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Multilevel linear modelling of the response-contingent learning of young children with significant developmental delays

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ABSTRACT

Aim: The purpose of the study was to isolate the sources of variations in the rates of response-contingent learning among young children with multiple disabilities and significant developmental delays randomly assigned to contrasting types of early childhood intervention.
Method: Multilevel, hierarchical linear growth curve modelling was used to analyze four different measures of child response-contingent learning where repeated child learning measures were nested within individual children (Level-1), children were nested within practitioners (Level-2), and practitioners were nested within the contrasting types of intervention (Level-3).
Results: Findings showed that sources of variations in rates of child response-contingent learning were associated almost entirely with type of intervention after the variance associated with differences in practitioners nested within groups were accounted for. Rates of child learning were greater among children whose existing behaviour were used as the building blocks for promoting child competence (asset-based practices) compared to children for whom the focus of intervention was promoting child acquisition of missing skills (needs-based practices).
Implications: The methods of analysis illustrate a practical approach to clustered data analysis and the presentation of results in ways that highlight sources of variations in the rates of response-contingent learning among young children with multiple developmental disabilities and significant developmental delays.

What this paper adds

The practical, nontechnical description of the multilevel, hierarchical linear modelling of the response-contingent learning of young children with significant developmental delays makes the results accessible to a broad audience of developmental disabilities researchers and practitioners. The results illustrate how sources of variation in the rates of children's response-contingent learning could be attributed primarily to type of child learning (intervention) opportunities and how differences in practitioners could be ruled-out as a factor related to rates of child learning. Intervention practices that used existing child behaviour as the building blocks for response-contingent learning proved more effective than intervention practices that focused on facilitating child acquisition of missing skills.

1. Introduction

Multilevel modelling of nested (clustered) data poses many challenges to researchers in developmental disabilities and special

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education where the focus of investigation is the learning or development of individuals with low incidence conditions (Rumrill, Cook, & Wiley, 2011; Ward, Miller, & Lamar, 2013). This is especially the case in studies of infants, toddlers, and preschoolers with multiple disabilities and significant developmental delays where the prevalence of these conditions is often less than 1% or 2% of the general population (e.g., Blackburn, Spencer, & Read, 2010; Parsons & Platt, 2013). This would be expected to result in studies with small sample sizes which could make clustered analysis potentially problematic (Blackford, 2007; Maas & Hox, 2005).

This paper includes a description of the multilevel, clustered analyses of the effects of contrasting types of intervention on the rates of response-contingent learning of young children with varied types of disabilities and significant developmental delays. Response-contingent learning refers to child use of an operant behaviour to produce or elicit environmental consequences (Tarabulsy, Tessier, & Kappas, 1996; Williams, 2001). Infants without disabilities or delays typically demonstrate the use of these types of behaviour as young as 2 months of age (e.g., Dunst, Raab, Trivette, Parkey et al., 2007; Hulsebus, 1973; Lipsitt, 1971; Rovee-Collier & Gekoski, 1979) whereas young children with disabilities and significant developmental delays often show a latency to learn these types of behaviour (Hutto, 2007).

The contrasting types of intervention differed only in terms of how child behaviour were identified and used to produce environmental consequences where the same types of contingency games (Dunst et al., 2010) and routines (Ware, 2016) were used to promote child learning. One approach involved reinforcement of behaviour in a child's repertoire but not used to produce an environmental consequence (e.g., Lancioni, Singh, O'Reilly, Oliva, & Groeneweg, 2005) and the other approach involved reinforcement of missing or emerging skills that resulted in an environmental consequence (see e.g., New & Cochran, 2007). The two approaches to early childhood intervention were described by Eloff and Ebersöhn (2001) as asset-based and needs-based practices respectively. Asset-based practices use existing child behaviour as the building blocks for child learning, whereas needs-based practices focus on facilitating child acquisition of missing skills. Asset-based practices are part of a family of positive approaches to strengthening individual functioning (Buntinx, 2013; Granlund, Wilder, & Almqvist, 2013) whereas needs-based intervention practices are part of a family of deficit approaches to intervention emphasizing amelioration of behaviour deficiencies (Ludlow, 1987).

The effects of the interventions on each child's contingency learning were evaluated on multiple occasions over an 8-week period of time where linear growth curve changes in child response-contingent learning were the dependent measures (Tate, 2004). Each type of intervention was implemented by the children's carers together with different early childhood intervention practitioners. The repeated measures of child response-contingent learning were nested within children, children were nested within practitioners implementing either intervention approach, and practitioners were nested within type of intervention. Fig. 1 shows the research design for the study. The main focus of analysis was the differential effects of the contrasting approaches to child response-contingent intervention (asset-based practices vs. needs-based practices) implemented by different practitioners (P) with different children (C) over the course of the eight weeks of intervention (t).

The analyses described in this paper compared the effects of the two types of interventions on child rates of learning controlling for the variances associated with the different practitioners nested within intervention group. We also examined the extent to which the sizes of effects for the interventions were similar to or different from data analyses not taking into consideration differences associated with practitioners (Raab, Dunst, & Hamby, 2016, 2017). The secondary focus of analysis was whether or not there were between practitioner differences in rates of child learning for practitioners facilitating carers' use of either the asset-based or needs-based intervention practices.

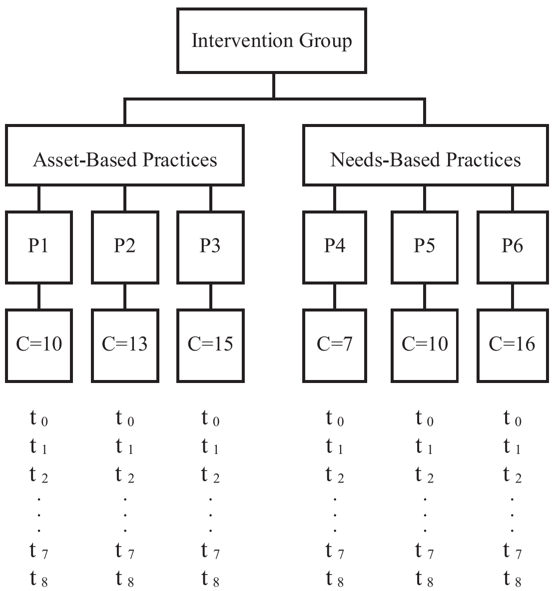

Fig. 1. Nested research design for evaluating the effects of the two contrasting types of intervention on child response-contingent learning. (NOTE. P = Early child intervention practitioner, C = Child study participants, and t = Repeated measurement occasions.).

Findings from the non-nested analyses of the study participants' rates of response-contingent learning are reported elsewhere (Raab et al., 2016, 2017). These results are included in comparative purposes to illustrate the similarities and differences in the two types of data analysis procedures. Detailed descriptions of the study methodology are included in those reports. We therefore provide only brief descriptions of certain aspects of the study inasmuch as our primary interest was the description of the multilevel analyses of the children's response-contingent learning and the sources of variations in rates of learning.

Multilevel linear modelling (Tabachnick & Fidell, 2013), also known as hierarchical linear modelling (Raudenbush & Bryk, 2002), was used to analyze the nested design and repeated (longitudinal) measures components of the study (Fig. 1). A practical, non-technical approach was used to describe the research methodology, results, and interpretation of data analysis in order for readers to be able to fully understand what was done, why, and what the results "tell us" about the differential effects of the two contrasting types of response-contingent intervention taking into consideration intervention effects related to any differences associated with practitioners implementing the contrasting types of response-contingent practices (e.g., Duncan, Jones, & Moon, 1996; Gardner, 2006; Peugh, 2010; Tate, 2004).

2. Method

2.1. Participants

Among 120 children referred to and screened for study eligibility, 81 children met the eligibility criteria and were randomly assigned to either of the two types of intervention. Random assignment was done using a simple allocation approach where assignment to either intervention group was done without relationship to prior group assignments (Schulz & Grimes, 2002). Ten children were lost to attrition and four carers never gave consent to participate. The final sample included 71 children (37 boys and 34 girls) allocated to either the asset-based (N = 42) or needs-based (N = 39) intervention practices groups. Both overall attrition (10%) and differential attrition (5%) met the What Works Clearinghouse (2014) standards for establishing a low level of bias.

The children were 17 months of age (SD = 10), on average, at the beginning of the study. The Mullen (1995) *Scales of Early Learning* were administered to each child at baseline to establish developmental status and degree of delay. The children were functioning developmentally, on average, at a 4 month level (SD = 3). The average developmental quotient of the children was 34 (SD = 25). There were no significant between intervention group differences for child chronological age, $t = 0.09$, $df = 69$, $p = .924$, child developmental age, $t = 0.23$, $df = 69$, $p = .817$, or child developmental quotients, $t = 1.09$, $df = 69$, $p = .282$.

The children had quite varied diagnoses, etiologies, and causes for their developmental delays. The children's conditions included Down syndrome, Digeorge syndrome, Rett syndrome, Menkes syndrome, Ohtahara syndrome, Coffin-Siris syndrome, and Cornelia de Lange syndrome; central nervous system disorders (lissencephaly, microcephaly, hydrocephaly); motor disorders (cerebral palsy, muscular dystrophy, centronuclear myopathy); birth-related conditions associated with poor developmental outcomes (e.g., extreme low birth weight with grade 3 or 4 intraventricular hemorrhaging); comorbidity (e.g., seizure disorders and visual impairments, hearing loss, or motor impairments); and significant developmental delays without known causes.

The children's carers included 65 mothers, 2 fathers, 2 foster parents, and 2 child guardians who implemented either intervention with the support and guidance of the early childhood intervention practitioners assigned to each group. There were no between intervention group differences for the carers' ages, $t = 0.21$, $df = 69$, $p = .835$, years of formal education, $t = 1.49$, $df = 69$, $p = .140$, or family socioeconomic status, $t = 0.79$, $df = 69$, $p = .436$.

Practitioners were employed based on their professional backgrounds and experiences with young children with disabilities and their families and were assigned to either intervention group depending on their beliefs and prior practices consistent with either an asset-based approach to early childhood intervention or a needs-based approach to early childhood intervention. The six practitioners had either bachelor's (N = 3) or master's (N = 3) degrees in early childhood education, early childhood special education, special education, or a related field (e.g., intellectual disabilities education). The practitioners had an average of 20 years (SD = 9) experience working with young children (Range = 8–35). All but one practitioner was female.

The practitioners assigned to either intervention group were provided extensive training over a 2-month period of time prior to the start of the interventions in terms of both the key characteristics of their assigned intervention approaches and the use of evidence-based adult learning procedures for promoting carers' use of either asset-based or needs-based practices (Dunst & Trivette, 2009; Dunst et al., 2010). This involved investigator description and demonstration of response-contingent learning games and routines, carers' use of the games or routines and practitioner-provided supportive guidance and feedback, and ongoing coaching throughout the course of the study. Additional details regarding practitioner training are described in Raab et al. (2016, 2017).

2.2. Procedure

Children were eligible to participate in the study if they did not display the ability to use behaviour to intentionally produce or elicit social or non-social environmental consequences as determined by early childhood intervention practitioner observations, carer reports, and developmental assessment results. Children randomly assigned to the asset-based practices group were observed in their families' homes and their carers asked to describe behaviour in their children's repertoire but not used to produce environmental consequences (e.g., random arm or leg movements not used as operant behaviour). The children randomly assigned to the needs-based practices group were administered a criterion-referenced assessment scale to identify missing or delayed behaviour skills (e.g., items failed at the ceiling level of performance).

The same types of contingency games and routines were used to reinforce either existing child behaviour to produce environmental consequences (asset-based practices) or missing or delayed skills to produce environmental consequences (needs-based practices). The games and routines all involved environmental arrangements where a child-specific target behaviour was associated with a social or non-social reinforcing consequence. Lancioni et al. (2001) noted that the two types of interventions differ in terms of asset-based practices requiring minimal effort on the part of a child to produce environmental consequences and the needs-based approach requiring "excessively high levels of effort" (p. 271) on the part of a child to produce environmental consequences.

Practitioners made weekly or every other week visits to the families' homes and together with the children's carers developed child-specific learning games and routines that carers implemented on days between home visits. Four to six learning games and routines were developed for each child. Carers maintained weekly logs of the particular games or routines used on each day of the week with the children. Carers recorded for each day of a week if he or she played each game or routine with their children. The logs were used to compute the number of different games and routines played per week and the frequency of child engagement in the games and routines. These counts were used as dependent measures for evaluating procedural fidelity. There were no significant between intervention group differences in the number of games and routines played per week, $t = 0.61$, $df = 69$, $p = .545$, or the number of days per week the games and routines were played, $t = 0.08$, $df = 69$, $p = .933$.

2.3. Learning measures

During each home visit, practitioners used investigator-developed recording forms to code both the number of learning opportunities (trials) afforded a child per game or routine and the number of trials that resulted in the use of a non-prompted child behaviour to produce a social or non-social environmental consequence. An average of 3–4 games or routines were observed and coded per home visit where each game lasted an average of six minutes. The average length of the games and routines was 5.19 min (SD = 2.20) for the asset-based group and 7.67 min (SD = 2.38) for the needs-based group, $t = 4.56$, $df = 69$, $p = .000$.

Different research assistants were assigned to either the asset-based practices or needs-based practices intervention groups and made joint visits with the practitioners on 27% of the total number of visits for determining interrater agreement for the learning measures. The recording form data were used to code the number of learning opportunities (trials) played for each game or routine and the number of learning opportunities (trials) that resulted in a nonprompted environmental consequence. Interrater agreement was calculated as the number of agreements per learning trial for each game or routine divided by the number of agreements plus non-agreements divided by 100. Agreement between the practitioners and research assistants ranged between 85% and 95% for both measures (Average = 91%).

Four learning measures were computed from the recorded data: (1) Number of child learning opportunities per game, (2) total number of child contingency behaviour per game having an environmental consequence, (3) average number of contingency behaviour per game having an environmental consequence, and (4) the percent of learning opportunities (trials) per game having an environmental consequence. These were computed separately for each week of intervention and were used as the repeated measures of child response-contingent learning for evaluating changes (growth) in learning across time.

2.4. Data preparation and analysis

Hierarchical linear growth curve modelling (Raudenbush, Bryk, Cheong, Congdon, & du Toit, 2011) and SPSS (SPSS Inc., 2005) were used to evaluate the differential effects of the two contrasting types of intervention with and without the effects of early childhood intervention practitioners nested under intervention type. Each child had an average of five sets of learning data over the course of the eight weeks of intervention which were used to compute intraindividual growth curve scores for each child learning measure. Each child had a sufficient number of repeated measures to compute linear growth curve scores (Singer & Willett, 2003).

The results from both 2-Level and 3-Level multilevel models are reported for comparative purposes as described earlier. The 2-Level model included tests for linear increases in child learning (Level-1) and tests for between intervention group differences in the slopes of child learning (Level-2). The 3-Level model included tests for linear increases in rates of child learning (Level-1), differences in rates of child learning for children nested within practitioners (Level-2), and differences in rates of child learning for practitioners nested within intervention group (Level-3). The two models differed in terms of accounting (3-Level) and not accounting (2-Level) for between intervention group differences associated with differences in rates of child learning for practitioners nested under intervention group (Woltman, Feldstain, MacKay, & Rocchi, 2012). That is, the 3-Level model but not the 2-Level model partitioned the variance in children's rates of learning into that associated with the contrasting approaches to intervention and that associated with differences among practitioners.

Inasmuch as all children were eligible for participation in the study because they did not use operant behaviour to produce environmental consequences, each child's growth curve measures were modelled with the baseline equal to zero. This was the case because "growth models should be selected so as that individual growth parameters are interpretable in terms of the psychological process being modelled" (Willett, 1989, p. 589). As a result, intercepts were not considered relevant because the main focus of investigation was accounting for differences in rates of child learning across the eight weeks of intervention and because not constraining the intercepts would provide unreliable estimates of baseline functioning. Prior analyses of the four child learning measures reported in this manuscript all were found to have linear functions. This was not unexpected given the fact that previous research has found that short-term longitudinal data typically have a linear function (Willett, 1989).

Substantive interpretation of the between intervention group differences were based on Cohen's *d* effect sizes for the average group slopes either controlling or not controlling for variances associated with practitioners nested within groups. The effect sizes for

Table 1
Fixed Effects Estimates for the Between Intervention Group Comparisons for the Level-2 and Level-3 HLM Analyses.

Child Learning Measures	Level-2 Results					Level-3 Results				
	Group Contrast[a]	SE	*t*-ratio	*p*-value	*d*	Group Contrast	SE	*t*-ratio	*p*-value	*d*
Number of Learning Trials per Game	.90	.24	3.68	.000	1.13	.85	.32	2.68	.055	1.18
Total Number of RC Behaviour	3.67	.72	5.14	.000	1.45	3.74	.77	4.84	.008	1.52
Average Number of RC Behaviour per Game	1.08	.21	5.26	.000	1.48	1.04	.31	3.34	.029	1.57
Percent of Trials with RC Behaviour	1.34	.73	1.83	.072	0.86	1.52	.66	2.31	.082	0.99

[a] Between intervention group coefficients for the differences in the rates of change (slopes) for the child learning measures.

the between group differences were computed using the formula $d = \mathrm{b}/\sqrt{\ }\mathrm{tau}$ (Feingold, 2009) where b is the regression coefficient for the between group slope differences and tau is the random effects variance component for the measurement occasion slopes. Effect sizes rather than statistical significant testing are now the recommended procedures for evaluating between group growth curve differences in multilevel data analysis (Feingold, 2013).

3. Results

Table 1 shows the results for the between group differences in the average slopes for the four child learning measures for 2-Level (Raab et al., 2017) and 3-Level HLM analyses. These coefficients are the final estimations of fixed effects for determining whether or not the average slopes for the two types of intervention are similar or different. These estimates are analogous to tests for interaction effects in between group X repeated measures ANOVAs.

The results from the 2-Level HLM analyses indicate that the average slopes for the two intervention groups were not the same as evidenced by the sizes of effects for the between group slope differences. The results from the 3-Level HLM analyses controlling for variances associated with practitioners nested within intervention groups were similar to those for the 2-Level results as evidenced by the sizes of effects for the between group slope differences. In each of the analysis of the four child learning measure in both the 2-Level and 3-Level HLM analyses, the rates of increases of child response-contingent learning in the asset-based group were larger compared to those in the needs-based group. The sizes of effects for the between slope differences were all very large indicating that there were differential and robust effects of the contrasting types of intervention favouring asset-based practices. The sizes of effect for the 2-Level and 3-Level analyses were also nearly identical for all four dependent measures which indicates that controlling for differences associated with practitioners nested within intervention groups did not substantially change the between intervention group differences. This was confirmed by the fact that there were no differences in the variances associated with the nested design random components in the 3-Level HLM analyses for any of the dependent measures, $\chi_s^2 = 2.09$ to 8.39, $df = 4$, $p_s = .077$–.500.

The children's average intraindividual learning growth curve rates, standard deviations, and 95% confidence intervals for each outcome measure for the individual practitioners in both intervention groups are shown in Table 2. Each child's linear growth curve slope score for each learning measure was computed using HLM and then analyzed using SPSS to obtain the average slope scores for

Table 2
Average Growth Scores for the Individual Early Childhood Intervention Practitioners in Each Intervention Group

Child Learning Measures	Asset-Based Practices			Needs-Based Practices		
	Mean	SD	95% CI	Mean	SD	95% CI
Number of Learning Opportunities						
Practitioners 1/4	1.32	0.60	[.89,1.75]	1.28	0.70	[.63, 1.93]
Practitioners 2/5	2.30	1.31	[1.51, 3.09]	0.55	0.39	[.27, .83]
Practitioners 3/6	1.98	2.42	[.64, 3.31]	1.40	1.01	[.86, 1.94]
Total Number of RC Behaviour						
Practitioners 1/4	4.25	2.78	[2.26, 6.24]	1.90	2.47	[−.39, 4.19]
Practitioners 2/5	7.15	4.29	[4.56, 9.75]	1.20	0.85	[.60, 1.81]
Practitioners 3/6	5.30	5.02	[2.52, 8.08]	1.72	1.36	[1.00, 2.45]
Average Number of RC Behaviour						
Practitioners 1/4	1.17	0.61	[.73, 1.61]	0.62	0.79	[−.12, 1.35]
Practitioners 2/5	2.23	1.35	[1.42, 3.04]	0.33	0.26	[.15, .52]
Practitioners 3/6	1.64	2.10	[.48, 2.80]	0.56	0.51	[.29, .83]
Percent of Trials with RC Behaviour						
Practitioners 1/4	7.63	2.70	[5.70, 9.56]	4.73	4.22	[.83, 8.63]
Practitioners 2/5	7.40	2.92	[5.63, 9.16]	4.53	2.39	[2.82, 6.24]
Practitioners 3/6	10.24	10.70	[4.31, 16.16]	5.67	3.48	[3.81, 7.52]

Notes: RC = Response-contingent child behaviour. Practitioners 1, 2, and 3 implemented asset-based practices and practitioners 4, 5, and 6 implemented needs-based practices. CI = Confidence interval.

Table 3
Decomposition of the Within Intervention Group Between Practitioner Nested Design Comparisons

Child Learning Measures	Degrees of Freedom	*F*-test	*p*-value
Number of Learning Opportunities			
Practitioners (P) Nested Within Groups	4, 65	1.33	.2668
P_s Nested Within Asset-Based Group	2, 65	1.46	.2404
P_s Nested Within Needs-Based Group	2, 65	1.21	.3046
Total Number of RC Behaviour			
Practitioners (P) Nested Within Groups	4, 65	1.21	.3152
P_s Nested Within Asset-Based Group	2, 65	2.31	.1075
P_s Nested Within Needs-Based Group	2, 65	0.11	.8951
Average Number of RC Behaviour per Game			
Practitioners (P) Nested Within Groups	4, 65	1.19	.3230
P_s Nested Within Asset-Based Group	2, 65	2.23	.1153
P_s Nested Within Needs-Based Group	2, 65	0.15	.8619
Percent of Learning Trials with RC Behaviour			
Practitioners (P) Nested Within Groups	4, 65	0.60	.6641
P_s Nested Within Asset-Based Group	2, 65	1.06	.3538
P_s Nested Within Needs-Based Group	2, 65	0.14	.8664

Note: RC = Response-contingent child behaviour.

individual practitioners in each intervention group. These intraindividual growth curve scores are the Level-1 model outputs in both the 2-Level and 3-Level HLM analyses.

The fact that the variability in the learning rates and confidence intervals are relatively large was not surprising given the heterogeneity in the children's diagnoses and etiologies and the wide range of variation in the children's developmental quotients as described in the Methods section. In every case except one, however, the average learning rates for the children in the asset-based intervention group indicate more rapid growth compared to those in the needs-based intervention group. In the majority of cases, the slopes for the asset-based intervention group practitioners were 2 or 3 times larger than those for the slopes for the needs-based intervention group practitioners.

Table 3 shows the results for the nested design analyses of Table 2 data. These were computed using SPSS for a 2-Between Intervention Group ANOVA with practitioners nested within groups and each child's HLM slope scores as the dependent measures in each of the four analyses. The comparisons between practitioners within the same intervention group indicate if the effects of a particular intervention are similar or different among the practitioners implementing the same intervention practice.

There were no significant differences for any child learning measure for practitioners nested within the two intervention groups. There also were no significant differences between the child learning rates for practitioners nested within the asset-based intervention group or for practitioners nested within the needs-based group. These results indicate that there were minimal (nonsignificant) amounts of variance in rates of child learning associated with differences in the practitioners facilitating carers' use of either the asset-based or needs-based intervention practices as evidenced by the 3-Level HLM results for analyses of the variances in child learning nested within intervention group as described above.

The differences in the children's rates of learning for the children nested within practitioners for the two types of intervention are illustrated for the average number of response-contingent behaviour per learning game for each week of intervention. These patterns of learning are shown in Fig. 2 for the children nested under each practitioner for the two types of intervention. These average slopes were computed from the Level-1 HLM outputs for the final estimations of fixed effects.

Several things can be gleaned from these growth curve results. First, the average slopes for the asset-based intervention group children increase at a faster rate compared to the average slopes for the needs-based intervention group children. This was confirmed by the results shown in Table 1. Second, the rates of child learning (slopes) for the practitioners implementing the asset-based intervention practices were more similar than different (as evidenced by Table 3 results) and the rates of learning (slopes) for the children nested within practitioners implementing the needs-based intervention were also more similar than different (also evidenced by Table 3 results).

4. Discussion

The methods of analyses and results from those analyses described in the paper illustrate how multilevel, hierarchical linear growth modelling was used to account for differences in rates of child response-contingent learning and how practitioner-related differences could be ruled-out as a source of variation in child learning. This was determined by HLM results which indicated that type of intervention was the primary source of variation in rates of child response-contingent learning. This is shown in Table 1 where the sizes of effect controlling for variability associated with differences in practitioners was partialled from the intervention effects. This was also confirmed by the SPSS multilevel, nested design analyses where none of the nested group comparisons were significantly different. The two sets of analyses, taken together, helped identify the fact that type of intervention practices accounted for the major differences in children's rates of learning. This was ascertained by the fact that the between intervention group differences

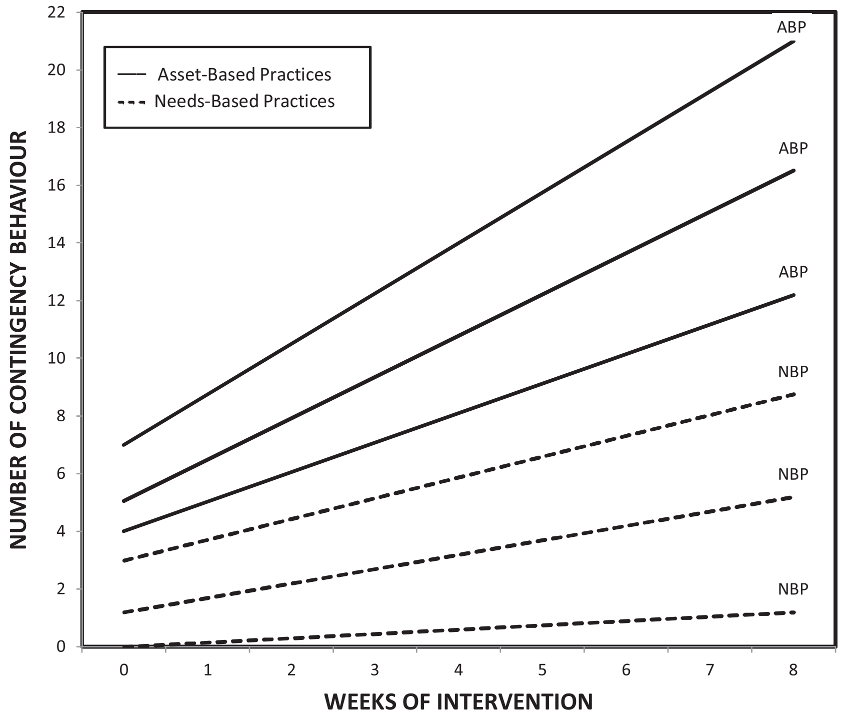

Fig. 2. Average number of child response-contingent behaviour per learning game and routine over the course of eight weeks of intervention. (NOTE. ABP = Practitioners implementing the asset-based practices and NBP = Practitioners implementing the needs-based practices).

were still present after variability associated with practitioners nested within groups was accounted for in the 3-Level HLM analyses (Table 1).

The methodology described in this paper also illustrates how HLM analyses can be supplemented by other multilevel data analysis procedures to rule-out competing or alternative explanations for observed differences in rates of child learning. In the example described in this paper, the HLM results for the 3-Level analyses indicated that the variability in children's rates of learning was due almost entirely to the differential effects of the contrasting types of response-contingent interventions confirmed by the results from the SPSS multilevel analyses.

Despite the fact that it is generally recommended that multilevel, hierarchical linear modelling include large sample sizes at the different levels in a multilevel model (e.g., Afshartous, 1995; Maas & Hox, 2005; Paccagnella, 2011), this is often not feasible in studies like the one described in this paper. This is the case because the number of participants potentially available for enrolment is small because of the low prevalence rate of the children's diagnoses or etiologies in the general population. As a result, a study of the sort described in this paper would unlikely ever include recommended sample sizes. This is at least one reason why studies of the response-contingent learning of young children with significant delays have been single participant rather than group design investigations (e.g., Dunst, Raab, Wilson, & Parkey, 2007; Hanson & Hanline, 1985; Lancioni et al., 2001; O'Brien, Glenn, & Cunningham, 1994; Watson, Hayes, & Vietze, 1982).

There is some evidence that unbiased estimates of fixed effects parameters with a small number of Level-3 groups can be obtained when the effect sizes for the between group differences are large as was the case in the present study (Reise & Duan, 2003). In fact, the sizes of effect were considerably larger than initially hypothesized based on previously reported nonrandomized study results (e.g., Dunst et al., 2010, Raab, Dunst, Wilson, & Parkey, 2009). The results reported in this paper suggest that in the presence of robust intervention effects and in the absence of variance accounted for by other variables, it is possible to perform multilevel analyses with data involving a small sample size with a small number of cluster groups (see also Moerbeek, 2014). We explicitly note, however, that the results suggest and do not confirm this assertion. This caveat is noted because few intervention studies of the sort described herein have yielded very large effect sizes for contrasting types of practices.

4.1. Conclusion

The study described in this paper is part of a line of research and practice spanning more than 30 years (Dunst, Cushing, & Vance, 1985; Dunst, Raab, Trivette, Parkey et al., 2007; Dunst et al., 2010; Dunst, Raab, Trivette, Wilson et al., 2007; Laub & Dunst, 1974; Raab & Dunst, 1997). Lessons learned from earlier studies informed progressive changes and improvements in the methods and procedures described in this paper as asset-based response-contingent learning games and routines. This particular approach to intervention with young children with multiple disabilities and significant developmental delays has proven highly effective as evidenced by the sizes of effect for the differences between the asset-based compared to a needs-based approach to intervention with young children with disabilities and delays. These value-added effects were demonstrated by the results from the randomized controlled design study described in this paper and the multilevel, hierarchical linear modelling of the children's response-contingent learning.

Conflicts of interest

The authors declare no actual or potential conflicts of interest that influenced the conduct of the study, the results, or the contents of the manuscript.

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References

Afshartous, D. (1995). Determination of sample size for multilevel model design. In V. S. L. Williams, L. V. Jones, & I. Olkin (Eds.). *Perspectives on statistics for educational research: proceedings of a workshop* (pp. 20–22). . Retrieved from https://www.niss.org/sites/default/files/technicalreports/tr35.pdf.

Blackburn, C. M., Spencer, N. J., & Read, J. M. (2010). Prevalence of childhood disability and the characteristics and circumstances of disabled children in the UK: Secondary analysis of the Family Resources Survey. *BMC Pediatrics, 10*, 21. http://dx.doi.org/10.1186/1471-2431-10-21 Retrieved from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2873517/pdf/1471-2431-10-21.pdf.

Blackford, J. U. (2007). Statistical issues in developmental epidemiology and developmental disabilities research: Confounding variables, small sample size and numerous outcome variables. In R. C. Urbano, & R. M. Hodapp (Eds.). *Developmental epidemiology of mental retardation and developmental disabilities* (pp. 93–120). San Diego, CA: Academic Press.

Buntinx, W. E. H. (2013). Understanding disability: A strengths-based approach. In M. L. Wehmeyer (Ed.). *The Oxford handbook of positive psychology and disability* (pp. 7–18). New York: Oxford University Press.

Duncan, C., Jones, K., & Moon, G. (1996). Health-related behaviour in context: A multilevel modelling approach. *Social Science & Medicine, 42*(6), 817–830. http://dx.doi.org/10.1016/0277-9536(95)00181-6.

Dunst, C. J., Raab, M., Trivette, C. M., Wilson, L. L., Hamby, D. W., & Parkey, C. (2010). Extended child and caregiver benefits of behavior-based child contingency learning games. *Intellectual and Developmental Disabilities, 48*, 259–270. http://dx.doi.org/10.1352/1934-9556-48.4.259.

Dunst, C. J., Cushing, P. J., & Vance, S. D. (1985). Response-contingent learning in profoundly handicapped infants: A social systems perspective. *Analysis and Intervention in Developmental Disabilities, 5*, 33–47. http://dx.doi.org/10.1016/S0270-4684(85)80004-5.

Dunst, C. J., Raab, M., Trivette, C. M., Parkey, C., Gatens, M., Wilson, L. L., ... Hamby, D. W. (2007). Child and adult social-emotional benefits of response-contingent child learning opportunities. *Journal of Early and Intensive Behavior Intervention, 4*, 379–391. Retrieved from http://www.baojournal.com/JEIBI/jeibi-issues.html.

Dunst, C. J., Raab, M., Trivette, C. M., Wilson, L. L., Hamby, D. W., Parkey, C., ... French, J. (2007). Characteristics of operant learning games associated with optimal child and adult social-emotional consequences. *International Journal of Special Education, 22*(3), 13–24 Retrieved from http://www.internationaljournalofspecialeducation.com/.

Dunst, C. J., Raab, M., Wilson, L. L., & Parkey, C. (2007). Relative efficiency of response-contingent and response-independent stimulation on child learning and concomitant behavior. *Behavior Analyst Today, 8*, 226–236. http://dx.doi.org/10.1037/h0100615 Retrieved from: http://psycnet.apa.org/fulltext/2008-05984-05010.html.

Eloff, I., & Ebersöhn, L. (2001). The implications of an asset-based approach to early intervention. *Perspectives in Education, 19*(3), 147–157.

Feingold, A. (2009). Effect sizes for growth-modeling analysis for controlled clinical trials in the same metric as for classical analysis. *Psychological Methods, 14*(1), 43–53. http://dx.doi.org/10.1037/a0014699.

Feingold, A. (2013). A regression framework for effect size assessments in longitudinal modeling of group differences. *Review of General Psychology, 17*(1), 111–121. http://dx.doi.org/10.1037/a0030048.

Gardner, R. C. (2006). *Hierarchical linear modeling: A primer. People within groups.* London, Ontario, Canada: Department of Psychology. University of Western Ontario. Retrieved from http://publish.uwo.ca/?gardner/DataAnalysisDotCalm/Manuscripts/daHLMmeasureswithinpeopleNEWFROMSPAIN.pdf.

Granlund, M., Wilder, J., & Almqvist, L. (2013). Severe multiple disabilities. In M. L. Wehmeyer (Ed.). *The Oxford handbook of positive psychology and disability* (pp. 452–474). New York: Oxford University Press.

Hanson, M. J., & Hanline, M. F. (1985). An analysis of response-contingent learning experiences for young children. *Journal of the Association for Persons with Severe Handicaps, 10*, 31–40.

Hulsebus, R. C. (1973). Operant conditioning of infant behavior: A review. *Advances in Child Development and Behavior, 8*, 111–158. http://dx.doi.org/10.1016/S0065-2407(08)60494-2.

Hutto, M. D. (2007). *Latency to learn in contingency studies of young children with disabilities or developmental delays.* Asheville, NC: Winterberry Press.

Lancioni, G. E., O'Reilly, M. F., Oliva, D., & Coppa, M. M. (2001). A microswitch for vocalization responses to foster environmental control in children with multiple disabilities. *Journal of Intellectual Disability Research, 45*(3), 271–275. http://dx.doi.org/10.1046/j.1365-2788.2001.00323.x.

Lancioni, G. E., Singh, N. N., O'Reilly, M. F., Oliva, D., & Groeneweg, J. (2005). Enabling a girl with multiple disabilities to control her favorite stimuli through vocalization and a dual-microphone microswitch. *Journal of Visual Impairment and Blindness, 99*, 179–182.

Laub, K. W., & Dunst, C. J. (1974). Effects of imitative and non-imitative adult vocalizations on a developmentally delayed infant's rate of vocalization. *Paper presented at the annual meeting of the North Carolina Speech and Hearing Association* May.

Lipsitt, L. P. (1971). Infant learning: The blooming, buzzing confusion revisited. In M. E. Meyer (Ed.). *Second western symposium on learning: Early learning* (pp. 5–21). Bellingham: Western Washington State College.

Ludlow, B. L. (1987). *Preschool programs for handicapped children.* Bloomington, ID: Phi Delta Kappa Educational Foundation. Retrieved from http://eric.ed.gov/?q=Preschool+programs+for+handicapped+children&id=ED294359.

Maas, C. J. M., & Hox, J. J. (2005). Sufficient sample sizes for multilevel modeling. *Methodology, 1*(3), 86–92. http://dx.doi.org/10.1027/1614-1881.1.3.86.

Moerbeek, M. (2014). Multilevel modeling in the context of growth modeling. *Annals of Nutrition and Metabolism, 65*, 121–128. http://dx.doi.org/10.1159/000360485.

Mullen, E. M. (1995). *Mullen scales of early learning: AGS edition.* Circle Pines, MN: American Guidance Service.

New, R. S., & Cochran, M. M. (2007). *Early childhood education: An international encyclopedia, Vol. 1*. Westport, CT: Praeger Publishers.

O'Brien, Y., Glenn, S., & Cunningham, C. (1994). Contingency awareness in infants and children with severe and profound learning disabilities. *International Journal of Disability, Development, and Education, 41*, 231–243. http://dx.doi.org/10.1080/0156655940410307.

Paccagnella, O. (2011). Sample size and accuracy of estimates in multilevel models: New simulation results. *Methodology, 7*(3), 111–120. http://dx.doi.org/10.1027/1614-2241/a000029.

Parsons, S., & Platt, L. (2013). *Disability among young children: Prevalence, heterogeneity and socio-economic disadvantage.* London: London University, lnstitution of Education, Economic and Social Research Council, Centre for Longitudinal Studies. Retrieved from http://eprints.ioe.ac.uk/21055/.

Peugh, J. L. (2010). A practical guide to multilevel modeling. *Journal of School Psychology, 48*, 85–112. http://dx.doi.org/10.1016/j.jsp.2009.09.002.

Raab, M., & Dunst, C. J. (1997). Extended benefits of active learning for young children with severe disabilities. *Paper presented at the International Conference on Children with Special Needs* November.

Raab, M., Dunst, C. J., Wilson, L. L., & Parkey, C. (2009). Early contingency learning and child and teacher concomitant social-emotional behavior. *International Journal of Early Childhood Special Education, 1*(1), 1–14 Retrieved from http://dergipark.ulakbim.gov.tr/intjecse/article/viewFile/5000016602/5000016447.

Raab, M., Dunst, C. J., & Hamby, D. W. (2016). Effectiveness of contrasting approaches to response-contingent learning among children with significant developmental delays and disabilities. *Research and Practice for Persons with Severe Disabilities, 41*(1), 36–51. http://dx.doi.org/10.1177/1540796915621189.

Raab, M., Dunst, C. J., & Hamby, D. W. (2017). Efficacy trial of contrasting approaches to the response-contingent learning of young children with significant developmental delays and multiple disabilities. *Journal of Educational and Developmental Psychology, 7*(1), 12–28. http://dx.doi.org/10.5539/jedp.v7n1p12.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2nd ed.). Thousand Oaks, CA: Sage.

Raudenbush, S. W., Bryk, A. S., Cheong, Y. F., Congdon, R. T., & du Toit, M. (2011). *HLM 7: Hierarchical linear and nonlinear modeling.* Lincolnwood. IL: Scientific Software International.

Reise, S. P., & Duan, N. (2003). Design issues in multilevel studies. In S. P. Reise, & N. Duan (Eds.). *Multilevel modeling: Methodological advances, issues, and applications* (pp. 238–248). Mahwah, NJ: Lawrence Erlbaum Associates.

Rovee-Collier, C. K., & Gekoski, M. J. (1979). The economics of infancy: A review of conjugate reinforcement. *Advances in Child Development and Behavior, 13*, 195–255. http://dx.doi.org/10.1016/S0065-2407(08)60348-1.

Rumrill, P. D., Jr., Cook, B. G., & Wiley, A. L. (2011). *Research in special education: Designs, methods, and applications* (2nd ed.). Springfield, IL: Charles C. Thomas.

Inc, S. P. S. S. (2005). *SPSS 14.0. Statistical package for the social sciences.* Chicago: Author.

Schulz, K. F., & Grimes, D. A. (2002). Generation of allocation sequences in randomised trials: Chance, not choice. *The Lancet, 359*, 515–519. http://dx.doi.org/10.1016/S0140-6736(02)07683-3.

Singer, J. D., & Willett, J. B. (2003). *Applied longitudinal data analysis: Modeling change and event occurrence.* New York: Oxford University Press.

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). London: Pearson.

Tarabulsy, G. M., Tessier, R., & Kappas, A. (1996). Contingency detection and the contingent organization of behavior in interactions: Implications for socioemotional development in infancy. *Psychological Bulletin, 120*, 25–41. http://dx.doi.org/10.1037/0033-2909.120.1.25.

Tate, R. (2004). lnterpreting hierarchical linear and hierarchical generalized linear models with slopes as outcomes. *Journal of Experimental Education, 73*(1), 71–95. http://dx.doi.org/10.3200/JEXE.71.1.71.

Ward, K., Miller, V., & Lamar, R. (2013). *Representative samples. paper presented at the council on research and evaluation webinar on overcoming challenges to conducting research with individuals with intellectual disabilities.* Washington, DC: Association of University Centers on Disabilities. Retrieved from https://aucd.adobeconnect.com/_a1005431686/challenge_research.

Ware, J. (2016). *Creating a responsive environment for people with profound and multiple learning difficulties* (2nd ed.). London: David Fulton Publishers.

Watson, J. S., Hayes, L. A., & Vietze, P. (1982). Response-contingent stimulation as a treatment for developmental failure in infancy. *Journal of Applied Developmental Psychology, 3*, 191–203. http://dx.doi.org/10.1016/0193-3973(82)90015-6.

What Works Clearinghouse (2014). *What Works Clearinghouse procedures and standards handbook.* Washington, DC: U.S. Department of Education, Institute of Education Sciences. Retrieved from http://ies.ed.gov/ncee/wwc/pdf/reference_resources/wwc_procedures_v3_0_standards_handbook.pdf.

Willett, J. B. (1989). Some results on reliability for the longitudinal measurement of change: implications for the design of studies of individual growth. *Educational and Psychological Measurement, 49*, 587–602.

Williams, B. A. (2001). The critical dimensions of the response-reinforcer contingency. *Behavioural Processes, 54*, 111–126.

Woltman, H., Feldstain, A., MacKay, J. C., & Rocchi, M. (2012). An introduction to hierarchical linear modeling. *Tutorials in Quantitative Methods for Psychology, 8*(1), 52–69. http://dx.doi.org/10.20982/tqmp.08.1. p052.