents. After that all parents signed an informed consent before start the study. The study has followed the Declaration of Helsinki and the ethical standards for the study in humans.

Procedures

This study focused in the interactions that occur in playground. Children were tested three times at school with a period of 15 minutes per each observation. The three observations were made in three different weeks in the same day of the week and schedule to ensure similar conditions of observation. The playground had a size of 98 m² and all the observations were recorded with two video cameras (GoPro Hero 2, 1080p, USA). A preliminary observation with overall setup was made to familiarize children with the protocol. The observations occurred during the break time (recess time) and children had total freedom to make decisions about how to spend the time.

The interactions were classified based on the following criterion: time spent in play/interaction with a colleague. The time spent in interaction was classified as the linkage indicator between nodes (children). It was defined as interaction the time spent in play, talk or face-to-face situation with a given colleague/colleagues. Collective play (such as team sports, running activities or share plays) was considered as interaction among all the involved children.

Two researchers that were submitted to a training protocol of two weeks made the observation. Researchers observed and codified more than ten hours during this training period. A test-retest training protocol with 20-days interval was made to ensure the reliability of the data.

Network analysis

The interactions codified as time in contact were recorded in weighted adjacency matrices. The linkage indicator was the time spent in interaction between colleagues and children were the nodes. Weighted graphs were classified in our study because the direction (digraphs) it was the same between peers. The three-adjacency matrices built after each session was than converted in a final adjacency matrix. The final adjacency matrix was imported in the Social Network Visualizer (SocNetV, version 1.9.) that is a software that allow to visualize the graphs and compute the network measurements (Kalamaras, 2014). Total links and network density were used to characterize the general properties of the graph. Outdegree, indegree and betweenness centralities were used to test the prominence level of each child. Following will be described the measures computed for this study.

Total Links

For a weighted graph G with n vertices, the total links index, L^w , of G is obtained by (Wasserman & Faust, 1994):

$$L^w = \sum_{i=1}^n \sum_{\substack{j=1 \\ j>i}}^n a_{ij}, \quad (1)$$

where a_{ij} are elements of the weighted adjacency matrix of a G (Clemente, Martins, & Mendes, 2016).

This measure allows characterizing the number of interactions that occurs in the group. Greater values of total links may suggest a greater homogeneity in the interactions between peers.

Network density

The density index for a weighted graph G with n vertices, Δ^w , of G is calculated as (Wasserman & Faust, 1994):

$$\Delta^w = \frac{2 \times L^w}{n(n-1)}. \quad (2)$$

where L^w is the total links index of a G .

Density values measure the overall affection between peers. Greater values mean a great affection and suggest great homogeneity in the interactions between peers.

Indegree centrality

Let n_i be a vertex of weighted graph G with n vertices. The standardized degree prestige

index, $\frac{L^w}{n_i}$, is the proportion of the weighted of vertices that are adjacent to n_i in which n_i is a vertex of weighted graph G with n vertices. It can be calculated as (Wasserman & Faust, 1994):

(3)

where k_i^w is the degree prestige index of the vertex n_i and a_{ij} are elements of the weighted adjacency matrix of a G (Clemente et al., 2016).

Greater values of indegree centrality suggest that this child may be more nominated for their peers to interact and to play.

Betweenness centrality

Given an unweighted graph $G = (V, E)$, with $n_i, n_j, n_k \in V$, $i, j, k = 1, \dots, n$. It can be calculated as (Rubinov & Sporns, 2010):

$$C'_b(n_k) = \frac{1}{(n-1)(n-2)} \sum_{\substack{n_i, n_j \in V \\ i \neq j \neq k}} \frac{g_{ij}(n_k)}{g_{ij}}, \tag{4}$$

where $g_{ij}(n_k)$ is the number of shortest paths between n_i and n_j that pass through n_k and g_{ij} is the number of shortest paths between n_i and n_j (Clemente et al., 2016).

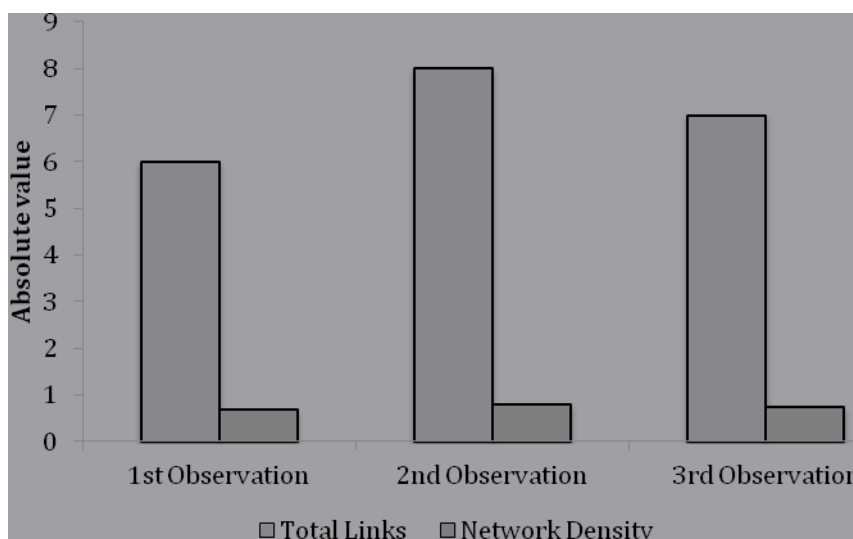
This measure identifies the level of intermediation between a child and their peers. Greater values of betweenness centrality mean that this child may act as a mediator inside the group.

Statistical procedures

Gender (male and female) was defined as factor for the analysis of variance. Indegree (IDC, and betweenness (BC) centralities were the dependent variables. Descriptive statistics (average and standard deviation) were computed for general measures and centrality levels. One-way ANOVA tested the variance between genders. Effect size was also calculated and interpreted using the follow criteria (Ferguson, 2009): no effect ($\eta^2 < 0.04$), minimum effect ($0.04 < \eta^2 < 0.25$), moderate effect ($0.25 < \eta^2 < 0.64$) and strong effect ($\eta^2 > 0.64$). SPSS software (version 23.0, Chicago, Illinois, USA) was used to compute the statistical procedures. A statistical significance of 5% was defined.

Results

Descriptive statistics for general characteristics of the children's' group and centrality levels of children may be observed in the following Figures 1 and 2, respectively. It was possible to observe an increase in the total links and network density from first to second observation. A variation of 33% in total links and 16.41% in network density were verified over the observations.



Analysis of variance has tested differences between genders. Significant differences were found between genders in IDC ($p = 0.027$; $ES = 0.476$; *moderate effect*) and BC ($p = 0.011$; $ES = 0.576$; *moderate effect*).

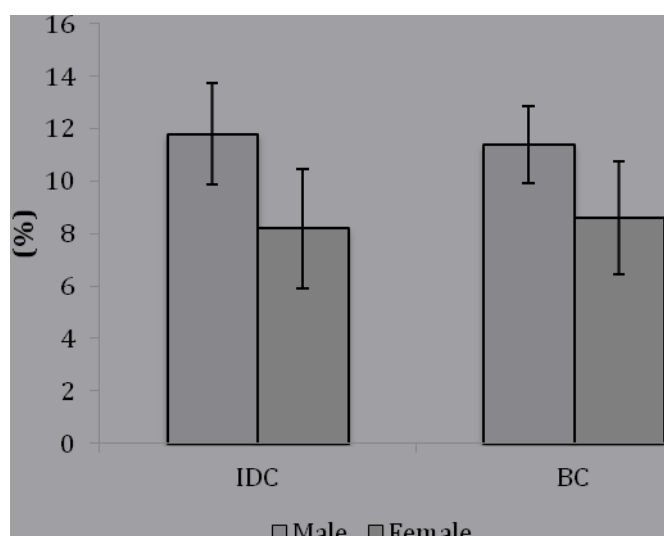


Figure 2. Descriptive statistics of centrality measures between genders.

Male children had in average more 43.90% than female children in IDC measure. It was also found that male children had more 32.56% than female in BC.

Discussion

This study aimed to analyse the interactions patterns of children in playground. Comparisons between the centrality levels of male and female children were conducted. The results obtained from social network analysis showed that male children had statistical greater levels of indegree and betweenness centralities.

The indegree centrality may classify the prestige of each child inside the group. Our results revealed that boys had statistical greater values of indegree centrality. This may reveal that boys can be more recruited to play. Moreover, the tendency to boys play more in group and girls more in dyads may justify the results obtained (Benenson, 1993). This may contribute the increase in the values of centrality, thus justifying the greater centralities of boys. Moreover, these results are in line with some approaches that justifies that females tend to be more intimacy and male more collective in their relationships (Strayer & Strayer, 1976).

The study of mediation behaviour by using the betweenness centrality also revealed that boys tend to link more colleagues than girls. Actually, the tendency to girls spent more time alone or in dyads may justify these results. Moreover, a study also suggest that girls may have more time spent in solitary-pretend play (Veiga et al., 2016). This specific behaviour of girls influences their centrality levels and justifies the smaller values in comparison with boys.

The results obtained in our study may be different from the studies conducted in classrooms. Activities in playground are quite different based on the fact that there are smaller number of toys or objects that lead to smaller tendencies to solitary-pretend play (Veiga et al., 2016). Nevertheless, further studies conducted with bigger samples may help to classify the profile of interactions in playground.

This study had some limitations. The sample of this pilot study may compromise the results obtained. More children and more observations must be conducted to generalize the evidences. Moreover, the observational methodology must be reviewed. Would be important to classify the interactions in categories such as running activities, team sports, playing with toys, playing with smart devices or just talk. Digraphs may also replace the graphs. Would be interesting to verify some patterns of interactions based on the profile of interaction and the direction of such interaction.

Despite of study limitations, the analysis carried out revealed that social network analysis may be used to identify the patterns of interactions between children in playground. Teachers and educators may use future studies with big samples to verify which kind of activities may influence the cohesion of the children and also how playground can be organized to increase the cooperation and the social activities among boys and girls.

Conclusion

This pilot study revealed that boys tend to be more prominent and social during free activities in playground. Network analysis revealed that boys had greater centralities levels, thus being in line with previous observational studies. The tendency of boys to play in-group and the girls to have more intimacy relationships with their friends may justify the obtained results. Future studies must consider analysing the direction of interactions and also analysing the network behaviour per different activities.

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