Developmental timing of first drug treatment and 10-year patterns of drug use

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Abstract

To examine the developmental timing of first drug treatment and its associations with 10-year drug use patterns, pooled data (N=1,318) from 4 longitudinal studies conducted in California was used to compare individuals first treated during young adulthood (26%) to those first treated at an older age. Treatment timing was associated with particular participant characteristics and experiences. Matched data showed that most people in both age groups exhibited a low level of drug use after first treatment, albeit fewer who were first treated during young adulthood maintained a low drug use level over time. Receipt of more drug treatment over ten years was associated with maintenance of low drug use levels among those first treated as young adults, but not among those first treated as older adults. Developmental timing of first drug treatment interacts with subsequent treatment experiences in ways that impact the course of drug use.

Keywords

drug use trajectories; substance abuse treatment; young adulthood; developmental timing of key life events; life course

1. Introduction

Approximately 23.1 million Americans (9% of the population) needed specialized treatment for a substance use disorder in 2010, but only 2.6 million (11%) of those in need received it (Substance Abuse and Mental Health Services Administration [SAMHSA], 2011). Some drug users do not perceive a need for treatment (SAMHSA, 2011) while others cease their use without formal treatment participation (e.g., Klingemann & Sobell, 2001). Scientific consensus statements endorse the effectiveness of treatment (National Institute on Drug Abuse [NIDA], 1999) yet long-term follow-up studies of treated individuals generally show that dependent users tend to persist in their drug use over their lifespan (Hser et al., 1997, 2001).

1.1. Drug treatment as a turning point

Significant heterogeneity in longitudinal drug use patterns has been documented (Boeri et al., 2011; Brecht et al., 2008; Genberg et al., 2011; Grella & Lovinger, 2011; Hser et al.,

2008a; Juon et al., 2011). Key life events that precipitate changes in drug use are of particular interest. These have consistently included incarceration, employment, and changes in family and social roles (Huang et al., 2011; Laudet & White, 2010; Sampson & Laub, 2005; Uggen, 2000). Relatively few studies exist on drug treatment and its longer-term effects on substance use patterns and no studies have empirically examined drug use patterns in relation to the developmental timing of first drug treatment.

1.2. Developmental stages

Young adulthood (ages 18–25) is recognized as a distinct developmental period in the life course (Arnett, 2000) when substance use typically peaks (Arnett, 2005; Chen & Kandel, 1995; Ellickson et al., 2004). Substance abuse at a young age is associated with continued use and dependence (Hser & Anglin, 2010; Schulenberg et al., 1996) and adverse impacts in other life domains such as educational attainment, employment opportunities, and social relationships (Kandel & Davies, 1990; Ringel et al., 2006; Wu et al., 2003), all of which can have significant lifelong consequences (Boden et al., 2008; Krohn et al., 1997; Sampson & Laub, 1993).

Contrary to the commonly held belief that a person must "hit rock bottom" before being ready to stop their drug use, some research indicates that the sooner substance use disorders are treated, the better the outcomes will be (Galloway et al., 2010) yet relatively few drug users enter treatment during young adulthood (Gayman et al., 2011). Nationwide, about 22% of 18–20 year olds and 19% of 21–25 year olds use illicit drugs, the highest rates among all age groups, (SAMHSA, 2006a), but the 18–25 year old group represents only about 25% of all treatment admissions (SAMHSA, 2008). Changes in drug use patterns during the transition from adolescence to young adulthood have been examined (Brook et al., 2011; D'Amico et al., 2009; Martin & White, 2005; Schulenberg et al., 2005). In contrast, little is known about drug use patterns after young adulthood and how they may be impacted by receipt of treatment.

1.3. Timing of drug treatment

A life course perspective (Elder, 1985, 1998) underscores how the timing of key life events can differentially affect their potential short- and long-term impacts. In the case of treatment for substance use disorders, age-related differences exist in relationships between pretreatment patient characteristics, treatment retention, and outcomes (Grella et al., 1999) and differences in treatment outcomes may be accounted for by factors associated with age such as type of substance dependence, treatment retention, social networks, and gender (Satre et al., 2004). Furthermore, compared to young adults in drug treatment, older adults exhibit more personal characteristics and treatment engagement experiences that aid favorable outcomes (Satre et al., 2003) and they seem to have better post-treatment outcomes (Satre et al., 2004). The timing of drug treatment appears to be significant (Scott et al., 2011) but its effects are poorly understood.

1.4. Current study

We apply a life course perspective to investigate associations between the developmental timing of first drug treatment and patterns of drug use over the subsequent ten years. Paying particular attention to those first treated during young adulthood, we address the following research questions. How are individuals first treated during young adulthood different from those first treated later in their characteristics at treatment entry, onset of key life experiences, and service system exposures (e.g., drug treatment, criminal justice system involvement, employment)? After controlling for demographics and other characteristics, are there different drug use trajectories between age-based groups over the ten years

following first drug treatment? Finally, is the developmental timing of first drug treatment associated with particular long-term patterns of drug use?

We hypothesized that first drug treatment would occur during young adulthood for relatively few individuals and that the group first treated during this developmental stage would exhibit more severe substance abuse and attendant problems but, after controlling for differences in participant characteristics, occurrence of first treatment during an earlier developmental stage would be associated with reduced drug use over time.

2. Materials and methods

2.1. Datasets

Analyses used data on 1,318 adults pooled from four longitudinal studies conducted in California that collected information using the Natural History Instrument (NHI; described below). We relied on projects with Natural History Interview data to maximize coverage of the drug use career. Projects included the following (with numbers in parentheses of subjects selected for the current analysis): the 12-year Cocaine Follow-up Study (n=310) (Hser et al., 2006; data collected in 1989–1991 and 2002–2003), the Methamphetamine Natural History Study (n=325) (Brecht et al., 2004; data collected in 1998–2002), the Treatment Process Study (n=193) (Hser et al., 2004; data collected in 1996), and the Treatment Utilization and Effectiveness Study (n=490) (Hser et al., 2003; data collected in 1995–1996). Studies included subjects recruited from drug treatment and non-drug treatment settings (emergency rooms, sexually transmitted disease clinics, jails).

2.2. Samples

Pooled data resulted in a total of 348 individuals first treated during young adulthood (age 18–25) and 970 during an older age (age >25), yielding sample sizes in each group that were sufficient for analyses. Of the total sample, 62.0% were male and 34.9% white, 41.3% African American, 18.9% Hispanic, and 4.9% Asian or other racial/ethnic group. On average, onset of criminal involvement (indicated by arrest) started at age 20, use of any drug first occurred at age 15, primary drug use began at age 21, and first drug treatment occurred at age 31. Across studies, mean age at recruitment ranged from 33 to 35.

In order to better focus on age differences, we created a matched sample. Five matching criteria were used: gender, race/ethnicity (White, African American, Hispanic, Other), primary drug type (alcohol, marijuana, cocaine, methamphetamine, heroin, other), age at first use of the primary drug, and age at first arrest. The final two criteria were dichotomized to optimize the number of cases that could be matched and to utilize substantively meaningful concepts. First use of the primary drug was coded as occurrence at age 14 vs. >14, congruent with literature indicating that initiation of drug use before age 15 is associated with continued and more severe drug use (Anthony & Petronis, 1995; Hser et al., 2008b; Office of the National Drug Control Policy, 2004; van Ours, 2006). Similarly, because criminal justice sanctions are different for juveniles and adults, first arrest was coded as occurrence at age 17 vs. >17. Ultimately, 267 subjects from each group composed the matched sample (N=534).

2.3. Instruments and measures

The Natural History Interview (NHI), from which the variables for this analysis were derived, was used in all four studies. The NHI was adapted from instruments designed by Nurco and colleagues (Nurco et al., 1975) and has been used with various drug-abusing populations. The NHI was designed to collect retrospective longitudinal quantitative data on drug use and related behaviors. The instrument consists of "static" and "dynamic" forms that

permit the capture of longitudinal, sequential data on drug use, employment, criminal involvement, treatment, and other behaviors over the life course of research participants (McGlothlin et al., 1977). Using a time-line, the interviewee notes major life events and then identifies time periods associated with specific behaviors, with periods delineated by changes in behavior. These reported data are translated to time series-type data of behaviors for each month. Test–retest and pattern reliability for the NHI have been shown to be acceptable (Chou et al., 1996; Hser et al., 1992).

Natural history interview data provide a monthly record of drug use and service system exposure since first drug treatment. For the present analyses, NHI data were used to identify adults who initiated their first drug treatment at a young age (age 18 to 25) or at an older age (age >25). NHI data also provided information on participant characteristics (e.g., gender, race/ethnicity, education, marital status), events occurring prior to first drug treatment, and age at onset of experiences (drug use, arrest, incarceration, and drug treatment).

The major outcome is primary drug use over the ten years after first drug treatment entry, defined as number of days per month using a specified substance. Primary drug type was self-identified by each participant in two of the studies that were utilized and in the two other studies it was assigned per study eligibility criteria. For 86.1% of cases, the primary drug type was the same drug for which first drug treatment was sought. Also analyzed were monthly NHI observations of any drug use, treatment participation, criminal justice system interaction, and employment over the ten years following first drug treatment.

2.4. Analytic approach

We compared the two groups that had different timing of first drug treatment, first using the unmatched (N=1,318) and then the matched (N=534) samples. For the unmatched and matched samples, we plotted mean days of drug use among older and younger adults for each of the ten years before and after first drug treatment. The ten-year pre-treatment observation period covered ages that were as young as 8 years old among those included in the younger adult group. To avoid presentation of data that might lend itself to misinterpretation, for the younger adult group we chose to display drug use covering only five years prior to first drug treatment. Group differences on characteristics were tested at $p<0.05$ with Chi-square statistics for categorical variables and ANOVA or multivariate analysis (SAS PROC GLM) for continuous variables. Some raw percentages were very similar but nevertheless were found to be different statistically, illustrating how large sample sizes increase statistical power, making it possible to detect even minor differences between groups. These small percentage differences were not considered substantively significant to unduly bias subsequent analyses. In addition, a full 10-years of data was not available for the entire sample because of death (n=14 of 534, or 2.6%) or for other reasons. More than half of the sample was available for analysis for each of the first six years of the 10-year observation period, more than one-third was available for each of the next three years, and just over one-quarter was available in the tenth year. The characteristics of those with and without a full 10 years of data were not significantly different in age at intake or in the project by which they were enrolled, however the older adult group did have a shorter mean observation period than the younger adult group.

Next, we used the matched sample to estimate a growth mixture model (with the number of classes ranging from 2 to 6) with Mplus 5.1 (Muthén & Muthén, 2007) to the outcome of primary drug use over the ten years following entry into first drug treatment. Research on power analysis for growth mixture models is underdeveloped however findings from limited simulation studies (e.g., Li & Hser, 2011; Nylund et al., 2007) indicate that the sample size for the present study is sufficient for a growth mixture model to detect the correct number of classes. In this model, the intercept, slope, and quadratic growth factors were specified

within each class to capture the heterogeneity of primary drug use patterns over time. The variance of intercept and slope factors and their covariance were free for estimation. The variance of the quadratic factor was constrained to be zero. We assumed that values that were missing due to death or for other reasons were missing at random (e.g., Muthen, 2004; Muthen et al., 2011).

Model selection was based on the fit statistics AIC (Akaike, 1987), BIC (Schwartz, 1978), adjusted BIC (ABIC; Sclove, 1987), Lo-Mendell-Rubin likelihood ratio test (LMR; Lo et al., 2001), and the bootstrap likelihood ratio test (BLRT; McLachlan, 1987; McLachlan & Peel, 2000), coupled with existing guidelines (Li & Hser, 2011) and substantive considerations of interpretability and implications of distinguishable trajectories. After model selection, subjects were divided into different groups with distinct trajectory patterns based on the estimated maximum posterior probability.

Finally, we conducted two separate polynomial logistic regression analyses on the classified group membership. In Model 1, we examined associations between timing of first drug treatment and distinct 10-year drug use trajectory patterns, controlling for other variables. Selection of variables for inclusion in the model was informed by the relevant literature as well as by the descriptive analysis of characteristics. In Model 2, we included interactions between developmental timing of first drug treatment and (a) significant main effects that emerged from Model 1 (i.e., gender, primary drug type) and (b) experiences (i.e., cumulative mean months of incarceration, drug treatment, and employment) that occurred during the same 10-year time period as when primary drug use patterns were observed.

3. Results

3.1. Participant characteristics, onset of key experiences, and service system exposures

Unmatched sample—First drug treatment occurred during young adulthood for about 26% of adults included in the unmatched sample and at an older developmental stage for about 74% of participants (Table 1, unmatched sample). Examination of participant characteristics at first treatment entry showed that compared to individuals who experienced first treatment as older adults, the young adult group included more women (48.8% vs. 34.1%); more Whites (42.4% vs. 32.2%) and Hispanics (27.0% vs. 11.8%) and fewer African Americans (25.0% vs. 47.1%); more individuals with less educational attainment; fewer married adults (12.9% vs. 21.1%); and fewer cocaine (26.4% vs. 53.1%) and alcohol (3.2% vs. 6.9%) users and more users of methamphetamine (47.7% vs. 27.4%), heroin (14.1% vs. 9.6) and marijuana (5.2% vs. 1.0%).

In addition, young adults first experienced all of the events that were examined at a younger mean age than older adults, including: use of any drug (13.2 vs. 15.3), the primary drug (17.0 vs. 22.7), and regular use of the primary drug (18.4 vs. 25.4); arrest (16.9 vs. 20.7) and incarceration (21.8 vs. 28.2); and drug treatment (22.1 vs. 34.3). When data were dichotomized, more young adults first used their primary drug at or before age 14 (21.8% vs. 8.1%) and more were also arrested at or before age 17 (59.2% vs. 39.4%). Young adults also took less time than older adults to receive their first drug treatment, as indicated by time from first use of any drug to first drug treatment (8.9 vs. 19.0 years) and by time from first use of the primary drug to first drug treatment (61.7 vs. 139.4 months).

In the year before first drug treatment, young adults used their primary drug for fewer months (8.3 vs. 9.2) and they were employed for fewer months (4.2 vs. 5.4) but there were no differences between groups in experiences with any drug use (about 10 months) or incarceration (about 1 month).

Over the 10 years after first drug treatment, individuals who experienced first treatment as a young adult reported more mean months of any drug use (47.4 vs. 42.0), primary drug use (33.6 vs. 27.1), and incarceration (9.3 vs. 4.9), and fewer months of employment (28.1 vs. 36.5). There was no difference between groups in the amount of drug treatment experienced (about 12 months) over this same time period.

Matched sample—Matching created two groups that were comparable on many of the pre-treatment characteristics that were examined (Table 1, matched sample). Differences remained between groups in education level (more young adults had less education), in all onset ages (events occurred at a younger age for young adults), and in some of the experiences that occurred in the year prior to first treatment (young adults reported fewer months of primary drug use and incarceration).

Over the ten years following first drug treatment, young adults in the matched sample had more months of primary drug use than older adults (34.9 vs. 21.0). As for other experiences that occurred during this time period, young adults had more months of incarceration (10.4 vs. 6.8) than older adults, the non-significant difference in exposure to drug treatment that was seen in the unmatched data remained, and the difference between groups in employment disappeared.

3.2. Drug use before and after first drug treatment

In the unmatched sample (Figure 1), young adults used drugs less than older adults in each of the five years before entry into first drug treatment although differences became non-significant in the time just prior to treatment entry. There was a decrease in drug use after first treatment compared to the use level that was evident prior to treatment entry among young and older adults. Over the ten years after entry into first drug treatment, young adults used drugs more than older adults and this was the case for most of each of the years that were examined. These comparisons were also made using the matched sample and findings were essentially the same (data not shown).

The older adult group was on average 10 years older than the younger adult group at their first drug treatment entry (see Table 1). These older adults used drugs at a mean of 63.6 months (53% of the time) over the 10 years prior to treatment (data not shown). Had these older adults started treatment 10 years earlier, and responded to treatment similarly as the group first treated during young adulthood (i.e., the group that used drugs 29% of the time on average over the 10 years following treatment), an approximately 24% reduction in drug use would occur. This reduction can be translated into the avoidance of an estimated average of 28.8 months of drug use over a 10 year period (24% reduction*12 months*10 years = 28.8 months).

3.3. Distinctive patterns of drug use trajectories after first treatment

We estimated growth mixture models (GMM) with different number of classes on 10-year patterns of primary drug use after first drug treatment. AIC, BIC, and ABIC always decreased as the number of classes increased in the GMM model. BLRT was significant (p<0.05) from the 2-class model to the 6-class model, however, LMR become non-significant (p>0.05) when we compared the 4-class vs. 5-class and 5-class vs. 6-class models. Li and Hser (2011) suggested that this discrepancy between LMR and other fit statistics could indicate the existence of non-normality within classes and relative robustness of LMR. More importantly, one of the residual variances of the 5- and 6- class models become non-significant, making these models less interpretable. As a result, the 4-class model was selected.

The selected model had four distinctive latent pattern classes (Figure 2). Most individuals were classed in the Remains Low (69.5%) group, followed by the Decreases then Increases (13.7%) group, the Remains High (10.1%) group, and the Increases then Decreases (6.7%) group. However, different proportions of young and older adults were included in each latent class. Compared to their older adult counterparts, more individuals first treated during young adulthood were members of the Remains High group (13.9% vs. 6.4%) and the Increases then Decreases group (9.4% vs. 4.1%) and fewer were members of the Remains Low group (62.5% vs. 76.4%).

3.4. Developmental timing of first drug treatment and drug use trajectory patterns

To examine associations between developmental timing of first drug treatment and 10-year drug use trajectory patterns, controlling for other variables, a polynomial logistic regression analysis of main effects (Table 2, Model 1) and interaction effects (Table 2, Model 2) was conducted. As indicated by the beta coefficients shown in Model 1, occurrence of first drug treatment during young adulthood was associated with an increased likelihood of membership in the Remains High group (1.345, $p<0.001$) and in the Increases then Decreases group (0.888, $p<0.05$) (reference group = Remains Low group). As for the other factors that were examined, a primary drug type of heroin (compared to other primary drug types) increased the likelihood of membership in the Remains High group (2.398, $p<0.001$) and in the Increases then Decreases group (1.393, $p<0.05$), being male decreased the likelihood of membership in the Decreases then Increases group (−1.142, $p<0.001$) and in the Increases then Decreases group (−1.278, $p<0.01$), and more months of incarceration over the 10 years after first drug treatment decreased the likelihood of membership in the Remains High group (−0.040, $p<0.05$).

When interaction terms were included (Model 2), most of the significant main effects remained and a significant interaction effect emerged. Across models male gender was negatively associated with membership in each of the groups that were examined but male gender was no longer statistically significant when interaction terms were included. The other factors that were statistically significant in both models were first drug treatment as a young adult, heroin as the primary drug type, and more months of incarceration over the 10 years after first drug treatment.

Moreover, a significant interaction effect was found indicating that each additional month of drug treatment received by those first treated as young adults decreased their probability of exhibiting a Decreases then Increases (reference group = Remains Low) drug use pattern (−0.065, $p<0.05$). The −0.065 coefficient means that each additional month of drug treatment received by those first treated as young adults decreased by approximately 0.3% their probability of exhibiting a Decreases then Increases drug use pattern. In simplified terms, after accounting for other differences, receipt of more drug treatment contributed to maintenance of a low level of drug use over time among those first treated as young adults but not among those first treated as older adults.

4. Discussion

4.1. Findings

As anticipated, relatively few of the individuals included in the present analysis initiated drug treatment during young adulthood. Occurrence of first drug treatment during young adulthood was associated with particular participant characteristics (female gender, White or Hispanic race/ethnicity, less educational attainment, single but previously married marital status, use of particular drug types, earlier onset of drug use and criminal justice system involvement) and prior experiences (fewer months of primary drug use and fewer months of employment).

As for outcomes, young adults had more months of drug use than older adults in the ten years after first treatment. When groups were made equivalent with matching, this difference between groups widened. During this same 10-year time period, young adults in both samples were incarcerated more than older adults, young adults had fewer months of employment in the unmatched sample but this pattern reversed direction and became statistically non-significant in the matched data, and both young and older adults received very little drug treatment over time.

Most adults, whether first treated as a young adult or as an older adult, exhibited a low level of drug use after first treatment, albeit fewer individuals first treated during young adulthood maintained a low level of drug use over time. Occurrence of first treatment during young adulthood was not associated with patterns of reduced drug use, however receipt of more drug treatment over time was associated with maintenance of a low level of drug use among those first treated as young adults but not among those first treated as older adults.

4.2. Implications

Few individuals in our study initiated drug treatment during young adulthood, a finding that is consistent with extant research (Gayman et al., 2011; SAMHSA, 2008). Participants were enrolled from settings that serve adults in need of health and other social services and thus may not be representative of the general substance using young adult population. Compared to the characteristics of young adults admitted to treatment nationwide in 2004 (SAMHSA, 2006b), our matched sample of young adults included more women, more African Americans and Hispanics, and more who reported their primary drug problem to be methamphetamine or cocaine instead of marijuana or alcohol. Nevertheless, when coupled with the finding that treatment during young adulthood was associated with particular characteristics, this finding that few in our sample initiated treatment during young adulthood lends further support for the need to develop and diffuse treatment interventions that engage different populations of substance-using adolescents and young adults (Godley et al., 2011).

Results indicate that first drug treatment is a key life event that impacts the course of drug use. Drug use patterns after treatment were heterogeneous, a finding that is consistent with the literature, but most adults in our sample, whether first treated as a young or older adult, exhibited a lower level of drug use after their first treatment. Some increased their use over time, indicating that the change in use patterns may have been temporary. Others did not respond to treatment right away but gradually decreased their use later on, indicating that treatment may have a delayed effect. A third group maintained a high level of use after treatment, indicating that they did not respond to treatment. This last group included more heroin users. Heroin addiction is often a chronic condition that may be best treated by long-term care strategies (Hser et al., 2007).

Receipt of more drug treatment after first treatment was associated with maintenance of low drug use levels among those first treated as young adults but not among those first treated as older adults. Sustained abstinence has been associated with more intense initial treatment, a greater cumulative treatment dosage, and early treatment re-engagement experiences (Hser et al., 2006; Li et al., 2010; Scott et al., 2005). Some evidence suggests that individuals who enter treatment sooner and stay longer are at less risk for mortality (Hser et al., 2006). Our finding may be indicative of how treatment effects can vary depending on how much cumulative treatment is received and when treatment exposures occur in the life course.

For both young and older adults very little drug treatment was received during the ten years following first treatment and, over the same time period, an equivalent amount of time was spent in incarcerated settings. Particular social contexts impose opportunities and constraints

in ways that impact health (Glass & McAtee, 2006). In particular, incarceration increases the likelihood of severe health limitations (Schnittker & John, 2007) and illnesses associated with stress (Massoglia, 2008), is independently associated with disparities in access to care (Kulkarni et al., 2010), and broadens disparities in health conditions (Wang & Green, 2010). Chronic health conditions are often the result of multiple multidimensional and interactive factors occurring on several levels simultaneously and over time (e.g., Bronfenbrenner, 1977; Kaufman & Poole, 2000). Of most interest is the identification of changes in drug use patterns that are related to exposure to treatment and the other health and criminal justice service systems that drug users commonly encounter (Hser et al., 2007). This approach is in keeping with the public health concept that information on service system exposure and its long-term impact on health can be used to diffuse innovations that more effectively prevent or alter adverse health behaviors (Greenhalgh et al., 2004). Future work should examine the cumulative and interactive effects of participant characteristics and key life events on drug use patterns over the life course.

Changes in drug use following treatment occurred at different stages of the life course, a finding that has potentially significant social and economic implications. Extrapolating from our data, we speculate that earlier drug treatment exposure could reduce the amount of time that individuals use drugs in their life. Moreover, treatment that occurs earlier may impact other life events and experiences (educational attainment, income-earning, and child-rearing) that typically occur during this time in the life course. Substance abuse in the United States exceeds an estimated $600 billion annually, exclusive of its social and public health implications (NIDA, 2011). Findings suggest that earlier treatment engagement combined with continuing care may lead to significant reductions in the economic and social costs of substance abuse. Additional studies are needed to better quantify the effects and broader cost-benefit implications of differential timing of drug treatment.

4.3. Limitations and strengths of the study

Findings need to be interpreted within the context of study limitations. The study sample was combined from several studies that enrolled participants from drug treatment and other health and social services settings in California. Thus, we were limited to using measures that the studies had in common and the study sample may not be representative of drug users outside of these settings, including those in the general population. Also, the years during which data collection was conducted by the different studies overlap but span several decades, representing distinctly different eras. Some research indicates that there is variation by birth cohort in illicit drug use patterns (Johnson & Gerstein, 1998) and treatment initiation (Joshi et al., 2001). How factors like these may confound the interpretation of results was not explored and constitutes an area for future research. Analysis relied on self-reported data and the length of the follow-up period varied by project. Recall or reporting bias may have occurred, however instruments employed in this study have been used in many previous studies with similar populations and have been demonstrated to provide acceptable reliability for longitudinal examination of self-reported drug use patterns (Murphy et al., 2010).

In addition, matching procedures eliminated many pre-treatment differences but a few remained (e.g., education level, exact onset ages), possibly influencing long-term trajectory patterns. Also, this approach excluded some study participants due to incomplete or inexact matching and the matched and unmatched samples may be different in ways that limit generalizeability. Future work might benefit from applying propensity score matching, an analytical approach to correct for selection biases (D'Agostino, 1998; Rosenbaum & Rubin, 1983, 1985) that is being applied by a growing number of substance abuse research studies (e.g., Evans et al., in press; Hser et al., 2011; Ye & Kaskutas, 2009) but was not used by the present study because of sample size restrictions. Also, a full 10 years of data was not

available on all participants, either because of death or for other reasons, and older adults had a shorter observation period than younger adults. In our growth mixture analysis, we assume missing values are missing at random (MAR; e.g., Muthen 2004; Muthen et al., 2011) but it is possible that the MAR assumption was violated. Analysis with further consideration of non-ignorable missing observations is an area for future research. Finally, as noted by the relevant literature on alcohol dependence (e.g., Dawson et al., 2006), it is difficult to determine if recovery is primarily the product of maturing out processes or if transitional life events cause recovery or are caused by recovery. Our study lacked a non-treated comparison group and it did not aim to establish causal mechanisms regarding the effects of drug treatment on drug use. Instead, a sample of treated drug users was examined to better understand how the developmental timing of treatment may be associated with changes in subsequent drug use patterns.

As for strengths, this study utilized a large and diverse sample of drug users sampled from diverse settings, it employed a longitudinal design, examining drug use and other behaviors over ten years, it focused on young adulthood, a phase of the life span that is inadequately understood, and it applied cutting edge statistical techniques (e.g., growth mixture analysis), congruent with recommendations that such methodologies are needed to advance understanding of the determinants of health (Etches et al., 2006). Furthermore, this study contributes to understanding of how the occurrence of critical life events during particular developmental stages may affect lifelong substance use and other behaviors, a topic that has been identified by extant literature as being little understood (Teruya & Hser, 2010).

4.4. Conclusion

Determining what treatment works best for whom and under what circumstances has been recognized as a key goal as such information can be used to tailor public health programs to better meet the needs of diverse populations (Institute of Medicine, 2009). We found that developmental timing of first drug treatment interacts with subsequent treatment experiences in ways that appear to impact the course of drug use. This study contributes to the literature by broadening understanding of lifelong drug use behaviors and how to prevent or change the course of drug use and addiction.

Acknowledgments

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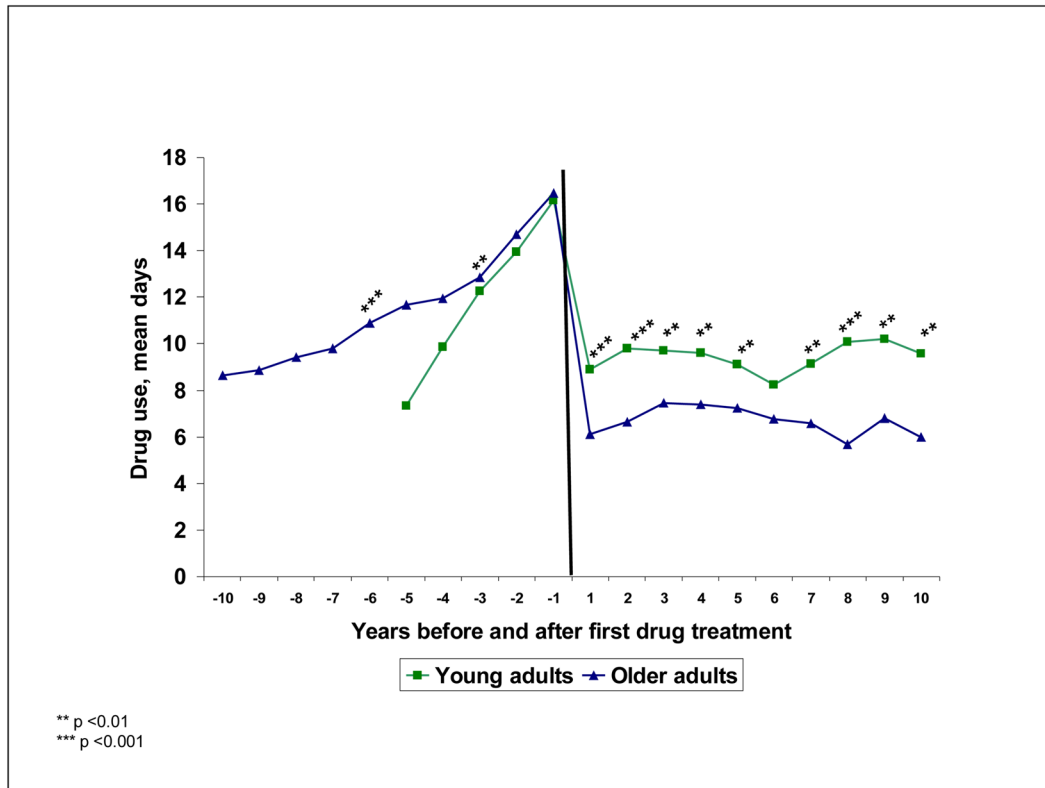
Figure 1.
Drug use before and after entry into first drug treatment, unmatched sample (n=1,318)

	Young Adults[c]	Older Adults[c]	Total Sample
Group membership, %			
Remains high	13.9	6.4	10.1
Decreases then increases	14.2	13.1	13.7
Increases then decreases	9.4	4.1	6.7
Remains low	62.5	76.4	69.5

[c]p<0.001 Note: Periods of incarceration were treated as periods of no drug use (zero-inflated). When sensitivity analysis was conducted to treat periods of incarceration as missing data, patterns of drug use remained the same (data not shown).

Figure 2.
Drug use trajectories 10 years after entry into first drug treatment (N=534)

Table 1

Sample characteristics, Mean (SD) or %

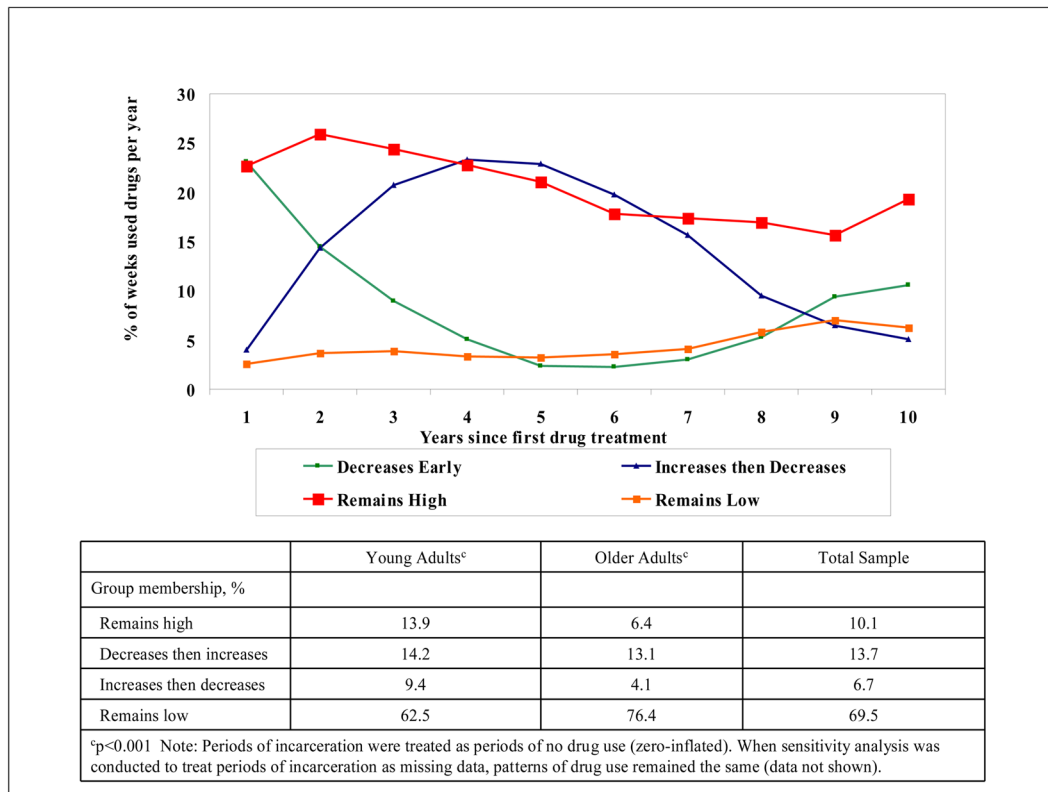|	Unmatched (N=1,318)		Matched (N=534)	
	Young Adults (N=348)	Older Adults (N=970)	Young Adults (N=267)	Older Adults (N=267)
At entry into first drug treatment				
Female	48.8 [c]	34.1 [c]	44.9	44.9
Race/ethnicity	c	c		
White	42.4	32.2	47.2	47.2
African American	25.0	47.1	26.9	26.9
Hispanic	27.0	11.8	21.7	21.7
Other	5.8	4.7	4.1	4.1
Education	c	c	a	a
Less than high School	34.8	23.7	32.9	27.7
High school or GED	28.7	28.7	21.5	25.8
Some college	36.5	47.6	35.6	46.4
Marital status	b	b		
Married	12.9	21.1	11.6	12.7
Single/never married	13.5	13.4	14.6	10.1
Divorced/separated/widowed	73.6	65.5	73.8	77.2
Project	c	c		
12-year Cocaine Follow-up (CTE)	6.6	29.6	8.2	10.5
Methamphetamine Natural History (METH)	37.1	20.2	40.5	38.2
Treatment Utilization and Effectiveness (TUE)	16.7	13.9	18.4	12.0
Treatment Process (TPROC)	39.7	36.3	33.0	39.3
Primary drug type	c	c		
Alcohol	3.2	6.9	3.0	3.0
Marijuana	5.2	1.0	1.0	1.0
Cocaine	26.4	53.1	30.0	30.0
Methamphetamine	47.7	27.4	52.1	52.1
Heroin	14.1	9.6	12.4	12.4
Other	3.5	2.3	1.9	1.9
Age at first				
Any drug use	13.2 (2.9) [c]	15.3 (4.4) [c]	13.3 (3.0) [c]	14.4 (3.5) [c]
Primary drug use	17.0 (3.2) [b]	22.7 (7.0) [b]	17.5 (2.8) [c]	21.1 (6.2) [c]
Regular use of primary drug	18.4 (3.9) [c]	25.4 (7.6) [c]	18.7 [c]	23.7 [c]
Arrest	16.9 (4.4) [c]	20.7 (7.6) [c]	17.3 [c]	19.4 [c]
Incarceration	21.8 (5.9) [c]	28.2 (8.7) [c]	22.0 [c]	25.5 [c]
Drug treatment	22.1 (2.2) [c]	34.3 (6.5) [c]	22.3 (2.2) [c]	32.9 (5.2) [c]
First used primary drug age 14 (vs. >14)	21.8 [c]	8.1 [c]	12.0	12.0

	Unmatched (N=1,318)		Matched (N=534)	
	Young Adults (N=348)	Older Adults (N=970)	Young Adults (N=267)	Older Adults (N=267)
First arrested age 17 (vs. >17)	59.2 [c]	39.4 [c]	54.4	54.4
Yrs from 1st any illicit drug use to 1st drug treatment	8.9 (3.5) [c]	19.0 (6.8) [c]	9.0 (3.6) [c]	18.5 (5.2) [c]
Mos from 1st primary drug use to 1st drug treatment	61.7 (41.2) [c]	139.4(92.4) [c]	58.0 (38.5) [c]	142.0(84.1) [c]
1-year pre-first treatment, total mos				
Any drug use	10.1 (3.4)	10.2 (3.3)	10.0 (3.5)	9.7 (3.6)
Primary drug use	8.3 (4.7) [c]	9.2 (4.0) [c]	8.0 (4.8) [c]	8.7 (4.3) [c]
Incarceration	1.1 (2.7)	1.1 (2.7)	1.2 (2.8) [b]	1.4 (2.9) [b]
Employment	4.2 (5.1) [c]	5.4 (5.4) [c]	4.4 (5.2)	4.7 (5.5)
10-years post-first treatment, total mos				
Used any drug	47.4 (36.1) [a]	42.0 (39.3) [a]	49.4 (33.5) [c]	33.5 (34.9) [c]
Used primary drug	33.6 (33.3) [b]	27.1 (31.7) [b]	34.9 (32.5) [c]	21.0 (26.7) [c]
Incarcerated	9.3 (16.5) [c]	4.9 (12.0) [c]	10.4 (17.8) [b]	6.8 (14.9) [b]
In drug treatment	12.9 (13.9)	11.8 (14.3)	12.7 (12.8)	11.5 (12.0)
Employed	28.1 (35.1) [c]	36.5 (41.6) [c]	31.5 (36.1)	28.7 (35.5)

[a]
$p < 0.05$.

[b]
$p < 0.01$.

[c]
$p < 0.001$.

Table 2

Polynomial logistic regression predicting membership in 10-year drug use trajectory groups (N=504)

	Model 1: Main effects			Model 2: Interaction effects		
	Remains high (vs. Remains low)	Decreases then increases (vs. Remains low)	Increases then decreases (vs. Remains low)	Remains high (vs. Remains low)	Decreases then increases (vs. Remains low)	Increases then decreases (vs. Remains low)
	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
Intercept	-3.229	-1.270	-1.301	-4.019	-1.886	-1.741
First drug treatment as young adult (vs. older adult)	1.345 [c]	0.417	0.888 [a]	2.525 [c]	1.490 [a]	1.172
Male (vs. female)	-0.502	-1.142 [c]	-1.278 [b]	-0.009	-0.838	-0.310
White race/ethnicity (vs. all others)	0.371	0.021	-0.251	0.423	-0.008	-0.209
High school (vs. < high school)	-0.144	0.312	0.155	-0.145	0.266	0.220
Married (vs. not married)	-0.585	-0.202	-0.292	-0.598	-0.202	-0.027
Project						
CTE (vs. TPROC)	-0.878	0.692	0.392	-0.959	0.675	0.333
METH (vs. TPROC)	-0.284	-0.046	0.257	-0.376	-0.103	0.267
TUE (vs. TPROC)	0.578	-0.159	0.648	0.574	-0.291	0.724
Primary drug type is heroin (vs. all others)	2.398 [c]	0.626	1.393 [a]	2.552 [c]	0.577	2.279 [b]
Age at 1st arrest (continuous)	0.048	0.034	-0.021	0.054	0.039	-0.011
Age at 1st use (continuous)	-0.018	-0.040	-0.050	-0.017	-0.033	-0.052
Over 10 yrs after first drug treatment						
Mos incarcerated (continuous)	-0.040 [a]	0.014	-0.007	-0.021	0.025 [a]	-0.029
Mos in drug treatment (continuous)	0.003	-0.019	0.003	0.012	0.012	-0.037
Mos employed (continuous)	-0.0006	-0.005	0.002	0.005	-0.011	0.003
Interactions: First drug treatment as young adult (vs. older adult) X						
Male (vs. female)	--	--	--	-0.841	-0.704	-1.508
Primary drug type is heroin (vs. all others)	--	--	--	-0.263	0.002	-1.697
Mos incarcerated over 10 years after 1st treatment (continuous)	--	--	--	-0.025	-0.016	0.034
Mos in drug treatment over 10 yrs after 1st treatment (continuous)	--	--	--	-0.022	-0.065 [a]	0.049
Mos employed over 10 yrs after 1st treatment (continuous)	--	--	--	-0.009	0.008	-0.001

[a] $p < 0.05$.

[b] $p < 0.01$.

[c] $p < 0.001$.