CANADIAN SOCIAL SCIENCE
Vol. **6**, No. **3**, **2010**, pp. 01-15

ISSN 1712-8056
www.cscanada.net
www.cscanada.org

The Guttman Approach to Modeling Drug Sequences:

Bridging Literature Gaps

L'APPROCHE GUTTMAN POUR LA MODÉLISATION DE SÉQUENCES DE DROGUE:
COMBLER LES LACUNES DOCUMENTAIRE

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Abstract: In addressing several literature gaps in the drug sequencing literature, this study investigated the sequencing of alcohol, cigarette, and marijuana initiation among a sample of rural American youth, by using age of initiation data to develop a Guttman scale of soft drug involvement. Explicit attention was paid to the role and importance of cigarette initiation in the soft drug sequence and an effort was made to determine whether the scalability of the sequence is impacted by the type of drug measures employed. To attend to these lines of inquiry, two Guttman scales were used to test a modified version of Kandel's (1975, 2002) drug sequencing hypothesis. The first scale utilized age of initiation data, while the second scale was developed with dichotomous initiation measures. Cross-sectional data were derived from a rural sample of American 6th, 9th, and 12th grade students. The type of initiation measures utilized had a direct bearing on scale fit and the degree to which the hypothesis was supported. Indicated are the implications that the findings have for school-based drug prevention programs.
Keywords: Guttman scale; cigarette initiation in the soft drug sequence; Modeling Drug Sequences

Résumé: Afin de combler les lacunes documentaires dans le séquençage de drogue, cette étude a étudié le séquençage de l'alcool, de la cigarette et de l'initiation de marijuana auprès d'un échantillon de jeunes américains en milieu rural, en utilisant des données d'âge d'initiation à développer une échelle de Guttman de l'utilisation de drogue douce. Une attention explicite a été accordée au rôle et à l'importance de l'initiation de cigarette dans la séquence de drogue douce et un effort a été fait afin de déterminer si l'évolutivité de la séquence est affectée par le type de mesures de drogue employé. Afin d'assister à ces lignes de l'enquête, deux échelles de Guttman ont été utilisées à tester une version modifiée de l'hypothèse de séquençage de drogue de

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* Received on March 2, 2010; accepted on May 30, 2010

Kandel (1975, 2002). La première échelle a utilisé les données d'âge d'initiation, tandis que la deuxième échelle a été développée avec des mesures d'initiation dichotomiques. Des données trans-sectionnelles ont été calculées à partir d'un échantillon des étudiants américains ruraux en 6ème, 9ème et 12ème année. Le type de mesures d'initiation utilisées a une incidence directe sur l'ajustement d'échelle et la mesure dans laquelle l'hypothèse a été soutenue. Les résultats utiles pour des programmes de prévention de la toxicomanie dans l'école.

Mots-clés: échelle de Guttman; initiation de cigarette dans la séquence de drogue douce; modélisation de séquences de drogue

The use of psychoactive drugs by people of all ages is an issue that warrants monitoring; however, juvenile drug use should be approached with considerably more concern (Golub & Johnson, 2001). Although a statistically normative behavior, the initiation and use of soft drugs (i.e., alcohol, cigarettes, and marijuana) during adolescence can carry high human costs (DeBellis & Clark, 2000). The human brain, which generally reaches maturity when individuals reach their 20s (Giedd, 2004), still is developing throughout the teen years. Youth who continue drug use not only are exposed to toxic chemicals at a time in which their brains are growing, but they subsequently are exposed for longer periods of time than individuals who initiate use in adulthood, when the brain is fully developed (DeBellis & Clark, 2000). Youth who initiate during childhood or early adolescence, and then develop patterned use, also may contend with homeostasis and drug tolerance at a relatively early age (Brown, Taper, Granholm, & Delis, 2000). These physiological processes taking place in the developing brain subject juveniles to significant risk for drug addiction (see, e.g., Brown et al., 2000; DeBellis & Clark, 2000).

Perhaps one of the major reasons why the health consequences of soft drug use continue to pose a major concern is because alcohol, cigarette, and marijuana use remain three of the most prevalent forms of drug use among youth (Johnston, O'Malley, Bachman, & Schulenberg, 2006). Although soft drug incidence rates have declined in recent years, these downturns are not as large as that observed for other delinquent acts (Johnston et al., 2007). Moreover, current initiation levels are still very high compared to those observed in the early 1990s (Johnston, O'Malley, & Bachman, 1996). Today, as many as 73% of 12th graders have initiated alcohol use, nearly 50% have initiated cigarette use, and slightly more than 40% have initiated marijuana use (Johnston et al., 2007). Recent incident estimates among early adolescents are particularly troubling. Nearly 50% of 13-year-olds who self-report soft drug use indicate initiating these drugs by 12 years of age or younger (Office of Applied Studies [OAS], 2005).

Descriptive data suggest that youth involvement in soft drug use is a fairly stable, sequential, and hierarchical phenomenon. The most common pattern of initiation is alcohol, followed by combined alcohol and cigarette use, and then combined alcohol, cigarette, and marijuana use (OAS, 2005). With respect to the temporal ordering in initiation, descriptive, cross-sectional findings from the 2004 National Survey on Drug Use and Health suggest that among adolescents who initiate all three drugs, alcohol tends to be initiated first by many youth, followed by cigarettes, and then marijuana (OAS, 2005).

KANDEL'S SEQUENCING HYPOTHESIS

The notion of drug involvement as a hierarchical and developmental phenomenon first was recognized by Kandel and colleagues (Kandel, 1975; Single, Kandel & Faust, 1974). Aside from observations of hierarchy, Kandel argued that drug involvement is time-ordered, sequential, and cumulative. Put forth as a drug sequencing hypothesis, one of two major components of stage theory, Kandel (1975, 2002) posited that drug involvement should be viewed as a continuum that is comprised of three discrete stages. Involvement begins with the most socially acceptable drugs, alcohol or cigarettes (Stage 1), proceeds to marijuana use (Stage 2), and finally to illegal, hard drugs (Stage 3), the least socially acceptable

psychoactive drugs. Assuming hierarchy in involvement, Kandel hypothesized that far fewer individuals progress to marijuana use than initiate legal (alcohol or cigarettes) drugs, while even fewer people initiate hard drug use than initiate marijuana use.

SEQUENCING RESEARCH

In an effort to evaluate the degree of empirical support for Kandel's drug sequencing hypothesis, numerous bibliographic scans and a search of several computer databases were conducted. A total of 30 prior studies based on US samples were identified and reviewed, all which examined sequencing in marijuana initiation and the initiation of at least one legal drug. This review brought four major issues to the forefront.

First, there is considerable longitudinal, prospective (see, e.g. Andrews, Hops, Ary, Lichtenstein, & Tildesley, 1991; Ellickson, Hays, & Bell, 1992; Hawkins, Hill, Guo, & Battin-Pearson, 2002) and cross-sectional, retrospective (see, e.g. Costello, Erkanli, Federman, & Angold, 1999; Federman, Costello, Angold, Farmer, & Erkanli, 1997) evidence to suggest that among American adolescents, involvement in drug use is a time-ordered, cumulative, and hierarchical phenomenon. In fact, roughly 85% of the studies (26/30) reviewed produced findings supportive of the ordering and cumulative and hierarchical features of drug initiation that Kandel proposed. Across these 26 studies, less than 2% of the samples from which findings were derived initiated marijuana or hard drugs prior to the initiation of legal drug use.

Second, some empirical ambiguity exists with respect to the role and importance of cigarette initiation. Of the 30 studies reviewed, 10 did not examine cigarette initiation separately from alcohol initiation (see, e.g. Brook, 1993; Brook, Whiteman, & Gordon, 1983; Fleming, Leventhal, Glynn, & Ershler, 1989; Golub, Labouvie, & Johnson, 2000; Golub & Johnson, 2001, 2002; Gfroerer, Wu, & Penne, 2002; Guerra, Romano, Samuels, & Kass, 2000; Mills & Noyes, 1984; Single et al., 1974), while several studies (e.g., Donovan & Jessor, 1983; Martin, Kaczynski, Maisto, & Tarter, 1996; White, Johnson, & Horowitz, 1986) did not even investigate the role of cigarette initiation. Comparatively, findings from two cross-sectional studies suggest that cigarette initiation does not constitute a distinct stage in Kandel's drug sequence (Gould, Berberian, Kasl, Thompson, & Kleber, 1977; Huba, Wingard, & Bentler, 1981). In contrast, four longitudinal, prospective (Andrews et al., 1991; Ellickson et al., 1992; Hawkins et al., 2002; Kandel, 1975) and three cross-sectional (Costello et al., 1999; Federman et al., 1997; Yu & Williford, 1992) studies revealed that alcohol initiation does occur prior to cigarette initiation for most adolescents who initiate legal drug use.

Third, over two-thirds of the studies (n = 21) used some form of Guttman scalogram analysis to investigate sequences in drug involvement. Of the 17 studies that used traditional Guttman scaling techniques, only eight (Andrews et al., 1991; Brook et al., 1983; Fleming et al., 1989; Gould et al., 1977; Huba et al., 1981; Single et al., 1974; Welte & Barnes, 1985; White et al., 1986) reported coefficients of reproducibility and scalability. Detailed below, a proper Guttman investigation of a given drug sequence necessitates that both the predictability and scalability of the sequence be calculated and reported, since these are the standards by which the degree of empirical support for a given sequence is evaluated (McIver & Carmines, 1982; Menzel, 1953).

The final theme deals with the type of drug initiation data that the majority of prior Guttman tests employed. A Guttman scale, in and of itself, infers, but does not ensure, that temporal ordering in the initiation of multiple drugs exists (Menzel, 1953; Single et al., 1974; Kandel, 1980). Given that the element of time clearly is evident in Kandel's (1975) sequencing proposition, with Stage 1 drugs initiated prior in time to marijuana, a proper Guttman test of drug sequencing requires that some type of time data be incorporated into analyses.

Although utilizing prospective drug data in Guttman scaling constitutes the optimal approach to ensuring that temporal ordering is established, cross-sectional research can make a contribution to the knowledge base. In particular, cross-sectional studies should use drug data that is based upon a measure

of time. Typically studies employing this method ask respondents to recall the age (or calendar year) that each type of drug was initiated. Of the 14 cross-sectional studies that yielded full support for Kandel's proposition using Guttman scaling, only two (Gould et al., 1977; Kandel & Yamaguchi, 2002) ensured temporal ordering, by incorporating age of initiation into respective sequencing models. The third cross-sectional test (Kandel & Yamaguchi, 1993) that used age of initiation data produced mixed findings, while the remaining Guttman scale tests used dichotomous (i.e., initiation and abstention) data, thereby failing to verify temporal ordering. Unfortunately, a dichotomous coding scheme does not provide a way to identify and organize affirmative responses according to the temporal order in which drugs were initiated. For example, in a typical Guttman scale developed with dichotomous response data, a scale score of 2 should mean that the respondent initiated the first and second stage drugs, but not the third stage drug (i.e., 1-1-0). As is clear, this scale score does not reveal which drug was initiated first, the first or second stage drug.

PURPOSE OF THE RESEARCH

In addressing the major literature gaps detailed above, the cross-sectional study aimed to investigate the sequencing of alcohol, cigarette, and marijuana initiation among youth, by using age of initiation data to develop a Guttman scale of soft drug involvement. The role and importance of cigarette initiation also was assessed. One basic research question (and attendant corollary) guided the research: *Is involvement in soft drug use a sequential and hierarchical phenomenon? If it is, what is the typical sequence?* Drawing upon findings from the literature review, this research question was addressed by testing a modified version of Kandel's (1975) drug sequencing hypothesis. Expressed as Hypothesis 1 (H1), this proposition took the following form: Among youth who initiate soft drug use, the most common hierarchical and cumulative pattern of initiation is one in which alcohol initiation occurs prior to cigarette initiation, and cigarette initiation occurs prior to marijuana initiation.

Given that the bulk of previous cross-sectional Guttman tests of Kandel's hypothesis used dichotomous initiation measures to model sequences, without accounting for the temporal ordering in initiation, it was surprising to find that no prior research had examined the degree to which different drug measures impact the fit of a Guttman scale. Although exploratory in nature, the study also addressed this research line, by comparing the relative fit of two Guttman scales. For the first scale, H1 was tested with age of initiation data. For the second scale, H1 was tested with dichotomous initiation data. This research avenue has never been taken up before, so it was expected that this comparison would be informative, regardless of the findings.

METHODS

Data Source and Sample

The secondary cross-sectional data used in testing H1 were derived from a school district-wide sample of 6th, 9th, and 12th grade students who completed the Primary Prevention Awareness, Attitude, and Use Survey (PPAAUS) in the spring of 2004. Funded by the Safe and Drug-Free Schools and Communities Act (J.S. White Surveys, 2004), the PPAAUS is a 98-item, machine-readable questionnaire designed to monitor the prevalence and extent of prosocial and antisocial behaviors and attitudes. Administered to 6th, 9th, and 12th grade students on a triennial basis since 1995 (J.S. White Surveys, 2004), the development of the PPAAUS was informed by the Communities that Care ® Youth Survey (Arthur, Hawkins, Pollard, Catalano, & Baglioni, 2002).

The school district is located in a northeastern American college town that serves a population of approximately 32,000 persons. The public school system from which the data were collected serves rural youth from two boroughs and two surrounding rural townships. Sixth grade students attend one of four elementary schools, 9th grade students attend one junior high school, and 12th grade students attend one senior high school. Although two private schools located within the school district provide

kindergarten-6th grade education, relatively few children attend these schools (230 total youth in 2006), as the majority of youth are enrolled in the public school system (City-Data.com, 2009). Compared to 33% nationally, roughly 25% of youth who attend schools within the district are eligible for free or reduced lunches (Pennsylvania Department of Education, 2007). The county school drop-out rate has been low in recent years (1.2%), with the majority of 2006 high school graduates (80%) self-reporting plans to continue some form of post-secondary education (The United Way of Pennsylvania [UWP], 2006).

After student participation was gained through a passive consent procedure, the 2004 PPAAUS was administered in standard classroom settings, with students marking their responses directly on the questionnaires. To guarantee confidentiality and response anonymity, students were instructed not to include any identifying information on their surveys. Teachers were provided written instructions and a script, as well as envelopes for survey collection. In each classroom, a student was delegated to collect the completed questionnaires, place them in an envelope, and take them to a designated collection area within respective schools (J. S. White Surveys, 2004).

J. S. White Surveys, an independent research company, was responsible for scanning, maintaining, and initially analyzing 2004 PPAAUS data for the school district (J. S. White Surveys, 2004). Before the data set was created, J. S. White Surveys employed a questionable response (QR) filtering technique, in an effort to identify inconsistent and questionable survey responses and generally ensure the quality of students' responses. As a result of QR filtering, survey data from 13 of the 766 students who completed the 2004 PPAAUS were excluded from the data set. Considering school district enrollment numbers (Hruska, 2004a, 2004b) in conjunction with the 753 6th, 9th, and 12th grade students who comprised the total sample, the 2004 PPAAUS response rate for 6th, 9th, and 12th grade students (after QR filtering) was 97%, 83%, and 84%, respectively. The total response rate (after QR filtering) was 88%.

The bulk of the total sample (N = 753) was white (86%) and fairly evenly distributed across gender (52% male), grade-level, and stage of adolescent development. Each of the three school grades constituted roughly one-third of the total sample (6^{th} grade, n = 281; 9^{th} grade,

n = 238; 12^{th} grade, n = 234). Students ranged in age from 11-19 years, with 11-13 year olds, 14-16 year olds, and 17-19 year olds each comprising about one-third of the sample (37%, 32%, and 31%, respectively).

Following the lead of other researchers (see Ellickson et al., 1992; Yamaguchi & Kandel, 1984), excluded from the study were students with missing data for one or more of the age of initiation measures, and students who provided the same age of initiation of all three soft drugs. Roughly 95% (n = 713) of the total sample provided useable data for the H1 tests. In particular, the sample size used in testing H1 consisted of 713 6^{th} (n = 273), 9^{th} (n = 226), and 12^{th} (n = 214) grade students. Of the 5% of cases excluded from analyses, 19 respondents had missing data for one or more of the survey items used in generating the age of initiation data, while 21 students self-reported three-way drug ties.

Measures

H1 was tested using two types of drug initiation data. First, H1 was tested with *age of initiation* data for alcohol, cigarette, and marijuana use. These data were derived from an item posed in the 2004 PPAAUS, which stated: "If you have ever used alcohol, cigarettes, or marijuana, mark the age at which you first used it." Aside from "never used," students could notate an age ranging from 8-18 years for each of the three drugs.

Second, in testing H1 with dichotomous initiation data, a dichotomous variable, *initiation*, was developed for each drug. In order to obtain these variables, age of initiation for alcohol, cigarettes, and marijuana were recoded into three distinct variables. The same survey items used to operationalize age of initiation were used in developing these measures. Students who notated an age of initiation for a given drug were ascribed a "1" (initiation) for that particular drug, or a "0' (abstention) if they notated that they "never used."

Analytic Strategy

H1 was tested through the use of Guttman scalogram analysis (a.k.a., Guttman scaling). The overarching purpose of this analytic technique is to determine whether scale items (e.g., individual types of drugs) capture progressively higher levels of a unidimensional, latent construct (Guttman, 1950). Since a latent variable cannot be directly observed, scale items constitute both manifest indicators and varying levels of its existence (McIver & Carmines, 1982). Hence, the latent construct, soft drug involvement, is viewed as a continuum.

In order to understand just how well-suited Guttman scaling is for testing H1, it is helpful to be familiar with two of its' underlying assumptions (unidimensionality and hierarchy). First, a Guttman scale assumes that scale items (together) represent a single dimension of a latent construct (McIver & Carmines, 1982). The degree to which a latent variable exists is evidenced by the scale's ability to accurately predict responses to all of its component items.

Second, scale items are assumed to differ from each other in magnitude. Referred to as the assumption of hierarchy, this difference in extremeness is based on the notion that individuals are not evenly distributed across the latent continuum. Given the increase in extremeness, progression from one stage to another is experienced by successively smaller numbers of individuals.

Coding Procedures

Age of initiation. To identify the temporal ordering in initiation, the age of initiation data were coded such that both the number of drugs and order of initiation were taken into account. Any student who reported abstention from a given drug was coded as "0" for that given drug. Hence, all soft drug abstainers had the same response pattern (0-0-0). Among respondents who notated an age of initiation for one, two, or three soft drugs, the ages at which these drugs were initiated were taken into account in coding their response patterns. A "1" was used to signify the drug that was initiated first, a "2" to signify the drug that was initiated second, and a "3" to signify the drug that was initiated third.

When ages of drug initiation are reported, ties in respective ages can occur, whereby two or more drugs are reported as having been initiated at the same age. Following common convention (see Golub & Johnson, 2001, 2002; Yamaguchi & Kandel, 1984), proportional probabilities were used to break two-way ties (e.g., alcohol and cigarette initiation at 15 years of age) and code temporal ordering accordingly. In particular, the proportion of respondents initiating each soft drug was calculated first without using data from cases with ties for those given drugs (e.g., 70% of untied respondents initiated alcohol use first versus 40% of untied respondents who initiated cigarette use first). These resultant proportions then were used to estimate the order of initiation for those respondents with two-way ties.

Dichotomous initiation. The traditional dichotomous coding scheme was employed in scaling the dichotomous initiation data. This procedure merely accounted for the initiation of each soft drug, and did not further distinguish initiation patterns in terms of temporal ordering. When this coding procedure is used, a student's score should indicate two things: position in the scale, which is indicative of the last stage of soft drug involvement that was reached, and how many and what types of soft drugs were initiated. For example, a student's scale score of "2" should mean that the student responded affirmatively to initiating alcohol and cigarettes (i.e., 1-1-0).

Scale Development and Analyses

Both Guttman scales were developed and analyzed manually, since versions of the data analysis software, Statistical Package for the Social Sciences (SPSS Incorporated, 2006), have not included the subprogram, GUTTMAN SCALE, since the 1990s. Three major steps were taken to develop each respective scale. For the sake of brevity, and since most prior Guttman scale tests utilized dichotomous data, what follows are the three major steps taken to develop the age of initiation scale.

A Guttman scalogram response matrix first was developed in Microsoft Office Excel (Microsoft Corporation, 2007) to display response patterns for the three drug scale items. Scale scores for each

student were calculated and placed in the last column of the matrix. Regardless of temporal ordering in initiation, a scale score is equal to the sum of all affirmative responses. The proportion of cases who responded affirmatively to initiating each drug then was calculated (McIver & Carmines, 1982). These scale item proportions were used to break any two-way ties in the temporal ordering of soft drug initiation. After these ties are broken, and all cases had a response pattern that reflected temporal ordering, these proportions were recalculated with all cases and listed as marginal statistics at the end of each drug item column (Golub & Johnson, 2001). Both scale items and cases were then arranged in order of magnitude, resulting in a hierarchical pattern of responses that resemble a triangle (McIver & Carmines, 1982). Rearranging both drug items and cases in this manner aided in identifying and counting errors.

After these three steps were taken, errors in the age of initiation Guttman scale were identified and counted. To identify errors, scale scores were referred to in drawing a horizontal line within each scale item column to constitute the cut-point between one-point differences in scale scores (Champion, 2000). An error constitutes a response that lies above or below a given horizontal line and counters the hypothesized response (Champion, 2000). For the marijuana initiation scale item, for example, all responses above and below the horizontal line should be "3" and "0," respectively. Hence, errors for this scale item constituted any number other than "3" found above the line and any number other than "0" found below the horizontal line.

Evaluating scale fit. Errors violate the assumption of cumulation; however, violating this assumption is expected, since rarely is a perfect Guttman scale obtained (DeVellis, 2003). Two indices are used in evaluating how much deviation from a perfect scale is tolerable: the index of reproducibility and the index of scalability. The index of scale reproducibility is an estimate of the goodness of fit between observed responses patterns and the hypothesized response pattern. This index, which results in a coefficient of reproducibility (CR), indicates how well one can reproduce (or predict) a student's scale item responses given only knowledge of the student's scale score (McIver & Carmines, 1982). The formula for the CR is expressed as: $CR = 1.0 - (E)/TR$ where, E = total response errors; TR = total responses or ([# items] X [# responses]).

With CR ranging from 0-1, a $CR \geq .90$ constitutes the minimum standard of acceptability (Guttman, 1950). A CR of .90 means that not only can one predict with 90% accuracy the scale item responses of a given student simply by knowing that student's scale score, but the hypothesized sequence of scale items also can be predicted with 90% accuracy given knowledge of students' scale scores.

The CR is a necessary, but insufficient, benchmark for determining scalability, because scale reproducibility can be impacted by the marginal distributions of scale items (Guttman, 1950). The index of scalability, which produces a coefficient of scalability (CS), provides a "check" against an inflated CR (Menzel, 1953). Instead of taking into account scale scores, the CS reflects the degree to which responses to scale items can be predicted given only knowledge of the marginal frequencies of the scale item responses. Ranging from 0 to 1, an indicator of scalability is $CS \geq .60$. A CS of .60 means that 60% of the total possible errors actually are not errors, but are responses consistent with those that are hypothesized (Menzel, 1953). According to Brown and Hudson (2002), the CS is expressed as: $CS = PI/1\text{-}MMR$ where, PI = percentage improvement, or CR-MMR; MMR = minimal marginal reproducibility, or $\sum p$ (or q, whichever is larger)/k, with p = % initiates for each scale item, q = % abstainers for each scale item, k = # scale items.

RESULTS

Sample Descriptives

Of the 713 youth who provided useable data for the study, 16% (n = 115) reported two-way drug initiation ties. Specifically, 8% (n = 57), 4% (n = 28), and 4% (n = 30) reported the same age for alcohol and cigarettes, cigarettes and marijuana, and alcohol and marijuana initiation, respectively. To break these two-way ties, the proportion of cases initiating each soft drug was calculated using the temporal

initiation data from the untied cases. Among untied cases (n = 598), 30% (n = 180), 12% (n = 71), and 0.16% (n = 1) indicated first initiating alcohol, cigarettes, and marijuana, respectively. Taking these initiation proportions into account, students who reported alcohol-cigarette ties were estimated to have had initiated alcohol first. Youth who had cigarette-marijuana ties were noted as having had initiated cigarettes first, and students who reported alcohol-marijuana ties were deemed as having initiated alcohol first.

With these two-ties broken, the sample can be described as follows. Roughly 48% (n = 344) were complete abstainers, having indicated abstention from all three soft drugs, while slightly more than half of the sample (n = 369) initiated at least one soft drug. Among the soft drug initiates, 96% (n = 354), 63% (n = 231), and 36% (n = 131) reported alcohol, cigarette, and marijuana initiation, respectively.

Age of Initiation Findings

Table 1 presents the soft drug sequencing behavior among the 369 students who reported initiating one or more soft drugs. These sequences take into account the temporal ordering of initiation. The majority of the soft drug initiates were polydrug initiates. Specifically, no soft drug initiates reported marijuana initiation only, 3.3% (n = 12) of initiates indicated cigarette initiation only, and 36% (n = 131) of initiates only started alcohol use.

Table 1: ***Temporal Ordering in Soft Drug Sequences***

Observed Sequences [a]	n	% of Soft Drug Initiates (n = 369)	% of Sample (N = 713)
Began with Alcohol Initiation	272	.737	.381
A → C → M	62	.168	.087
A → C	62	.168	.087
Alcohol only	131	.355	.184
A → M	7	.018	.010
Began with Cigarette Initiation	96	.260	.135
C → A → M	36	.097	.050
C → A	31	.084	.043
Cigarettes only	12	.033	.017
C → M → A	14	.038	.019
C → M	3	.008	.004
Began with Marijuana Initiation	1	.002	.001
M → A → C	1	.002	.001

[a] A = alcohol initiation; C = cigarette initiation; M = marijuana initiation

The soft drug initiation sequence outlined in H1 was supported, from a percentage frequency perspective. As illustrated in Figure 1, the hypothesized sequence was found to be the most common, with transitions in the sequence (i.e., cumulation in drug initiation) experienced by successively smaller numbers of students. Taking into account the temporal ordering of initiation, the majority (74%) of soft drug initiates began soft drug use with alcohol. Comparatively, only 26% of initiates began soft drug use with cigarettes, while one student reported initiating marijuana first.

The second drug most commonly initiated was cigarettes. Among those who initiated two or three soft drugs (n = 226), 55% (n = 124) initiated cigarettes second, compared to 30% (n = 67) and 15% (n = 34) who initiated alcohol and marijuana use second, respectively. With respect to the hypothesized soft drug initiation sequence, among the 141 alcohol initiates who initiated a second drug, 88% (n = 124) initiated cigarette use. Finally, a total of 123 students (17.3% of the sample) initiated all three soft drugs. Of these polydrug initiates, 80% (n = 98) initiated marijuana last, with roughly 63% (n = 62) of these students exhibiting the soft drug initiation sequence outlined in H1.

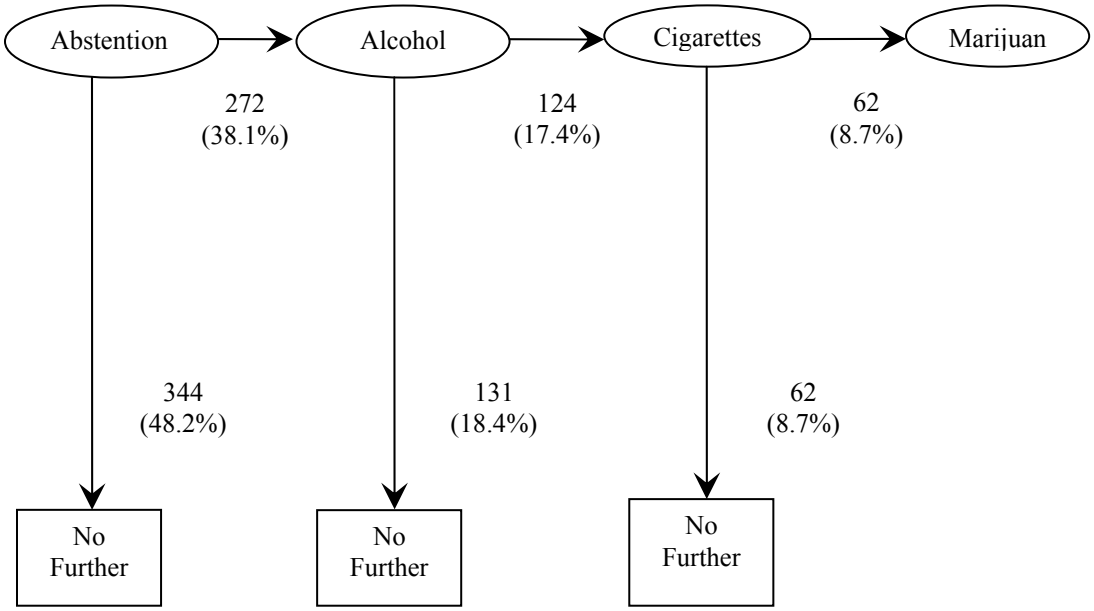

Figure 1: This transition diagram depicts H1, the most common soft drug initiation sequence found in the data (n = 713).

Although H1 was the most commonly supported sequence from a percentage frequency perspective, a proper test of H1 required that the CR and CS be calculated. With knowledge of the total number of errors (246), the number of scale items (3), and the number of cases (713), a CR value of .89 was produced. Falling just shy of the minimal acceptability benchmark offered by Guttman (1950), this value means that not only can one predict with 89% accuracy the scale item responses of a given student simply by knowing that student's scale score, but the H1 sequence also can be predicted with 89% accuracy given knowledge of students' scale scores. In determining the scalability of the H1 sequence, a CS value of .66 was produced. This value exceeds the minimal scalability benchmark suggested by Menzel (1953), thereby providing evidence that the soft drug scale items are scalable. This coefficient means that 66% of the total possible errors actually were not errors, but were responses consistent with those hypothesized.

Excluding two-way ties. Although the most common initiation sequence identified in the data was consistent with H1, the CR fell slightly short of the threshold for minimal acceptability. Given this finding, as well as the fact that more errors were identified in the cigarette scale item than in the alcohol

or marijuana scale items, it became evident that the two-way tie breaks for alcohol-cigarette initiation may have artificially inflated the number of alcohol initiates, thereby providing inflated support for H1.

To assess the internal validity of the H1 age of initiation findings, attention was directed at determining whether the CR would improve if the cases with two-way drug ties were excluded from the analysis. To assess this, a second Guttman scale based upon age of soft drug initiation data was developed and analyzed. For this particular scale, Guttman scalogram analysis was employed using data from 598 of the original 713 students whose drug initiation data were used in testing H1. All soft drug initiates among these 598 students provided discrete ages of initiation. Taking into account the temporal ordering of soft drug initiation for those students who reported initiation, a total of 174 errors were identified. Considering these errors, the number of scale items (3), as well as the number of cases (598), a CR of .90 was produced. While this value meets the minimal acceptability benchmark for the CR, the .58 value for CS did not quite meet the minimal scalability benchmark. Importantly, these particular findings indicate that whether the two-way drug ties were included or excluded had no considerable bearing on the accuracy of the Guttman scale fit.

Dichotomous Initiation Findings

In order to determine whether the type of soft drug data utilized has a direct bearing on the fit of the H1 soft drug sequence, the second Guttman test took advantage of dichotomous initiation data. The same cases (N = 713) that were used to develop the first Guttman scale were used in this scale, although, for this particular scale, the use of dichotomous measures precluded the ability to account for temporal ordering in soft drug initiation. A total of 44 errors were identified. Taking into account these errors, the number of scale items (3), and the number of cases (713), a CR of .98 was produced, a value far exceeding the .90 benchmark of minimal acceptability. With a MMR of .664, and a percentage improvement value of .316, a CS of .94 was obtained. This value far exceeds the minimal scalability benchmark of .60. These coefficients indicate that when the dichotomous initiation data were used, not only could one predict with 98% accuracy the scale item responses of a given student simply by knowing that student's scale score, but the initiation sequence outlined in H1 also could be predicted with 98% accuracy given knowledge of students' scale scores. Moreover, 94% of the total possible errors actually were not errors, but were responses consistent with those outlined in H1. Had this been the sole Guttman scale used to test H1, the hypothesis would have been fully supported.

DISCUSSION

In addressing several gaps in the drug sequencing literature, the current research made a number of contributions to the drug sequencing knowledge base, and on several interrelated fronts. Taking together both the descriptive results and the sequencing findings from the Guttman scale tests, general support was yielded for H1. From a descriptive standpoint, more students self-reported the initiation of alcohol use than cigarette or marijuana use, while a larger number of students indicated initiating cigarette use than marijuana use. From a sequencing perspective, evidence of hierarchy and cumulation in the soft drug sequence was obtained. As well, the H1 sequence was found to be generally acceptable in terms of predictability and scalability. Soft drug involvement typically began with alcohol. Among alcohol initiates, cigarettes constituted the second soft drug that was most commonly initiated. Compared to the number of alcohol only initiates, however, the number of alcohol and cigarette initiates was smaller. Finally, a smaller proportion of alcohol and cigarette initiates proceeded to initiate marijuana use. These findings converge with those from four longitudinal studies (Andrews et al., 1991; Ellickson et al., 1992; Hawkins et al., 2002; Kandel, 1975).

Importantly, these findings also revealed that the number of errors that were identified in the H1 sequence varied according to the type of initiation data that was employed. In turn, this difference in error had a direct impact on the both the reproducibility and scalability of the H1 sequence. When the age of initiation data were utilized, the fit of the Guttman scale was nearly acceptable; however, due to a larger number of errors, scale fit was not nearly as strong as that obtained when the dichotomous

initiation data were utilized. Since the temporal ordering inferred by a Guttman scale only implies, but does not necessarily prove, that temporal ordering in the initiation of multiple drugs exists, the age of initiation scale provided a more stringent and valid test of H1. This discrepancy in scale fit has clear methodological implications. The differential scale fit obtained calls into question the use of dichotomous initiation data in developing Guttman-based drug sequencing models. Further, the results underscores the possibility that Kandel's (1975) drug sequence may not fit a valid Guttman scale quite to the extent that it is assumed in the literature.

School-Based Policy Implications

Given that the drug prevention budgets of American public schools have become constrained in recent years (see, e.g., Carnevale Associates, 2006, 2007; Drug Strategies, 1999; Pentz, 1996), it appears reasonable, from both an economic and empirical perspective, that a potentially promising way to prevent or delay adolescent involvement in soft drug use may be to focus the bulk of attention on preventing (or delaying) alcohol initiation. The supportive H1 findings lend credence to this policy proposal.

A number of evaluations of school-based drug prevention programs also support this approach to soft drug prevention, in finding that directing explicit efforts toward preventing or delaying alcohol initiation among youth, particular among early adolescents, can prove beneficial in indirectly working toward preventing (or delaying) cigarette and marijuana initiation (Botvin, Griffin, Diaz, Scheier, Williams, & Epstein, 2000; Hawkins et al., 2002). In directing efforts to prevent alcohol initiation, for example, the comprehensive, school-based drug prevention program, "Life Skills Training," has been shown to reduce alcohol incidence rates among 7th, 8th, and 9th grade students (Botvin, Baker, Renick, Filazzola, & Botvin, 1984), as well as prevent and delay cigarette, marijuana, and hard drug initiation for up to three years later (see, e.g., Botvin, Baker, Dusenbury, Botvin, & Diaz, 1995; Botvin, Baker, Dusenbury, Tortu, & Botvin, 1990; Botvin et al., 2000). Etiological research also suggests that directing prevention efforts toward targeting risk factors for alcohol initiation, particularly during the elementary school years, may be an effective strategy for preventing progression in the soft drug sequence (Hawkins et al., 2002; Kandel, Yamaguchi, & Chen, 1992; Pentz & Li, 2002).

Study Limits and Recommendations

Due to several study limits, the findings should be interpreted with some care. Some threats to the validity of the H1 findings remain plausible, particularly with respect to the age of initiation data. These threats include recall decay, forward telescoping, and lengthy period of recall (particularly among the 12th graders). Importantly, however, the impact that these threats pose were minimized, since students who reported three-ways drug ties were excluded from both hypothesis tests. As well, the findings from the extended Guttman scalogram analysis indicated that excluding cases with two-way drug ties had not considerable bearing on Guttman scale fit.

The inherent limitations of cross-sectional data also are recognized. The convergence in the study's results with those obtained by prior prospective research does appear to bolster, however, the validity of the H1 findings.

Several other recommendations for future research stem from the study. Needing replication is the differential scale fit that was obtained, particularly since the current investigation constituted the first published comparison of drug measurement strategies. While future research should use longitudinal data to replicate the findings reported here, the current study demonstrated that cross-sectional data are not entirely useless. By incorporating a measure of time into scale development, the findings from future cross-sectional, Guttman scale investigations of drug sequencing can more appropriately supplement those yielded from prospective data.

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