Impairment and Control: Bilateral Relationship between Alcohol Use Disorder and Working Memory

Jiahuan Liu[1, *]

[1]Department of Psychology, James Cook University, Singapore

*Corresponding author: jiahuan.liu@my.jcu.edu.au

Abstract. Alcohol use disorder (AUD) is a common addictive psychological disease in modern society. AUD can induce a cluster of health and working memory (WM) problems, including Korsakoff's syndrome, irrational decision-making, impaired executive function, and impulsivity. Neuropsychological evidence shows that prefrontal cortex (PFC) function is impaired in AUD patients and their dopamine (DA) level is unstable. The present essay aims to discuss the relationship between AUD and WM from three points of view. Firstly, the behavioral and neuropsychological deficits of AUD subjects were summarized and categorized in detail. Secondly, the potential mechanism of WM impairment is discussed. Thirdly, various kinds of neuropsychological and behavioral treatments for AUD were critically reviewed and evaluated. While the pharmacological treatment was supported by various empirical studies and validated in different subtypes of AUD, the emerging behavioral therapy was revealed to be more secure and side-effect free than traditional medications.

Keywords: Alcohol use disorder; working memory; prefrontal cortex; dopamine; behavioral treatment.

1. Introduction

An impaired ability to cut back or stop drinking in the face of detrimental social, occupational, or health effects is a hallmark of alcohol use disorder (AUD). People with AUD normally face enormous health consequences, including mortality, cardiovascular disease, liver disease, and malignant neoplasms. Brain imaging studies and other neurologic deficits, such as working memory, executive function, emotional signal processing, and visuospatial deficits, show that excessive alcohol use also damages the brain [1]. Korsakoff's syndrome, which is marked by cognitive decline and significant memory deficits including both retrograde and anterograde amnesia, may emerge in the most severe instances in AUD patients.

Working memory (WM), as a type of impaired cognitive abilities in AUD patients, is defined as a memory process in which information is temporarily stored and integrated for later manipulation and use. The four parts of the WM model—the phonological loop, visual sketchpad, episodic buffer, and central executive—were first put forth by Baddeley in 1998. In detail, Phonological loop consists of an articulatory loop and an acoustic store that stores phonological information and prevents it from being attenuated by repetition. The visual spatial sketchpad stores visual and spatial information, such as the color of an image or building location on a map. The episodic buffer temporally stores episodic information, including musical information, semantic information, and other environmental cues. The function of the central executive system is to allocate attention and decide what information is needed for current work.

In AUD patients, poor WM performance is mainly reflected in two aspects. In terms of behavior, AUD patients are unable to control their drinking behavior, relapse from abstinence, and continue drinking despite negative physical, psychological, and social consequences [2]. Tolerance and withdrawal are two typical behavioral symptoms in AUD patients. The former refers that patients had to drink more to get the same effect, whereas the later refers to a cluster of feelings when stopping drinking, such as anxiety, sweating, and nausea. The medial prefrontal brain of AUD patients had dysregulation, whereas the anterior prefrontal cortex had reduced activity. They are parts of the brain that are involved in cognitive executive function and personal attention allocation [3].

By reviewing several empirical studies, the present essay summarized the cognitive deficits and potential mechanisms in AUD formation and abstinence. WM was revealed to be an important factor in both processes. The paper also reviewed the quality and efficiency of new treatments for AUD which were based on WM training programs. Comparisons were made between the new therapy and traditional pharmacological treatments,

2. Behavioral and neuropsychological WM deficits in AUD patients

2.1 Behavioral deficits

Working memory, like other cognitive abilities declines with age, however, some specific diseases, such as AUD, can decrease an individual's WM capacity, even in a young population [4]. In an experiment examining the effect of age on working memory, researchers divided 59 participants between 19 and 76 years into two groups (young and aged adults). No memory complaints were found in the pretest and nobody reported memory difficulties in their everyday life. A Listening Span Task (LST) was then administered. A phrase had to be heard, and the subject had to decide if it was true or untrue. Simultaneously, participants needed to store the last word of each sentence for later recall. It was found that older adults have a much harder time remembering words than younger people, which makes sense since WM gets worse with age [4].

An internet questionnaire and research on people with hangovers showed that the completion time of execution ability and WM questionnaires was significantly correlated with the severity of hangovers and blood alcohol content [5]. This finding revealed that alcohol consumption is negatively correlated with WM performance [5]. Also, it was found that the amount of alcohol in the blood has a moderately positive relationship with how bad the hangover is, and the worse the hangover, the longer it took people to answer questions about execution ability and WM [5].

2.2 Neuropsychological deficits

Many brain-imaging technologies have been used to observe cortical and subcortical brain activities of neuropsychological deficits in AUD patients. Although multiple brain structures are confirmed damaged in AUD patients, the compromised prefrontal cortex (PFC) has been observed in many AUD patients. Additionally, there is evidence that AUD reduces brain volume in the frontal and subcortical regions. This means that patients have trouble with executive functions and especially with tasks that require cognitive control.

Crego and colleagues conducted an experiment to test Spanish university students whether their visual WM capacity was impaired by binge drinking [3]. 95 students, with 53 control subjects and 42 binge drinkers, were asked to complete a pair of continuous performance tasks while event-related potential (ERP) and electroencephalogram (EEG) data were collected from their brains [3]. Researchers found that drinkers and non-drinkers did not differ in WM task performance, although there was a smaller positive component at the right anterior prefrontal cortex (aPFC) in binge drinkers. This result revealed that subtle neural changes happened in AUD patients even when no behavioral changes were observable.

Despite the various brain structural changes in AUD, the abnormal dopamine (DA) level in AUD patients also received many research interests. DA is a neurotransmitter that transmits excitation signals in the brain. The prefrontal cortex (PFC) is a region that receives enormous DA projections from the medial dorsal thalamus, where DA is produced. It has been observed that an individual's cognitive performance is very sensitive to the change of DA in the PFC. In an experiment, participants were given low and high concentrations of dopamine-suppressing drugs to control DA levels in the brain and completed cognitive tasks during the study [6]. The findings demonstrated a relationship between subpar WM performance and both low and high DA levels. It was thought that a "inverted U" pattern, or an optimal amount of DA, should be present in the PFC to ensure that neither too little DA nor too much DA is connected to effective WM function [6].

3. WM impairment mechanism in AUD patients

3.1 AUD Formation

Like other drug addictions, AUD has been proposed as the result of a mismatch between two decision-making systems: an amygdala-based impulsive system of immediate prospects and a prefrontal cortex-based reflective system of future prospects. The immediate prospect system is an impulsive, bottom-up system that triggers quick, automatic, and obligatory affective and emotional responses to external stimuli. The future prospect system is a top-down, reflective system that focuses on more logical and rational reasons and leads to behavior that is good for a person's long-term future.

AUD patient always has difficulty in suppressing their impulse to drink, because withdrawal responses to alcohol leave patients in a range of uncomfortable states, including racing hearts, sweating, and anxiety. The impulsive system would stimulate an individual's drinking behavior to relieve anxiety. But if the patient is taking abstinence therapy, he would probably know that there are many health benefits to quitting alcohol. So, AUD patients will try to control the impulse to drink, which is a typical decision process that is driven by the reflective system. In summary, the mismatch between the two decision-making systems in binge drinking people is a major reason of AUD formation and also causes poor performance in various cognitive tasks that require rational and logical thinking.

3.2 AUD Abstinence

Abstinence is the process of quitting binge drinking and regaining mental health in former AUD patients. Researchers have found that quitting drinking can fix the damage that overdosing on alcohol did to the brain's structure [7]. The restoration of brain structure can further lead to improvement in WM capacity and better self-control.

By using a structural Magnetic Resonance Imaging (MRI) method, researchers found a rise in bilateral hippocampus volume in abstinence patients, a structure that participates in short-term and long-term visual memory processing [7]. This is consistent with another cross-sectional study that compared cognitive function in abstaining AUD patients and healthy controls and found performance improvement on a spatial WM task in abstaining patients. Moreover, an experiment revealed that AUD patients who have kept abstinence for more than one year outperformed those who just began abstinence, although the control group had the best performance on cognitive tasks [8]. A longitudinal study revealed that, AUD patients who can keep abstinence for 6 months showed better WM performance on a two-back task [9]. However, the effect of abstinence is limited while not all cognitive control deficits can be reversed by continuing abstinence. Even though some other cognitive abilities improved, it was challenging to maintain WM over time, especially in older participants [9]. In summary, these empirical findings emphasize the importance of alcohol abstinence, which makes the treatments and therapies key.

4. Pharmacological and behavioral therapy for AUD

4.1 Pharmacological therapy

Pharmacological treatment has been revealed to be an effective way to control and prevent relapse in different kinds of AUD patients [10]. Early-onset alcoholics (EOA), also known as Type II alcoholics, who are characterized by an early onset age, multiple antisocial behaviors, and high family inheritability. In addition, EOA typically respond better to ondansetron in clinical settings [10]. After years of excessive drinking, type I alcoholics get AUD later in life and may respond more well to naltrexone and selective serotonin reuptake inhibitors clinically [11]. In an eight-week long double-blind placebo experiment, 20 early-onset alcoholics were randomized to receive naltrexone + ondansetron or placebo as their weekly treatment. Participants who received ondansetron + naltrexone had significantly fewer drinking days during the study and a future trend of abstinence [11].

However, traditional pharmacological treatments for AUD, such as Disulfiram, naltrexone, and acamprosate, as well as other off-label medications, have been shown to be unsuitable in many cases due to side effects such as hepatic toxicity and dysfunction. Recent therapists say that behavioral treatments like WM training can help AUD patients improve their cognitive functions and cut back on their drinking [2].

4.2 Behavioral therapy

Interview of motivation, contingency management, and cognitive behavioral therapy are just a few of the behavioral and psychological evidence-based therapies that have recently been incorporated into AUD therapy. Aside from their primary goals of lowering desire and attentional bias or enhancing emotion regulation, medications and cognitive-behavioral approaches may also indirectly improve cognitive control during crucial decision-making moments [12]. Brain imagery research has revealed that bilateral parietal cortices have shown increased activity during WM tasks in adolescents with AUD [12]. In contrast, bilateral cerebellar areas and the left precentral gyrus have shown diminished responses, which reflects the increase in impulsive behavior and decrease in inhibitory ability in AUD patients. Based on these findings, some therapists are trying to train the WM through cognitive behavioral methods to enhance the top-down process of inhibiting the impulse to drink alcohol. Notice that WM training has better effects on cognitive recovery and improving WM than self-control-based abstinence, which also showed a recovery of workability and attention distribution.

In a WM training therapy program, researchers recruited fifty AUD patients who were interested in attending behavioral therapy and curing their AUD syndrome [2]. A commercial cognition training software called Cogmed® was introduced to all participants and installed on their smartphones [2]. Various kinds of cognitive training programs, such as remembering sequences of visual stimuli on a grid or remembering sequences of numbers, were packaged into the program, and participants needed to practice them daily and upload their results to the experimenter. After an eight-week training session, all participants were tested again on their WM performance and compared with their pretest results. In line with the hypothesis, people in the therapy group drank less alcohol every day, while people in the control group drank a lot more [2].

5. Conclusion

AUD is a common addictive psychological disease in modern society. Individuals with AUD display modest neurobehavioral deficits on a range of cognitive tasks including those measuring WM, which was initially proposed by Baddeley, demonstrating a cognitive function that allows individuals to deal with mental tasks. There are two potential mechanisms that could explain the influence of AUD on WM. The mismatch between impulsive and reflective system, and the effect of abstinence. Based the process of AUD formation and abstinence, behavioral training programs were suggested to cope with poor cognitive performance in AUD patients.

While the pharmacological treatment was supported by various empirical studies and verified in different subtype of AUD patients, the emerging behavioral therapy revealed to be more secure and side-effect free than traditional medications. Also, commercial software for cognitive training is well-designed and published in the medical market. The development of behavioral therapies in the clinical circumstance showed a wide prospect of applying neuropsychological results into use. In future studies, this is where we can do more research on to identify what the best and most effective training methods are for the AUD and to what extent the cognitive training is limited.

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