ED255C
Assignment#4

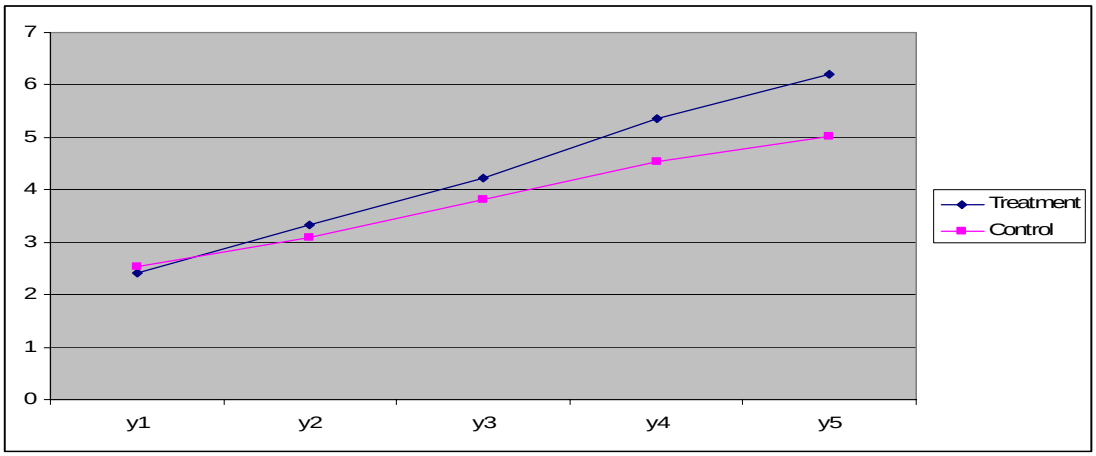
Examining the Intervention Effect on Reading Achievement Using Muthen and Curran's Multiple Group Analysis Approach to Growth Modeling

Introduction

This reports aims at investigating intervention effects on reading achievement using a growth model in line with Muthen and Curran's multiple group analysis approach (1997)[1]. The artificial data, which was generated by the Mplus Monte Carlo facility, consists of 512 subjects in the control group and 488 in the intervention group. One pre-intervention reading achievement assessment was observed at the baseline followed by four post-intervention measurements at equidistant times.

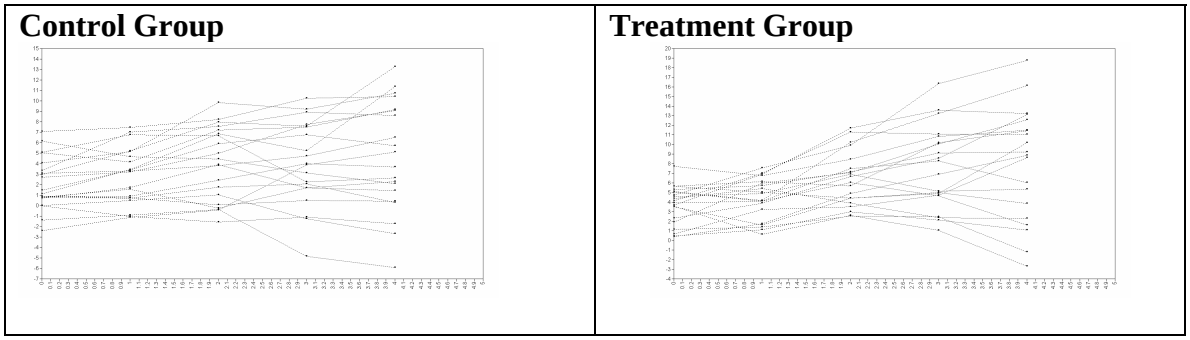
The plot in Figure 1 displays the overall mean of reading achievement over the five timepoints for both the control and treatment groups. Since the mean reading score at the baseline for the control group (2.583) is very close to the one for the treatment group (2.407), the randomization seems to be successful. Although an overall linear increasing trend is observed for both control and treatment groups, the rate of increase in the treatment group over time appears to be higher than in the control group. A sample plot of 20 students for each group also displays a higher growth rate of the treatment group as compared to the control group, indicating that there is a treatment effect on reading achievement (Figure 2).

Figure 1 Treatment group vs. Control group: Overall Mean of Reading Achievement over time



[1] Muthén, B. & Curran, P. (1997). General longitudinal modeling of individual differences in experimental designs: a latent variable framework for analysis and power estimation. *Psychological Methods*, 2, 371-402

Figure 2 Individual Trajectory in Control group vs. Treatment group



Before fitting a growth model to the data, ANCOVA was carried out using the last timepoint as the outcome and the first timepoint as the baseline covariate in order to establish a general pattern of the development of reading achievement. Adjusting for the baseline, there was a significant treatment effect – $F(1, 996)=8.99$, $p=0.028$. However, no interaction between the treatment and the baseline was found – $F(1, 996) = 0.11$ $p=0.7395$. Thus, a growth model, consistent with Muthen and Curran's multiple group analysis approach and which used all timepoints, was created to examine the treatment effect and to compare its results to ANCOVA, which only used two time points.

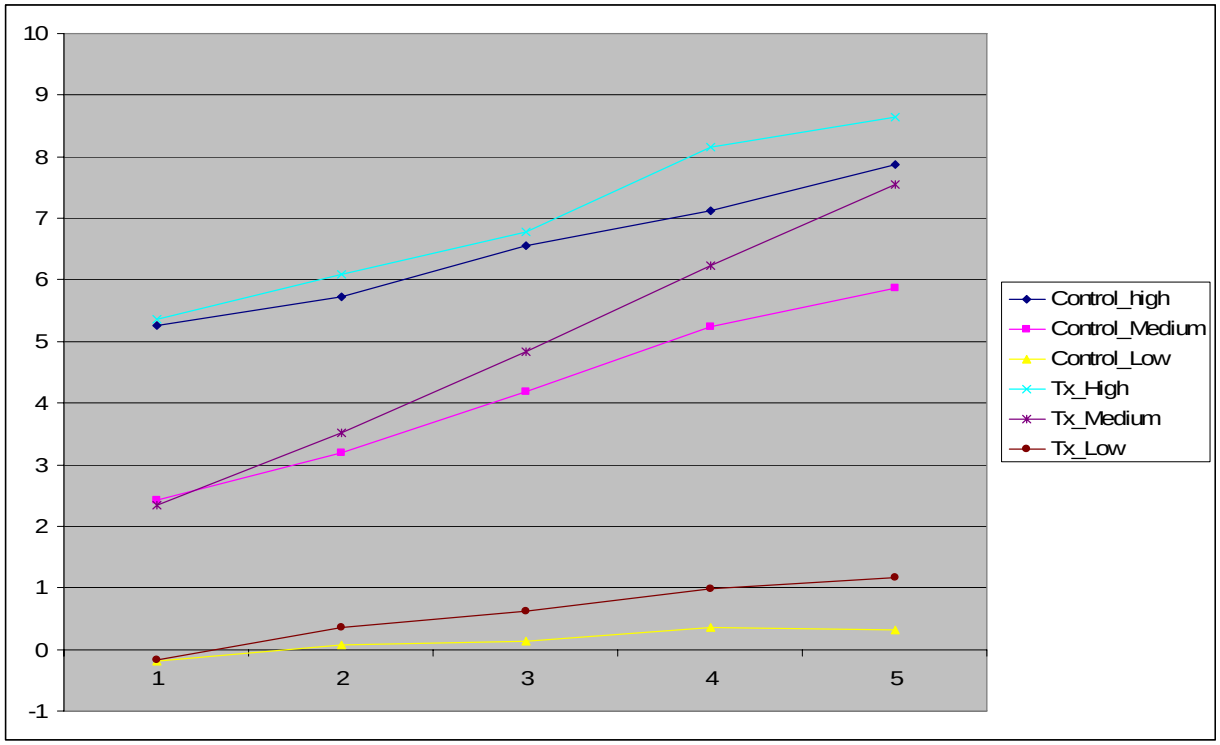
Table 1 displays the change in mean over time for three sub-groups (Low, Medium and High), which were obtained by dividing the groups into the first through third quartiles at the first timepoint, in both the control group and the treatment group[2]. By looking at Figure 3, in general, all subgroups in the treatment group have higher rates of change over time compared to the subgroups in the control group. It is noteworthy that the rate of change over time for the medium group in the treatment population seems to be the highest of any other sub group. This indicates that students with medium baseline values might have the most benefit from the prevention. In order to discover for whom the intervention is most effective, at the fourth step of Muthen and Curran's approach, interaction between initial status and treatment will be examined not only by comparing the treatment group versus the control group but also by comparing the three subgroups within the treatment group to the three subgroups within the control group.

Table 1 Mean change over time for subgroups of Control group versus subgroups of Treatment group

	Control				Treatment			
	Overall	**High**	**Medium**	**Low**	**Overall**	**High**	**Medium**	**Low**
Time1	2.583	5.264	2.429	-0.189	2.407	5.359	2.333	-0.173
Time2	3.094	5.720	3.194	0.071	3.322	6.089	3.519	0.354
Time3	3.815	6.560	4.191	0.132	4.233	6.769	4.839	0.629
Time4	4.530	7.122	5.242	0.366	5.363	8.147	6.230	0.985
Time5	5.024	7.874	5.876	0.314	6.204	8.650	7.541	1.168
N	512	138	246	128	488	113	253	122

[2] The values of the 25% and 75% quantiles were 0.83 and 4.04 respectively. Subgroups were demarcated as follows: first, the range of the "Low" group was defined as any value lower than .83; second, the "Medium" group was defined as values between .83 and 4.04; and finally, the "High" group contained all values greater than 4.04.

Figure 3 Reading achievement of three subgroups based on the baseline values at Time 1



Two group analysis based on Muthen and Curran's approach

Step1: Control group analysis

As a first step, I fit a two factor – intercept and slope – linear growth model with equidistant time scores (the time scores 0, 1, 2, 3, 4 were used). The Chi-square test for model fit indicates that the model fits the data very well. (χ^2_{10} = 7.671, p = 0.6609, RMSEA = 0.000). The linear growth model estimated the mean of reading achievement at initial status to be 2.52 and there was significant variation across individuals at initial status (p<.001). The mean and variance of the growth rate were 0.636 and 0.923 respectively and both were significantly different from zero at p<.001. Thus, it seems that individuals in the control group, on average, increase their reading achievement by 0.636 and this growth rate varies across individuals in the control group. This seems to be a typical growth pattern of reading achievement since individuals naturally obtain learning ability as they get older.

Evidence of nonlinear growth was also investigated by separately adding a quadratic factor and by freeing time scores. However, the results of the addition of a quadratic factor seem to indicate the absence of quadratic growth, since the mean of the quadratic factor[3] in this adjusted growth model was not significantly different from zero. Also, in the growth model with freed time scores for y4 and y5, the free time scores were not significantly different from the fixed time scores, 3 and 4. In general,

[3] The variance in the quadratic factor was fixed at zero because of nonconvergence.

adding a quadratic factor ($\chi^2_9 = 7.643$, p = 0.5704) and freeing time scores ($\chi^2_8 = 7.155$, p = 0.5200) did not seem to improve the model fit. Therefore, I chose the simple linear growth model as the final model for the control group.

Step2: Treatment group analysis.

After analyzing the treatment group separately, the second step in the analysis found that a simple linear growth model, i.e. a two-factor linear growth model with equidistant time scores, was a good fit for the treatment group as well ($\chi^2_{10} = 13.303$, p = 0.2072, RMSEA = 0.026). The mean of reading achievement at initial status was 2.392 and there was significant variation across individuals at the baseline (p<.001). The mean growth rate, 0.957, seems higher compared to the mean of the growth rate in the control group. The variance of the growth rate slope was significantly different from zero at p<.001. This indicates that the average growth rate of reading achievement in the treatment group is 0.957 and this growth rate varies across individuals. A growth model with a quadratic factor and a growth model with freed time scores were also fitted to see whether or not there is a non-linear pattern in the trajectory of reading achievement. Since no evidence of a non-linear growth pattern was found, the simple linear growth model was also chosen for the treatment group.

Step3: Two-group analysis without interactions.

As a third step, the control and treatment groups were analyzed simultaneously in a two-group analysis. The intercept and slope factors were forced to be equal across the treatment and control groups. The residuals were allowed to be correlated at adjacent time points since it is natural that the reading achievement at one time point might be related to the level at the next time point. Additionally, the baseline covariate, poverty status of the student's family, was added to the model. The level of poverty was significantly and negatively associated with initial status (-0.953, p<.001) and rate of growth of achievement (-0.231, p<.001), indicating that students with a higher poverty level appear to have lower initial status and lower growth rates in term of reading achievement trajectories than students with a lower level of poverty.

The two-group analysis included an added growth factor for the treatment group in order to capture the treatment effect. The variance of the added growth factor was fixed at zero based on the assumption of no variation across individuals for this factor. The two-group model fitted the data reasonably well ($\chi^2_{24} = 31.035$, p = 0.1528, RMSEA = 0.024 Loglikelihood=-11714.891, BIC=23609.383). The mean of the added growth factor was 0.332 and was significantly different from zero (p<.001) pointing out that there is a significant intervention effect on reading achievement.

Step4: Two-group analysis with interactions.

In this step, the interaction between treatment and initial status was examined by allowing the initial status factor in the treatment group to influence the added linear growth factor. The added linear growth factor has zero variance so that its variation is solely determined by the variation associated with its initial status. Adding the regression slope parameter to the two-group analysis model did not improve

the model ($\chi^2_{23} = 30.302$, p = 0.1409, RMSEA = 0.025, Loglikelihood=-11714.524, BIC=23615.558)[4]. Moreover, the regression slope was 0.033 and was not significantly different from zero. Therefore, comparing the overall treatment group to the overall control group yielded no interaction between initial status and treatment.

However, when each subgroup in the control group was compared to each subgroup in the treatment group, significant interaction between treatment and initial status in the Medium group was found. Thus, initial status seems to be a good predictor for the added linear growth rate factor for the medium group because the regression of the added linear growth factor on the initial status factor has a significant positive estimate of the slope (slope =0.270, $p<0.05$). On the other hand, significant interaction between treatment and initial status in either the low or high group could not be found (p>.05)

Step5: Sensitivity analysis of final model.

A two-group model without interaction was selected as a final model to explain the treatment effect for the overall treatment population. The reading achievement scores at baseline in the treatment group were very close to the ones in the control group. In order to test whether or not randomization was successful, the two-group model allowed the initial status mean of the treatment group to deviate from the zero value of the initial status factor in the control group. The chi-square difference with one degree of freedom was .668 with p >0.05, indicating a successful randomization.

To assess whether there was an overall effect of treatment on the growth factors, the treatment effect parameter – the intercept of the added growth factor for treatment – was set at zero. This resulted in a significant worsening of the fit relative to the model with 24 degrees of freedom (The chi-square difference test value with one degree of freedom was 25.14 with p<.001.). The hypothesis that there was no treatment effect was therefore rejected indicating that, on average, the students in the treatment group have significantly higher growth rates than those in the control group.

Table 2 represents the estimates of the two-group model without interaction with 24 degree of freedom. The variances for initial status and linear growth rate factors are significantly different from zero, indicating students vary at initial status and their trajectories of reading achievement vary over time. Since the mean of the added growth factor is positive and significant, the individuals in the treatment group have, on average, an additional growth rate of 0.322 indicating that there is a significant treatment effect.

Discussion

Based on the Muthen and Curran's multiple group analysis approach, the two-group growth model without interaction found that there is a significant overall treatment effect on reading achievement. Poverty level as a covariate in the model was found to be negatively related to reading achievement trajectory factors. Although the multiple group analysis approach clearly confirmed that there is a significant overall treatment effect, the interaction between initial status and treatment effect was not found in this approach. Interestingly, however, when the treatment group was broken into three

[4] -2LL=0.734, p>.05

subgroups obtained at the reading achievement baseline, the Medium group showed not only the overall main effect of treatment but also effects from interaction. This points out that among those who are in the middle range of reading achievement at the baseline, the students who have initially higher reading achievement scores are more likely to gain benefits from the intervention. Therefore, it is very important to find subgroups within treatment populations in order to determine for whom the intervention is the most effective. Since the designation of these three groups was arbitrary, a growth mixture model should be considered to uncover subgroups while taking initial status and growth rate into account.

Table 2 Final Two group Growth model

Parameter	**Control group N=512**	**Treatment group N=488**	**Both**
Growth factors			
Initial status			
M			0[a]
Variance			3.299(0.230)
Linear growth rate			
M			0.640(0.045)
Variance			0.968(0.057)
Added linear growth rate			
Intercept		0.332(0.066)	
Residual variance		0[a]	
Growth factor covariances			
Initial-status linear growth rate			0.335(0.086)
Covariate			
Initial status			-0.953(0.060)
Growth rate			-0.231(0.033)
Residual variances for outcome variables			
Time 1	0.343(0.200)	0.548(0.210)	
Time 2	0.948(0.155)	0.943(0.164)	
Time 3	1.551(0.189)	1.496(0.200)	
Time 4	2.145(0.407)	2.256(0.429)	
Time 5	2.061(0.537)	2.988(0.588)	
Residual covariances for outcome variables			
Time 1-2	-0.078(0.147)	-0.034(0.156)	
Time 2-3	-0.015(0.105)	-0.149(0.112)	
Time 3-4	-0.046(0.159)	-0.173(0.173)	
Time 4-5	-0.123(0.403)	-0.097(0.431)	
Common intercept for the outcome variables			2.495(0.060)

Note: Standard errors are given in parentheses; $\chi^2_{24} = 31.035$, N=1000, p = 0.1528,

[a] This parameter is fixed in this model