The impact of heroin on frontal executive functions

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Abstract

Our study examined the impact of heroin on frontal executive functioning in three cognitive domains, namely attention, impulse control, and mental flexibility and abstract reasoning. It was hypothesized that heroin addiction would lead to deficits in these three cognitive domains. Fifty-five participants, 30 heroin addicts, and 25 normal controls were invited to participate in this study. Each participant was individually interviewed for demographic data and tested by the selected neuropsychological measures. The findings indicate that heroin addiction has a negative effect on impulse control, while attention and mental flexibility/abstract reasoning ability were not affected.

Keywords: Heroin; Frontal executive functions; Neuropsychology

1. Introduction

Heroin belongs to the family of opiates. Because of its capability of crossing the blood–brain barrier, it is a very potent agent in producing euphoria. Despite its propensity to neuropsychological consequences, research on the impact of heroin use on cognitive activities has been scarce both in the East and the West. Among the very few studies on heroin addiction and its effect on human cognitive functioning, inconsistent findings were reported.

Brown and Partington (1942) studied the intellectual functions of 371 native, white, male narcotic drug addicts by comparing their performance on the Wechsler–Bellevue Intelligence Scale with the normative data of the test as well as the performance of a group of 42 hospital attendants. No significant differences on the Full scale, Verbal scale, and Performance scale

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IQ scores were reported. Fields and Fullerton (1974) studied 69 hospitalized male veterans between 18 and 35 years of age. They belonged to the heroin addiction group, the brain-damaged group, and the control group. Comparing the performance of these three groups on various neuropsychological instruments, again the heroin addiction group did not perform significantly worse than the control group.

Strang and Gurling (1989) believed that substance-specific effects of heroin on neuropsychological functions should be examined within the context of long-term use of high doses of heroin. They recruited seven participants according to this criterion. Apart from the slightly poor performance of the recruited heroin addicts on tests of perceptual-motor speed and verbal recognition memory, a striking observation of this study was that daily use of high doses of heroin on a long-term basis did not produce any deleterious effect on cognitive functioning.

Guerra, Sole, Cami, and Tobena (1987) proposed that time of measurement was a significant methodological issue in studies on heroin addiction and neuropsychological functioning. They evaluated their subjects during the predetoxification and postdetoxification stages on selected neuropsychological measures. They observed rapid improvements in performance between these two times of measurement. No significant differences between their sample of detoxified heroin addicts and the demographically matched controls were observed.

Some other studies of the effect of heroin use on human cognition produced significant findings. Korin (1974) studied perceptual-motor disturbance among psychotic heroin addicts, nonpsychotic heroin addicts, psychotic nonopioid addicts, and nonpsychotic nonopioid addicts. They concluded that perceptual-motor deficits were associated with heroin used. Both psychotic and nonpsychotic heroin addicts committed more errors on the Bender–Gestalt Test. Moreover, the heroin addicts were found to have an increased number of perseveration errors and rotations in their drawings as well as constricted use of space of paper when compared with the nonopioid addicts. Hill and Mikhael (1979) studied the neuropsychological functions of the tactual-spatial memory and fine motor skills of the heroin addicts, and observed that they performed worse than the normal controls. Rounsaville, Novelty, Kleber, and Jones (1981) compared neuropsychological performance on several measures between heroin addicts and people with epilepsy. They reported that both groups were neuropsychologically impaired but were presented with different profiles of cognitive impairment. Ahmad, Ahmad, and Bindra (1989) also reported that heroin addicts performed poorer than normal controls on tests of intelligence, memory, attention and concentration, and perceptual-motor coordination.

The report of Davis and Templer (1988) may enlighten our understanding of the long-term effect of heroin use. They studied 28 children and adolescents who were exposed to narcotics in utero. The findings indicated that these narcotic-exposed children displayed an array of deficits in the cognitive, perceptual-motor, and behavioral realms. The findings on the Burks Behavior Rating Scales suggested that they were impulsive, undersocialized, inattentive, more susceptible to school adjustment difficulty, and presented with more interpersonal problems. They concluded that exposure to narcotics leads to some long-term neuropsychological and behavioral deficits, and that the drug effects can last for at least 6–15 years.

In view of all these discrepant findings, this study revisited the issue and examined the cognitive effect of heroin addiction. In this connection, Hong Kong provides a fertile site for research on the cognitive effect of heroin use because, unlike in the West, heroin is the most popular drug of abuse among drug addicts in Hong Kong. According to the Central Registry of
Drug Abuse Thirty-nine Report\(^1\) (Narcotics Division of Hong Kong Government Secretariat, 1997), among the 18,593 out of the pool of 19,626 drug addicts surveyed for types of drugs that they used, 86.6% of them reported having used heroin. Weinstein and Shaffer (1993) suggested that drug addiction could lead to neuropsychological deficits in seven areas, namely decreased spontaneity, difficulty in mental and/or behavioral shifting, difficulty in sustaining attention, impulsiveness, impaired social awareness, impaired insight, and impaired abstract reasoning. These seven areas of deficits are indeed deficits of frontal executive functions, which can be recategorized into three major domains: (1) attention, (2) impulse control, and (3) mental flexibility and abstract reasoning. Following Weinstein and Shaffer’s model, our study examined the impact of heroin addiction on frontal executive functions in these three domains of cognitive functions. Heroin, being a powerful analgesic and sedative capable of crossing the blood–brain barrier, may lead to significant neuropsychological sequelae in attention, impulse control, and/or mental flexibility and abstract reasoning.

2. Method

2.1. Participants

Fifty-five people were invited to participate in this study. Thirty participants were in the heroin addiction group (HA) (mean age = 24.47, S.D. = 4.67; mean years of education = 8.83, S.D. = 1.12). Twenty-five of them served as normal controls in the normal comparison group (NC) (mean = 20.48, S.D. = 5.01; mean years of education = 10.72, S.D. = 0.68). The participants in HA were screened by a Correctional Services Officer trained to be familiar with the inclusion criteria for the HA group, which were (1) the participants had to be primary heroin users who met at least three criteria of Opioid Use Disorders listed in the Diagnostic and Statistical Manual of Mental Disorders—4th edition (American Psychiatric Association, 1994) at any time in the same 12-month period before they were admitted to the Drug Addiction Treatment Center (American Psychiatric Association, 1994); (2) they should not have any history of physical and/or psychiatric conditions affecting cognitive functions according to their medical records. The mean years of heroin use of HA was 4.68 years. The mean months of abstinence was 13.7 months. The participants in NC were nonheroin users recruited from multiple sources including different youth groups and centers. They were people free of any history of physical and mental disorders affecting neuropsychological functions.

In this study, there was no significant difference in gender composition of the two groups ($\chi^2$(df = 1) = 1.849; ns). However, other demographic characteristics in the dimensions of age ($t = 3.051$, df = 53, $P = .004$) and level of education ($t = −7.382$, df = 53, $P < .001$) could not be matched. This indeed is a valid reflection of the social consequence of substance use that addicts tend to be younger and have a lower level of education than their peers as reported in the Central Registry of Drug Abuse Thirty-ninth Report (Narcotics Division of Hong Kong Government Secretariat, 1997). In view of the reality that it would be almost impossible to

\(^1\)Central Registry of Drug Abuse (CRDA) published regular reports half-yearly on statistics from different sources for the purpose of analyzing the characteristics of the reported addict population at any given time.
match the two groups in the dimensions of age and education, the confounding effect of age and level of education were controlled statistically by using the covariate procedure.

2.2. Measures

Four measures were used in this study. The Serial Seven Subtraction Test (SSST, Smith, 1967) was selected to evaluate sustained attention ability. The Color Trails Test (CTT, Maj et al., 1993) was used for measuring the more complex divided attention ability. The domain of impulse control was measured by the qualitative score of the Porteus Maze Test (PMQS, Porteus, 1942, 1956). The domain of mental flexibility and abstract reasoning was measured by the Wisconsin Card Sorting Test (WCST, Heaton, 1981). The instructions and/or English stimuli of these measures were translated into Chinese, reviewed by an expert panel of five members to judge their cultural relevance, clarity, and comprehensibility, and then pilot tested.

The SSST was used to assess the subject’s focused attention. Each subject was asked to subtract seven from 100 repeatedly until there was less than seven. Both number of errors and time taken were recorded as the indicators of the subjects’ focused attention. Shum, McFarland, and Bain (1990) studied the construct validity of the SSST and reported that the test measured the ability to focus on mental processing and this construct was same for the normal subjects and patients with head injury.

The CTT has the sensitivity and specificity of the standard Trail Making Test (D’Elia, Satz, Uchiyama, & White, 1996; Lee & Chan, 2000a, 2000b). Different from the Trail Making Test, the CTT does not require knowledge of modern European alphabet to complete the test. The CTT-Part 1 requires the subject to make pencil lines to connect 25 encircled numbers randomly arranged on a page, and the CTT-Part 2 requires the subject to encircle the numbers in alternating color. The 2-week test–retest reliability of the CTT-Part 1 and CTT-Part 2 were .644 and .787, respectively (D’Elia et al., 1996). The results from factor analytic studies supported the construct validity of the CTT time variable as a measure of divided attention (D’Elia et al., 1996).

The PMQS was selected for measuring the subjects’ impulsivity (Porteus, 1942, 1956). The Porteus Maze Test required the subjects to trace a series 10 mazes with increasing difficulty without going into blind alleys or crossing lines to avoid drawing around to reach an opening (Porteus, 1956). A scoring system was derived to record the qualitative errors of the subjects. These qualitative errors include: (a) Crossed line—every place in any test where a line has been crossed or touched is counted. (b) Cut corners—every corner cut is counted. (c) Lifting pencil—number of times of each subject lifts the pencil during the course of test. (d) Wavy lines—a series of photographs of penalized performances are provided in the manual (Porteus, 1942). Those that are judged equal or worse than the sample are counted as error. (e) Wrong direction—wherever the subject’s drawing indicates an intention to go up the wrong path, an error is scored. (f) Failure in first third of test—a qualitative error is scored if the subject fails in a trail by going up a blocked path nearly to the end of test is scored as a qualitative error. (h) Errors in first two mazes—qualitative errors (not failure) occurring the first two mazes receive additional penalties in the total Qualitative Score. The score and degree of impulsiveness are positively correlated. The study conducted by Gow and Ward (1982) on 90 adolescent student in the regular school showed that those students who were rated as a below-average on the
Teachers’ Rating Scale of Impulsivity, obtained significantly higher Qualitative Score on the Porteus Maze Test than the other students. It provided an evidence of the concurrent validity of Porteus Maze Test.

The WCST was chosen to measure the subjects’ problem in perseveration and abstract thinking. Three scores, perseverative errors, number of trials, and number of categories completed, were recorded according to Heaton’s (1981) administration procedure. Regarding the interscorer and intrascorer reliability, the study conducted by Axelrod, Goldman, and Woodard (1992) on 30 psychiatric adult inpatients who completed the WCST showed that the interscorer reliability was .92 and the intrascorer reliability was .94 for perseverative errors. Both types of reliability were excellent. The factor analytic studies on the WCST demonstrated that the number of categories achieved loads on both “complex intelligence” and “planning-organization” factors whereas the perseverative errors showed a significant planning component (Diagneault, Braun, Gilbert, & Proulx, 1988).

2.3. Procedures

All potential participants were explained the aims of our study. Voluntary participation was sought. Each participant was then individually interviewed for demographic data and then administered the measures used in this study in standardized order of sequence. The participants in HA were assessed in the interview rooms, one in each of the two individual centers. The participants in NC were interviewed in rooms arranged by the youth groups and centers or in the neuropsychology laboratory in our department.

2.4. Data analysis

The univariate analysis of covariance procedure (ANCOVA) was employed to assess the differences in performance between the HA and NC on the selected outcome measures using the SPSS software package.

Table 1
Mean, standard deviation, the means on the neuropsychological functioning tests

<table>
<thead>
<tr>
<th></th>
<th>Heroin addict group</th>
<th>Normal comparison group</th>
<th>F</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td>SSST: time spent</td>
<td>55.72</td>
<td>21.54</td>
<td>63.26</td>
<td>44.38</td>
</tr>
<tr>
<td>SSST: number of errors</td>
<td>2.53</td>
<td>2.87</td>
<td>1.32</td>
<td>1.18</td>
</tr>
<tr>
<td>CTT1: time spent</td>
<td>34.42</td>
<td>8.75</td>
<td>28.66</td>
<td>8.81</td>
</tr>
<tr>
<td>CTT2: time spent</td>
<td>67.65</td>
<td>16.61</td>
<td>59.17</td>
<td>14.56</td>
</tr>
<tr>
<td>WCST: number of perseverative errors</td>
<td>19.43</td>
<td>12.81</td>
<td>13.92</td>
<td>8.78</td>
</tr>
<tr>
<td>WCST: number of categories completed</td>
<td>4.30</td>
<td>2.09</td>
<td>5.68</td>
<td>0.95</td>
</tr>
<tr>
<td>WCST: number of trials</td>
<td>107.83</td>
<td>22.89</td>
<td>98.48</td>
<td>20.90</td>
</tr>
<tr>
<td>Porteus Maze Qualitative Scores</td>
<td>33.40</td>
<td>22.83</td>
<td>18.64</td>
<td>12.96</td>
</tr>
</tbody>
</table>

Time spent is in seconds, CTT1 is Color Trails Test-1, CTT2 is Color Trails Test-2, SSST is Serial Seven Subtraction Test, WCST is Wisconsin Card Sorting Test.

* df (1,51).
3. Results

Descriptive statistics of the performance of the two groups of participants as well as the results of the ANCOVA are presented in Table 1.

The results showed that only the PMQS were significantly different between the two groups \[F(1,51) = 4.278, P = .044\]. The other findings were not statistically significant \[F(1,51) = 0.004–3.431, P = .07–.948\].

4. Discussion

The findings of the present study suggest subtle impulse control difficulty as a result of heroin use. Our participants in the HA did significantly worse on the Porteus Maze Test. They tended to be reckless, ignore the rules and regulations of the task, and lack an overall plan for solving the task. According to the normative data presented by Porteus (1956), the critical value of the PMQS for males was 29, whereas for females it was 32 (Porteus, 1942). In this study, the mean PMQS for the HA was 33. This score is way above the critical cut-off, indicating that heroin addiction, even after a duration of 5 years, adversely affects a person’s ability to inhibit the impulse for more well-planned and adaptive social and cognitive behaviors. However, whether impulse control problem predisposes or is a consequence of heroin use is a question worth of future research.

Other cognitive skills studied, including attention and mental flexibility/abstract reasoning, appeared to be unaffected. Given that the mean years of heroin use was about 5 years among our HA participants, we suggest from our findings that heroin used for about 5 years may not bring about any significant detrimental effect on the frontal executive functions measured, other than impulse control. The long-term effect of heroin use on frontal executive functions needs further research, longitudinal or cohort study, for verification. Furthermore, the reversibility of the effect of heroin use on cognitive functions, as observed in our study of its effect on impulse control, opens another avenue for future research. Future studies may also attempt to differentiate the effect of heroin addiction and the mechanisms underlying delinquency on the observed impaired neuropsychological functions. Donovan, Soldz, Kelley, and Penk (1998) observed that heroin addicts are characterized by distinctive hostility, depression, and alienation. Could these personality traits relate to the impaired neuropsychological functioning observed which then predispose heroin addiction? Cross-cultural characteristics of heroin use should be examined. Patalano (1998) reported that there were strong cross-cultural similarities in the personality makeup of heroin users in India and America. Would this also be applicable to the Chinese culture? Further exploration of this issue would provide further insight into the aetiological mechanism of substance use. Program evaluation should be conducted to guide the development of cost-effective treatment programs for drug addiction.

The results of the present study provide some support for Weinstein and Shaffer’s (1993) proposition that one of the sequelae of long-term substance use is neuropsychological difficulties. The difference in our findings and those of previous studies (Brown & Partington, 1942; Fields & Fullerton, 1974; Guerra et al., 1987; Strang & Gurling, 1989), which found no difference between the samples of detoxified addicts and controls on neuropsychological
measures, may be explained by the characteristics of the HA in this study as well as other possible methodological discrepancies (e.g., Brandt & Doyle, 1983).

The mean age of the heroin addicts’ first-time use of heroin was 19.67 years old. About 7% of the heroin addicts started to use heroin at the age of younger than 15, and about 84% of them began to use heroin between the ages of 15 and 24. This epidemiological pattern is similar to that reported by Kumar et al. (1996). The involvement of the young and unemployed, and the detrimental effect of heroin used on the fetus during pregnancy (King, 1997) implies an urgent need for early intervention by cost-effective rehabilitation programming. Given that impulsivity control is an important element in effective rehabilitation of heroin addicts, based on the findings of our study, a number of points may be incorporated in the planning and implementation of heroin treatment programs. In view of their impaired impulse control, a small group size is preferred so as to cut down the level of environmental stimulation and distraction. Furthermore, each group session should be limited to a small size so that each participant has adequate individual supervision during group activities. Also, the heroin treatment program should be conducted in a quiet environment, which helps the heroin addicts focus on the process of the activities (Morse & Montgomery, 1992). The therapist should adopt more interactive means of training to assist with the skills acquisition of the heroin addicts. Role playing is a good way to help them to grasp practical skills, for example, job interview skills, which should be an effective strategy for those who have had difficulty with employing their abstract reasoning ability to generalize skills learned to other novel situations (Bandura, 1986). Frequent practices should be encouraged.

References


