Multilevel synthesis of peer-tutoring interventions investigating the effect on social and academic outcomes

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Multilevel Synthesis of Peer-Tutoring Interventions Investigating the Effect on Social and Academic Outcomes

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ABSTRACT

Peer-tutoring is a process to enable peers act as a teacher who, then, can help others to understand a concept, develop positive social behaviors, and achieve significant academic success (Doganay, 2007; William, Greenwood, & Parker, 2013). Even though past research emphasizes that student’s academic and social outcomes increase positively with using peer-tutoring (Delquadri et al., 1986), literature needs to be improved by reporting effect sizes with confidential intervals for both general education and special education students (Bowman-Perrott et al., 2013). In this study, we attempt to investigate the effectiveness of peer-tutoring to increase both academic and social performance. This study takes particularly the multiple baseline design as a Single Case Experimental Design (SCED). By using the multilevel meta-analytic model (Van den Noortgate, & Onghena, 2003a; 2003b; 2008). The overall average effectiveness over cases and over studies can be estimated without losing information about individual studies and individual cases. In this research, peer-tutoring is found to be an effective evidence-based practice to enhance both academic and social outcomes such as math, reading, social interactions and developing positive behavior.
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INTRODUCTION

Peer-Tutoring

Peer-tutoring has been one of the most convincing methods of evidence-based practice for more than 40 years (Cohen, Kulik & Kulik, 1982, Delquadri, Greenwood, Whorton, Carta, & Hall, 1986: Masteropieri, Spencer, Scruggs, & Talbott, 2001). Peer tutoring is a process to render peers to become teachers who can help others to understand a concept, develop positive social behaviors, and achieve significant academic success (Bowman-Perrott, Davis, Vannest, Williams, Greenwood, & Parker, 2013). The basic difference between peer-tutoring and other peer related methods is that in peer-tutoring both learner and teacher roles are given to the peers concurrently (Webb, Troper, & Fall, 1995). This difference helps teachers to create a cooperative learning environment (Tindall, 2009). Fantuzzo, Davis, & Ginsburg (1995) identified two subcategories of peer tutoring, namely reciprocal peer-tutoring and cross-age peer-tutoring. In reciprocal peer-tutoring, peers, who are at the same level, take the tutor and tutee roles alternately. On the other hand, in cross-age peer-tutoring, tutors should be at the higher level than tutees either academically or by age, and they keep their roles during the process (Falchikov, & Bylthman, 2001). According to Topping and Ehly (1998), the purpose of peer-tutoring is to ensure transforming knowledge between peers both inside and outside the classroom. Not only peers but also parents can get involved in peer-tutoring process (Tindall, 2009).

According to Toppings (1996), peer-tutoring has ten dimensions:

1. Curriculum content – peer-tutoring can be applied to both academic or social outcomes.
2. Contact constellation – tutors can work with a group, or with an individual tutee.
3. Years of study – tutors and tutees can be a
4. The same level or different level in a study.

5. Ability – tutors and tutees can have equal ability and work together instead of working with higher level tutors.

6. Role continuity – switching the tutor and tutee roles provides innovation and helps peers to develop self-esteem.

7. Place – peer tutoring can be applied in numerous locations.

8. Time – peer tutoring can be applied both in and outside of class.

9. Tutee characteristics – all students can take the tutee role.

10. Tutor characteristics – tutors are not necessarily the best students in class. It is better if average students are selected because both tutors and tutees can have a chance to find cognitive challenges.

11. Objectives – behavior development, academic achievement, self-concept gains etc.

Research show that peer-tutoring has positive effects on academic outcomes (Leung, 2015) and social interaction between general education students and students with disabilities (Goldstein, Kaczmarek, Pennington, & Shafer, 1992; Okilwa & Shelby, 2010). Besides, peer-tutoring is an effective method across different content areas such as reading (Oddo, Barnett, Hawkins, & Musti-Rao, 2010), math (Cohen et al., 1982; Hawkins, Musti-Rao, Hughes, Berry, & McGuire, 2009), science (Bowman-Perrott, Greenwood, & Tapia, 2007) and computer literacy (Fogarty & Wand, 1982). Similarly, peer-tutoring is an effective practice across different types of education tracks such as general education (Lo & Cartledge, 2004), special education (Goldstein et al., 1992) and alternative placements (Bowman-Perrott et al., 2007).

The effects of peer tutoring may differ depending on the targeted outcome. Cook, Scruggs, Mastropieri and Casto, (1985) found larger effects of peer tutoring interventions for children with
disabilities in language and math, when compared to reading. Similarly, Lueng’s (2015) found in his comprehensive meta-analysis that peer tutoring had similar effects on math and reading; but, larger effects in other content areas (e.g., physical education, arts, science). According to Ding and Harskamp (2011), students who practiced peer tutoring in chemistry class, got higher test grades. Miller, Toppings & Thurston (2010) found that peer tutoring had positive effects on using scientific language, and led students to think in a scientific way. In addition, Nobel (2005) indicated in his research that peer tutoring is an effective method for students with learning difficulties. In his research, peer tutoring helped students to learn more easily, and remember what they learned before.

Although past research emphasizes the increase of students’ academic and social outcomes when using peer tutoring (Delquadri et al., 1986), most of them are not summarizing the literature using single-case experimental design (SCED) studies. Literature needs to be improved by reporting effect sizes with confidence intervals with using SCED for both general education and special education students (Bowman-Perrott et al., 2013).

**Single-Case Experimental Designs**

Single-case designs provide a methodologically rigorous method for documenting intervention effectiveness that is well suited for educational and clinical settings (Kazdin, 2011; Kratochwill, Hitchcock, Horner, Levin, Odom, Rinskopf, & Shadish, 2010). SCED involve multiple cases, subjects or participants that are measured repeatedly over time (Shadish & Sullivan, 2011). An SCED has three important characteristics according to WWC standards: (1) data are gathered, analyzed and interpreted for one entity (this entity can be one participant or a group of participants, e.g., a classroom, a school or an organization), (2) the participant(s) is (are) observed repeatedly during baseline(s) and treatment phase(s), and (3) outcomes during and after the
treatment are compared with outcomes prior to treatment (Barlow & Hersen, 1984; Kazdin, 2011; Kratochwill et al., 2010).

In the literature, SCEDs (Gingerich, 1984) are given different names, such as single-subject experimental design (Guralnick, 1978; McReynolds, & Thompson, 1986), N = 1 design (Strube, Gardner, & Hartmann, 1985), N of 1 design (Gorsuch, 1983), interrupted time series (Michielutte, Shelton, Paskett, Tatum, & Velez, 2000), and small-n design which has more than one subject (Kratochwill & Levin, 1992). A basic SCED has an A-phase followed by a B-phase. For this reason, it is called an AB design or interrupted time series designs (as the baseline condition is interrupted by a treatment). In AB design, it is hard to decide the source of change in outcome scores when the treatment is started. The change could depend on the method used during treatment or it could be a result of some other factor which occurred at the same time of the introduction of the treatment (Shadish, Cook, & Campbell, 2002). Barlow et al., 2009 suggested to use more complex types of SCEDs such as multiple baseline design (MBD), reversal design and alternating treatment design to resolve this limitation. According to Shadish and Sullivan’s (2011) systematic review of 809 published SCED studies in the field of educational science and psychology, MBDs are the most popular SCED types.

**Multiple Baseline Design**

According What Works Clearinghouse (WWC, 2010), there are six features and four steps that we need to follow during visual analysis. These six features are level, trend, variability, an immediacy of effect, overlap and consistency. These six steps are predictable baseline pattern, examine data within each phase, compare data phases, and integrate all information only if we have at least three observations (Kratochwill et al., 2010). The visual analysis needs to be done after evaluating the single case experiment. The critical features required for meeting the SCED
standards (Kratochwill et al., 2010) are (1) active manipulation of the independent variable (i.e., the intervention “peer coaching”), (2) interobserver agreement was given for each participant, (3) at least three observations demonstrating an intervention effect at three different points in time, and (4) a minimum of five data points within a phase for all phases except the first baseline contain at least five observations. MBDs help to meet these features and standards. Similarly, Ferron, Bell, Hess & Rendina-Gobioff (2009) focused on multiple baseline designs to control the bias factor of using eight or fewer cases. In this study, we focus solely on MBDs as this design is internally valid as it allows for demonstration of the effectiveness of the treatment at different point in time. (Barlow & Hersen, 1984; Koehler & Levin, 2000). As an example, MBD helps educators to study how to decrease disruptive behaviors in class. Similarly, applying MBD might be helpful to examine the results of teaching methods in teacher preparation programs. Besides, MBD has conceptual and practical strengths. Researchers can focus on a single participant to see the effects of different treatments (Ferron, & Scott, 2005). When researchers are studying complicated and time consuming treatments, MBDs allow them to focus on specific individuals at the same time. In addition, MBDs provide a demonstration the effect of an intervention without withdrawing the treatment (Kazdin, & Kopel, 1975).

**Meta-Analysis of SCEDs**

Multilevel meta-analysis models are extended version of the piecewise regression first introduced by Center, Skiba and Casey (1885-1886). This extension provides effective analytical techniques for the synthesis of SCED data (Kratochwill et al., 2010; Shadish, Kyse, & Rindskopf, 2013). A meta-analysis combines the results of several studies addressing the same research question (Glass, 1976). This quantification is needed in SCED to contribute to evidence-based
research and to inform research and practice the multilevel meta-analytic model takes the
hierarchical structure of the data into account (measurements are nested within cases and cases in
turn are nested within studies). Besides, multilevel synthesis helps to estimate of the average
treatment effect across cases and across studies in addition to case-specific treatment effects.
Similarly, within-case, between-case and between-study variance can be estimated using
multilevel synthesis, and it allows to include predictors at the different levels, modelling
autocorrelation, and having heterogeneous variance (Moeyaert, Ferron, Bretvas & Van den
Noortgate, 2014).

Multilevel synthesis is common in social and academic areas (Jenson, Clark, Kircher, &
Kristjansson, 2007; Kratochwill et al., 2010), and provides a way to analyze nested data
(Raudenbush, & Bryk, 2002). In the past, multilevel synthesis of SCED studies received little
attention because meta-analyses mainly focused on combining the results of group comparison
studies (Kratochwill et al., 2010). In contrast to SCED studies, in group-comparison studies, there
is a widespread agreement about how these effect sizes should be expressed, what the statistical
properties of the estimators are (e.g., distribution theory, conditional variance), and how to
translate from one measure (e.g., a correlation) to another (e.g., Hedges’ g). However, the
evidence-based movement has emphasized the need for quantitative summaries of the results in
SCEDs, especially for making them available for meta-analytic purposes (Jenson et al., 2007). In
order to contribute to evidence-based research (Shadish & Rindskopf, 2007), three-level models
can be used to combine multiple single-case studies measuring the same outcome variable. In this
research, we focused on the three-level model to investigate the effects of peer tutoring on
academic and social outcome scores. We will start introducing the two-level model for didactical
purposes to continue with the three-level model (which is a straightforward extension of the two-level model).

**Purpose of Study**

Peer tutoring, which has been found to play a positive role in student-centered education, has not only aided tutors and the tutored (Lassegard, 2008), but has been conducive in creating cooperation among students which cannot be provided by teachers themselves (Ishikawa, 2012). Therefore, in this study, we attempt to investigate the effectiveness of peer-tutoring on both academic and social performance for children with special needs using SCEDs. This study focuses on summarizing multiple baseline design data. By using the multilevel meta-analytic model, the overall average effectiveness over cases and over studies will be estimated in addition to individual study and case specific treatment effects. The between-case and the between-study variability in treatment effects will be estimated. If a lot of variability is found, moderators will be added in order to explain the variability in effect sizes.

More specifically, the following research questions are of interest:

1. Is peer-tutoring an effective intervention to improve social skills and academic performance?
2. How different is the immediate effect of peer-tutoring on outcomes between case and between studies?
3. How different is the effect of peer-tutoring on the time trend between case and between studies?
METHOD

Identification and Selection of Papers

Primary level studies were retrieved using the following scientific databases: PsychInfo, Web of Science, MEDLINE PubMed, and Educational Resources Information Clearinghouse (ERIC). SCED studies investigating the effectiveness of peer-tutoring on academic and/or social outcomes published between 1980 and 2014 were eligible for inclusion. The keywords used in the scientific databases were a specification of the study design in combination with the treatment (i.e., intervention) specification of interest. For single case experimental research design, the keywords were: “single-case”, “single subject”, "N of 1”, “small N”, “multiple baseline design”, “alternating treatments design”, “reversal design”, “withdrawal design”, and “interrupted time series.” For peer tutoring, the keywords were: “peer tutoring”, “reciprocal peer tutoring”, “class-wide peer tutoring”, “peers as tutors”, “peer-mediated instruction”, “peer-assisted learning”, and “across-age tutoring”. More specifically the following keywords both for peer tutoring and single case were specified such as “peer tutoring” and “single-case”, “peers as tutors” and "N of 1", “peer-mediated instruction” and “reversal design” used during the database search one by one. This initial search yielded a total of 220 unique articles or dissertations that have the potential to be included in the meta-analysis. In addition, journals known to publish SCED articles were searched. Some of the journals did not allow specifying multiple keywords and as a consequence, “single-case” was used as keyword. An overview of the number of identified articles per scientific database can be found in Figure 1.
Inclusion and Exclusion Criteria

The search was limited to English work, investigating peer-tutoring as intervention to increase social behavior or academic performance, and making use of a single-case design. Only work with a substantive aim was eligible. All articles published in 2014 or earlier were eligible for inclusion. Articles not investigating peer-tutoring as intervention, not evaluating social or academic outcomes or only focusing on the tutor were excluded. Designs other than SCED, such as group comparison design studies, methodological papers (e.g., simulation studies and theoretical papers) or illustration papers were automatically excluded. Regarding the selection of SCED designs, we first focused on AB, MBD, (reversal) phase change design or ATD. Other types of designs such as Multiple Probe Design (MPD) are excluded due to the fact that there are currently no recommendations that have been made about how to code the design matrix of these types of SCED designs. Finally, we decided to include only MBDs because they are the most valid SCEDs.

Figure 1. Overview of the number of identified articles per scientific database.
Two independent researchers read all the titles and the abstracts of the 220 retrieved articles and decided whether the article should be included or excluded based upon the inclusion and exclusion criteria listed above. For 50% of the studies, the second independent researcher read the abstract, and the percentage agreement for inclusion and exclusion is 78.45% between these two researchers. 177 articles were excluded. Of those 177 articles, 46 articles were excluded because the intervention was not peer tutoring. In 21 studies, the design was not single-case experimental design research. 20 research articles were excluded because the focus was on group-comparison designs. Since data retrieval from graphs are needed for the analysis, 26 research articles without graphical presentations were also excluded. In seven studies, no baseline levels were reported and as a consequence, the effectiveness of the treatment could not be evaluated. Seven studies had only tutor graphs and consequently were not of interest for this study. An additional 36 studies were excluded because the experimental designs were multiple probe designs, reversal or ATD designs. Six studies were excluded because neither academic nor social outcomes were investigated. Three studies had multiple interventions and therefore the unique effectiveness of the peer-tutoring intervention could not be evaluated. Two articles were excluded because of an unclear graphical presentation of the data. Finally, three articles were excluded because they were duplicates. The two independent researchers agreed to include 43 MBD articles meeting the inclusion criteria. The percentage agreement between the two independent researchers equaled 93.43%.

**Dependent and Independent Variables**

**Dependent Variables**

Two dependent variables (i.e., outcome scores) were of interest in current study, namely: academic performance and social skills. Academic performance involves: a measure of reading or
literacy skills (i.e., reading fluency, comprehension, accuracy, phonological/morphological awareness, language, literacy, idiom comprehension) or a measure of math skills (i.e., basic math abilities such as calculation). Social skills were measured by social interactions with peers such as aggression during free play and positive behaviors during lunch time.

**Independent Variables**

*Treatment.* The intervention under investigation in this study is peer-tutoring. The following categories of peer-tutoring were identified: (1) peer-mediated repeated reading, (2) total class peer tutoring, (3) class-wide peer tutoring, (4) pause, prompt, and praise, (5) cooperative learning groups, (6) peer coaching, and (7) peer-mediated inference making activities.

*Population.* Ten different populations could be identified. These categories involved (0) normal functioning students, (1) students with autism, (2) struggling readers, (3) students with learning problems, (4) students with a handicap (mental health disability, mild handicap) (5) students with ADHD, (6) students with behavioral disorders, (7) students with language problems, (8) students with emotional disorders and (9) deaf students.

*Age and gender.* The age and gender from both the tutor and the tutee were coded. Age is a continuous predictor, while gender is a dichotomous predictor (0 if female and 1 if male).

*Effect size.* (0) N/A, (1) PND, (2) mean, (3) approach one: no assumptions, (4) visual inspection, (5) visual analysis were categorized for effect size estimation.

**Data Analysis**

WebPlot Digitizer 2.0 was used to analyze. “WebPlotDigitizer” is a free software to use. The basic procedures for extracting the data follows a similar routine which includes: (1) importing the graph into the program, (2) defining the coordinate system, and (3) clicking on each data point
(from the first observation to the last observation). Two columns of values are obtained: a column containing X-values (i.e., the independent variable representing time, going from the beginning of the experiment to the end of the experiment) and a column with the Y-values (i.e., the dependent variable, representing the outcome scores per X-value). A last step is copying or exporting the data to Microsoft Excel or a text file for secondary analyses. WebPlotDigitizer appeared to be the most reliable, valid and user-friendly data retrieval software program (Moeyaert, Maggin, & Verkuilen, 2016).

Two-Level Model

In order to analyze data from MBDs, a two-level hierarchical linear model will be used as this takes the hierarchical nature of multiple-baseline data into account: measurements are nested within cases. A randomly selected study was used to demonstrate the MBD. In this randomly selected study, researcher attempted to examine the efficacy of cross-age peer-coaching for students who had symptoms of ADHD by using multiple baseline design. Figure 3 shows that there is a negative treatment effect (Vilardo, DuPaul, Kern, & Hojnaski, 2013).

In addition to two level model, researches could use an autoregressive integrated moving average approach (Velicer & Fava, 2003), an ordinary least square regression analysis (Huitema & McKean, 1998), or a generalized least squares regression analysis (Maggin et al., 2011). We choose to use the hierarchical linear model because we want to take the nested structure of the data into account and we want to estimate the between-case variability in treatment effects. The mathematical equation representing a two-level hierarchical linear model, assuming a stable baseline level, a change in level and a trend during the treatment is presented in Equation 1:

Level 1

\[ Y_{ij} = \beta_{0j} + \beta_{1j} \text{Phase}_{ij} + \beta_{2j} \text{Phase}_{ij} \times \text{Time}_{ij} + \epsilon_{ij} \sim \text{N}(0, \sigma_{e}^2) \]  \quad (1)
In Eq. (1), we added time as a predictor during the treatment phase, and we centered time around the first measurement occasion of the treatment phase. $Y_{ij}$ is the outcome score for observation $i$, nested within participant $j$ and is regressed on a dummy coded variable, $\text{Phase}_{ij}$, and the interaction between $\text{Phase}_{ij}$ and a time variable $\text{Time}_{ij}$. $\text{Phase}_{ij}$ equals 0 when observation $i$ within case $j$ belongs to the baseline, 1 otherwise. $\text{Phase}_{ij} \times \text{Time}_{ij}$ indicates the trend during the treatment phase going from 0 to the end of the experiment during the treatment. As a consequence, $\beta_{0j}$ indicates the baseline level for participant $j$, $\beta_{1j}$ indicates the immediate treatment effect and $\beta_{2j}$ represents the trend during the treatment phase. A first order autoregressive residual variance is assumed. The level 1 coefficients are allowed to vary at the second level because each participant may not have the same baseline level, treatment effect and time trend during the treatment. This is reflected in Eq. (2). By using this method, the overall average baseline level, treatment effect and time during treatment can be estimated in addition between-case variance.

Figure 2. Graphical Display of the Coefficients in Eq. (1)
Level 2:

\[
\begin{align*}
\beta_{0j} &= \hat{\theta}_{00} + u_{0j} \\
\beta_{1j} &= \hat{\theta}_{10} + u_{1j} \\
\beta_{2j} &= \hat{\theta}_{20} + u_{2j}
\end{align*}
\]

\[
\begin{bmatrix}
u_{0j} \\ u_{1j} \\ u_{2j}
\end{bmatrix} \sim N \left( \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_{u0}^2 & \sigma_{u0u1} & \sigma_{u0u2} \\ \sigma_{u1u0} & \sigma_{u1}^2 & \sigma_{u1u2} \\ \sigma_{u2u0} & \sigma_{u2u1} & \sigma_{u2}^2 \end{bmatrix} \right)
\]

(2)

In Eq. (2), we assume that the residuals are independent, identical, and multivariate normally distributed. \(\hat{\theta}_{00}\) indicates the average baseline level across cases, \(\hat{\theta}_{10}\) indicates the immediate treatment effect across cases and \(\hat{\theta}_{20}\) indicates the time trend during the treatment across cases. The case-specific baseline level, treatment effect and time trend can deviate from the average baseline (\(\hat{\theta}_{00}\)), average treatment effect (\(\hat{\theta}_{10}\)) and treatment effect on trend (\(\hat{\theta}_{20}\)). This is captured by the between-case variance in baseline (\(\sigma_{u0}^2\)), treatment (\(\sigma_{u1}^2\)) and trend during the treatment (\(\sigma_{u2}^2\)). Similarly, covariance between baseline and treatment can be estimated by \(\sigma_{u0u1}\). With using variance components, researchers could identify the Case-specific effects are obtained by empirical Bayes estimates (Moeyaert at al., 2014).
Figure 3. Graphical Display of Positive Social Engagement

Combined Model

\[ Y_{ij} = (\theta_{00} + u_{0j}) + (\theta_{10} + u_{1j}) D_{ij} + (\theta_{20} + u_{2j}) D_{ij} * T_{ij} + e_{ij} \sim N(0, \sigma^2_e) \] (3)

The equations can demonstrate study characteristics to explore variations. For this reason, we inserted the level 2 Equation in the level 1 Equation to combine the data over cases for two level, and we included case specific as a second level predictor in Eq. (3).

Three-Level Model

The two-level model needs to be extended to a three-level model because we want combine data across cases and across studies. Van den Noortgate and Onghena (2008) suggested that by adding an additional index in Eq (1) we can extend the two-level model to a three-level model. We used \( k \) to refer to “study”. According to Eq. (4), \( Y_{ijk} \) demonstrates the outcome scores at measurement occasion \( i \) for case \( j \) from study \( k \). Eq. (4) is a straightforward extension of Eq (1) with the only difference being the addition of index \( k \).

Level 1

\[ Y_{ijk} = \beta_{0jk} + \beta_{1jk} Phase_{ijk} + \beta_{2jk} Phase_{ijk} * Time_{ijk} + e_{ijk} \sim N(0, \sigma^2_e) \] (4)

In Eq (4), we used time as a predictor during the treatment phase, and we centered time around the first measurement occasion of the treatment phase. \( \beta_{0jk} \) represents the average outcome score for case \( j \) of study \( k \) during the baseline. Similarly, \( \beta_{1jk} \) and \( \beta_{2jk} \) are the case-specific estimated immediate treatment effect and time trend during the treatment respectively. The level two and level three equations are represented in Eq. (5) and Eq. (6).
Level 2:

\[
\begin{align*}
\beta_{0jk} &= \theta_{00k} + u_{0jk} \\
\beta_{1jk} &= \theta_{10k} + u_{1jk} \\
\beta_{2jk} &= \theta_{20k} + u_{2jk}
\end{align*}
\]

\[u_{0jk}, u_{1jk}, u_{2jk} \sim N\left(0, \begin{bmatrix} \sigma^2_{u_0} & \sigma_{u_0} & \sigma_{u_0} \\ \sigma_{v_0} & \sigma^2_{u_1} & \sigma_{u_1} \\ \sigma_{v_0} & \sigma_{v_1} & \sigma^2_{v_2} \end{bmatrix}\right)\]  

(5)

In Eq. (5), we assume the residuals to be independent and identical, and multivariate normally distributed. \(\theta_{00k}\) indicates the study-specific average baseline level, \(\theta_{10k}\) indicates the study-specific immediate treatment effect, and \(\theta_{20k}\) indicates the study-specific time trend during the treatment. Case-specific baseline level, treatment effect and time trend can deviate from the average study-specific baseline \((\theta_{00k})\), treatment effect \((\theta_{10k})\) and treatment effect on trend \((\theta_{20k})\), reflected by the participant-specific residuals \((u_{0jk}, u_{1jk} \text{ and } u_{2jk})\).

Level 3

\[
\begin{align*}
\hat{\theta}_{0jk} &= \gamma_{00k} + u_{0jk} \\
\hat{\theta}_{1jk} &= \gamma_{10k} + u_{1jk} \\
\hat{\theta}_{2jk} &= \gamma_{20k} + u_{2jk}
\end{align*}
\]

\[v_{0jk}, v_{1jk}, v_{2jk} \sim N\left(0, \begin{bmatrix} \sigma^2_{v_0} & \sigma_{v_0} & \sigma_{v_0} \\ \sigma_{v_1} & \sigma^2_{v_1} & \sigma_{v_1} \\ \sigma_{v_2} & \sigma_{v_2} & \sigma^2_{v_2} \end{bmatrix}\right)\]  

(6)

The case-specific effects are allowed to vary at the third level (because it is unlikely that all cases have the same baseline, etc.). Three In Eq. (6), \(\gamma_{00k}\) indicates the average baseline level, and \(\gamma_{10k}\) indicates the immediate treatment effect across the individual cases j and study k, and \(\gamma_{20k}\) indicates the time trend during the treatment. Three-level model gives opportunity to researchers to have more general conclusions. If we found less variability then the treatment is working consistently across studies.

Combined Model

\[
Y_{ijk} = (\theta_{00k} + u_{0jk}) + (\theta_{10k} + u_{1jk}) D_{ij} + (\theta_{20k} + u_{2jk}) D_{ij}^* T_{ij} + e_{ij} \sim N(0, \sigma^2 e)\]  

(7)

In addition to the Eq. (3), we combined the data over cases and over studies, and we included case specific and study specific characteristics as a second level predictor in Eq. (7). The
difference between baseline performance and treatment effect might possibly vary over studies when we add time as a predictor.
RESULTS

Descriptive Statistics

A total of 43 multiple baseline design studies met all inclusion criteria and were included in the multilevel meta-analysis. As it is common in single-case experimental design studies, multiple cases (i.e., participants, in this context tutees) are the focus of interest of study. This resulted in an average of 7.07 participants per study ($Min = 2$ $Max = 42$, $Mdn = 6$, $SD = 5.08$). Each participant is measured repeatedly across time across different levels of the independent variable (i.e., the intervention). We found an average of 13.73 measurement occasions per participant ($Min = 0$, $Max = 297.20$, $Mdn = 10.99$, $SD = 15.03$). As mentioned in the methods section, multiple predictors were coded (i.e., gender, age of the tutee, age of the tutor, study design, study quality and the population). First, we kept track of gender. 34.2% of the tutees were female, whereas 54.9% were male. This means that for 10.9% of the participants’ gender was missing. Second, we kept track of the tutor’s gender. 16.8% of the tutors were female, whereas 16.4% were male. This means that for 66.8% of the participants’ gender was missing. The age of the tutees ranged from 3 to 25, with a mean of 9.13 ($Mdn = 9.00$ $SD = 3.23$). Similar results were found for the tutor age: age range for tutors is 4 to 18, with a mean age of 10.10 ($Mdn = 10.0$ $SD = 3.28$). The third coded predictor is study quality. 76.6% of studies have strong WWC standards, and 9.5% of studies have weak WWC standards. On the other hand, we did not meet WWC standards in 13.8% of studies.

A forth predictor we were interested in is the type of outcome. We distinguished between academic outcomes and social outcomes because there might be a differential effect of the peer-tutoring intervention on the type of outcome. In 68.1% of the cases, an academic outcome was the
criterion (such as reading fluency/comprehension/accuracy, phonological/morphological awareness, language, literacy, idiom comprehension, basic math abilities, standardized tests etc.). In addition, 31.9% of the cases were involved social outcome (such as self-report on motivation/attitude and/or social/behavioral outcomes; social interactions with peers etc.)

A fifth predictor was the population: 21.1% of tutees are normal students not having any disorder according to their school reports. The rest of the students were enrolled in special education classes which is determined by the experts. In this study, it is found that of those special education students, 21.1% had autism, 14.8% had emotional disorder, 13.2% had mild handicap, 6.6% had learning disability, 6.3% had ADHD, 2.6% were deaf, 0.3% had behavioral disorder and 1.3% had intellectual disability. In addition, 2.3% of those students were identified as having language difficulties by their teacher because English was their second language. Finally, 10.5% of those students were identified as having reading difficulties through the administration of reading test by their teachers.

The final predictor we were interested in is the analysis techniques. 45.2% of the studies used mean percentile. 17% of them used PND. 17% of them used solely visual analysis. 2% of them used PAND. Finally, 18.7% of them did not report which method they used.

**Results Two-Level Analysis**

In this study, we randomly selected one MBD study to demonstrate the two-level model. In the selected study, researchers examined the effects of reciprocal peer-tutoring on repeated reading with special need students (Oddo et. al, 2010). They used MBD across four participants, and they conclude that reading fluency and comprehension increased after four-week intervention for targeted students. Inter-observer agreement measures were collected for approximately 33%
of the sessions across student participants for this study. However, after eight-week intervention, many students did not have additional increase in their repeated readings.

Table 1

Summary Results Basic Two-Level Hierarchical Linear Model

<table>
<thead>
<tr>
<th>Parameter Estimated</th>
<th>Estimate</th>
<th>SE</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Baseline level ($\hat{\theta}_{00}$)</td>
<td>13.05</td>
<td>2.77</td>
<td>4.71*</td>
</tr>
<tr>
<td>Average Treatment level ($\hat{\theta}_{10}$)</td>
<td>20.54</td>
<td>6.47</td>
<td>3.18*</td>
</tr>
<tr>
<td>Average trend during the treatment ($\hat{\theta}_{20}$)</td>
<td>1.86</td>
<td>0.66</td>
<td>2.84*</td>
</tr>
</tbody>
</table>

| Baseline Level ($\sigma_{u_{00}}^2$) | 16.54 |
| Treatment Level ($\sigma_{u_{11}}^2$) | 150.02 |
| Trend in Treatment ($\sigma_{u_{22}}^2$) | 0.99 |
| Covariance between baseline level and treatment effect ($\sigma_{u_{00}u_{11}}$) |  |
| Residual Variance ($\sigma^2e$) | 31.81 |
| Autocorrelation | 0.70 |

The results of the two-level analysis are displayed in Table 1. The overall average baseline level (i.e., reading skills before peer tutoring) was significantly different from zero [$\hat{\theta}_{00} = 13.05, t(62) = 2.77, p < .01$]. The overall average treatment effect was positive and equaled 20.54 ($SE = 6.47$). This indicated that there was an increase in the reading skills after peer tutoring. In addition, this effect was statistically significant [$\hat{\theta}_{10} = 20.54, t(62) = 6.47, p < .01$]. Similarly, average trend during the treatment was statistically significant [$\hat{\theta}_{20} = 1.86, t(62) = 2.84, p < .01$]. The autocorrelation coefficient was positive and large ($\varphi = .70$). This indicated that measurement closer in time were more related to each other than measurements further away in time. Each proceeding error could be predicted by the previous error. Because the statistical
software program R 3.4.0 did not provide the Standard Error (SE) and Z value for variance and covariance components, we did not have these results in Table 1.

Two-level model is an effective method which provides an information about the relationship between each participant. Between-case variance is related with the measurement occasion which the time variable is centered around treatment. (Moeyaert et al. 2014). Afterwards the individual case-specific effects are estimated, and the results of the case-specific baseline level, immediate treatment effect and time trend during the treatment can be found in Table 2. Case-specific results illustrate that there is some variability in treatment effect between cases.

Table 2

*Case Specific Results*

<table>
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<tr>
<th>Case</th>
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<tr>
<td></td>
<td>Time during treatment</td>
<td>$\beta_{12}$</td>
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<tr>
<td>Case 2</td>
<td>Baseline Level</td>
<td>$\beta_{02}$</td>
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<td></td>
<td>Treatment Effect</td>
<td>$\beta_{12}$</td>
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<tr>
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<tr>
<td>Case 3</td>
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<td>Treatment Effect</td>
<td>$\beta_{13}$</td>
</tr>
<tr>
<td></td>
<td>Time during treatment</td>
<td>$\beta_{23}$</td>
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<tr>
<td>Case 4</td>
<td>Baseline Level</td>
<td>$\beta_{04}$</td>
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<tr>
<td></td>
<td>Treatment Effect</td>
<td>$\beta_{14}$</td>
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<tr>
<td></td>
<td>Time during treatment</td>
<td>$\beta_{24}$</td>
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</table>
Results Three-Level Analysis

A three-level hierarchical linear model, introduced in Eq. (5), was used to combine MBD data across cases and across studies. In this part of our study, we will discuss the peer tutoring effects on academic and social outcomes. In total, we have 43 studies and 304 cases.

Academic Outcomes

Table 3 shows that the overall average baseline level was statistically significantly different from zero \( \gamma_{000} = 26.19, t(4617) = 6.11, p = .000 \). The overall average treatment effect was positive and equaled 14.54 (SE = 3.85). This indicated that peer tutoring has a statistically significant positive effect on academic outcome scores such as reading, math and spelling. \( \gamma_{100} = 14.54, t(4617) = 3.78, p < .01 \). A positive time trend during the treatment was found, equaling 0.82 (SE = 0.18). That meant that the treatment became gradually more effective over time \( \gamma_{200} = 0.82, t(4617) = 4.46, p < .01 \). The estimated autocorrelation was positive and statistically significant (\( \varphi = .27 \)). This indicated that the measurements closer in time were more related to each other compared to the measurements further away in time.
Table 3

Summary Results Basic Three-Level Hierarchical Linear Model for Academic Outcomes

<table>
<thead>
<tr>
<th>Parameter Estimated</th>
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<tbody>
<tr>
<td>Fixed Coefficient</td>
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<tr>
<td>Average Baseline level</td>
<td>$\gamma_{000}$</td>
<td>26.19</td>
<td>4.29</td>
<td>6.11*</td>
</tr>
<tr>
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<td>$\gamma_{100}$</td>
<td>14.57</td>
<td>3.85</td>
<td>3.78*</td>
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<tr>
<td>Average Trend During Treatment</td>
<td>$\gamma_{200}$</td>
<td>0.82</td>
<td>0.18</td>
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</table>

(Co)Variance Component

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<tr>
<th>Between-Study (Co)Variance</th>
<th>Between-Case (Co)Variance</th>
<th>Baseline Level</th>
<th>Immediate Treatment Effect</th>
<th>Treatment Effect on Trend</th>
<th>Residual Variance</th>
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<td>Immediate Treatment Effect</td>
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<tr>
<td>Treatment Effect on Trend</td>
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<tr>
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<td>$\sigma^2_{\mu_{0}}$</td>
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<td>Treatment Effect on Trend</td>
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<tr>
<td>Autocorrelation</td>
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</table>

Social Outcomes

According to Table 4, the overall average baseline level was statistically significant \([\gamma_{000} = 11.34, t(2290) = 2.79, p = .005]\). Likewise, the overall average treatment effect was positive and equaled to 13.04 \((SE = 5.62)\). This meant that peer tutoring has a statistically significant positive effect on social outcome scores. \([\gamma_{100} = 13.04, t(2290) = 2.32, p = .02]\). However, the autocorrelation coefficient was negative and small \((\varphi = -0.12)\). This indicated that measurement closer in time was not more related to each other than measurements further away in
time. Each proceeding error could be predicted by the previous error. On the other hand, when we looked at time trend, the treatment effect on trend was positive and equaled 0.52 (SE = 0.15) which meant a significant increase across time in the targeted social outcome scores. In other words, this effect was statistically significant at the .000 significance level [$\gamma_{200} = 0.52, t(2290) = 3.53, p = .000$].

Table 4

Summary Results Basic Three-Level Hierarchical Linear Model for Social Outcomes

<table>
<thead>
<tr>
<th>Parameter Estimated</th>
<th>Parameter</th>
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<th>SE</th>
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<tr>
<td>Fixed Coefficient</td>
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<td></td>
</tr>
<tr>
<td>Average Baseline level</td>
<td>$\gamma_{000}$</td>
<td>11.34</td>
<td>4.06</td>
<td>2.79*</td>
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<tr>
<td>Average Treatment level</td>
<td>$\gamma_{100}$</td>
<td>13.04</td>
<td>5.62</td>
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<tr>
<td>Average Trend During Treatment</td>
<td>$\gamma_{200}$</td>
<td>0.52</td>
<td>0.15</td>
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DISCUSSION

This research demonstrates the use of multilevel synthesis of peer-tutoring interventions investigating the effect on social and academic outcomes. Peer-tutoring is found to be an effective evidence-based practice for both academic and social outcomes such as math, reading, social interactions and developing positive behavior by using multiple baseline design. In the first part of the study, we presented the effects of peer tutoring on reading skills by using basic two level modeling. The results of this model demonstrate that peer tutoring has strong positive effects on reading skills for students with autism. Similar positive effects were found by Oddo et al. (2010). In the second part, we extended our research to 43 multiple baseline design studies: 21 focused on social outcomes, and 22 on academic outcomes. We used a basic three level model to estimate the overall average treatment effect and the trend during the treatment over cases and over studies. The analysis were performed separately for academic and social outcomes.

Using two-level and three level models we summarized single-case data over cases and over studies to contribute to evidence-based practice, theory and research. This is one of the advantages of multilevel modeling. The multilevel modeling technique is the most promising approach in to summarize SCED studies as it takes the nested data structure into account (Moeyaert et al., 2013). Another major advantage of the multilevel synthesis is that it allows a flexible way to explain variability in treatment effects between cases and between studies by adding moderators. This is a suggestion for further research. This research is limited to MBDs to estimate effects of peer tutoring on academic and social outcomes. Different designs such as multiple probe, reversal and alternating treatment designs should be considered in future research. We only presented a basic two-level and three-level model, but more complex models might be more appropriate: heterogeneous variance, trends during the baseline, non-linear trends, dependent outcomes,
combining different SCED types etc. Under certain assumptions some models are more appropriate than other models, depending on the research questions and SCED study characteristics (Moeyaert et al., 2014).
REFERENCES


Ishikawa, Y. (2012). The influence of learning beliefs in peer-advising sessions: Promoting


Mastropieri, M. A., Scruggs, T., Mohler, L., Beranek, M., Spencer, V., Boon, R. T., & Talbott, E.
Can middle school students with serious reading difficulties help each other and learn anything? *Learning Disabilities Research & Practice, 16*(1), 18-27.


APPENDIX

Demonstration of the data set

<table>
<thead>
<tr>
<th>Name study</th>
<th>STUDY</th>
<th>CASE</th>
<th>Session</th>
<th>Outcomes</th>
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<th>Design</th>
<th>Type</th>
<th>Outcome</th>
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<th>Quality</th>
<th>Age</th>
<th>Gender</th>
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