

**Full Longitudinal Mediation Modeling Analysis of HIV/AIDS Knowledge, Self-Efficacy and Condom-Use Intention in Youth**

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### Abstract

**Objective:** More advanced methods than the conventional mediation analysis in social and behavioral health research are needed to determine causal relationship and to evaluate intervention effects and mechanisms. This paper illustrates one such method with real data.

**Method:** Using three waves of longitudinal data from “Focus on Youth in the Caribbean” project, we applied the *full longitudinal mediation model*(FLMM) to test the causal relationship from HIV/AIDS knowledge to condom self-efficacy, further to condom-use intention. We demonstrated how to use Mplus to fit FLMM to the data due to its capacity to handle missing values with a full information maximum likelihood method. **Results:** Participants were 493 youth aged 9 to 14 at baseline. The data fit the FLMM satisfactorily. Results showed that HIV/AIDS knowledge and self-efficacy for condom use formed a self-enhancement system over time; HIV/AIDS knowledge significantly and causally related to intention to use condoms through a *multi-path mediation process*; and self-efficacy for and intention to use condoms during sex formed a *positive feedback loop*. **Conclusions:** Findings of this study demonstrate several strengths of FLMM, expanding the conventional mediation analysis. FLMM represents one of the advanced methods to analyze theory-guided social and behavioral studies examining complex causal relationships. Study findings also underscore the need for study on the use of this method in guiding and analyzing educational intervention trials.

**Keywords:** Mediation, longitudinal data analysis, full longitudinal mediation modeling analysis, causal interference HIV/AIDS, risk behaviors.

## Introduction

Panel data collected through behavioral intervention trials offer a great opportunity to obtain longitudinal evidence of causal relationships to advance social and behavioral studies. Conventional mediation modeling analyses, including longitudinal mediation focus on single-path connections. This analytical approach does not capture additional information in the data that might also be very important to understand the causal relationship among study variables. This paper is then aimed to illustrate an advanced method, termed as full longitudinal mediation modeling (FLMM). Three waves of longitudinal data from an NIH funded project “Focus on Youth in the Caribbean” are used to demonstrate the new method by testing the theory-granted causal relationship from HIV/AIDS knowledge to condom self-efficacy, further to condom-use intention.

Although statistical methods alone cannot prove causality, the correct application of a rigorous method in data analysis can strengthen evidence of a causal relationship. This method has two prerequisites. First, it requires a research question based on a valid theory to support a potential causal or causal chain relationship. The statistical method is designed to extract evidence from data to support the causal relationship. Second, it requires longitudinal data to test the theory-guided relationship while avoiding the reverse impact of the outcome on predictors. To date, no statistical method exists for detecting the reverse impact of one variable measured at a later time on another variable measured at an earlier time. Conducting a mediation analysis of longitudinal data, however, provides a method to examine causal relationships.

Mediation analysis is a statistical method frequently used by social and behavioral scientists to understand the complex relationships among study variables. Researchers can apply it in observational studies to sharpen their understanding of an observed relationship between

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independent and outcome variables by adding mediators. In intervention research, mediation analysis can help elucidate intervention mechanisms and streamline intervention components in order to maximize intervention effects on purposeful behavior change. Several books (Hayes, 2013; Jose, 2013; MacKinnon, 2008) and numerous published articles (e.g., Baron & Kenny, 1986) have described mediation analysis in detail. However, published studies using mediation modeling analysis are often based on cross-sectional data gathered at a single time point. Thus, these studies cannot account for reverse impact in their path model (MacKinnon, 2008). Some scholars may argue that a “mediational model is a causal model” in that “the mediator is presumed to cause the outcome and not vice versa.” (Kenny, 2014). However, even statistically significant results from mediation modeling cannot guarantee the proposed direction of a causal relationship without longitudinal data.

A conventional mediation analysis often focuses on a single mediation path from a predictor to a mediator and, further to an outcome. With longitudinal panel data, researchers can explore multiple paths among the predictor, mediator, and outcome variables. Specifically, longitudinal data can accommodate autoregressive effects, contemporaneous effects, and cross-lagged effects (MacKinnon, Fairchild, & Fritz, 2007). An auto-regressive effect is when a variable at a specific time step (i.e., at time  $t$ ) is influenced by the same variable at its previous time steps (i.e., at time  $t-1$  or  $t-2$ ). Contemporaneous effects are effects of the mediator on the outcome in the same wave. Cross-lagged effects allow for the possibility of reverse causality in the model, which is more reasonable than assuming only one temporal relationship between the variables. Although these multi-path mediation mechanisms may more accurately reflect the causal dynamics of these variables, they cannot be obtained with conventional mediation analysis method.

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By contrast, in a FLMM, effects from all potential mediation paths are analyzed first, and then summed up to assess the total direct effects, indirect effects, and total effects. In addition, with information for all potential mediation paths with longitudinal data of the predictor, mediator and outcome, FLMM can yield data that allows researchers to identify potential reverse effects or feedback mechanisms in social work and behavioral health research (Chen et al., 2010). Information regarding multi-path mediations, and positive and negative feedbacks are essential to advance our understanding of mechanisms in etiological studies and to devise and evaluate intervention studies. However, such invaluable information is not available in published studies with data analyzed using conventional mediation analysis methods (Hayes, 2013; Li, Chen & Yu, 2016; Yu, Chen, Yang et al, 2017).

To better address the advantage of FLMM, we investigate the causal chain from HIV/AIDS knowledge to condom use self-efficacy to condom use intention. We select the causal chain of these three variables based on two considerations. First, the relationship among these variable is supported by well-established Protection Motivation Theory (PMT) (Rogers, 1975, 1983). Therefore, we will be more confident to draw causal relationship based on findings from FLMM. Second, we make use of longitudinal data from an intervention trial to evaluate the effect of the program “Focus on Youth in the Caribbean” (FOYC) in promoting HIV protective behaviors.

FOYC is adapted intervention from “Focus on Kids”, an eight-session educational program tested to be effective in promoting HVI prevention behaviors among high risk adolescents in the United States (Stanton et al, 1996). To evaluate if the adopted program FOYC also works for youth in the Bahamas, an randomized controlled trial was conducted with funding support from NIH. Longitudinal data of HIV/ADIS knowege, condom-use self-efficacy (i.e.,

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having confidence in one's ability to use condoms) and intention to use condom were collected at baseline, 12, 24, and 36 months post intervention.

The adapted program FOYC has been proven to be effective in reducing risk behavior and promoting protective behaviors (including HIV/AIDS knowledge, condom-use self-efficacy, intention and condom use) at 6, 24 and 36 months post intervention (Chen et al, 2009; Gong et al, 2009, Chen et al 2010). Conventional mediation analysis was conducted to demonstrate the effect of FOYC by enhancing condom-use self-efficacy to promote intention and behavior of condom use (Chen et al, 2012). However, no study has been conducted to test the causal relationship between HIV/AIDS knowledge, condom-use self-efficacy and intentions to use condoms during sex, one of the key theories supporting the original program Focus on Kids and the adapted program FOYC.

In this study, we used FOYC data collected at the first three waves to ensure a chained longitudinal mediation relationship from HIV/AIDS knowledge to condom-use self-efficacy, further to condom-use intention. With FOYC data, we can adequately demonstrate the new method of FLMM; and findings from FLMM analysis will add new evidence directly supporting PMT and indirectly supporting the success of the adapted FOYC in reducing HIV risk among youth in the Bahamas.

### **Materials and Methods**

#### **Source of Data**

Data used for this study were derived from the Bahamas Project – Focus on Youth in the Caribbean (FOYC). Funded by the National Institutes of Health (NIH), this project was launched to evaluate the effect of FOYC on HIV protective behaviors (particularly condom use) among

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youth in the Bahamas. A total of 1,360 sixth graders from 21 public schools in the Bahamas were randomized into three groups: (a) FOYC for students; (b) FOYC for students plus parental education; and (c) control conditions – environmental conservation education. FOYC was found to be effective in promoting HIV protective behaviors at 12, 24, and 36 months post-intervention (Chen, et al., 2009; Chen, et al., 2010; Gong et al., 2009). The present study used data from the control group to examine to what extent condom use self-efficacy (i.e., having confidence in one's ability to use condoms) mediated the relationship between students' HIV/AIDS knowledge and their intention to use condoms. Because the control group did not receive the designated interventions, we determined that the control group data would more realistically present the underlying relationship among these variables than would data from either intervention group.

A key component of FOYC is to educate youth about HIV/AIDS and to promote their condom-use self-efficacy, which is assumed to increase an individual's intention to use condoms during sex. This causal chain from HIV/AIDS knowledge to condom use self-efficacy to condom use intention is based on the well-established PMT (Rogers, 1975, 1983). This theory is based on the social cognitive model, which has been widely used in social and behavioral research studies to predict many different types of health behaviors (Li et al., 2020; Xiao et al., 2014; Xu & Chen, 2016). Findings of this study with FOYC data would add new evidence validating PMT and support the success of this PMT-based educational program in reducing HIV risk among youth outside of the United States.

### **Variables and Measurement**

FOYC collected data on many variables. We selected the first three waves of data on three key variables (i.e., HIV/AIDS knowledge, condom use self-efficacy, and the intention to use

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condoms) to demonstrate the application of longitudinal mediation analysis. Readers should note that a longitudinal mediation analysis requires at least three waves of data to explore a causal relationship among three variables. Additionally, in a conventional mediation analysis using three waves of data, the predictor variable measured at baseline is used to predict the mediator at first follow-up, which in turn is used to predict the outcome at the second follow-up (MacKinnon, 2008). By contrast, our study used data on the three variables from all three waves of assessments for a *full longitudinal mediation* analysis.

**HIV/AIDS knowledge.** This variable was the predictor variable in our longitudinal mediation analysis. It was measured using participants' responses to a set of 15 statements, some true (e.g., "Anybody can get AIDS") and some other false (e.g., "What you eat can give you AIDS"). These true or false statements were scored 0 (when a participant incorrectly identified the statement as true or false) or 1 (when they correctly identified the statement as true or false). Higher scores indicated more knowledge.

**Self-efficacy for condom use.** This variable was the mediator variable. Using a six-item scale, it measured participants' perceived ability to obtain, use, and/or convince their partner to use condoms, to ask for condoms in a store or clinic, and to refuse sex without a condom. A typical question was, "I could not convince my partner that we should use a condom if he/she doesn't want to." All items were assessed using a 5-point Likert scale from 1 (*No, I could not*) to 5 (*Yes, I could*). The Cronbach alpha of the scale was 0.8 or greater for all three waves. Mean scores were computed for analysis so that higher scores indicated stronger condom use self-efficacy.

**Intention to use condoms.** This variable was the outcome. Participants were asked, "How likely is it that you will use a condom if you were to have sex in the next six months?" Participants

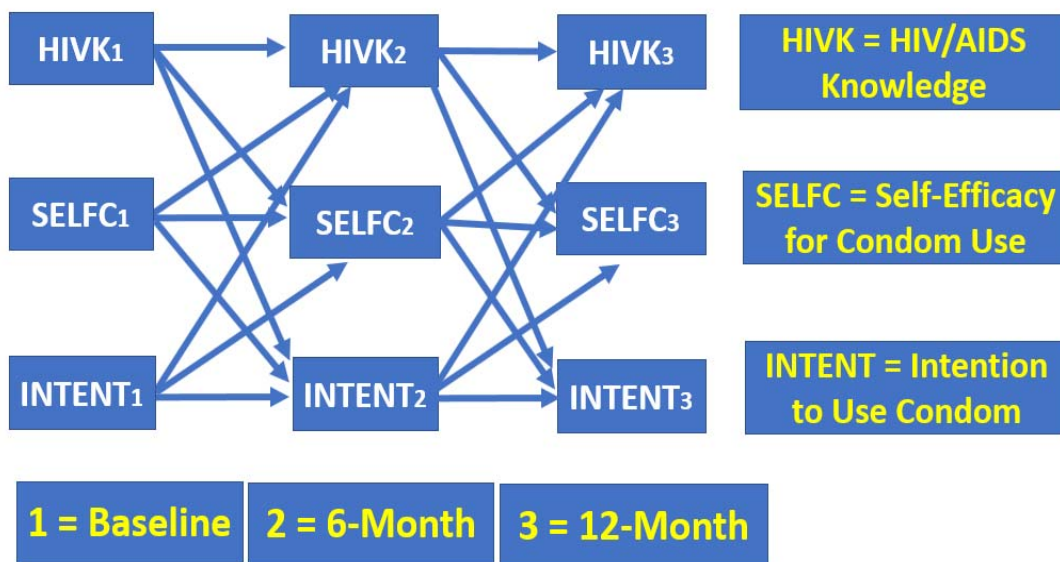


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responded using a five-point Likert scale with responses including 1 (*No*), 2 (*Probably not*), 3 (*Don't know*), 4 (*Maybe*), and 5 (*Yes*). Response scores were used in the mediation modeling analysis, with higher scores indicating a stronger intention to use a condom during sex.

### Process for Full Longitudinal Mediation Modeling (FLMM)

A full longitudinal mediation model was proposed (Figure 1) to guide the statistical analysis. In this model, we considered following potential longitudinal relationships, including (a) first-order autoregressive longitudinal effects for the three variables from time 1 to time 2 and from time 2 to time 3 (linked by the horizontal arrows); (b) cross-lagged effects among the three variables from time 1 to time 2 and from time 2 to time 3 (diagonal arrows); and (c) second-order autoregressive and second-order cross-lagged effects for the three variables from time 1 to time 3 (not shown in Figure 1 to avoid overflowing the figure).

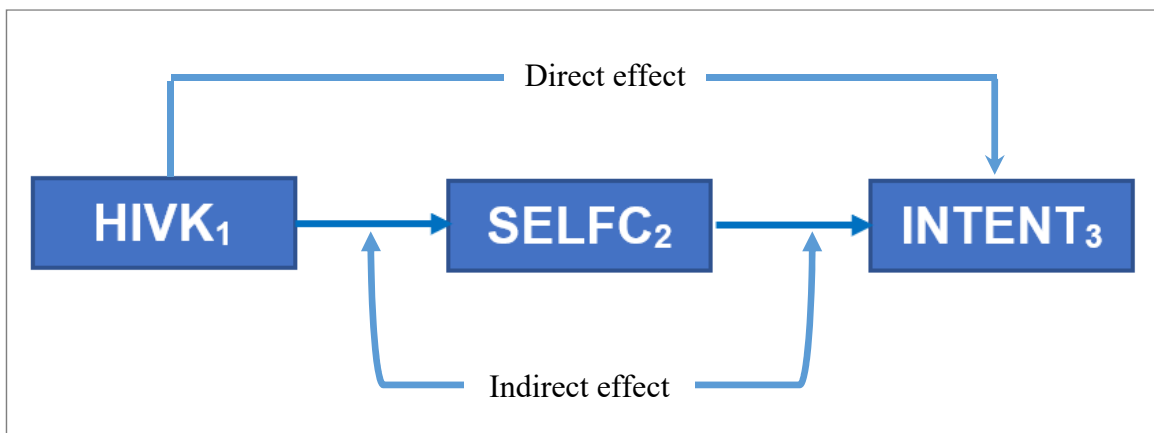


**Figure 1.** A Proposed Full Longitudinal Mediation Model. Paths from baseline to 12-month are not included, such as HIVK1 to HIVK3, SELFC3, and INTENT3 (to avoid overflowing the figure).

This model allows us to test for a number of potential causal relationships with the estimated direct and indirect effects. For example, we can test for the theory-based causal chain

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illustrated in Figure 2, which is a typical mediation model with three variables measured at three different time points. In Figure 2, the path links HIV/AIDS knowledge at time 1 (HIVK<sub>1</sub>) to condom use self-efficacy at time 2 (SELFC<sub>2</sub>) to intention to use condoms at time 3 (INTENT<sub>3</sub>). The relationship between HIVK<sub>1</sub> and INTENT<sub>3</sub> provides a measure of the direct effect of HIV/AIDS knowledge on the intention to use condoms. Multiplying the effect of HIVK<sub>1</sub> on SELFC<sub>2</sub> with the effect of SELFC<sub>2</sub> on INTENT<sub>3</sub> provides a measure of the indirect effect (or the mediation effect) between HIV/AIDS knowledge and intention to use condoms. The total effect is simply a sum of the direct effect and indirect effect.



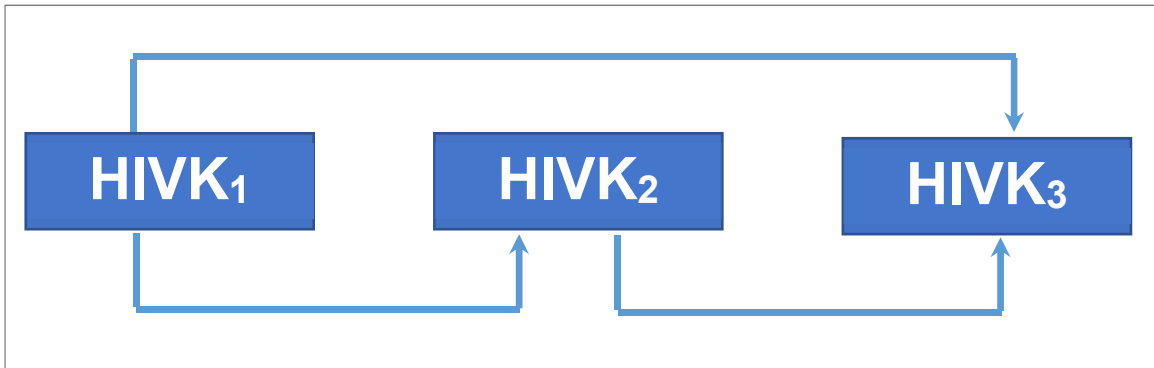
**Figure 2.** The social cognitive theory-based causal chain from HIV/AIDS knowledge (HIVK<sub>1</sub>) to condom use self-efficacy (SELFC<sub>2</sub>) to intentions to use a condom during sex (INTENT<sub>3</sub>): A conventional mediation model

Note: Total effect = indirect + direct effect

In addition to the conventional mediation analysis depicted in Figure 2, results from the full longitudinal mediation analysis can be used to test autoregressive effects (commonly referred to as a *self-enhancement process*) (Chen et al., 2012). Figure 3 displays a proposed self-enhancement model of the autoregressive effects of HIV/AIDS knowledge over time. Knowledge

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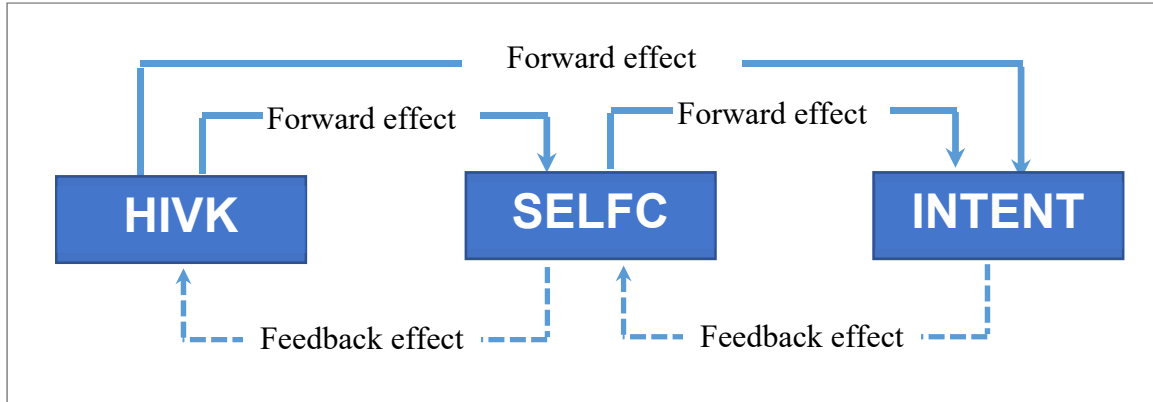
at the baseline can enhance itself both at 6-month and at 12-month; knowledge at 6-month can enhance itself at 12-month.



**Figure 3.** Testing Self-Enhancement Model of HIV/AIDS Knowledge Over Time. The same model can be applied to assess condom use self-efficacy and intention to use a condom.

Notably, a full longitudinal mediation model also allows researchers to test feedback relationships reported in other studies (Chen et al., 2010). Figure 4 depicts three feedback loop relationships. First, it depicts the feedback relationship between HIV/AIDS knowledge and condom use self-efficacy. The causal relationship from HIV/AIDS knowledge to condom use self-efficacy can be assessed with HIVK<sub>1</sub> and SEFC<sub>2</sub>; the reverse impact of condom use self-efficacy on HIV/AIDS knowledge can be assessed with SELFC<sub>1</sub> and HIVK<sub>2</sub>. Second, Figure 4 depicts the feedback loop between condom use self-efficacy and the intention to use condoms. Third, it depicts the long feedback loop between HIVK, INTENT, and SELFC.

<Insert Figure 4 about here>



**Figure 4.** Testing Potentials of Different Feedback Effects with a Full Longitudinal Mediation Model. The figure shows the HIVK-SELFC loop, the SELFC-INTENT loop and the long HIVK-INTENT-SELFC loop.

Note: HIVK: HIV/AIDS knowledge; SELFC: condom use self-efficacy; INTENT: intention to use condom during sex.

### Implementation of Longitudinal Mediation Modeling

The full longitudinal mediation model in Figure 1 was fitted using structural equation modeling (SEM) in Mplus (Muthén & Muthén, 2010). We also used a full information maximum likelihood method (implemented in Mplus) to obtain parameter estimates and test models. A satisfactory data-model fit should have a statistically nonsignificant chi-square ( $p > 0.05$ ), a standardized root mean square residual (SRMR) less than or equal to .08, a comparative fit index (CFI) and Tucker–Lewis index (TLI) greater than or equal to .95, a root mean square error of approximation (RMSEA) less than or equal to .08, and a statistically nonsignificant  $p$ -value for the test of close fit (Bollen & Long, 1993). Significance tests for mediation analysis were conducted using the joint significance test (MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002) as well as a bootstrapping approach (implemented in Mplus).

We accounted for missing values using the full information maximum likelihood (FIML) estimation in Mplus (Muthén & Muthén, 2010) to estimate the parameters from the longitudinal mediation analysis. FIML can use all available information from an incomplete sample to estimate

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population parameters, producing unbiased parameter estimates with small variances, correct Type I error rates, and high statistical power.

### Results

#### Data Description

Table 1 summarizes the sample characteristics and the three key variables measured at three time points, both overall and by gender. As shown in Table 1, the gender-based difference is very minimal and not significant among participants' age, HIV/AIDS knowledge, condom use self-efficacy, or the intention to use condoms at all three waves. Therefore, we used the total for the final analysis.

**Table 1.** Characteristics of the Study Participants and the Key Variables

Variable	Male	Female	Total
<u>Age at baseline in years</u>			
Range	9 to 12	9 to 14	9 to 14
Mean (SD)	10.439(0.657)	10.364(0.623)	10.398(0.640)
<u>HIV/AIDS knowledge: n, mean(SD)</u>			
HIVK <sub>1</sub>	226, 8.779(5.512)	267, 8.393(4.931)	493, 8.570(5.204)
HIVK <sub>2</sub>	215, 8.563(4.940)	249, 8.867(4.617)	464, 8.726(4.767)
HIVK <sub>3</sub>	202, 8.198(4.216)	230, 9.739(4.731)	432, 9.019(4.558)
<u>Self-efficacy for condom use: n, mean(SD)</u>			
SELFC <sub>1</sub>	226, 7.916(12.585)	266, 14.662(11.657)	492, 16.157(12.188)
SELFC <sub>2</sub>	214, 19.121(9.351)	246, 17.102(10.170)	460, 18.041(9.839)
SELFC <sub>3</sub>	201, 19.851(9.923)	228, 16.789(9.826)	429, 18.224(9.978)
<u>Intention to use condom: n, mean(SD)</u>			
INTENT <sub>1</sub>	201, 3.965(1.656)	253, 3.660(1.572)	454, 3.795(1.615)
INTENT <sub>2</sub>	210, 4.586(1.548)	234, 4.209(1.624)	444, 4.387(1.598)
INTENT <sub>3</sub>	200, 4.435(1.724)	218, 4.491(1.621)	418, 4.464(1.669)

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As seen from the total sample (Table 1), there were missing values. Specifically, at the three time points, there were 4, 33, and 65 missing values for HIV/AIDS knowledge; 5, 37, and 68 missing values for condom use self-efficacy; and 43, 53, and 79 missing values for the intention to use condoms. Therefore, we used FIML to estimate the parameters from the full longitudinal mediation analysis (Muthén & Muthén, 2010).

### **Data-Model Fitting**

Fitting the full longitudinal mediation model (as depicted in Figure 1) to the data, we found a satisfactory model fitting. The  $\chi^2$ -test of model fit statistic was 3.926 ( $df = 2$ ,  $p = .140$ ). The RMSEA was 0.044 (90% CI = [0.000, 0.109]). The CFI was 0.997. The TLI was 0.955. The SRMR was 0.015. We include the example Mplus syntax for this model in Appendix A in order to promote the reproducibility of our research and to encourage public use of the full longitudinal mediation analysis.

### **Longitudinal Effects**

Table 2 summarizes the results based on the full longitudinal mediation model as shown in Figure 1. As seen in Table 2, HIVK<sub>1</sub> (i.e., HIV/AIDS knowledge at baseline) had a statistically significant relation with HIVK<sub>2</sub> at the 6-month ( $\beta = 0.399$ ,  $p = 0.000$ ) and 12-month timepoints ( $\beta = 0.138$ ,  $p = 0.020$ ) respectively. HIVK<sub>2</sub> at 6-month was also significantly related to HIVK<sub>3</sub> at 12-month ( $\beta = 0.522$ ,  $p = 0.000$ ). This evidence of a significant autoregressive effect suggests a self-enhancement process driving the accumulation of HIV/AIDS knowledge over time (Chen et al, 2012), as depicted in Figure 3. These findings add new evidence supporting the validity of

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PMT as well as the success of the adapted interventions FOYC in promoting protective behavior among youth in the Bahamas (Chen et al, 2009, Gong et al, 2009, Chen et al, 2010).

**Table 2.** *Parameter Estimates for the Longitudinal Mediation Model in Figure 1*

From	To	Estimate	p-value	To	Estimate	p-value	To	Estimate	p-value
HIVK1	HIVK3	0.138	0.020	SELFC3	0.047	0.004	INTENT3	0.043	0.059
HIVK2	HIVK3	0.522	0.000	SELFC3	-0.001	0.930	INTENT3	0.027	0.208
SELFC1	HIVK3	0.160	0.270	SELFC3	0.118	0.015	INTENT3	0.066	0.414
SELFC2	HIVK3	-0.003	0.988	SELFC3	0.426	0.000	INTENT3	0.109	0.230
INTENT1	HIVK3	0.077	0.381	SELFC3	0.057	0.066	INTENT3	0.156	0.002
INTENT2	HIVK3	-0.021	0.822	SELFC3	0.125	0.000	INTENT3	0.276	0.000
HIVK1	HIVK2	0.399	0.000	SELFC2	0.023	0.071	INTENT2	0.064	0.004
SELFC1	HIVK2	0.250	0.067	SELFC2	0.384	0.000	INTENT2	0.319	0.000
INTENT1	HIVK2	0.147	0.139	SELFC2	0.088	0.004	INTENT2	0.086	0.075

HIVK<sub>1</sub> (HIV/AIDS knowledge at baseline) was not statistically related to SELFC<sub>2</sub>, the self-efficacy for condom use at 6-month ( $\beta = 0.023, p = 0.071$ ), but it was significantly related to SELFC<sub>3</sub> at 12-month ( $\beta = 0.047, p = 0.004$ ). This result suggests a delayed effect by which HIV/AIDS knowledge takes more than 6-month to show its effect on enhancing condom use self-efficacy, as suggested by the cognitive theory (Rogers, 1975 & 1983). Furthermore, neither HIVK<sub>1</sub> at baseline nor HIVK<sub>2</sub> at 6-month was significantly associated with the intention to use condoms. This result suggests that the effect of HIV/AIDS knowledge on condom use intention is likely mediated by condom use self-efficacy at 12-month but not at 6-month, which differs from the mediation model depicted in Figure 2. These important findings would be missed if analyzed using the conventional methods.

The statistical significance of the longitudinal relationships between SELFC (i.e., condom use self-efficacy) and the other two variables slightly differed from those found for HIV/AIDS

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knowledge. Similar to our HIVK results, we found significant positive autoregressive relationships between SELFC<sub>1</sub>, SELFC<sub>2</sub>, and SELFC<sub>3</sub> across the three time points, which suggests a self-enhancement mechanism for the development of condom use self-efficacy over time (refer to Figure 3). SELFC<sub>1</sub> at baseline was significantly related to INTENT<sub>2</sub> (i.e., condom use intention at 6-month) ( $\beta = 0.319, p = 0.000$ ); but SELFC<sub>2</sub> was not significantly associated with INTENT<sub>3</sub> (i.e., condom use intention at 12-month).

Compared to the other two variables, we observed a different longitudinal relationship pattern for INTENT (i.e., the intention to use condoms) using the model in Figure 1. Foremost, this variable did not demonstrate a self-enhancement process, as INTENT<sub>1</sub> was significantly related INTENT<sub>3</sub> at 12-month ( $\beta = 0.156, p = 0.002$ ) but not to INTENT<sub>2</sub> at 6-month ( $\beta = 0.086, p = 0.075$ ). This result suggests that, among Bahamian youth, the intention to use a condom is less stable relative to HIV/AIDS knowledge and condom use self-efficacy.

Additionally, INTENT<sub>1</sub> (i.e., the intention to use condoms at baseline) was significantly related with SELFC<sub>2</sub> at 6-month ( $\beta = 0.088, p = 0.004$ ) and INTENT<sub>2</sub> at 6-month was significantly related to SELFC<sub>3</sub> at 12-month ( $\beta = 0.125, p = 0.000$ ). These two coefficients quantified the direction (positive) and strength of the two feedback loops. These results indicate the existence of a positive feedback impact by the intention to use condoms on condom use self-efficacy (Figure 4).

### **Direct, Indirect, and Total Effects with Single Mediation Path**

Guided by Figure 2, we estimated the effect from HIVK<sub>1</sub> (HIV/AIDS knowledge at baseline) to INTENT<sub>3</sub> (intention to use condoms at 12-month) as mediated by SELFC<sub>2</sub> (condom use self-efficacy at 6-month) following the conventional approach with a single mediation path. In Table 2, the estimated  $\beta = 0.023$  ( $p = 0.071$ ) for HIVK<sub>1</sub> to SELFC<sub>2</sub> and the estimated  $\beta = 0.109$



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( $p = 0.230$ ) for SELFC<sub>2</sub> to INTENT<sub>3</sub>; therefore, the estimated indirect effect = 0.003 (i.e.,  $0.023 \times 0.109$ ) with  $p = 0.355$  (estimated through bootstrapping). As shown in Table 2, the total effect from HIVK<sub>1</sub> to INTENT<sub>3</sub> was the estimated  $\beta = 0.043$  ( $p = 0.059$ ), thus the estimated direct effect = 0.040 (i.e.,  $0.043 - 0.003$ ). Based on this result, we found no significant mediation effect when only considering one mediation path. This indicates that there is a notable limitation to utility of the conventional mediation analysis, which separates one component from the whole.

### Direct, Indirect, and Total Effects with Multiple Mediation Paths

Table 3 summarizes the estimated direct, indirect, and total effects, estimated based on the full longitudinal mediation model and the effects from all mediation paths. Key findings from Table 3 follow.

**Table 3.** Direct Effect, Indirect Effect and Total Effect from Full Longitudinal Model with Multiple Mediation Paths.

From	To	Total Direct Effect	p-value	Total Indirect Effect	p-value	Total Effect	p-value	VAF
INTENT1	HIVK3	0.077	0.381	0.075	0.167	0.152	0.128	49.34%
SELFC1	HIVK3	0.160	0.270	0.123	0.207	0.282	0.053	43.62%
HIVK1	HIVK3	0.138	0.020	0.207	0.000	0.345	0.000	60.00%
INTENT1	SELFC3	0.057	0.066	0.048	0.004	0.105	0.001	45.71%
SELFC1	SELFC3	0.118	0.015	0.203	0.000	0.321	0.000	63.24%
HIVK1	SELFC3	0.047	0.004	0.017	0.057	0.064	0.000	26.56%
INTENT1	INTENT3	0.156	0.002	0.037	0.041	0.193	0.000	19.17%
SELFC1	INTENT3	0.066	0.414	0.137	0.001	0.202	0.004	67.82%
HIVK1	INTENT3	0.043	0.059	0.031	0.009	0.074	0.001	41.89%

Unlike results from the single mediation path analysis in the previous section, we found a significant indirect effect from HIVK<sub>1</sub> (HIV/AIDS knowledge at baseline) to INTENT<sub>3</sub> (intention to use condoms at 12-month). Although the estimated direct effect ( $\beta = 0.043$ ,  $p = 0.059$ ) from HIVK<sub>1</sub> to INTENT<sub>3</sub> was not statistically significant, we found that the indirect effect ( $\beta = 0.031$ ,

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$p = 0.009$ ) through three paths – (a) HIVK<sub>1</sub>-HIVK<sub>2</sub>-INTENT<sub>3</sub>; (b) HIVK<sub>1</sub>-SELFC<sub>2</sub>-INTENT<sub>3</sub>; and (c) HIVK<sub>1</sub>-INTENT<sub>2</sub>-INTENT<sub>3</sub> – and the total effect (i.e., a sum of the direct and indirect effects;  $\beta = 0.074$ ,  $p = 0.001$ ) were all significant. Notably, this finding suggests the significance of all the three mediation paths by which HIV/AIDS knowledge promotes future condom use intention, offering more and better information than findings from the single-path model.

We found similar direct, indirect, and total effects for HIVK<sub>1</sub> to HIVK<sub>3</sub>, for SELFC<sub>1</sub> to SELFC<sub>3</sub>, and for HIVK<sub>1</sub> to SELFC<sub>3</sub> (Table 3). The indirect effects observed in this study contain all potential indirect effect path that can be detected only by FLMM analysis. Information from multiple paths is not only closer to the reality but also enhance statistical power to test the proposed causal relationship.

We further calculated the variance accounted for (VAF) in this mediation analysis. According to the guidelines in Hair et al. (2014), full longitudinal mediation can be warranted if  $VAF > 80\%$ , otherwise, partial mediation can be claimed if VAF is between 20% to 80% and no mediation if  $VAF < 20\%$ . As seen in Table 3, most of the mediations have strong VAF in the range of 40% to 70%, indicating strong partial mediations, except that 19.17% VAF for “INTENT1” to “INTENT3”, and 26.56% for “HIVK1” to “SELF3”, which are borderline mediations.

### Conclusions and Discussion

The present study demonstrates the application of FLMM in analyzing three waves of data collected by an educational HIV prevention program. To our knowledge, this is the first study to deploy the full longitudinal mediation analytical method in health behavior and social work research. Using theory-guided measures, FLMM can extract valuable information conventional mediation analysis cannot from longitudinal data for testing causal relationships in social

behavior research. This is because in most studies, longitudinal mediation modeling only focuses on a single path from a predictor to a mediator further to an outcome. Even if multi-mediators are involved, casual relationships are still assessed on individual paths.

FLMM shows its advantages by expanding the conventional single-path mediation model so that researchers can draw conclusions based on all possible connections among the study variables. In addition to demonstrating several advantages of FLMM generally, our work also adds new findings to the literature on HIV/AIDS knowledge, condom use self-efficacy, and the intention to use condom during sex among adolescents. In addition to etiological studies to advance knowledge and mechanisms of health behavior, FLMM may also be used to guide and evaluate educational intervention trials for purposeful behavior change.

### **Longitudinal Self-Enhancement of HIV/AIDS Knowledge and Condom Use Self-Efficacy**

A notable finding of the FLMM is the existence of a phenomenon we term *self-enhancement*. For instance, we found that measurements of HIV/AIDS knowledge at three different times were all longitudinally and positively related to each other. The measurement of this variable at baseline positively related to the measurements at the first and second follow-ups, and the measurement at the first follow-up also positively related to the measurement at the second follow-up. The condom-use self-efficacy variable also demonstrated self-enhancement; the variable for intention to use condoms did not. Although self-enhancement for condom use self-efficacy has been reported in a previous study (Chen et al, 2010), we are the first to demonstrate self-enhancement of HIV/AIDS knowledge.

Findings regarding the self-enhancement mechanism suggest that compared to youths' intention to use condoms, their HIV/AIDS knowledge and condom use self-efficacy are more

stable over time. Knowledge and self-efficacy constitute the foundational components for supporting intentional and purposeful behavioral change, as posited by cognitive theory (Rogers, 1975 & 1983) and demonstrated through empirical studies (Xiao et al., 2014; Xu & Chen, 2016). Despite the lack of empirical data suggesting a direction of the connection from these two variables to intention to use condoms, we can make confident claims about their relative importance and comparative stability.

### **Multiple Mediation from HIV/AIDS Knowledge to Intention to Use Condoms**

Another new and important finding of our study is that multi-path longitudinal mediation has demonstrable analytical superiority compared to single-path mediation in the conventional method (Baron & Kenny, 1986; Hayes, 2013; Jose, 2013; MacKinnon, 2008). When we used the conventional approach, we did not find support for the theory-based relationship that condom use self-efficacy can mediate the relationship between HIV/AIDS knowledge and intention to use condoms, as the mediation effect yielded by the conventional approach was not statistically significant. By contrast, findings from our multi-path longitudinal mediation demonstrated that the relationship between HIV/AIDS knowledge at baseline and intention to use condoms at 12-month was fully mediated in three paths through HIV/AIDS knowledge, condom use self-efficacy, and intention to use condoms at 6-month. Beyond finding empirical evidence of the theory-based relationship, multi-path mediation provides a method for determining the overall effect by extracting information from individual paths. Although this approach uses data from individual paths, it delivers more factual and useful results than a single-path mediation model. We, therefore, recommend that researchers examining complex causal relationships use this approach whenever possible.

### **PMT Theory and Success of FOYC**

From our perspective, causal inference would be greatly strengthened if a study is guided by a valid theory and data are analyzed using advanced method. In addition to demonstrate the utility of FLMM, findings of this study add new data supporting the validity of PMT originally developed by Rogers (1975, 1983). PMT has been significantly use in predicting health related behavior in general (Rajendran et al, 2017; Milne et al 2000) in general and HIV-related behaviors (Milne et al, 2000; Chen et al, 2012). Findings of this study further strengthen demonstrate the utility of PMT in social and behavioral studies to advance social work research and practice.

In addition to predicting behaviors, PMT has also been frequently used in guiding interventions to achieve purposeful behavior changes (Chen et al, 2009, 2012; Rajendran et al, 2017; Milne et al 2000; Stanton et al, 1996). FOYC and its mother program Focus on Kids (Stanton et al, 1996) are typical example. The demonstration of the longitudinal causal relationship from HIV/AIDS knowledge to condom-use self-efficacy and further to condom-use intervention with data from FOYC adds additional evidence supporting the validity of FOYC in enhancing HIV protective behavior among youth in the Bahamas by adapting a US-tested program.

### **Feedback Loop Evaluation**

Beyond its ability to calculate self-enhancement and multi-path mediation, another important application of the full longitudinal mediation analysis is that it can provide data for assessing the existence and strength of a feedback effect. Although data on feedback effects is essential for understanding human behavior – particularly social and health behavior – few studies to date have examined feedback impact (Chen et al., 2010). With our full longitudinal mediation model, an outcome variable measured at an early time can be used to assess its relationship with

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a predictor and an outcome measured at a later time – a capability with a vast number of potential applications for social science researchers. In addition to advancing etiological research, such information can be used to guide and strength the development of educational intervention programs for purposeful behavior change.

For example, in this study we found a significant feedback effect from intention to use condoms (i.e., the outcome) on condom use self-efficacy (i.e., the mediator). Namely, our analysis demonstrated this feedback effect between baseline and 6-month as well as between 6-month and 12-month. This finding provides empirical data supporting preexisting theories of the mutual impact between self-efficacy and behavioral intention in cognitive theory (Rogers, 1975, 1983). Such feedback information can be used to guide and strength the development of educational intervention programs with condom use self-efficacy and intention as key components to promote condom use.

### **Recommendations and Limitations**

The primary purpose of this study is to demonstrate and promote the application of full longitudinal mediation analysis. Although there are several advantages to this method compared to the conventional mediation analysis, full longitudinal mediation analysis is harder to conduct. To facilitate the application of this method, we have included the Mplus code to the end of this study for interested readers to use in analyzing their own data. These readers should keep in mind that when applying this method, they should select their variables based on established theory. Theory-based variables form a hypothetical causal chain; mediation analysis generates data supporting (or not) the hypothesized causal relation. Our proposed method will not help if the selection of study variables is not informed by a meaningful behavioral theory.

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Our study's findings should be considered in light of their limitations. Data used for this study are derived from another project that was not originally devised for testing full longitudinal mediations of variables. Additionally, because all data were self-reported, reporting errors possibly occurred even though the measurement scales used for data collection were reliable and had a strong Cronbach alpha. Readers should, therefore, interpret our study results with caution. Finally, the complexity of a full longitudinal mediation model increases rapidly as the number of variables increases. This model requires at least three variables (i.e., a predictor, a mediator, and an outcome) with three waves of measurements.

Despite these limitations, full longitudinal mediation analysis provides an advanced method for producing informative empirical evidence in theory-guided causal relationship research. We hope that this paper will add a new powerful method to the extant toolkit of statistical methods for advancing social behavioral studies. Findings of this study also underscore the need for research to evaluate the use of full longitudinal mediation in develop and evaluate educational behavior intervention trials.

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### Appendix A. Mplus Program to Analyze Bahamas Longitudinal Data (Model in Figure 1).

DATA:

FILE IS dControlW123.dat;

VARIABLE:

NAMES ARE

HIVK1 HIVK2 HIVK3 SELFC1 SELFC2 SELFC3 INTENT1 INTENT2 INTENT3 ID;

MISSING IS \*;

USEVARIABLES ARE

HIVK1 HIVK2 HIVK3 SELFC1 SELFC2 SELFC3 INTENT1 INTENT2 INTENT3;

ANALYSIS:

BOOTSTRAP = 1000;

MODEL:

HIVK3 on HIVK1; HIVK3 on HIVK2; HIVK3 on SELFC2; HIVK3 on INTENT2;

HIVK2 on HIVK1; HIVK2 on SELFC1; HIVK2 on INTENT1; HIVK3 on SELFC1;

HIVK3 on INTENT1;

SELFC3 on SELFC1; SELFC3 on SELFC2; SELFC3 on HIVK2; SELFC3 on INTENT2;

SELFC2 on SELFC1; SELFC2 on HIVK1; SELFC2 on INTENT1; SELFC3 on HIVK1;

SELFC3 on INTENT1;

INTENT3 on INTENT1; INTENT3 on INTENT2; INTENT3 on HIVK2; INTENT3 on SELFC2;

INTENT2 on INTENT1; INTENT2 on HIVK1; INTENT2 on SELFC1; INTENT3 on HIVK1;

INTENT3 on SELFC1;

!!! Indirect effect

Model indirect:

HIVK3 ind INTENT1; HIVK3 ind SELFC1; HIVK3 ind HIVK1;

INTENT3 ind INTENT1; INTENT3 ind SELFC1; INTENT3 ind HIVK1;

SELFC3 ind INTENT1; SELFC3 ind SELFC1; SELFC3 ind HIVK1;

OUTPUT: stdyx; CINTERVAL (BCBOOTSTRAP);