


RESEARCH ARTICLE

# Methodological moderators of average outdegree centrality: A meta-analysis of child and adolescent friendship networks

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## Abstract

Empirical articles vary considerably in how they measure child and adolescent friendship networks. This meta-analysis examines four methodological moderators of children's and adolescents' average outdegree centrality in friendship networks: boundary specification, operational definition of friendship, unlimited vs. fixed choice design, and roster vs. free recall design. Specifically, multi-level random effects models were conducted using 261 average outdegree centrality estimates from 71 English-language peer-reviewed articles and 55 unique datasets. There were no significant differences in average outdegree centrality for child and adolescent friendship networks bounded at the classroom, grade, and school-levels. Using a name generator focused on best/close friends yielded significantly lower average outdegree centrality estimates than using a name generator focused on friends. Fixed choice designs with under 10 nominations were associated with significantly lower estimates of average outdegree centrality while fixed choice designs with 10 or more nominations were associated with significantly higher estimates of average outdegree centrality than unlimited choice designs. Free recall designs were associated with significantly lower estimates of average outdegree centrality than roster designs. Results are discussed within the context of their implications for the future measurement of child and adolescent friendship networks.

**Keywords:** Children; adolescents; social network; friendship; outdegree; methodological moderators

## 1. Introduction

Peer social networks—especially friendship networks—are widely recognized as important contexts for understanding the development of both positive and negative behaviors in childhood and adolescence (Laninga-Wijnen and Veenstra, 2021). Specifically, peer selection and influence processes are related to internalizing behavior (e.g., Neal and Veenstra, 2021), externalizing behavior (e.g., Sijtsema and Lindenberg, 2018), and substance use (e.g., Henneberger et al., 2021). Additionally, conceptual papers highlight how child and adolescent friendship networks play a role in relational phenomena like interpersonal racism (Kornienko et al., 2022) and intergroup contact (Wölfer and Hewstone, 2017). Given their developmental significance, studies of child and adolescent friendship networks have increased rapidly in recent years (Neal, 2020).

A recent systematic review suggests that empirical articles vary considerably in how they measure child and adolescent friendship networks (Neal, 2020). Specifically, articles may vary in boundary specification (i.e., classroom, grade, school), operational definitions of friendship (i.e., friends vs. best/close friends), and data collection designs (i.e., unlimited vs. fixed choice designs, roster vs. free recall designs). These variations in methodology may alter respondents' reports of friendships, which in turn may affect the network topology and most network metrics.

To understand whether methodological choices are associated with systematic differences in respondents' reports of friendships, I focus on one network metric that is commonly reported in empirical articles of child and adolescent friendship networks: *average outdegree centrality* (i.e., the average number of outbound friendship nominations).

In this paper, I conduct a meta-analysis that pools estimates from English-language peer-reviewed articles to examine methodological moderators of children's and adolescents' average outdegree centrality in friendship networks. I begin with a review of the literature on the measurement of child and adolescent friendship networks and four methodological choices that may alter average outdegree centrality: boundary specification, operational definition of friendship, unlimited vs. fixed choice design, and roster vs. free recall design. Next, I present the methods and results of a meta-analysis examining how these methodological choices are related to 261 estimates of average outdegree centrality from 71 articles and 55 unique datasets of child and adolescent friendship networks. Based on these findings, I end with implications and recommendations for the future measurement of child and adolescent friendship networks.

### **1.1 Measurement of child and adolescent friendship networks**

Friendships are defined as non-hierarchical relationships that are based on mutual affection, reciprocity, and loyalty (Bagwell and Schmidt, 2013; Laursen and Veenstra, 2021). Although friendships are often conflated with other types of relationships such as liking or affiliation (i.e., spending time together), focus group and survey data examining early adolescents' definitions of friendship suggest that they are a unique "multidimensional role relation composed primarily of relational norms, expectations for mutual behavior" (Kitts and Leal, 2021, p. 161). Given their significance for identity exploration (Laursen and Veenstra, 2021) and peer processes (Laninga-Wijnen and Veenstra, 2021; Valente et al., 2013), friendships are the most commonly studied type of relationship among children and adolescents, comprising the focus of over half of social network articles in developmental psychology (Neal, 2020).

Neal (2020) recently conducted a systematic review of the methods of 201 empirical articles examining child and adolescent networks in developmental psychology and found remarkable variation in measurement. First, although the majority of data collection takes place in schools, researchers vary in whether they set the network boundaries at the classroom, grade, or school level. Second, although the majority of articles measure friendship networks, researchers vary in whether they examine friendships generally or only best/close friendships. Third, when collecting friendship network data, researchers vary in whether they allow respondents to name an unlimited number of friends or a fixed number of friends. Fourth, when collecting friendship network data, researchers vary in whether they ask respondents to identify friends on a pre-defined roster or whether they ask respondents to freely recall the names of friends. These methodological variations likely have implications for the measurement and resulting structure of child and adolescent friendship networks. However, to date, there have been limited attempts to pool available empirical articles to examine whether methodological choices lead to systematic differences in the measurement of child and adolescent friendship networks.

In this study, I focus on the role of methodological choices in shaping one network metric: *average outdegree centrality*. Average outdegree centrality is a fitting network metric to examine for theoretical, technical, and practical reasons. Theoretically, average outdegree centrality reflects the average number of outbound nominations in a network (Freeman, 1979). Because these outbound nominations are a direct reflection of how children and adolescents perceive and report their own friendships, they may be particularly sensitive to variation in boundary specification, operational definitions of friendship, and data collection designs. Technically, average outdegree centrality is a basic building block of a social network. Thus, if methodological choices are associated with average outdegree centrality, they may also be associated with other topological measures of network structure (e.g., transitivity, clustering). Practically, average outdegree centrality is very commonly

reported in articles of child and adolescent friendship networks. Therefore, there are ample available reported estimates of average outdegree centrality that can be used in a meta-analytic study of methodological moderators. Given these theoretical, technical, and practical considerations, I aim to answer the following research question: *Do differences in boundary specification, operational definitions of friendship, or data collection designs have moderating effects on estimates of child and adolescent friendship average outdegree centrality?*

### 1.2 Boundary specification and outdegree centrality

The selection of which actors to include in the network—or *boundary specification*—is a critical methodological choice, particularly for whole network studies that attempt to measure relationships within an entire social system (Adams, 2020; Laumann et al., 1992; Marsden, 1990). Social network researchers often lament the *boundary specification problem*. Specifically, it is not always easy to determine which actors to include in the measurement of a network and misspecification can have grave consequences. As described by Laumann et al. (1992), inadvertently omitting key actors during the boundary specification of the network “distorts the overall configuration of actors in a system” and therefore “may render an entire analysis meaningless” (p. 63).

Two different strategies are commonly applied during boundary specification (Adams, 2020; Laumann et al., 1992; Marsden, 1990). Realist approaches rely on actors in the network to specify the boundaries of the network based on their phenomenological experience while nominalist approaches rely on objective lists of members to specify the boundaries of the network. Network studies of children and adolescents most commonly adopt a nominalist approach given that membership lists are commonly available in school settings. However, even though the majority of these studies take place in schools, there is substantial variation in whether researchers choose to specify boundaries at the *classroom*, *grade*, or entire *school*. Specifically, among articles examining child and adolescent networks in developmental psychology, Neal (2020) found that 40.3% specified network boundaries at the classroom-level, 29.9% at the grade-level, and 17.4% at the school-level. Boundary specification can sometimes be objectively constrained by the structural organization of education in a particular country or locale (e.g., whether schools are organized by classroom or grade). However, in many cases, researchers can choose among different boundary specifications but rarely provide a theoretical justification.

Broader boundary specifications (i.e., school-level) are less likely to artificially constrain children’s and adolescents’ friendship nominations than narrower ones (i.e., classroom-level). Therefore, different boundary specifications may lead to differences in estimates of average outdegree centrality. Valente et al. (2013) compared different boundary specifications in adolescent friendship networks and found that outdegree centralities from the same adolescent friendship networks measured with different network boundaries (i.e., classroom and grade) were positively correlated. They concluded that “researchers wanting to measure degree centrality may be able to do so reliably at various boundary specifications” (Valente et al., 2013, p. 315). However, research that pools data on child and adolescent friendship networks across multiple articles to examine associations between boundary specification and average outdegree centrality could provide stronger evidence of this claim. *Therefore, the first aim of this meta-analysis is to examine whether different network boundary specifications (i.e., classroom, grade, school) moderate the average outdegree centrality of child and adolescent friendship networks.*

### 1.3 Friendship definition and outdegree centrality

Because friendship involves perceived expectations and norms (Kitts and Leal, 2021), it is usually measured via self-report. However, there is variation in the self-report name generators used to assess friendships in child and adolescent friendship networks. In particular, among empirical

articles on child and adolescent networks in developmental psychology, Neal (2020) found that 55.2% measured friendship networks. Of these, 34.3% measured *best or close friends* and 20.9% focused more broadly on *friends*. Similar to decisions about boundary specification, a theoretical justification was rarely provided for how friendship was operationally defined in these studies.

Variation in the *operational definitions of friendship* likely play a role in shaping estimates of average outdegree centrality, with name generators focused on best or close friends yielding smaller estimates of average outdegree centrality than name generators focused more broadly on friendships. However, to date, there is limited research that examines how different types of name generators are related to estimates of average outdegree centrality in child and adolescent friendship networks. *Therefore, the second aim of this meta-analysis is to examine whether operational definitions of friendship (i.e., friend vs best/close friend) moderate the average outdegree centrality of child and adolescent friendship networks.*

#### **1.4 Unlimited vs. fixed choice and outdegree centrality**

In addition to varying in boundary specification and operational definitions of friendship, research on child and adolescent friendship networks also vary in data collection design. One such variation is whether researchers collect self-reported data on friendship networks using *unlimited* or *fixed choice* design. An unlimited design allows respondents to nominate as many or as few friends as they choose. In contrast, a fixed choice design places a cap on the number of friendship nominations that a respondent can make. Fixed choice caps can be explicit (i.e., the number of allowed nominations is noted in the wording of the name generator question) or implicit (i.e., the number of allowed nominations is not noted in the wording of the name generator question but the number of spaces available for listing nominations is limited) (Adams, 2020). Adams (2020) notes that social network studies commonly use a small fixed choice cap of three to five because it is “thought to be sufficient to capture ties that are especially close” (p. 20).

Because fixed choice designs can reduce response burden, they are very common in research on child and adolescent networks. In a recent review of empirical articles on child and adolescent networks in developmental psychology, nearly half (49.75%) used a fixed choice design (Neal, 2020). However, although fixed choice designs are ubiquitous in developmental research, the caps used in these designs are known to bias nominations and distort the structure of measured networks (Holland and Leinhardt, 1973). As Adams (2020) notes “Such caps—whether explicit or implicit—can shape the number of nominations provided in unanticipated ways.” (p. 21). If a cap is too low, respondents may not be able to report all of their true friendships, leading to an underestimation of average outdegree centrality. Conversely, if a cap is too high, respondents may feel pressured to match their report of true friendships to the cap even if they have fewer friends, leading to an overestimation of average outdegree centrality.

Given the potential for fixed choice designs to bias nominations and distort the underlying network structure, some researchers have recommended against using them (Neal, 2020). However, given their potential to reduce response burden, it would be helpful to know if there are certain fixed choice caps that are less likely to lead to biases in average outdegree centrality when compared to unlimited choice. *Therefore, the third aim of this meta-analysis is to examine whether the use of capped nominations in a fixed choice design moderates the average outdegree centrality of child and adolescent friendship networks.*

#### **1.5 Roster vs. free recall and outdegree centrality**

Another aspect of data collection design that varies considerably is whether researchers use a *roster* or *free recall* approach to measure children and adolescent friendship networks (Neal, 2020). A roster design allows respondents to nominate friends from a pre-populated list of the names of all

possible actors in the network. In contrast, a free recall design asks respondents to write out the names of nominated friends (Adams, 2020; Marsden, 2011).

Roster and free recall designs have different advantages and disadvantages. Roster designs can reduce respondent burden and increase the efficiency of survey delivery (Marsden, 2011). However, in cases where the names are not randomized, there are mixed results on whether these designs are prone to name order effects. Specifically, while some prior studies found that names listed earlier on a roster received more nominations (Marks et al., 2016; Poulin and Dishion, 2008), others found limited evidence of name order effects (Liu et al., 2024). In addition, providing a list of all possible actors may lead respondents to inflate their nominations, leading to an overestimate of average outdegree centrality. Free recall designs can be used in cases where it would not be feasible or practical to list every possible actor in the network (Adams, 2020). However, these designs can increase response burden and require researchers to match respondents' nominations to the names of actors in the network. Additionally, respondents may have problems remembering to name all of their friends in free recall designs, leading to an underestimate of average outdegree centrality (Brewer, 2000).

In a review of adult network studies, Brewer (2000) found that free recall designs yielded fewer nominations than comparable recognition-based designs (including rosters). However, to date, there is less information on whether roster and free recall designs leads to differences in average outdegree centrality estimates in research on child and adolescent networks. *Therefore, the fourth aim of this meta-analysis is to examine whether the use of a roster versus a free recall design moderates the average outdegree centrality of child and adolescent friendship networks.*

## 2. Method

To examine the role of methodological moderators in predicting variation in average outdegree centrality, this meta-analysis pools data from English-language peer-reviewed journal articles reporting on child and adolescent social networks. The meta-analysis follows the 2020 Preferred Items for Systematic Reviews and Meta-Analyses (PRISMA) statement Page et al. (2021) and was prospectively registered on the Open Science Framework at <https://osf.io/fuyce/>. Data and materials related to screening, search process, and statistical analyses are available at <https://osf.io/5y2dt/>.

### 2.1 Eligibility criteria

Several eligibility criteria were used to select relevant peer-reviewed journal articles for inclusion in this meta-analysis. Specifically, given the focus of this meta-analysis on methodological moderators of average outdegree centrality in child and adolescent friendship networks, articles must include an empirical analysis of whole friendship networks among children and adolescents ages 0 to 18. Ego network studies were excluded because they are relatively uncommon in the literature on child and adolescent networks (Neal, 2020) and exhibit major design differences from whole network studies, especially with respect to boundary specification and data collection designs. Articles were included if the network data were collected between 2000 and 2022. This ensures that the network data were collected during a period when digital technologies like cell phones and household internet were more widely available. Additionally, articles must be written in English.

This meta-analysis focuses on one network metric that is commonly reported in empirical articles: average outdegree centrality. Therefore, articles must include at least one estimate of outdegree centrality averaged across individuals in the network. In a few cases, multiple articles reported identical (or duplicate) average outdegree centrality estimates. In these cases, only one of the articles was included and the other articles that contained only duplicate estimates were excluded.

To conduct the meta-analysis, sample sizes and standard deviations must be provided for average outdegree centrality estimates. When this information was not provided in the article, I contacted authors to request it (see below). However, in cases where I could not reach the authors or where they could not provide sample sizes or standard deviations, articles were excluded.

## 2.2 Search strategy

I identified articles to include in this meta-analysis by searching APA PsycINFO, APA PsycArticles, and Sociological Abstracts for English-language peer-reviewed articles published between 2000 and 2022. All searches were conducted on January 4, 2023.

The searches included keywords in two categories (see Figure 1 for the full search strategy). First, because social network studies often use different terminology (e.g., “social network,” “friendship network,” “peer network”) and different types of analysis (e.g., stochastic actor-oriented models, exponential random graph models), a variety of keywords were included to capture articles that use different social network methods. Second, because this meta-analysis covers a population between the ages of 0 and 18, several keywords were included to capture articles that focus on samples of children and adolescents (e.g., “child,” “youth”). Articles retrieved as part of the search needed to include at least one keyword in each of these two categories in their abstract (see the *Supplementary Information* at <https://osf.io/5y2dt/> for a list of all keywords).

## 2.3 Abstract and full-text screening

Abstract and full-text screening proceeded in several steps. First, I removed all duplicates. Second, I screened the abstracts of all articles returned via the search strategy and excluded any articles that clearly did not meet the eligibility criteria (e.g., no children or adolescents, not empirical, not a network study). Third, if it was not clear whether an article met the eligibility criteria from the abstract, I obtained the full text and excluded any articles that did not meet the eligibility criteria.

## 2.4 Data extraction and coding

To examine methodological moderators of average outdegree centrality, I extracted and coded the following data items from each eligible article:

### 2.4.1 Average outdegree centrality

Average outdegree centrality is the main outcome of this meta-analysis. Eligible articles often reported multiple estimates of average outdegree centrality. Whenever possible, I extracted all average outdegree centrality estimates reported for the total study sample in an article. However, in some articles, average outdegree centrality was only provided for specific subgroups (e.g., girls, boys). When estimates were not available for the total sample, I extracted the average outdegree centrality estimates for specific subgroups.

### 2.4.2 Sample sizes and standard deviations

To calculate sampling variances used in the meta-analysis, I extracted the sample size and the standard deviation for each average outdegree centrality estimate. In some cases, articles provided estimates of average outdegree centrality but did not include the sample sizes or standard deviations. In these cases, I emailed the corresponding authors to request this information. Corresponding authors provided this additional information for estimates in 17 articles. However, for 40 articles, I was unable to reach the author or the author was unable to provide the requested



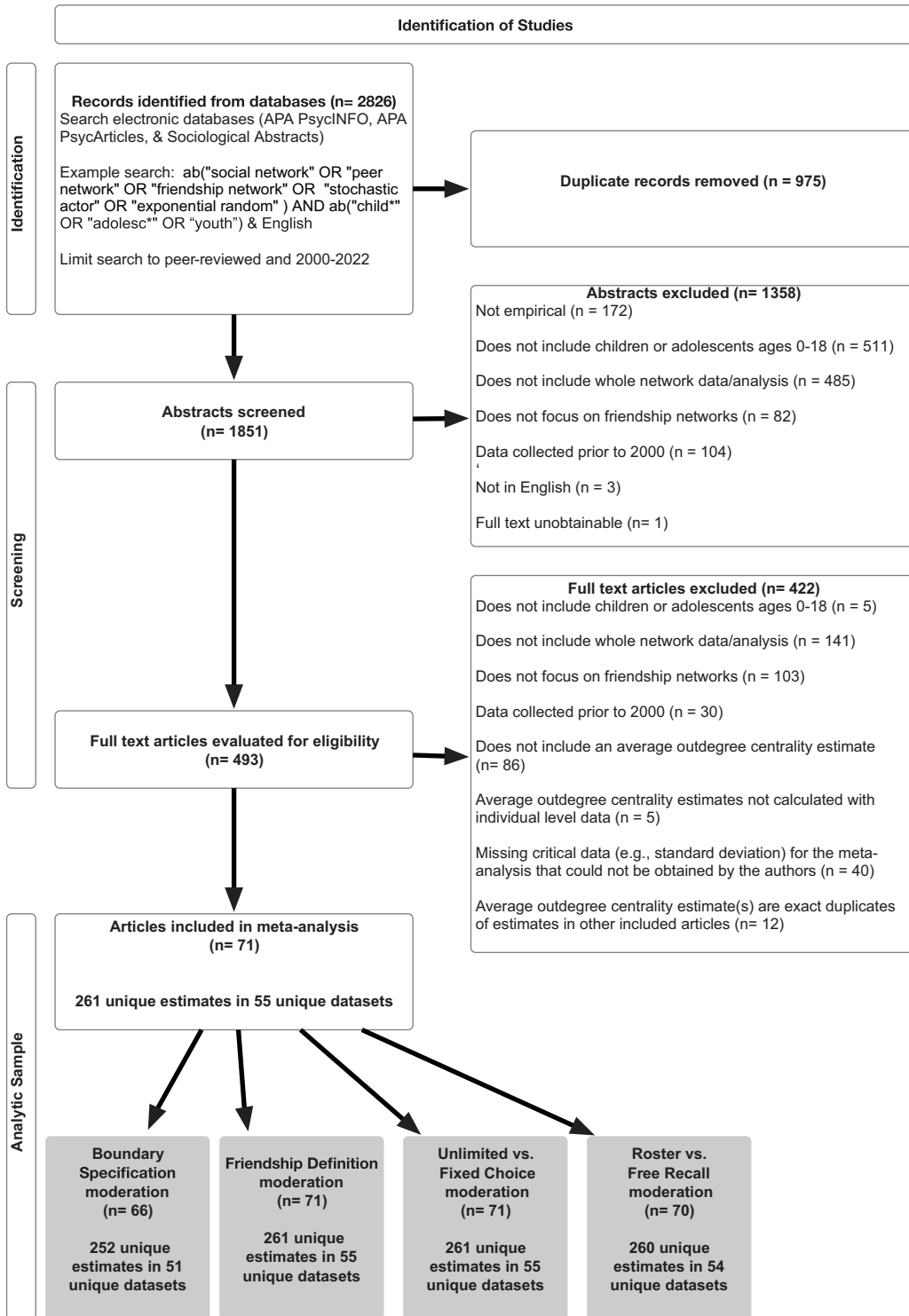


Figure 1. PRISMA flow diagram of abstract and article screening.

standard deviations or sample sizes. In these latter cases, articles and their reported estimates were excluded from the meta-analysis.

#### *2.4.3 IDs and panel information*

Each eligible article included in the meta-analysis received a unique article ID code. Some eligible articles used the same datasets and thus had overlapping samples, when estimating average outdegree centrality. Therefore, each dataset included in the meta-analysis received a unique dataset ID code that could be used to account for overlapping samples across articles.

Some eligible articles reported longitudinal panel data and thus included several estimates of average outdegree centrality within the same sample over time. A panel ID was used to account for estimates that were part of the same longitudinal panel. In addition, for average outdegree centrality estimates that were part of the same longitudinal panel, I extracted information about the time point when the data were collected. Specifically, I extracted how much time had elapsed (in months) since baseline. For example, if the estimate was collected at baseline, I entered 0. If the estimate was collected 6 months after baseline, I entered 6.

#### *2.4.4 Boundary specification*

For each average outdegree centrality estimate, I extracted the specified network boundary. Coded categories included classroom, grade, multiple grades, school, community, and other (e.g., summer program). Only a small minority of articles included average outdegree centrality estimates with network boundaries specified as multiple grades, community, or other. Therefore, in the moderator analysis for boundary specification, I used a categorical variable that included the three most common boundary specifications in the literature: classroom, grade, and school.

#### *2.4.5 Friendship definition*

From the description of the name generator used to collect data, I extracted the operational definition of friendship used to obtain each estimate of average outdegree centrality. The moderator analysis for friendship definition used a binary variable reflecting whether friendship definition included friends or only close/best/good friends.

#### *2.4.6 Unlimited vs. fixed choice design*

From the description of the name generator used to collect data, I extracted whether each estimate of average outdegree centrality was measured using an unlimited or a fixed choice design. A design was counted as fixed choice if it involved either explicit caps (i.e., the number of allowed nominations was limited in the wording of the question) or implicit caps (i.e., the number of spaces provided to list nominations was limited).

For all estimates of average outdegree centrality derived using fixed choice designs, I also extracted the total number of nominations permitted. In the moderator analysis for unlimited vs. fixed choice design, I used a variable with three categories: unlimited design, fixed choice design with a cap under 10, and fixed choice design with a cap of 10 or more. This allowed me to test for the possibility of underestimation of average outdegree centrality in fixed choice designs with low caps and overestimation of average outdegree centrality in fixed choice designs with high caps.

#### *2.4.7 Roster vs. free recall design*

From the description of the name generator used to collect data, I coded whether each average outdegree centrality was measured using a roster or free recall design. The moderator analysis



for roster vs free recall designs included a binary variable reflecting these two mutually exclusive design options.

## 2.5 Data synthesis

I tested the effects of methodological moderators on estimates of average outdegree centrality using separate multi-level random effects models. Specifically, these models were estimated using the `rma.mv` function in the `metafor` package in R (Harrer et al., 2021; Viechtbauer, 2010). The three-level specification of the models accounted for multiple estimates nested in articles nested in datasets (Konstantopoulos, 2011). In addition, for each multi-level random effects model, I used an estimated variance-covariance matrix that adjusts for the use of multiple estimates within articles that were drawn from the same longitudinal panel data (Berkey et al., 1998).

## 2.6 Supplementary and sensitivity analyses

I conducted several supplementary and sensitivity analyses to check the robustness of the results. First, to check whether articles excluded due to missing sample sizes or standard deviations were similar to those included in the meta-analysis, I summarized their estimates and categorization on moderator variables. Notably, the raw mean of the average outdegree centrality estimates from excluded articles was very similar to the pooled meta-analytic estimate reported below.

Second, to examine whether results of the meta-analysis were sensitive to outliers, I checked the data for univariate outliers with standardized residuals above 3 or below  $-3$ . I also checked the data for multivariate outliers that were more than three times the mean Cook's distance. I repeated all analyses excluding univariate and multivariate outliers and found that these results mirrored the results reported below.

Third, to examine whether results were similar for average indegree centrality, I repeated all analyses reported here using average indegree centrality estimates instead of average outdegree centrality. Results for all four moderators were the same for average indegree centrality as the results for average outdegree centrality reported below.

Fourth, to determine there were age-related differences in average outdegree centrality estimates, I conducted a supplementary analysis to examine the moderating effect of participant age on average outdegree centrality. This supplementary analysis yielded no significant differences in average outdegree centrality between samples drawn from the two most common age categories in articles included in this meta-analysis: early adolescents (ages 10–14) and adolescents (ages 15–18).

Fifth, to determine whether participant response rates were associated with average outdegree centrality estimates, I conducted a supplementary analysis to examine the moderating effect of response rates on average outdegree centrality. This supplementary analysis yielded no significant moderating effect by participant response rate, alleviating potential concerns that missing data could systematically bias average outdegree centrality.

Detailed results for all supplementary and sensitivity analyses can be found in the *Supplementary Information* at <https://osf.io/5y2dt/>.

## 3. Results

### 3.1 Search results

The PRISMA flow diagram for abstract and full-text screening is presented in Figure 1. The initial searches in APA PsycINFO, APA PsycArticles, and Sociological abstracts yielded 2,826 articles. 975 of these articles were removed as duplicates, leaving 1,851 articles that were eligible for abstract

**Table 1.** Summary of estimates included in the meta-analysis ( $k = 261$ )

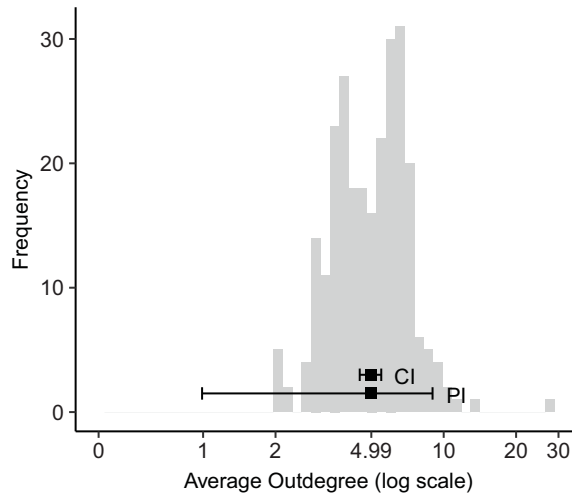
<b>Variable</b>			
Number of estimates	261		
Mean sample size (SD)	1074.34 (2021.9)		
Mean publication year (SD)	2017.02 (3.5)		
<b>Boundary specification</b>			
Classroom	96 (36.78%)	School	20 (7.66%)
Grade	136 (52.11%)	Other	9 (3.45%)
<b>Friendship definition</b>			
Close/best friends	194 (74.33%)	Friends	67 (25.67%)
<b>Unlimited vs. fixed choice</b>			
Unlimited	83 (31.8%)	Fixed 10+	103 (39.46%)
Fixed <10	75 (28.74%)		
<b>Roster vs. free recall</b>			
Roster	135 (51.72%)	Missing	1 (0.38%)
Free recall	125 (47.89%)		

screening. After screening the abstracts of these articles, 1,358 were excluded based on study eligibility criteria. This left 493 articles as eligible for full-text screening. Upon reviewing the text of these 493 articles, an additional 422 were excluded based on study eligibility criteria (see Figure 1 and *Supplementary Information* for exclusions at the abstract and full-text screening stages). This resulted in a final sample of 71 articles in the meta-analysis. A table with information about all 71 articles and their complete bibliographic details is provided in the *Supplementary Information*.

The 71 articles in the final sample included 261 unique estimates of average outdegree centrality from 55 unique datasets. Table 1 provides a summary of these 261 estimates by each of the four moderators included in this meta-analysis. The model testing moderation by boundary specification excluded 9 articles that did not bound friendship networks at the classroom, grade, or school-level. Additionally, the model testing moderation by roster vs. free recall design excluded one article that was missing information on design. An additional table providing information about the sample demographics of the 261 included estimates is provided in the *Supplementary Information*. It is important to note that although the inclusion criteria allowed estimates to be drawn from samples of children and adolescents ages 0 to 18 years, in practice the majority of estimates were drawn from samples of early adolescents (ages 10 to 14,  $k = 153$ ) or adolescents (ages 15 to 18,  $k = 56$ ).

### 3.2 Pooled estimate of average outdegree centrality

Figure 2 includes a histogram of the extracted estimates of average outdegree centrality from the 71 articles in the final sample. A multi-level random effects meta-analysis of the 261 extracted estimates of average outdegree centrality provided a pooled estimate of 4.99 ( $SE = 0.26$ ). The top



**Figure 2.** Histogram of extracted estimates of average outdegree centrality ( $k = 261$ ). The multi-level random effects meta-analytic estimate is included along with the 95% confidence interval and prediction interval.

bar in Figure 2 provides the 95% confidence interval [4.48, 5.50] while the bottom bar in Figure 2 provides the 95% prediction interval for this estimate [0.99, 8.99]. These findings suggest that, on average, children and adolescents nominate 4.99 friends and that future social network studies are likely to find average outdegree centrality estimates of between 0.99 and 8.99 friends.

### 3.3 Moderator analysis: boundary specification

A multi-level random effects meta-analysis testing the moderating effects of boundary specification yielded no significant differences in estimates of average outdegree centrality ( $Q_M(df = 2) = 4.07, p = 0.13$ ). The first section of Figure 3 displays the meta-analytic estimates of average outdegree centrality and 95% confidence intervals for child and adolescent friendship networks bounded at different levels. These estimates were not significantly different when the network boundary was specified at the classroom ( $k = 96$ , estimate = 4.83 [CI: 4.04, 5.61]), grade ( $k = 136$ , estimate = 5.67 [CI: 4.82, 6.52]), or school-level ( $k = 20$ , estimate = 4.23 [CI: 3.07, 5.38]). These findings suggest that outbound friendship nominations are not affected by different boundary specifications.

### 3.4 Moderator analysis: friendship definition

A multi-level random effects meta-analysis testing the moderating effects of friendship definition yielded significant differences in estimates of average outdegree centrality ( $Q_M(df = 1) = 60.51, p < .0001$ ). The second section of Figure 3 displays the meta-analytic estimates of average outdegree centrality and 95% confidence intervals for child and adolescent friendship networks that use different name generators. Using a name generator focused on best/close friends was associated with significantly lower estimates of average outdegree centrality ( $k = 194$ , estimate = 3.76 [CI: 3.14, 4.38]) than using a name generator focused on friends ( $k = 67$ , estimate = 7.34 [CI: 6.53, 8.14]). These findings suggest name generators focused on close/best friends yield fewer outbound friendship nominations than name generators focused on friends.

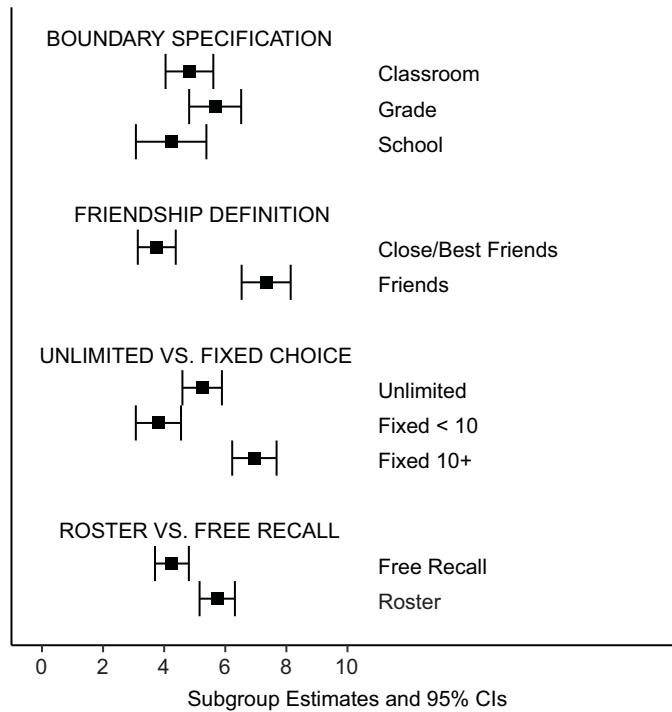


Figure 3. Multi-level random effects meta-analytic estimates and 95% confidence intervals for moderator analyses.

### 3.5 Moderator analysis: unlimited vs. fixed choice design

A multi-level random effects meta-analysis testing the moderating effects of unlimited and fixed choice designs yielded significant differences in estimates of average outdegree centrality ( $Q_M(df = 2) = 51.67, p < .0001$ ). The third section of Figure 3 displays the meta-analytic estimates of average outdegree centrality and 95% confidence intervals for studies with unlimited choice, with a fixed choice cap under 10 nominations, and with a fixed choice cap of 10 or more nominations. Fixed choice designs with under 10 nominations were associated with significantly lower estimates of average outdegree centrality ( $k = 75$ , estimate = 3.81 [CI: 3.07, 4.55]) while fixed choice designs with 10 or more nominations were associated with significantly higher estimates of average outdegree centrality ( $k = 103$ , estimate = 6.95 [CI: 6.23, 7.68]) than unlimited choice designs ( $k = 83$ , estimate = 5.24 [CI: 4.60, 5.89]). These findings suggest that depending on where the nomination cap is set, fixed choice designs can underestimate or overestimate average outdegree centrality compared to unlimited choice designs.

### 3.6 Moderator analysis: roster vs. free recall design

A multi-level random effects meta-analysis testing the moderating effects of roster and free recall designs yielded significant differences in estimates of average outdegree centrality ( $Q_M(df = 1) = 21.17, p < .0001$ ). The last section of Figure 3 displays the meta-analytic estimates of average outdegree centrality and 95% confidence intervals for studies with roster and free recall designs. Free recall designs were associated with significantly lower estimates of average outdegree centrality ( $k = 125$ , estimate = 4.25 [CI: 3.70, 4.81]) than roster designs ( $k = 135$ , estimate = 5.74 [CI: 5.16, 6.32]). These findings suggest that free recall designs will yield fewer outbound friendship nominations than roster designs.

## 4. Discussion

Studies of child and adolescent friendship networks are common, but vary considerably in their boundary specification (i.e., classroom, grade, school), operational definitions (i.e., friends vs. best/close friends), and features of data collection (i.e., unlimited vs. fixed choice, roster vs. free recall) (Neal, 2020). Often, these different methodological choices are made without a clear theoretical justification. However, different methodological choices can have implications for the underlying topology of the measured network. This meta-analysis pools 261 estimates from 71 articles and 55 unique datasets to examine methodological moderators of one network metric commonly reported in studies of child and adolescent friendship networks—average outdegree centrality. By systematically examining how different methodological choices change average outdegree centrality estimates, the meta-analysis makes an important and comprehensive contribution to our understanding of the measurement of child and adolescent friendship networks.

Although the boundary specification problem is well-documented in the social network literature (Laumann et al., 1992), there were no significant differences in average outdegree centrality between studies that bounded child and adolescent friendship networks at the classroom, grade, and school-levels. These meta-analytic findings suggest that the measurement of average outdegree centrality in child and adolescent friendship networks is robust at different boundary specifications. This is consistent with prior work by Valente et al. (2013) who found positive correlations in outdegree centrality among the same adolescent friendship networks bounded at the classroom and grade-levels. Given these findings, researchers who are interested in measuring outdegree centrality in child and adolescent friendship networks may choose to bound friendship networks at the school, grade, or classroom-level based on pragmatic considerations (i.e., response burden, school organization) in addition to theoretical considerations. Although the boundary specification may not affect each respondent's number of outbound friendship nominations, because it affects the size of the network, it may affect other topological metrics such as density.

Studies that used a name generator focused on “best or close friends” had significantly lower average outdegree centrality estimates than studies using a name generator focused more broadly on “friends.” Notably, the magnitude of difference was quite large with studies focused on “best/close friends” yielding a pooled estimate of 3.76 friends and studies focused on “friends” yielding a pooled estimate of 7.34 friends. This difference might seem obvious because operationalizing friendship as “friends” is much more inclusive than operationalizing friendship as only “best/close friends.” However, it is important because studies rarely theoretically justify why they chose a name generator that focused on “friends” or only “best/close friends.” These different operationalizations lead to different measurements of the socializing networks surrounding children and adolescents and could have implications for the resulting network structure as well as our understanding of peer selection and influence processes. Given these implications, it is important for researchers to provide a strong theoretical justification for their operational definition of friendship (Neal, 2020).

Fixed choice designs are currently more common than unlimited choice designs in child and adolescent network research (Neal, 2020). However, this meta-analysis demonstrated that studies using fixed choice designs differed significantly in their estimates of average outdegree centrality from studies using unlimited choice designs. Specifically, studies with low nomination caps (i.e., under 10) had significantly lower estimates of average outdegree centrality than studies with an unlimited choice designs. Conversely, studies with high nomination caps (i.e., 10 or more) had significantly higher estimates of average outdegree centrality than studies with an unlimited choice design. These findings are consistent with past research that suggests that fixed choice designs can distort the structure of social networks (Holland and Leinhardt, 1973). On the one hand, when the nomination cap is too low, children and adolescents may be unable to list all of their friends,

thus underestimating average outdegree centrality. On the other hand, when the nomination cap is too high, children and adolescents may feel pressure to list more friends than they actually have, thus overestimating average outdegree centrality (Adams, 2020). Given these pitfalls, researchers examining child and adolescent networks should avoid fixed choice designs and instead should use unlimited choice designs whenever possible.

Studies using free recall designs had significantly lower estimates of average outdegree centrality than studies using roster designs. This finding is consistent with prior work on adult networks which found that free recall designs can lead to fewer nominations than roster designs (Brewer, 2000). It is difficult to tell what mechanisms might be driving differences in average outdegree centrality between roster and free recall designs. However, it is possible that free recall designs lead to fewer nominations because children and adolescents forget to mention less salient friends or write down fewer names due to response burden. Alternatively, providing a full roster may lead children and adolescents to inflate their friendship nominations. Given these findings, researchers should carefully consider the advantages and disadvantages of roster and free recall designs and their implications for network measurement when planning child and adolescent network studies.

This meta-analysis makes an important contribution to the literature on child and adolescent networks by pooling data from 71 articles to systematically demonstrate how methodological choices are related to estimates of average outdegree centrality. However, results should be interpreted with four scope limitations in mind. First, this meta-analysis aimed to explore methodological moderators of average outdegree centrality in child and adolescent network research. However, characteristics of the sample including age, gender composition, and geographic region could also serve as potential moderators of average outdegree centrality. Future research could consider associations between these sample characteristics and average outdegree centrality estimates. Second, this meta-analysis only focused on friendship networks. Although friendships are the most commonly studied relationship in child and adolescent network research (Neal, 2020), they are distinct from affective relationships (i.e., liking) and affiliative relationships (i.e., hanging out) (Kitts and Leal, 2021). Future research could examine whether the methodological choices explored in this meta-analysis perform similarly in networks reflecting these additional important relationships in childhood and adolescence. Third, given the availability of data, this meta-analysis was only able to focus on average outdegree centrality, as it is commonly reported in published studies of child and adolescent friendship networks. Future research is needed that examines how methodological choices are related to other topological features of the network like transitivity and clustering. Fourth, this meta-analysis only included estimates published in English-language journals and therefore missed estimates of average outdegree centrality that were published in other languages. Only 35.6% of the included estimates were drawn from samples in English-speaking countries (see the *Supplementary Information*). Indeed, estimates reflected samples from a diversity of countries. Nevertheless, future meta-analyses could include articles published in other languages.

Methodological choices can affect the average outdegree centrality of child and adolescent friendship networks. As a set, findings from this meta-analysis suggest a need for careful consideration and theoretical justification when designing studies of child and adolescent friendship networks. More specifically, researchers should theoretically justify their operational definition of friendship, use unlimited choice designs, and consider the pros and cons of roster and free recall designs. Such actions will ultimately improve the measurement and understanding of child and adolescent friendship networks, which are a critical relational context for developmental processes.

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