

Title: Airbag Moderation: The definition and statistical implementation of a new methodological model

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Abstract

This paper presents a new methodological model termed Airbag Moderation: That the relationship between two variables varies as a function of a third, and that this third variable depends upon one of the others. Airbag Moderation extends and bridges a number of theories and it can be implemented using existing statistical models and software packages. Airbag Moderation is more suitable than Moderation for conceptualizing and testing a range of theories, interventions, and policies across educational, social, and behavioral research. An empirical example demonstrates the effectiveness of UK Sure Start Children's Centres as an intervention in the context of financial disadvantage and the internalizing behaviors of preschoolers. Parallel statistical implementation follows via two Structural Equation Models featuring either a statistical interaction term or a random coefficient. Both indicate that greater use of a Children's Centre is a significant Airbag Moderator of the relationship between financial disadvantage and internalizing behaviors in preschoolers.

Keywords: Evaluation Methodology, Moderation, Structural Equation Modeling

1. Introduction

One set of methodological tools widely used in investigations of educational effectiveness are multivariate models that posit how three or more variables relate to one another, particularly the notions of Moderation, Mediation, and Interaction. Although these concepts have existed in educational research since the 1950s (notably Saunders, 1955; 1956), the past sixty years have seen many attempts to clarify their definitions in relation to one another and in relation to how researchers can translate these methodological models into actual statistical models for use in not just educational research but also in other areas of social and behavioral research as well. Perhaps the most famous paper differentiating Mediation and Moderation and documenting techniques for their statistical implementation is that of Baron and Kenny (1986; 88k+ citations as of November 2019) but there have been many others including: McClelland and Judd (1993); Hinshaw (2002); Little, Card, Bovaird, Preacher, and Crandall (2007); Preacher, Rucker, and Hayes (2007); MacKinnon and Luecken (2008); Wu and Zumbo (2008); Judd and Kenny (2010); and Hayes (2012). The paper by Hayes (2012) also documents the release of the PROCESS macro for the IBM SPSS statistical software package – software that has made the statistical implementation of these methodological models easier than ever before by freeing researchers from requiring knowledge of Structural Equation Modelling and its associated statistical software.

With such a long history, simultaneous usage across multiple substantive applications, and lasting popularity, the methodological models of Mediation, Moderation and Interaction face conflicting narratives regarding definitions and statistical implementation (for a review of reasons and examples see Hall & Sammons, 2013). While the corpus of papers cited above have resulted in a reduced conflation of Mediation and Moderation (e.g. via common use of the term “indirect effect” such as within Goodnight, Bates, Staples, Petit, & Dodge, 2007), more persistent is the conflation of Moderation and Interaction. The conflation of

Moderation and Interaction is deep-rooted problem in quantitative education research – to the extent that it is even present within the 1950s papers mentioned above by Saunders (1955, 1956). Figure 1 illustrates the difference between the methodological models of Moderation and Interaction by showing three methodological models (A1, A2, A3) that each contain different relationships (different arrows) between the same three concepts of X, Y and Z. However, it is when these methodological models are statistically implemented (when the reader moves from row A to row B in Figure 1) that issues of conflation arise. Figure 1 shows that there is a common technique for statistically implementing all three of the methodological models that are shown in row A – this being a statistical model that contains a statistical interaction term (statistical models B1, B2.1, B3.1 in Figure 1). Note however that a common technique for statistical implementation does not mean that the underlying relationships (methodological models A1, A2, A3 in Figure 1) are equivalent. Rather and to reiterate, the methodological models shown in Figure 1 show distinct conceptual relationships and this is evidenced by the fact that the two methodological models of Moderation (A2 and A3) also have their own unique and distinct techniques by which they can be statistically implemented (respectively labelled B2.2 and B3.2 in Figure 1). In addition, we conjecture that the methodological models of Moderation and Interaction may continue to be conflated with one another because the word “Interaction” is also used in the shared approach to their statistical implementation.

[Insert Figure 1 here]

Conflations over definitions and statistical implementations aside, the methodological models of Moderation, Interaction, and Mediation have secondary utility for researchers (education-focused or otherwise) because they can be variously combined and extended. Perhaps the two most well-known of these combinations and extensions of Mediation and Moderation are the distinct (yet unfortunately similarly worded) methodological models termed ‘mediated-

Moderation’ and ‘moderated-Mediation’ (see Wu and Zumbo, 2008). However, there exist common educational (as well as social and behavioral) phenomena that these models, their combinations, and their extensions fail to describe. As a result, the modern educational researcher who uses quantitative methods (particularly multivariate models) still lacks a full set of methodological tools. Section 2 describes one of these phenomena, names it, demonstrates its common occurrence in a wide range of educational social and behavioral processes and then describes the means by which it can be statistical implemented. To explain the nature of this phenomena we draw on the work of Masten (2001) who presented an extension to Moderation termed, “risk-activated Moderation” that uniquely describes the functioning of immune system responses and automobile airbags (see Figure 2). However, Masten’s extension to Moderation:

1. Was not generalized as a methodological model (instead being limited to just the substantive body of literature concerned with risks to health);
2. Was not integrated into the existing conceptualizations of Interaction, Moderation, nor their combinations or extensions;
3. Did not include a method by which one could statistically implement this concept.

Our paper addresses all these gaps in knowledge. It also provides an application of the new methodological model of “Airbag Moderation” to the field of Educational Effectiveness Research (Section 4). While Masten’s paper proposed a substantive model about risk-activation, our paper presents a methodological model that is not specific to ‘*risk*’ or to any set of concepts. Our paper does this alongside integrating this new *methodological* model within existing methodological literature, and alongside the novel conceptualization of how this new methodological model may be statistically implemented using both existing statistical methods and a newly proposed technique.

[Insert Figure 2 here]

2. Airbag Moderation

We illustrate the methodological model of Airbag Moderation as shown in Figure 3 and we define this model in the following words, “The relationship between two variables varies as a function of a third – *and this third variable depends upon one of the others*“. Where the relationship between two variables is hypothesized in the terms of statistically independent and dependent variables, then an Airbag Moderator is statistically dependent upon the independent variable, and the relationship between the dependent and independent variables is statistically dependent upon the Airbag Moderator. Note that the dependent variable need not be statistically dependent upon the Airbag Moderator.

[Insert Figure 3 here]

3. Statistical Implementation of Airbag Moderation

Airbag Moderation is a methodological model that can be statistically implemented through the use of several different statistical models, three of which are presented in this paper: 1. via models including a statistical interaction term; 2. via random coefficient modelling; 3. via mixture modelling. Some of these statistical models already exist but have never before been conceptualized as statistical implementations of an underlying methodological model (i.e. models for describing the world – as Airbag Moderation does), nor – logically - have they therefore been conceptualized as presenting different options for statistically implementing the same methodological model (particularly for statistical models including a statistical interaction term and for mixture modelling). Further, the statistical implementation of Airbag Moderation through random coefficient modelling involves the specification of a statistical model that is wholly new (another novelty in this paper). This new random coefficient model

builds on work from Muthén and colleagues (Muthén & Muthén, 1998-2017; Muthén, Muthén, & Asparaouhov, 2015) and is the most accurate/specific means of statistically implementing the relationships hypothesized to exist in Airbag Moderation. In other words, the new statistical model described in this paper (based on random coefficient modelling) provides a one to one correspondence with the methodological model of Airbag Moderation as regards the relationships that are hypothesized to exist (see Figure 3).

Implementation via statistical interaction terms. One method of statistically implementing Airbag Moderation is to do so via the specification of a statistical interaction term within a broader statistical model. Two distinct approaches exist that can be applied for this purpose. The first is to use the “special case” of mediated-Moderation involving only three measures (“special” because mediated-Moderation normally involves four measures) that was proposed by James and Brett (1984) and further described by Preacher, Rucker and Hayes (2007; shown in Figure 4). The reason for the suitability of this model for testing a hypothesis of Airbag Moderation is given by the authors themselves, “...*The path linking X to Y (c’) is moderated by M*” (Preacher, Rucker & Hayes, *ibid*; p.194).

[Insert Figure 4 here]

The mathematical equations describing the statistical model that are shown Figure 4 are given below (Equations 1 and 2). These are drawn from the work of Preacher, Rucker & Hayes (*ibid*, p.196), and therefore similar notation is used here, with lowercase subscripted letters representing constant terms/coefficients (with c' in particular denoting the direct effect of X on Y). X represents an independent variable, Y represents the dependent variable, M represents a Mediator variable, and u and v represent error terms/residuals.

$$M = a_0 + a_1X + u \quad (1)$$

$$Y = b_0 + c'X + (b_1 + b_2)M + v \quad (2)$$

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The statistical implementation of Airbag Moderation via specification of a statistical model featuring a statistical interaction term can also be achieved through the use of, “the Causal Inference Approach to Mediation” (Robins & Greenland, 1992). This is because the causal inference approach to Mediation involves the creation of a statistical model within which is specified a statistical interaction term between an independent variable and a Mediator variable while a third variable depends upon both (see Kenny, 2018; Pearl, 2013). In other words, both the three variable mediated-Moderation model of James and Brett (1984) and the causal inference approach to Mediation of Robins and Greenland (1992) hypothesize the same fundamental measures (letters) and relationships (one-way arrows) that are shown in Figure 4. However, this does not imply that these two approaches are statistically equivalent (e.g. in their assumptions and mathematical formulae); only that, in the context of this paper, both present statistical models that can implement Airbag Moderation. This is akin to the different bivariate correlation tests (Pearson, Spearman, and Kendall) all having the potential to be useful in answering a research question that mentions an association between two variables.

It is also important to note that the statistical model shown in Figure 4 is not equivalent to the illustration of the methodological Airbag Moderation that is shown in Figure 3. As discussed in Section 1, how variables are hypothesized to relate to one another in the abstract is different to how this representation is enacted within subsequent statistical analysis. For example, within Airbag Moderation the dependent variable is not specified to depend upon the Airbag Moderator. This is not the case with either the statistical model of James and Brett (1984) or the approach to Mediation outlined by Robins and Greenland (1992). Finally, the statistical model of James and Brett (1984) is available within the IBM SPSS Process Macro of Hayes (2012) as “Model 74”.

Implementation via random coefficient modelling. Airbag Moderation can also be implemented via the specification of a statistical model featuring a random coefficient (“random coefficient modelling”). This approach is a simple extension of a technique for statistically implementing Moderation that was presented by Muthén, Muthén and Asparaouhov (2015). These authors also provide a practical guide for implementing Moderation via random coefficient modelling within their well-known Mplus software package (see Example 3.9 in Muthén & Muthén, 1998-2017; pp.29-30): First, the regression slope between an independent variable and a dependent variable is conceptualized to vary across sampled units. Second, this variation (commonly treated as non-existent in traditional general linear models though common in hierarchical linear models/multilevel models) is then estimated via the specification of a latent variable often labelled, “s” for the regression slope. Third, this latent variable is then specified as statistically dependent upon a third variable (the Moderating variable). An illustration of this model is shown in Figure 1 (Models B2.2 & B3.2). For readers familiar with multilevel (hierarchical linear) modelling, it is important to note that this specification of a random coefficient describes a latent variable and not a multilevel structure.

The one-to-one correspondence between the methodological model of Moderation (see Figure 1) and its statistical implementation via random coefficient modelling therefore provides the foundation for a technique for the testing hypotheses of Airbag Moderation – and one that is clearly distinct from a statistical model featuring a statistical interaction term. The difference between how Moderation and Airbag Moderation may be implemented via a statistical model featuring a random coefficient mirrors the fundamental difference between Moderation and Airbag Moderation themselves (see Figures 1 & 3). To statistically implement Airbag Moderation via random coefficient modelling requires only that the Airbag

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Moderator be specified as statistically dependent upon the independent variable. This model is shown in Figure 5 alongside its abridged Mplus syntax.

[Insert Figure 5 here]

The mathematical equations describing the statistical model shown in Figure 5 are given below (Equations 3, 4 and 5). For consistency, the same notation is used within these equations as within Equations 1 and 2 except that the subscript i is used to indicate that here, values of variables are specific to individual observations in the random coefficient model. A represents the Airbag Moderator variable, while S denotes the random coefficient. X and Y represent the independent and dependent variables, lowercase subscripted letters represent constants, and u , v , and w represent error/residual terms as before.

$$A_i = a_0 + a_1X_i + u \quad (3)$$

$$S_i = b_0 + b_1A_i + v \quad (4)$$

$$Y_i = c_o + S_iX_i + w \quad (5)$$

Implementation via mixture modelling. A third technique for statistically implementing Airbag Moderation is to use statistical mixture modelling in which latent groups are identified within a heterogeneous population. This use of mixture modelling extends the subgroup comparison method of implementing Moderation in two ways: 1. by facilitating exploration of unknown groups (latent classes); 2. By making group membership dependent upon the independent variable whose effects are considered to vary across the groups. Muthén and Muthén (1998-2017) provide examples of Mixture Models that clearly (though unintentionally) illustrate their appropriateness for statistically implementing Airbag Moderation (compare Figure 6 with Figures 2 & 3).

[Insert Figure 6 here]

4. Substantive Applications of Airbag Moderation

There are many substantive applications to which the new concept of Airbag Moderation may be applied. For example, within educational research Airbag Moderation describes the effect intended through the provision of Free School Meals (FSM) to students from low-income families: reduced differences between students in terms of subsequent educational progress (e.g. Goodchild, Faulks, Swift, Mhesuria, Jethwa & Pearce, 2017). Further, Airbag Moderation also describes the intended function of targeted and specialist interventions within the provision of special education (e.g. Law, Reilly & Snow, 2013): A need is identified and responded to in order to facilitate subsequent attainment, development, and/or wellbeing.

Concerning social and educational policy, Airbag Moderation also describes any instance in which a policy is designed to target a group to facilitate some outcome, particularly an outcome in which a gap between two or more groups is narrowed. For example, Head Start in the USA (e.g. Lee, Zhai, Brooks-Gunn, Han & Waldfogel 2014) and Sure Start Children's Centres in the UK (e.g. Sammons et al., 2015). This application of Airbag Moderation is also relevant to a core purpose of educational effectiveness research: investigating and reducing educational inequalities (Kyriakides & Creemers, 2011).

Within behavioral research and policies that focus more on individual development, Airbag Moderation describes a number of the 'protective' states, traits, and behaviors related to concepts such as resilience, buoyancy, mental hardiness, and grit (e.g. Khine & Areepattamannil, 2016). Furthermore, Airbag Moderation can also describe the conceptual opposite: the functioning of a number of the states, traits, and behaviors that are conceived to conferring vulnerability. For example, attainment (e.g. within health or education) can trigger complacency which in turn moderates the effect of the attainment such that it becomes

a risk factor for subsequent attainment and other outcomes (e.g. Bodla, Bodington, Abraham, Adams & Jaunoo, 2016). These examples also illustrate how Airbag Moderation substantively extends Masten's (2001) "risk-activated Moderation" by differentiating this idea into two new and distinct notions that we term, '*Airbag Protection*' and, '*Airbag Vulnerability*'.

Within behavioral research and policy concerning health, Airbag Moderation describes the functioning of an immune system in response to an infection within the context of health outcomes (Masten, 2001). However, Airbag Moderation also describes other processes including "John Henryism" (e.g. Mujahid, James, Kaplan & Salonen, 2017): That the effects of prolonged stressors on health can be magnified by these stressors triggering coping mechanisms that come with unintended negative side effects. The namesake definition concerns social discrimination (the prolonged stressor) triggering an individual to respond with greater personal effort (the triggered coping mechanism), and a subsequent increased likelihood of these socially discriminated individuals experiencing poorer health in the long term (the unintended side effect).

5. Empirical Example of Airbag Moderation

Background: The core purpose of Sure Start Children's Centres (SSCCs; as a policy, program, and intervention) is to reduce inequalities in child development with a focus on the most disadvantaged families (UK Department for Education, 2013). However, the effectiveness of SSCCs in this regard has proven difficult to establish, partly because their offer is localized to the unique needs of different communities.

Research Question: To what extent is the longer-term use of an SSCC associated with a household's financial disadvantage, and does longer-term use of an SSCC alter the extent to

which household financial disadvantage is associated with the internalizing behaviors of preschoolers?

This question can be articulated more succinctly by using the terminology that has been introduced in the preceding sections of this paper:

Does longer-term use of a SSCC constitute an Airbag Moderator of the relationship shared between household financial disadvantage and the internalizing behaviors of preschoolers?

Methods: Statistical analysis of the data from the prospective longitudinal Evaluation of Children's Centres in England project (ECCE; see Evangelou, 2016; Sammons et al., 2015; Sylva et al., 2015). Ethical approval for the ECCE project was granted by the University of Oxford's Research Ethics Committee. Both SSCCs and sampled families participated following opt-in consent.

Participants. The ECCE study followed 2,608 children (and their families) for two years (2012-2014) as these children aged from mean age 14 months (range: 9 to 18 months; Standard Deviation, SD = 3 months) to mean age 38 months (range: 31 to 44 months; SD = 3 months; see Sammons et al., 2015). All recruited families were registered as a potential user of one of 117 SSCCs at the beginning of the study. Of the 2,608 children (and their families) studied, 2,568 were included in this empirical example due to the ECCE study having successfully collected data from them on "internalizing behaviors" at mean age 38 months and because it is commonly accepted practice to exclude participants (here n=40) who lack data on a dependent variable from inferential statistical analyses (e.g. Von Hippel, 2007).

Measures. Internalizing behaviors (reflecting "mood disorders such as anxiety, fear, and depression"; Montgomery & Maunders, 2015, p.38) in the sampled preschoolers were measured at 38 months via primary caregiver report using the Strengths and Difficulties

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Questionnaire (SDQ; Goodman, 2001; mean = 6.09, SD = 3.37). The total duration that a family used their registered SSCC (in months with breaks in use possible; mean = 20.24 months, SD = 16.31) was measured via retrospective primary caregiver report between the beginning and end of the study at three occasions: At the beginning, at the end, plus when the sampled children were at mean age 22 months. Household financial disadvantage was measured at the beginning of the study via information from a self-report parental questionnaire. Financial disadvantage was represented with a binary variable where: 1 = the “most disadvantaged” (25%) and 0 = the “less disadvantaged” (75%). These categories arose from the results of a two-step cluster analyses performed by the ECCE project which yielded three categories of financial disadvantage: “most” (25%), “least” (27%), and “average” (48%). Within the binary variable used in this paper, the “less disadvantaged” category merged the “least” and “average” categories. For further details of these measures see Sammons et al. (2015).

The two-step cluster analyses performed by the ECCE project featured ten binary measures that recorded a family’s receipt of eight types of financial assistance from the UK State, whether at least one adult in a household was working, and whether a home was rented versus owned/being purchased. The ECCE cluster analyses yielded three categories that distinguished these ten measures: “*Least disadvantaged*” (all families owned or were buying their own homes [no family rented], all had at least one adult in work, none received financial assistance from the State); “*Average disadvantage [for the sample]*” (40% owned or were buying their own homes, all had at least one adult in work, <1% received income support); and “*Most financially disadvantaged*” (83% rented their homes, 81% had no adults in work, 61% received income support). Again, for further of this measure and the analyses that produced it see Sammons et al (2015).

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Inferential Statistical Approach. The three variables in this example were grand mean centered using the statistical software package SPSS (IBM; Version 24) before any further statistical analyses were undertaken. This procedure was carried out to facilitate the convergence of subsequent statistical models as well as to ease the interpretation of results. There were no data missing from the three variables included in this example. All children with data on internalizing behaviors (n=2,568) also had complete data concerning their families' use of the SSCC that they were registered with since the ECCE study began and complete data on their household's level of financial disadvantage. For demonstrative purposes, two statistical models were specified that each implemented the Airbag Moderation in a unique fashion (following Section 3): a statistical model featuring a statistical interaction term (Figure 4) and a statistical model featuring a random coefficient (Figure 5). Both statistical models involved the specification of an aggregated Multilevel Structural Equation Model (MSEM; kids and families nested within registered SSCCs) that used robust maximum likelihood within the statistical software package Mplus Version 7.4 (Muthén & Muthén, 1998-2017).

The two MSEM models specified to test the hypothesized Airbag Moderation were implemented for their own unique reason. First, statistical models featuring a statistical interaction term are well known to researchers who use statistical analyses. Second, statistical models featuring a random coefficient provide a one-to-one correspondence with the hypothesized methodological model of Airbag Moderation.

Results#1: Figure 7 illustrates the results of the aggregated MSEM featuring the specification of a statistical interaction term between the measures of household financial disadvantage (at mean child age 14 months) and a family's use of their SSCC (between mean child ages 14 and 38 months). No absolute model fit indices were available as this was a saturated statistical model. There was a supplemental statistically significant indirect effect of a

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household experiencing the greatest financial disadvantage (at mean child age 14 months) upon a preschooler's internalizing behaviors at mean child age 38 months ($B = 0.03$ standard deviations; standard error = 0.01; $p = 0.046$). Figure 7 illustrates the route of this statistically significant indirect effect: greater household disadvantage was linked with greater subsequent use of a registered SSCC, and greater use was linked with greater internalizing problems.

[Insert Figure 7 here]

Figure 8 uses a Johnson-Neyman plot (Johnson & Neyman, 1936) to illustrate the extent to which the relationship between greater household financial disadvantage and greater preschooler internalizing behaviors (the relationship being shown on the y-axis of Figure 8) and the statistical dependency of this relationship upon the duration that a family used their registered Children's Centre (variation of duration being shown on the x-axis of Figure 8). The strength of the (positive) relationship between household financial disadvantage and preschooler internalizing behaviors ($B = 0.94$ standard deviations, standard error = 0.13, $p < 0.001$) was smaller in magnitude, on average, for families who had used their registered Children's Centre for a longer period.

[Insert Figure 8 here]

Conclusion#1: Longer term use of a Sure Start Children's Centre (SSCC) significantly reduced the magnitude of the positive relationship between household financial disadvantage and internalizing behaviors in preschoolers. Furthermore, longer term use of an SSCC was also significantly associated with greater household financial disadvantage. As such, longer term use of Sure Start Children's Centres (SSCCs) constituted an Airbag Moderator of the relationship between household financial disadvantage and preschooler internalizing behaviors.

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Moreover, there was also a supplemental yet significant indirect effect of greater household financial disadvantage on greater preschooler internalizing behaviors that was linked to the longer term use of registered SSCCs. This seemingly counter-intuitive result was also observed elsewhere by the ECCE project where it was speculated to be due to the efforts of Children's Centre staff to keep the most disadvantaged families engaged with services for longer periods (see Sammons et al., 2015).

Results#2: Figure 9 illustrates the results of the aggregated MSEM featuring the specification of a random coefficient. No absolute model fit indices were available due to this statistical model estimating a random coefficient.

[Insert Figure 9 here]

Figure 10 provides a scatter plot with superimposed line of best fit to illustrate the extent to which greater household financial disadvantage was associated with greater preschooler internalizing behaviors (on the y-axis) and the statistical dependency of this relationship upon the duration that a family used their registered Sure Start Children's Centre (on the x-axis).

[Insert Figure 10 here]

Conclusion#2: Longer term use of a Sure Start Children's Centre (SSCC) had a negative association with the relationship that was shared between household financial disadvantage and the internalizing behaviors of preschoolers: Longer use significantly lessened the extent to which disadvantage was positively associated with internalizing behaviors. Furthermore, longer term use of an SSCC was also significantly associated with greater household financial disadvantage. As such, longer term use of Sure Start Children's Centres (SSCCs) constituted an Airbag Moderator of the relationship between household financial disadvantage and preschooler internalizing behaviors.

Comparison of results: Although the hypothesized Airbag Moderator was implemented with two statistical models the results that they returned were consistent: Greater household disadvantage was linked with significantly greater use of an SSCC, and greater use lessened the link between disadvantage and internalizing behaviors (compare Figures 8 & 10). Moreover, this conclusion demonstrates the effectiveness of Sure Start Children's Centres as both a UK social/educational policy and as an intervention on the ground.

However, the two statistical models that were used for implementing this Airbag Moderation also differed in that they returned inconsistent additional supplemental results – primarily the indirect effect that was only identified when specifying a statistical interaction effect. This indirect effect was estimated as a consequence of the broader statistical model requiring that a statistical dependency be estimated between the Airbag Moderator and the (statistically) dependent variable – a bivariate relationship that does not feature in the methodological model of Airbag Moderation. The two sets of results provided by this empirical example provide a clear illustration that Airbag Moderation can be statistically implemented in a straightforward manner: either through the application of, or the adaptation of, statistical techniques that already exist.

6. Discussion

This paper presents a new methodological model termed Airbag Moderation: That the relationship between two variables varies as a function of a third, and that this third variable depends upon one of the others. Airbag Moderation builds upon the concept of Moderation (Sections 1 & 2), underlies a wide range of preexisting theories (Section 4), and can be easily implemented via existing statistical models and software packages (Sections 3 & 5). Figure 11 illustrates the newly proposed methodological model of Airbag Moderation alongside the

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three documented methods of statistical implementation (one of which is newly proposed) plus three example substantive applications concerning educational research.

[Insert Figure 11 here]

The new methodological model of Airbag Moderation has a number of implications that variously confirm, expand upon, and at times challenge existing theories within both methodological and substantive fields of research. First, the use of Airbag Moderation rather than Moderation prompts a more accurate conceptualization (and then investigation/evaluation) of a number of policies, practice, behaviors, and interventions across education, social, and behavioral research (as well as research in other fields; e.g. immune system responses, Masten, 2001). Airbag Moderation therefore facilitates new areas for inductive theory building and new opportunities for deductive theory testing. For example, some interventions are intended to target a group (e.g. Head Start and Sure Start) meaning that their success is predicted not just upon an intervention effect (which can be tested via Moderation analysis) but also upon the success of the targeting element alongside the intervention (uniquely tested via Airbag Moderation analyses). Thus Airbag Moderation permits the possibility of new conclusions. Not just when evidence supporting Airbag Moderation is found, but also when evidence is found that does not support this idea, for example, when a significant intervention effect is identified alongside a failed targeting element.

Second, the substantive application of Airbag Moderation to distinguish the new terms *Airbag Protection* and *Airbag Vulnerability* both from each other and from Masten's (2001) "Risk-Activated Moderation" offers a novel conceptualization to researchers who are interested in exploring variation in developmental trajectories. These concepts demonstrate the context specificity of developmental risks: whether a process or an event promotes or

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confers a risk to development can depend entirely upon the moderating processes and/or events that this process or event triggers.

Third and although it may seem contradictory, we agree with those methodologists who state that a variable cannot be a Mediator and a Moderator at the same time (e.g. Jacoby & Sassenberg, 2010). Instead we suggest that a number of these variables might be better conceived of as Airbag Moderators. The example applications provided in Section 4 illustrate variables that might be better conceptualized in this manner, but there are surely others and these need to be both documented and then empirically tested. It is also important to note that Airbag Moderation is not the same as the three-variable Moderated-Mediation that was described by Preacher, Rucker and Hayes (2007). The latter merely provides one of the statistical models that can be used to statistically implement Airbag Moderation, but it is not the only statistical model that can do so, and as shown in Section 5, this statistical model comes with a number of additional obliged statistical pathways that must also be specified and tested (i.e. it does not provide a one-to-one correspondence with Airbag Moderation).

Fourth, a possible alternative name for Airbag Moderation is “Indirect Self-Moderation”. This alternative name builds upon the methodological model of “Self-Moderation” that was presented by Hall and Sammons (2013): that variation in an independent variable can alter how it is related to a dependent variable. This hypothesis describes a variety of commonly observed effects, perhaps the simplest concerning the dosage of drugs and the subsequent impacts on health. An increased dosage of some drugs prompts that drug to demonstrate a substantively different relationship with a health outcome (e.g. dosage-dependent drug toxicity). From this, Airbag Moderation therefore describes a means by which Self-Moderation can occur: An independent variable may moderate its own relationship with a dependent variable by triggering an intermediate Moderator. Note that this is also conceptually opposite to the methodological “conditional indirect effects” that are described

by Preacher, Rucker and Hayes (2007). Using this methodological terminology, Airbag Moderation/Indirect Self-Moderation can also be labelled as an ‘indirect conditional effect’. However, we suggest the term, “Airbag Moderation” be used for these effects as this label does not feature statistical terminology and is inclusive of research in all substantive areas.

Strengths, limitations, and future directions: One of the greatest strengths of this paper is that it bridges existing work from different fields (both substantive and methodological) in order to make novel contributions that are broad in their applicability. In turn, this sets the scene for a broad range of future applications that can extend upon the methodological, substantive, and synergistic elements within this paper. For example, Airbag Moderation sets the scene for researchers to develop further methodological and statistical models concerning Mediation and Moderation.

A second strength of this paper is that the methodological model that it defines and the methods of statistical implementation that it describes are both well-grounded in prior papers. This has the potential to facilitate uptake by researchers that is both faster and more comprehensive than a methodological model that is developed and/or statistically implemented from scratch. As such, the barriers to the uptake for Airbag Moderation by researchers are minimal should they both see a substantive application and be versed in the existing statistical models for implementing Moderation.

However, this paper is also limited in that it constitutes only a first step towards a complete documentation of the new concept of Airbag Moderation. More research is needed that continues to integrate and extend the disparate methodological and substantive bodies of literature that discuss the foundational concept of Moderation. In particular, more methodological work is needed including sensitivity analyses and extensions of Airbag Moderation into both multinomial and multilevel frameworks following papers such as

Preacher, Zhang and Zyphur (2016). Additional papers are also needed that re-hypothesize and re-test a wide variety of relationships that are currently hypothesized and tested as instances of Moderation. In particular, it seems insufficient (and therefore arguably inappropriate) for interventions and policies that feature targeting to be conceptualized as instances of Moderation; this because Moderation excludes the effect of the targeting that is accounted for within Airbag Moderation.

A second limitation of this paper concerns the empirical example. No such example can adequately demonstrate the applicability of Airbag Moderation across its full range of potential applications. Neither are the example applications provided across the different substantive fields in Section 4 comprehensive or exhaustive. As a result, there remain both potential applications and potential strengths and weaknesses of Airbag Moderation that only future research can identify.

Conclusions: Airbag Moderation is a new methodological model that challenges the current conceptualization of multiple concepts and processes within educational research as well as social and behavioral research more broadly. For example, Head Start, Sure Start, targeting interventions for students with Special Educational Needs, and the provision of Free School Meals to impoverished students, are all aspects of education that are designed to function as Airbag Moderators. As a tool for researchers who use quantitative methods, Airbag Moderation is also easily implemented via the application of a number of preexisting statistical techniques available within commonly-used software packages.

Declaration of Interest Statement. The authors declare that no financial interest or benefit has arisen from the direct applications of this research.

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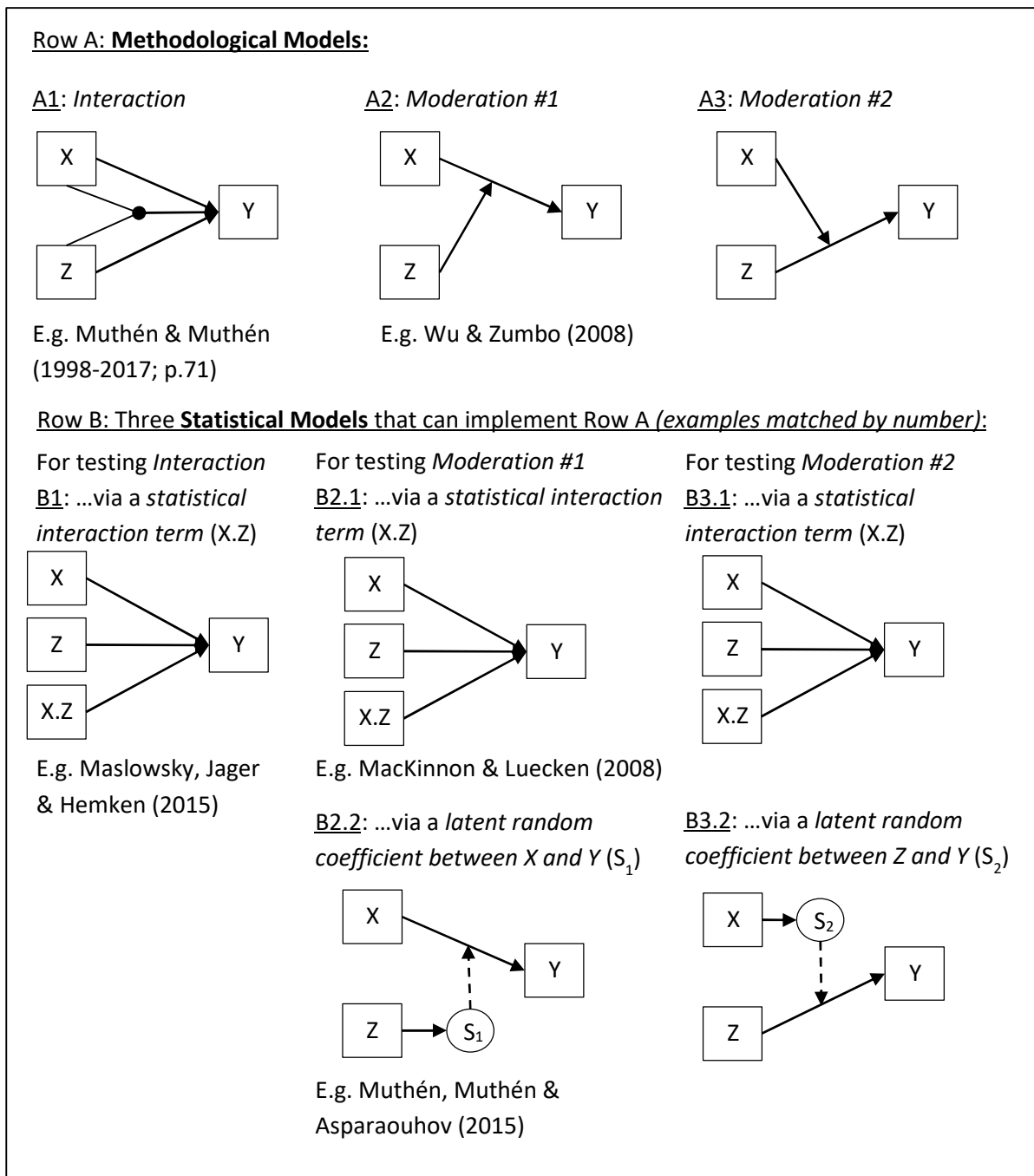
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Figure 1. Distinguishing the methodological models of Interaction and Moderation and illustrating examples of both the common and the unique statistical models that implement these



Note: Towards a comprehensive description, a hypothetical relationship between X and Y would be

Mediated by Z if an arrow pointed from X to Z and another from Z to Y. Likewise, a hypothetical relationship between Z and Y would be Mediated by X if an arrow pointed from Z to X and another from X to Y

Figure 2. “...A risk-activated moderator analogous to an automobile airbag or immune system response.” (Masten, 2001; p.231)

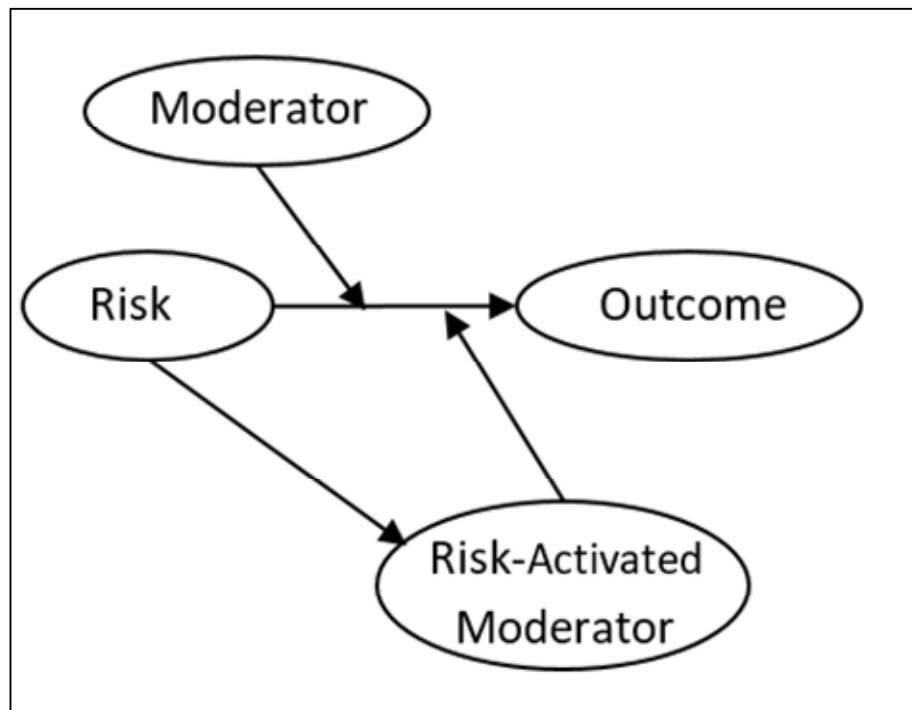


Figure 3. An illustration of the hypothesis of Airbag Moderation

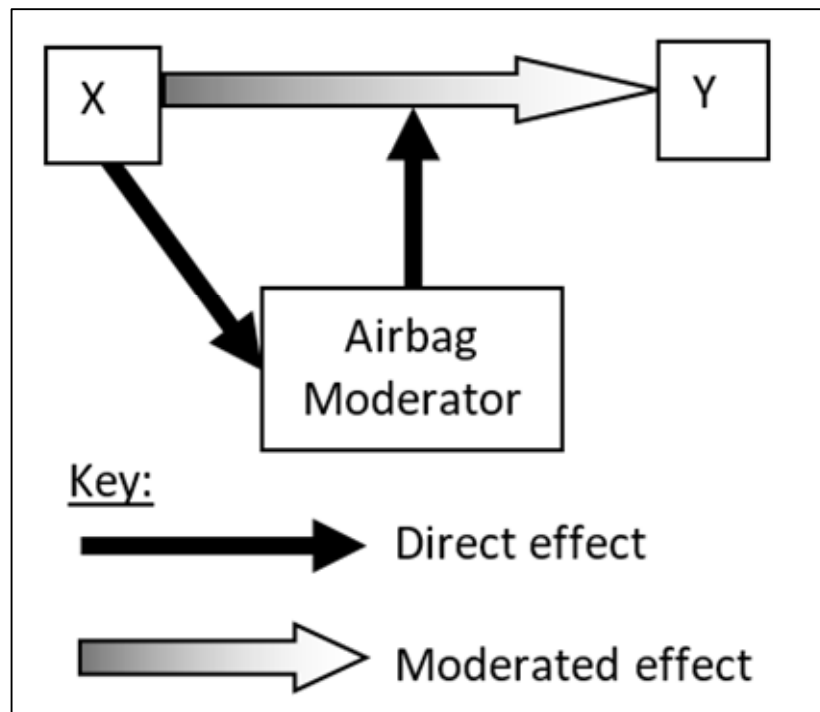
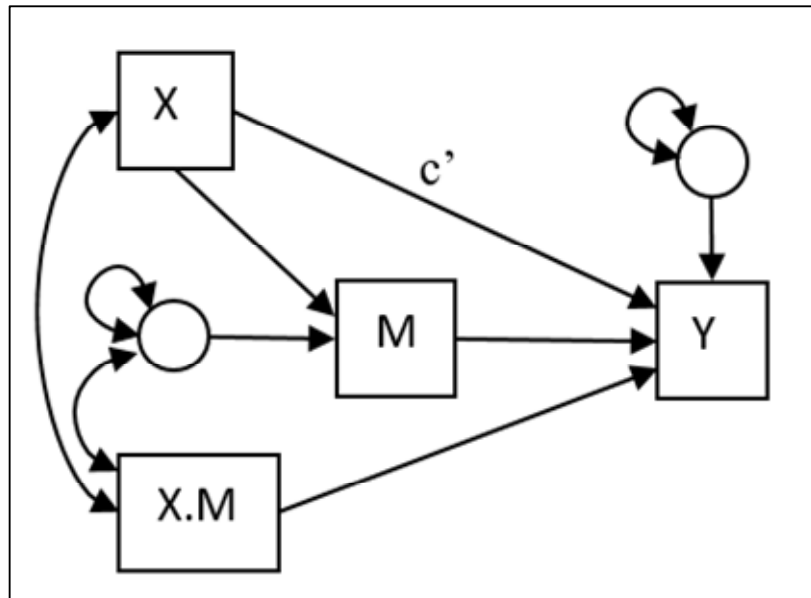


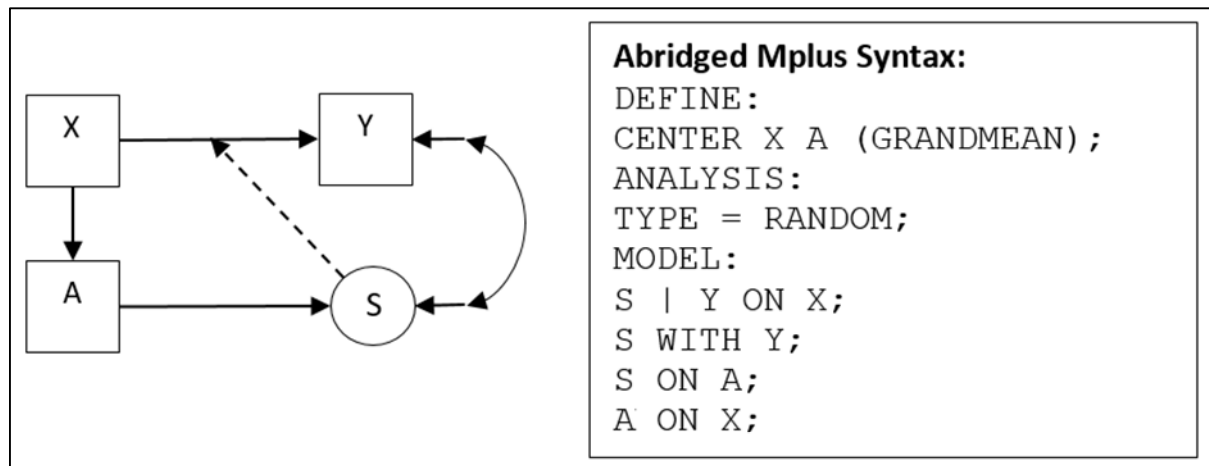
Figure 4. The statistical implementation of Airbag Moderation using a statistical model featuring a statistical interaction term, “...The path linking X to Y (c') is moderated by M ”

(Preacher, Rucker & Hayes, 2007; p.194)



Note: $X.M$ refers to a statistical interaction term between the variables X and M where M is an abbreviation for a Mediator

Figure 5. The statistical implementation of Airbag Moderation using a random coefficient model. An extension of Example 3.9 provided in Muthén and Muthén (1998-2017; pp.29-30) presented with accompanying abridged Mplus syntax



Notes: A= 'Airbag Moderator'; S=the regression 'slope', a latent variable that captures variation in the statistical dependency of Y on X

Figure 6. An statistical mixture model that constitutes an intentional statistical implementation of Airbag Moderation, “*Example 8.17: A continuous-time survival mixture analysis using a cox regression model*” (Muthén & Muthén, 1998-2017; p.259)

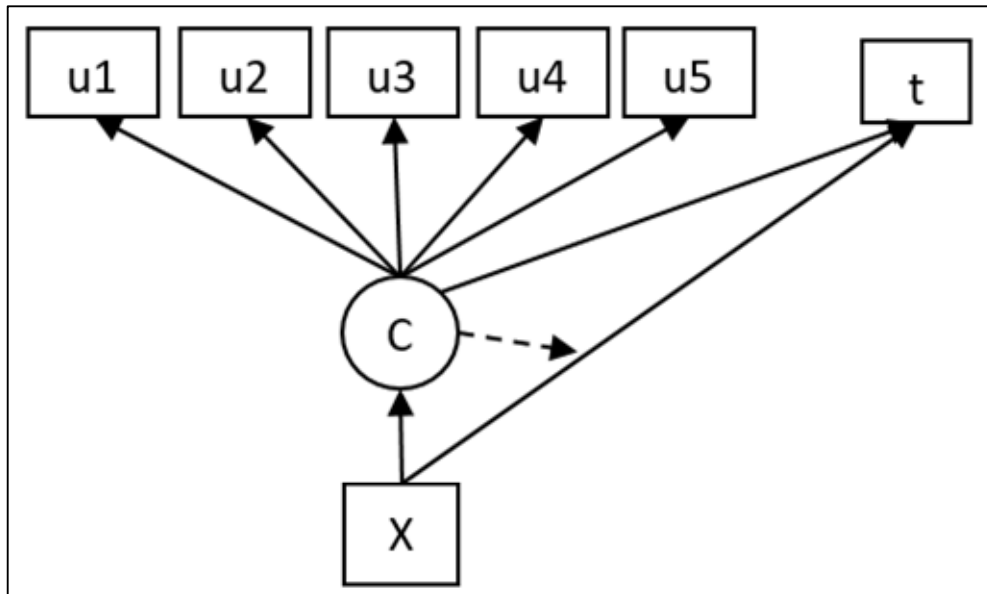
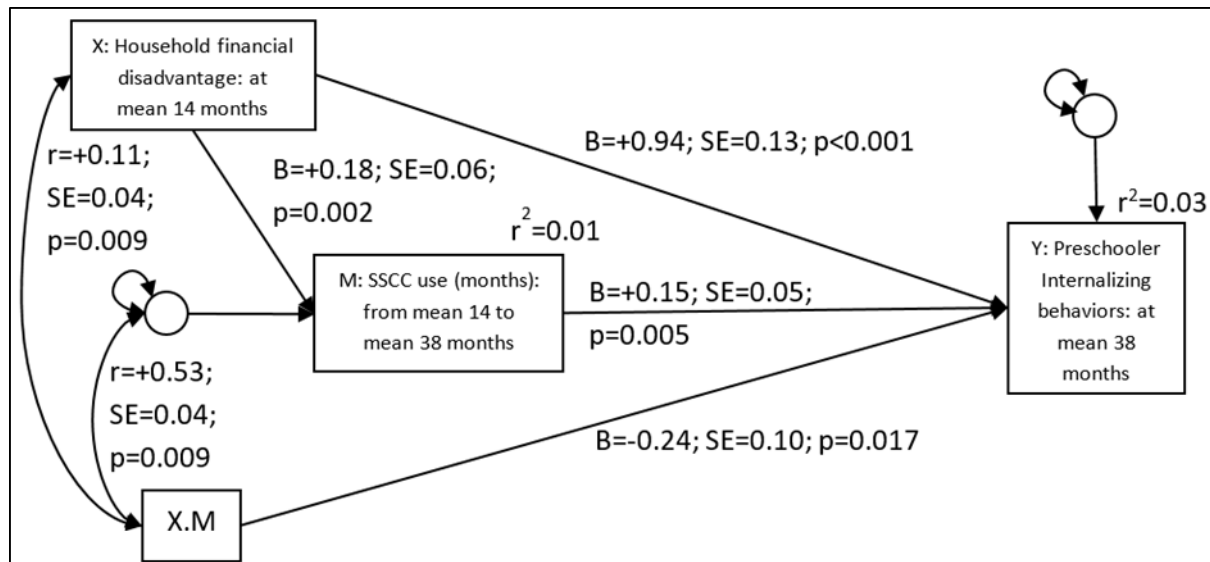


Figure 7. The relationship between household financial disadvantage and preschooler internalizing behaviors: Airbag Moderation by the longer term use of Sure Start Children's Centres. Implementation via the specification of statistical model featuring a statistical interaction term



Notes: *X.M* refers to a (multiplicative) statistical interaction term between the variables *X* and *M*; *B*=Unstandardized Regression Coefficient (Standard Deviations); *r*=Pearson Correlation Coefficient; *SE*=Standard Error; r^2 =total proportion of variance statistically accounted for; SSCC means Sure Start Children's Centre

Figure 8. The statistical interaction between household financial disadvantage and the longer term use of Sure Start Children's Centres upon preschooler internalizing behaviors (Johnson-Neyman plot with 95% confidence intervals)

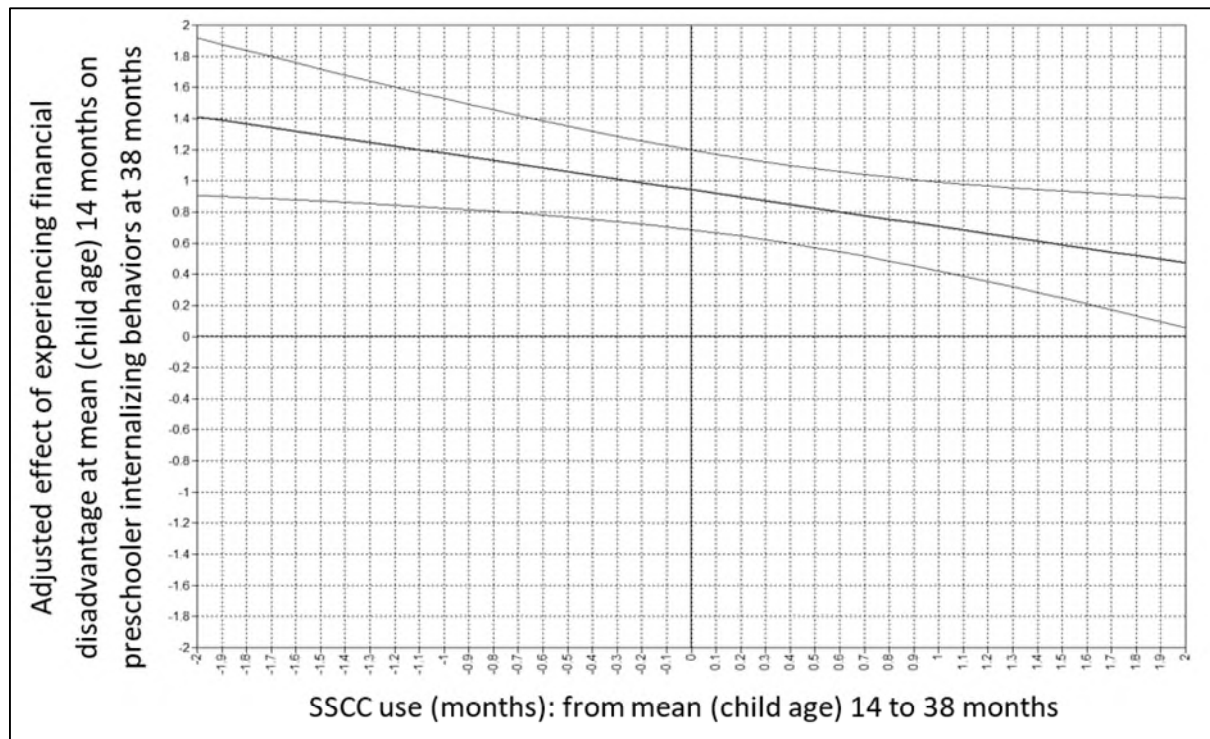
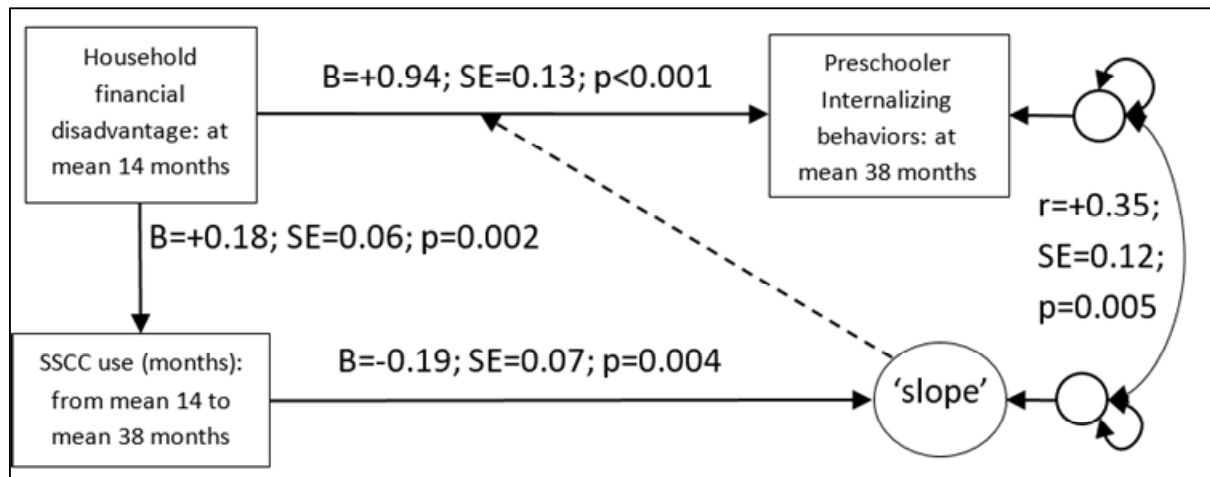


Figure 9. The relationship between household financial disadvantage and preschooler internalizing behaviors: Airbag Moderation by the longer term use of Sure Start Children's Centres. Statistical implementation via the specification of a random coefficient



Notes: B= Unstandardized Regression Coefficient (Standard Deviations); SE=Standard Error; Mplus did not estimate the total proportion of variance accounted for (r^2) for either of the variables statistically dependent upon any other ('slope', internalizing behaviors); SSCC means Sure Start Children's Centre

Figure 10. A scatterplot with a line of best fit illustrating the relationship between household financial disadvantage and preschooler internalizing behaviors (‘slope’) as a statistical function of the longer term use of Sure Start Children’s Centres

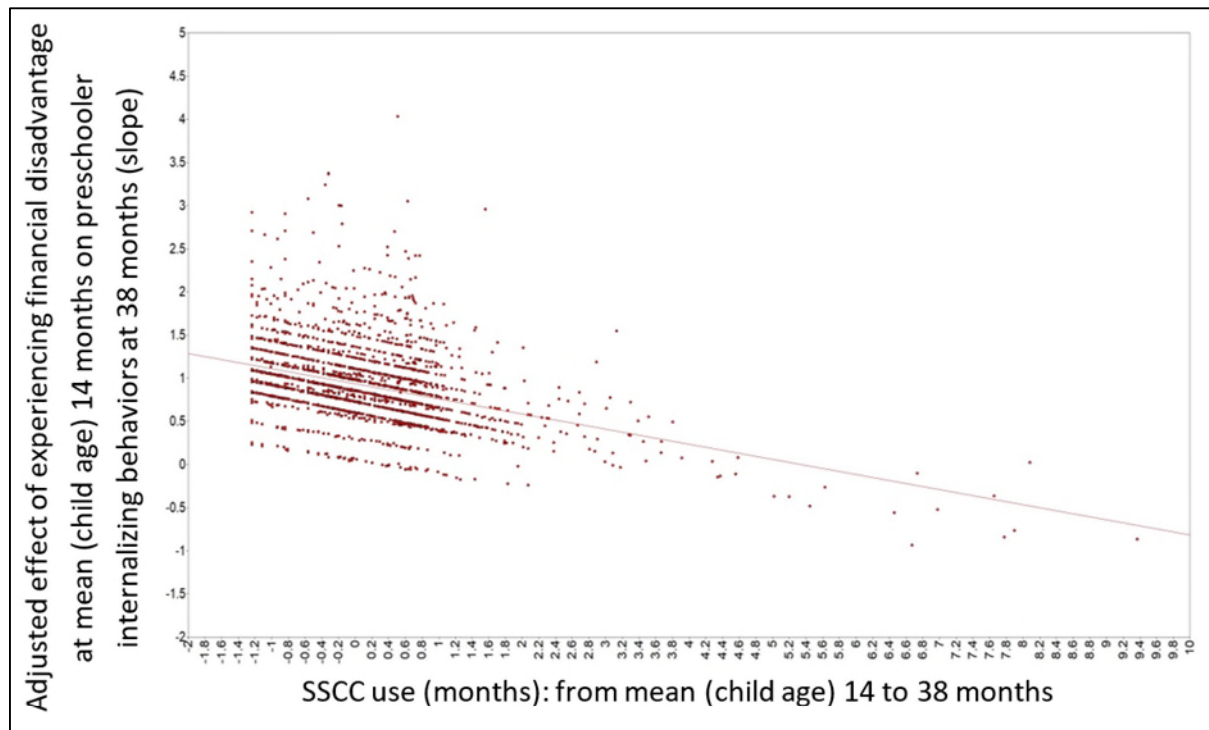


Figure 11. The new Methodological Model of Airbag Moderation, three Statistical Models that can implement Airbag Moderation, and three substantive applications of Airbag Moderation

