Abstract Change in the number of drug users is considered as a form of over-time diffusion within a cohort. The learning mechanisms by which this occurs are conceptualized in terms of differential reinforcement, i.e. positive reinforcement and inhibition. These notions are formalized in a differential equation model, which has the Gompertz equation as a solution. The model is tested with data sets on the age of first use of heroin and marijuana. For cigarette use, the parameters are estimated for synthetic as well as real cohort data. Comparisons are made between these two types of data and it is suggested that the exponential function relates the parameters for real cohorts.

A SOCIAL LEARNING MODEL OF THE FIRST USE OF DRUGS (HEROIN, MARIJUANA, CIGARETTES)[a]

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The major processual theory of deviant behavior grew out of the work of Sutherland (1939, 1947). Burgess and Akers (1966) reformulated the theory and incorporated the learning principles that had been discovered in experimental behavioral science in the preceding years. Akers (1977) later used the differential association-reinforcement theory or, alternatively, the social learning theory as the main, integrating perspective in discussing various kinds of deviant behavior. The formulation of the theory

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in this textbook will be used extensively in the next section.

At the same time mathematical sociologists investigated the phenomena of use diffusion and the adoption of new roles and tried to find mathematical expressions to describe their corresponding trends. Here again, the notions brought forward by learning psychologists were gradually incorporated to explain the underlying processes of diffusion and role adoption.

The indicated convergence of interest in the two lines of sociological inquiry is made explicit in this paper. There are three purposes. First, one of Hamblin's social learning models is derived with concepts from differential association-reinforcement theory. The model is used to describe and interpret the cumulative adoption of roles in cohorts (cf.Hamblin,Koller,Pitcher,1979), and is similar to the one developed by Hernes (1973) to explain the entry into first marriage and the one used by Pitcher (1978) to describe the entry into the parenthood role. The model has also been tested for different types of data (Pitcher,Hamblin,Miller, 1978;Hamblin,Miller,Saxton,1979). The theory is mainly developed to describe the spread of heroin use among peers, but the model is also tested on data relating to the first use of marijuana and cigarettes. Second, differences in fit and parameter estimates are investigated that emerge when the model is tested with synthetic cohort as opposed to real cohort data. The data on heroin and marijuana only allow a period analysis of the model, but the data on cigarettes are available in sufficient detail to allow a cohort analysis. Third, the implications of the model are explored in a parameter analysis of the real cohort data.

Social Learning Theory

Burgess and Akers' reformulation of Sutherland's theory starts with the basic proposition that "deviant behavior is learned according to the principles of operant behavior" (Akers:42). Operant behavior occurs as a result of instrumental conditioning. This means that the behavior is not an automatic response to eliciting stimuli (like it is in classical conditioning), but depends on the feedback received or produced from the environment.

To explain the results of instrumental conditioning, the concepts reinforcement and punishment are introduced, which refer to the processes whereby a stimulus has the effect of either increasing or decreasing the likelihood of a response. Both of these processes can be promoted by the addition of stimuli or by the removal of stimuli. Thus, there are four stimulus-response types: positive and negative reinforcement, and positive and negative punishment. These four types need not all be present or distinguishable in the learning of any kind of behavior.

Important in understanding the change from conforming to deviant behavior is the principle of differential reinforcement, which says that "whether deviant or conforming behavior occurs and persists depends on the past and present rewards or punishment for the behavior, and the rewards and punishment attached to alternative behavior" (Akers:57). In order to apply this principle to the problem of first use of heroin three additional theoretical considerations are necessary. First, there are no direct (there simply cannot be) past rewards or punishments for the deviant behavior. Second, of the four possible stimulus-response types only positive reinforcement is applicable. Reinforcement is reflected by an increase of a certain response or behavior and, in this case, means change from nonuse to use of the drug. It is positive reinforcement because "the first experience is typically not solely for the sake of trying the drug but for gaining acceptance, identification, and status in the group" (Akers:90), that is, there is increase of the (feedback) stimulus as well. The alternative, conforming behavior, is not necessarily subjected to the same conditioning at the same time. Third, there are no explicit dynamic elements incorporated in the principle of differential reinforcement. Nevertheless it is plausible to argue that the counteracting force can be more influential at different ages, that is, the older people are, the more they are involved in regular roles and the more they acquire fixed habits and lifestyles. Hirschi argued similarly that a person can be committed to either conventional or deviant behavior, but "most people, simply by the process of living in an organized society, acquire goods, reputation, prospects that they do not want to risk losing" (Hirschi,1969:21). Also, one can be predominantly involved in conventional activities just because "a person may be simply too busy doing conventional things to find time to engage in deviant behavior" (Hirschi:22). I thus argue that the involvement in and commitment to the alternative, conforming behavior may very well increase over time. This is equivalent to saying that the restraints or inhibitions to engage in the deviant role are increasing over time.

In this application differential reinforcement implies that the initiation of deviant behavior depends on the present rewards for the behavior (i.e. positive reinforcement) and the past and present (i.e. accumulated) rewards and punishments attached to the alternative, conforming behavior. These latter stimuli associated with conforming behavior increase the restraints against engaging in the deviant behavior.

The process of differential reinforcement is accompanied by the process of differential association, which holds that the occurrence of deviant or conforming behavior depends on the normative evaluation of that behavior. In other words, deviant behavior is likely to occur if deviant norms (norms that are considered deviant in the dominant value system of a society) are considered more desirable than conforming norms or at least if there are "verbalizations", "rationalizations" and "vocabularies for adjustment and motives" (Cressey, 1953) that neutralize the undesirability in the definition of behavior as something deviant.

In addition to the mechanisms of differential reinforcement and differential association people can learn behavior by imitation of the role performance of others (Akers:48). Imitation can be conceptualized in instrumental conditioning terminology as vicarious reinforcement. 'Alter' provides a model of behavior of which 'ego' decides if it is worthwile to imitate. Ego is not subjected to a form of conditioning. Imitation, as a mechanism of learning, was stressed by Tarde (1903) and has been used as the main mechanism in some diffusion studies (Chapin,1928;Rogers,1962) which appeared before and after the development of the learning principles by the psychological conditioning theorists.

A Social Learning Model

Hamblin has successfully developed and applied several mathematical models to account for diffusion processes and underlying all of them are social learning premises (Hamblin et al.,1976,1979,1979). One of these models will be derived here with concepts from the preceding section to clarify the correspondence between the mathematical model and differential association-reinforcement theory.

It was argued that the process of differential reinforcement when applied to the first use of drugs implies two counteracting forces: (a) the positive reinforcement of using the drug obtained from the drug using group, and (b) cumulated restraints on the part of the potential drug user because of involvement in alternative roles. Equation (1) expresses these notions formally as

$$D_a = \frac{p}{R_a} \quad , \qquad (1)$$

where D_a=differential reinforcement over time, a=age, p=rate of positive reinforcement and R_a=age-accumulated restraints.

As a further specification of the functional form of restraints, it was argued that the older people become, the less likely they are to start using the drug. It is likely that the rate of restraint is proportionally higher at older ages than at younger ages. Therefore the rate of change in restraints to the deviant role is specified as some proportion (i) of the present restraints, that is

$$\frac{dR}{da} = i\ R \quad , \qquad (2)$$

where R and a are defined as before and i is referred to as the inhibition rate.

A number of mathematical representations can be found in the literature to account for learning by imitation (Coleman,1964). The simplest of these (Coleman:41-42) is

$$\frac{dU}{dt} = c\,U \quad , \qquad (3)$$

where U= the number of people using an item at time t, t= time, c= a parameter of proportionality and dU/dt= the number of people acquiring the item per unit time. In this application time is presented in the form of age.

If imitation were the only learning mechanism involved, parameter c in equation (3) would be an appropriate formal representation. However, the social learning theory implies that parameter c is not a structural parameter, since it is a composite measure of two other parameters. Thus, parameter c is replaced by the variable that captures these two basic parameters, differential reinforcement (D_a). Equation (3) then becomes

$$\frac{dU}{da} = D_a\,U \quad , \qquad (4)$$

where U= cumulated number of people using the drug at age a.

To arrive at a form which allows an empirical test of the model, equation (1) is inserted into (4) to obtain $dU/da = (p/R_a)\,U$. For R_a the solution of equation (2) is substituted, that is $R_a = R_0 e^{ia}$, where R_0 represents initial restraints and e is the base of the natural logarithm. Thus one obtains

$$\frac{dU}{da} = \frac{p}{R_0 e^{ia}}\,U = g\,b^a\,U \quad , \qquad (5)$$

where $g = p/R_0$, which will be called the gross rate of positive reinforcement, since it contains the rate of reinforcement p divided by a constant R_0, and where $b = e^{-i}$. This differential equation should describe the process involved in the diffusion of drug use in cohorts.

Solving equation (5) by integration, it is found that

$$U_a = \frac{U_0}{e^{g/\ln b}}\, e^{g/\ln b\,.\,b^a} = A\,e^{k\,b^a} \quad , \qquad (6)$$

where $k = g/\ln b$ and $A = U_0/e^k$.

Equation (6), known as the Gompertz equation, describes the first use of drugs with three parameters: A, k and b. However, the essential parameters of the theoretical model are $i = -\ln b$, the inhibition rate, and $g = k \ln b$, the gross rate of positive reinforcement.

Data and Methods

Quite understandably, it is difficult to obtain satisfactory data on any aspect of an illegal activity such as the use of heroin. The main sources of data are: (a) reports of agencies that are responsible for federal treatment programs (most of the time entering clients are asked to fill in some intake-form, and these data are published), and (b) police records, which generally refer to criminal users (i.e. users who are criminal beyond the use of heroin). Both of these data sources are probably biased. Thay emphasize the characteristics of heavy users. Also, Hunt and Chambers (1976:80) note that white users are underrepresented in treatment data, because many urban treatment programs have a specific minority focus.

The data in this analysis come from users entering federal treatment programs. Ages of first use of heroin are reported for those entering these programs in 1969, 1971 and 1973 (the number of admissions in these years were 1147, 9922 and 16,861). For 1969 and 1971 the percentage of first users from 26 to 30 years old (which only represents about six percent of the total) was inferred, following the complete data of 1973. These data and those on the first use of marijuana (6373 admissions in 1973) are summarized by Hunt and Chambers (1976:78). The diffusion of a third drug, cigarettes, is also analyzed to allow further comparisons of the parameter estimates with the heroin data. These data refer to women of 25 years and older, who answered the questions about cigarette smoking which were added to the Current Population Surveys of 1955 and 1966. Data on men were too incomplete to be used. The reason for this was that too many men were absent during the interviews and it was felt that the wife's estimate of the age at which the husband started smoking could be misleading (Ahmed and Gleeson,1970:9). The total sample size of these surveys was about 45,000 persons 18 years of age or older in 1955, and 69,000 persons in 1966. Disregarding nonresponse and insufficient tobacco smoking information, the effective sample size of women 25 years of age or older was 10,904 in 1955, and 17,812 in 1966. These data were reported by Ahmed and Gleeson (1970).

A distinction can be made between cohort data and period data. A cohort is defined as "a group of individuals who experienced the same significant...event during a specified brief period of time, usually a year, and who may be identified as a group at successive later dates on the basis of this common...experience" (Shryock and Siegel et al.,1973:712). Thus, one speaks of cohort data if the data allow such an identification. Period data refer to a type of event which occurred over many years (i.e. involving many cohorts) but which is observed during a specified brief period of time (usually one year). Due to the problem of the availability of data, the choice between cohort and period analysis often exists just in theory. "Because observations for several cohorts recorded in a single year may be combined as if they were the observations of a single cohort recorded over several years, period aggregations are often referred to as 'synthetic' cohorts. We may distinguish, therefore, real cohorts from synthetic cohorts: the latter are represented by period data combined in such a way as to reflect hypothetical experience over a span of years or a life time" (Shryock and Siegel:713).

The data used in the first part of this analysis refer to synthetic cohorts, since the data on heroin and marijuana use are only available in that form. A question which naturally arises is whether use of real cohort data in a test of the model implies differences in fit and parameter estimates. This issue is dealt with by comparing the results of a period analysis with a cohort analysis for the cigarette data.

The parameters of equation (6) were estimated with the SPSS nonlinear regression program, using both the Marquardt and Gauss minimization methods as a check on possible inaccurate estimates from a local minimum. In three of the twelve data sets reported in table 2, the two methods gave different results -- in one of these the differences were negligible, in the other two cases a graph of residuals clearly revealed that the Gaussian method yielded inaccurate estimates.

Since accumulated percentages rather than absolute number of users were used for the estimation, the asymptote of the curve (represented by parameter A of equation (6)) was 100 percent for all data sets. Thus, equation (6) reduced to a two-parameter model.

Results for Synthetic Cohorts

The results are presented in table 1, which includes additional information on the six data sets, the estimates for the parameters k and b of equation (6) and the estimates (computed from k and b) of the two parameters of model (5) -- g, the gross rate of positive reinforcement and i, the inhibition rate.

To evaluate the fit of the model the intraclass correlation r_i is reported. Robinson (1957,1959) suggested that the intraclass correlation -as a measure of agreement-, rather than the Pearsonian correlation, be used in comparisons of observed and theoretically deduced values of a variable. He also proposed the coefficient

Table 1: Parameter estimates for the Gompertz model on age of first use of marijuana, heroin and cigarettes with year of sample, sample size, number of categories and fit.

First use of	Year	N	No. of ages	A	-k	b
Marijuana	1973	6,373	17	100	455.11	.6395
Heroin	1969	1,147	21	100	350.60	.7056
Heroin	1971	9,922	21	100	257.19	.7146
Heroin	1973	16,861	21	100	240.47	.7257
Cigarettes	1955	10,904	26	100	151.64	.7699
Cigarettes	1966	17,812	26	100	84.52	.7741

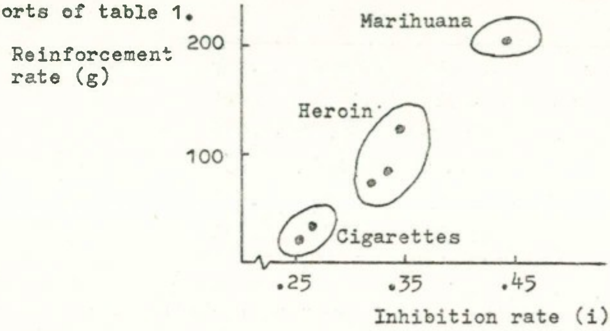
Table 1: (Continued)

First use of	Year	g	i	r_i
Marijuana	1973	203.44	.4470	.993
Heroin	1969	122.24	.3487	.991
Heroin	1971	86.43	.3360	.989
Heroin	1973	77.09	.3206	.995
Cigarettes	1955	39.66	.2615	.827
Cigarettes	1966	21.64	.2561	.832

of agreement, but since this measure can be easily obtained from the intraclass correlation in this application by computing $\frac{1}{2}(r_i + 1)$, that coefficient is not reported separately (the difference between the two is that r_i may vary from -1 to +1 and the coefficient of agreement from 0 to 1). For a given set of data, the intraclass correlation never comes out higher than the Pearsonian correlation. The fit was computed from the decumulated predicted and observed values. That is, while the parameter estimates of the model were obtained by the use of age-accumulated data, both predicted and observed values were transformed to rate data to compute the intraclass correlation. The results in table 1 show that the model describes the diffusion of heroin and marijuana very accurately and the diffusion of cigarette use somewhat less accurate, though still satisfactory.

Looking at the parameter estimates for heroin first, one may observe that the level of reinforcement (g) declines over the four year time span, especially between 1969 and 1971. This may indicate that during this period the focal concern of hard-drug using groups became less concentrated on the use of heroin and more on other activities that could be pursued, while maintaining a status within these groups. The reluctance to start experimenting with heroin (i), however, also declined steadily during this period. A similar change can be observed with respect to cigarette smoking by women between 1955 and 1966 -- a drop in reinforcement rate is accompanied by a decrease in inhibition rate. The tight relationship

Figure 1: Reinforcement and inhibition rates for the synthetic cohorts of table 1.



between the two parameters of the model holds across all six data sets, as can be seen in the plot of figure 1. The linear Pearsonian r^2 is .979.

The three types of drugs studied here form distinct clusters in the scattergram. In order to interpret this result one has to realize that the three types cover almost the entire range of drug use, from conventional to illegitimate behavior. Cigarette smoking for women had become quite conventional in the 1950s and 1960s. In 1966 the 25-34 year old women even reached the tipping point, i.e. over 50 percent had become regular cigarette smokers by the age of thirty three. Heroin use, on the other hand, represents highly deviant behavior, while marijuana use balances on the delicate boundary between conventional and deviants norms. Becker (1963), for example, showed how the Marijuana Tax Act of 1937 was linked to the organizational achievement of the Federal Bureau of Narcotics, which was established in 1930. If the FBN would not have had to prove the legitimacy of its existence, the legal status of marijuana use might have been different at present. The marginal position of marijuana use is also reflected by the low level of law enforcement in many states, a result of the wide gap between legal and public norms about its use.

Since cigarette smoking is quite conventional but not essential to gain status in groups, the corresponding rates of both reinforcement and inhibition are low. That is, in comparison to the other drugs, cigarette smoking is less stimulated in groups, but the reluctance to start using cigarettes is relatively low too. This latter results is plausible since the widespread public awareness of the dangerous aspects of smoking only started with the publication of the Surgeon General's Report in 1964 (U.S.P.H.S., 1964). The effects of that event can only be marginally reflected in the data analyzed here.

In general, heroin use occurs in subcultural settings, where several types of hard drugs may be used. Here the use of drugs is more essential to the existence of the group than is true for cigarette smoking. On the other hand, the danger of addiction to heroin may be perceived as higher than addiction to cigarettes. Thus, both reinforcement and inhibition rates are higher than for cigarette smoking.

Finally one might argue that marijuana use takes on a special position in relation to the other drugs due to its boundary status. Because it is not conventional like cigarette smoking, reinforcement of its use is higher. People don't offer a cigarette, but they do offer a 'joint'. But marijuana use is not considered highly deviant either and use is not restricted to subcultures or even retreatist settings, so that the opportunities for reinforcement are also large. It might be tempting to interpret the relatively high inhibition rate for marijuana use as part of an often suggested escalation process, in which use of softer drugs is seen to lead to use of harder drugs. For example, Goode (1969:48) cites a pamphlet of the former Federal Bureau of Narcotics, saying "... it cannot be too strongly emphasized that the smoking of the marijuana cigarette is a dangerous first step on the road which usually leads to enslavement by heroin ...". Goode however argues that this position is too deterministic and that progression towards use of harder drugs largely depends on normative approval within the marijuana using groups, that is, "even daily use of marijuana will not involve the individual in heroin use if it is absent from the group in which he interacts and finds his significant others" (Goode:58). A second, opposite process may also account for the high inhibition rate of marijuana use. According to this argument the increased number of "stakes in conformity" (Hirschi:138-145) that people acquire over time, make them reluctant to risk the consequences of more or less deviant acts, such as marijuana smoking. In summary, starting from the boundary position of marijuana use, one process may lead further into the field of deviance and one process further into the field of conformity and it is suggested that this double outcome accounts for the high inhibition rate of marijuana use.

Comparison of Cohort and Period Analysis

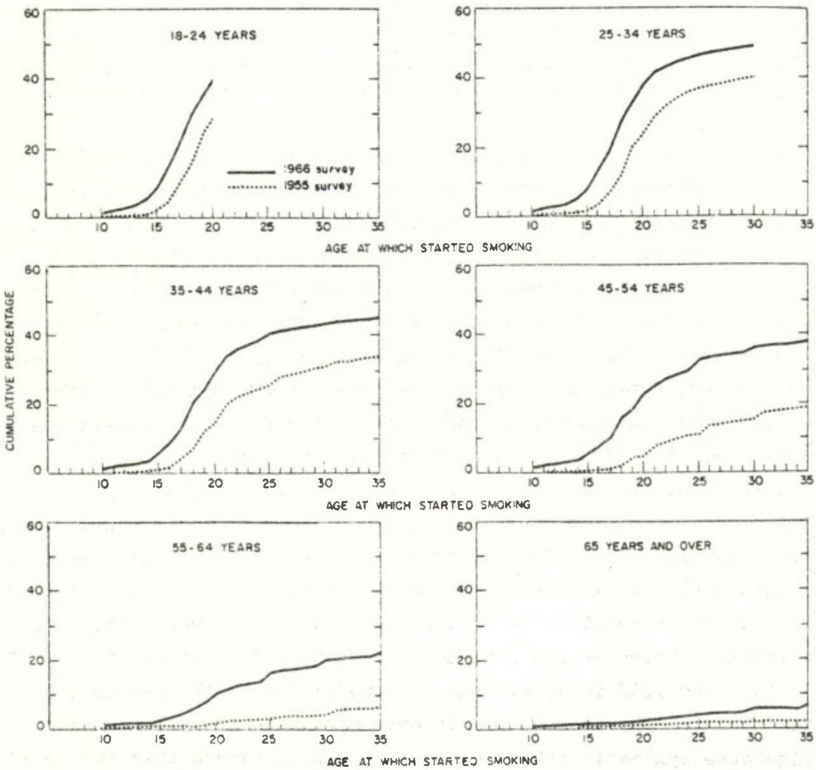
Because the data were not available in a more disaggregated form, data of a synthetic cohort of heroin and marijuana users were analyzed to test the model. The data on cigarette smoking, however, are available for real cohorts. In fact, these data were presented as cohort data in the original publication and I aggregated the data for women 25 years and older to obtain period data. In this section the real cohort data are analyzed and the results compared with those obtained from the period data.

Figure 2 shows the curves of age of first use of cigarettes for six age groups, observed in 1955 and 1966. These age groups represent almost overlapping birth cohorts. In the analysis, the results of which are reported in table 2, the data were not accumulated percentages of all smoking women (resulting in an asymptote of 100 percent) but of all women. Therefore the A parameter now shows the steadily increasing asymptote for the later cohorts. This implies that the A parameter value for the cohort data cannot be compared with the A parameter of the period analysis (which is therefore presented in parentheses in table 2). The parameter values for k and b were not reported to save space, but they can be reconstructed using the identities reported under equation (6).

The fit of the model, judged from the intraclass correlation on the rate data, is generally satisfactory. Typically, the fit is high for the three age groups between 25 and 54 years old (in 1955 the mean r_i is .778 and in 1966 .855 for these three groups) for which the data clarly exhibit a sigmoid pattern. A much lower fit is obtained for the age groups of 55 and over (for these the mean r_i in 1955 is .327, in 1966 .376). Somewhat unanticipated, the model also fits the J-curve of the 18-24 year cohort very accurately, in fact better than the S-curves of the three subsequent cohorts.

What is the relationship between the fit of the model for the real cohort data compared to the synthetic cohort data? Obviously,

Figure 2: Cumulative percentage of females becoming regular cigarette smokers prior to age specified, by age at time of survey.



Source: Ahmed and Gleeson, 1970.

Table 2: Parameter estimates for the Gompertz model on first use of cigarettes for six age groups, observed in 1955 and 1966, and estimates from period data (taken from table 1).

Age at time of survey	1955 A	1955 g	1955 i	1955 r_i	1966 A	1966 g	1966 i	1966 r_i
18 - 24	38.33	3456.41	.5030	.967	48.50	259.83	.3978	.930
25 - 34	40.49	386.44	.3779	.935	49.40	139.13	.3590	.929
35 - 44	33.20	65.28	.2820	.835	44.41	70.31	.3127	.883
45 - 54	19.50	12.52	.1937	.565	38.08	15.01	.2358	.753
55 - 64	10.56	1.06	.0893	.289	23.82	4.57	.1676	.468
65+	1.80	7.00	.1839	.366	10.94	0.40	.0681	.283
25+	(100)	39.66	.2615	.827	(100)	21.64	.2561	.832

the model fits data of two of the real cohorts better and of three of the real cohorts poorer than the synthetic cohort data. To establish the relation more rigorously, it would be erroneous to compute the simple average of the intraclass correlations for the five age groups of 25 years and older and to compare that result with the intraclass correlation of the synthetic cohort. Rather, the weighted average should be taken, in which the weight for each real cohort represents its relative size in the synthetic cohort. Moving from the younger to the older real cohorts, these weights were .45, .34, .15, .04 and .01 in 1955, and .31, .30, .24, .11, .03 in 1966. The weighted average of the intraclass correlation for the real cohorts in 1955 is (.45x.935)+ ... +(.01x.366)= .812 . Here, as elsewhere, five in stead of two or three significant digits were used in the actual calculations. For 1966 the weighted intraclass correlation is .800 . These two values were about the intraclass correlations obtained in the period analysis, i.e. .827 in 1955 and .832 in 1966. Since the model fitted the heroin and marijuana synthetic cohort data even more accurately than the cigarette synthetic cohort data, it may be inferred that the model would fit real cohort data on those illegal drugs very accurately as well.

Next the parameter estimates from the period analysis are compared with those from the cohort analysis. The estimates for the oldest age group will be deemphasized in this comparison, since the weight of this group in the synthetic cohort is minimal. The period analysis revealed that both reinforcement and inhibition parameters decreased from 1955 to 1966. The cohort analysis uncovers the differential pattern in which this trend took place. For the three age groups covering the 35 to 64 years age span, both reinforcement and inhibition increased from 1955 to 1966 and the overall decline which the period analysis revealed, is due in large part to a sharp decrease of both parameters for the 25-34 year age group. For a tentative explanation one might reason that this age group consists of the 1921-1930 birth cohort in 1955, and of the 1932-1941 birth cohort in 1966. The women of the 1921-1930 birth cohort were adolescents and young adults during the second World War, which required their increased participation in the laborforce giving them a relatively independent status within the family. The women of the 1932-1941 birth cohort on the other hand were later to become the more housebound females of the 1950s. Thus, the reinforcement to which the women of the 1921-1930 birth cohort were subjected might have been much higher than for the (approximately) subsequent birth cohort.

Additional Results for Real Cohorts

The cohort analysis can be continued with an investigation of the parameter estimates for the age groups in 1955 and 1966. Since the purpose of this parameter analysis is not a comparison with the period analysis, all six cohorts will be considered. The relationships to be discussed were also tested for the five cohorts of 25 years and older, but the results were essentially the same and are therefore not reported separately.

In the theory section the inhibition rate was introduced to account for restraints that increase with age and, in agreement with that argument, parameter i is positive for all six age groups. But apparently, looking at the estimates of table 2, this rate is not constant over age groups, but is becoming smaller as the age groups get older. The positive reinforcement rate is also declining for the older age groups. In general terms these trends may be understood as follows. The inhibition rate reflects how rapid or slow people are willing to change lifestyles, while the reinforcement rate measures the impact of the environment on behavior. Younger people's lifestyles are in general less fixed than older people's, that is, they are more willing to experiment. Also younger people are easier affected by norms of the groups in which they participate. The first -willingness to change- is an internal, psychological factor and the second -environmental impact- measures the influence of external sources on one's decisions. Not surprisingly, these two factors are related. In fact, environmental impact may be seen as a function of willingness to change.

Two alternative, formal hypotheses are suggested to account for the relationship between the reinforcement rate (environmental impact) and the inhibition rate (willingness to change). The first hypothesis holds that a relative change in the rate of reinforcement (dg/g) is proportional (m) to a relative change in the rate of inhibition (di/i), that is

$$\frac{dg}{g} = m \frac{di}{i} \quad . \qquad (7)$$

Solving this equation, one obtains

$$g = B\, i^{m} \quad , \qquad (8)$$

where B depends on initial conditions and parameter m.
The second hypotheses is somewhat simpler and holds that the relative change in the rate of reinforcement is proportional (n) to the rate of inhibition itself, that is

$$\frac{dg}{g} = n\, i \quad , \qquad (9)$$

or

$$g_i = g_0\, e^{ni} \quad , \qquad (10)$$

where g_0 is the initial condition of the reinforcement level.

The results of the tests of these two hypotheses are reported in table 3. The Pearsonian r^2 is used to measure the fit to the data. By common standards both specifications fit quite well, but

Table 3: Analysis of parameter estimates for the six cohorts of table 2.

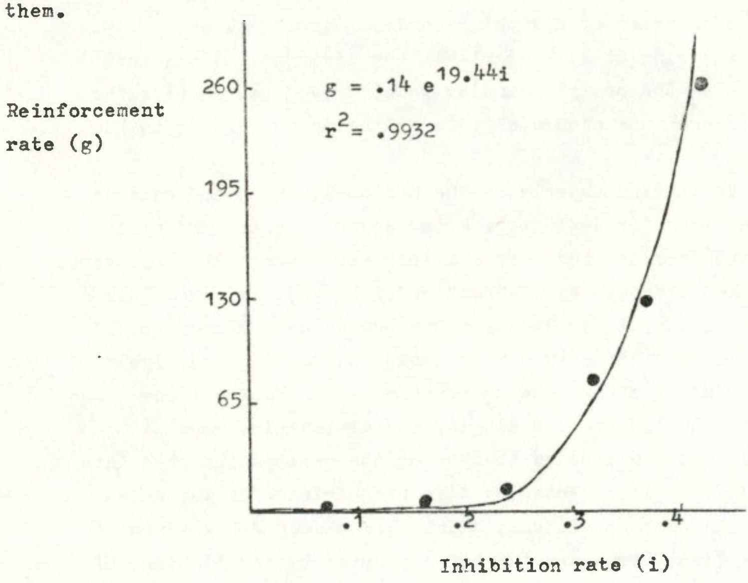
Power function, equation (8)

Year	B	m	r^2
1955	10.54	4.661	.9509
1966	8.48	3.635	.9714

Exponential function, equation (10)

Year	g_0	n	r^2
1955	.2243	19.50	.9958
1966	.1376	19.44	.9932

Figure 3: Reinforcement and inhibition rates for the six real cohorts in 1966 of table 2 and the exponential function relating them.



the exponential function is clearly preferred. Figure 3 presents the data for the cohorts in 1966 and the exponential function fitted to those data.

The two models that were tested in this parameter analysis are ad hoc hypotheses, developed in response to what the data revealed. Both of these models have been used extensively in psychophysical research (Marks,1974). The tentative status of the models as they were applied here might disappear after replications, another research tradition of psychophysics.

Conclusion

Obviously the model developed in this paper has limitations. There are many other variables -such as color, socioeconomic background and city size- that may offer not just additional, but other kinds of explanations for variations in drug use. The emphasis on the learning process, which is involved in the adoption of a deviant role, does not necessarily diminish the importance of other approaches (social disorganization theory, conflict theory, social control theory), which stress the structural properties of deviant behavior. Structural and processual theories provide complementary insights. Within this delineated area the social learning model proved to describe the diffusion of drug use accurately, in synthetic as well as in real cohorts.

A basic conviction underlying the social learning approach is that explanations for deviant behavior do not require different arguments and premises than explanations for conventional behavior. Both types are learned, by interaction with other persons. This perspective appears to be valid, since the data on conventional cigarette smoking, boundary-status marijuana smoking and highly deviant heroin use can all be understood or rationalized about within the limits of a single, social learning model.

The model was constructed to incorporate various insights into the ways behavior is affected by ties with friends of the same age. Sutherland's propositions, which were stated forty years ago for the first time, are further supported by the findings of this report.

References

Ahmed,P.I. and G.A.Gleeson

1970 Changes in Cigarette Smoking Habits between 1955 and 1966. Washington, U.S.Government Printing Office, 396-234.

Akers,R.L.

1977 Deviant Behavior: A Social Learning Approach. 2nd ed. Belmont, Wadsworth Publishing Company Inc.

Becker,H.S.

1963 Outsiders. New York, Free Press.

Burgess,R.L. and R.L.Akers

1966 A Differential Association-Reinforcement Theory of Criminal Behavior. Social Problems 14:128-147.

Chapin,F.S.

1928 Cultural Change. New York, Century.

Coleman,J.S.

1964 Introduction to Mathematical Sociology. New York, Free Press.

Cressey,D.

1953 Other People's Money. Glencoe,Ill.,Free Press.

Goode,E.

1969 Multiple Drug Use among Marijuana Smokers. Social Problems 17:48-64.

Hamblin,R.L. and J.L.L.Miller

1976 Reinforcement and the Origin, Rate and Extent of Cultural Diffusion. Social Forces 54:743-759.

Hamblin,R.L.,J.L.L.Miller and D.Saxton

1979 Modeling Use Diffusion. Social Forces 57:799-811.

Hamblin,R.L.,D.B.Koller and B.L.Pitcher

1979 Adopting Cultural Roles: A Diffusion Model. Unpublished Manuscript. Tucson, University of Arizona.

Hernes,G.

1973 The Process of Entry into First Marriage. American Sociological Review 37:173-182.

Hirschi,T.

1969 Causes of Delinquency. Berkeley and Los Angeles, University of California Press.

Hunt,L.G. and C.D.Chambers
1976 The Heroin Epidemics, A Study of Heroin Use in the United States, 1965-75. New York, Spectrum Publications Inc.

Marks,L.E.
1974 The New Psychophysics. New York, Academic Press.

Pitcher,B.L.
1978 Family Formation Patterns: A Social Learning Model. Dissertation. Tucson, University of Arizona.

Pitcher,B.L.,R.L.Hamblin and J.L.L.Miller
1978 The Diffusion of Collective Violence. American Sociological Review 43:23-35.

Rogers,E.M.
1962 Diffusion of Innovations. New York, Free Press.

Shryock,H.S.,J.S.Siegel and Associates
1973 The Methods and Materials of Demography. 2nd ed. Washington, U.S.Government Printing Office.

Sutherland,E.H.
1939 Principles of Criminology. 3rd ed. Philadelphia, J.B.Lippincott.
1947 Principles of Criminology. 4th ed. Philadelphia, J.B.Lippincott.

Tarde,G.
1903 The Laws of Imitation. Translated by Elsie Clews. New York, Holt, Rinehart & Winston.

Robinson,W.S.
1957 The Statistical Measurement of Agreement. American Sociological Review 22:17-26.
1959 The Geometric Interpretation of Agreement. American Sociological Review 24:338-345.

U.S.Public Health Service
1964 Smoking and Health. Report of the Advisory Committee to the Surgeon General of the Public Health Service. Washington, PHS publication no. 1103.