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Altered attentional control strategies but spared executive functioning in chronic cannabis users

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ABSTRACT

Background: Cannabis use has increased rapidly in recent decades. The increase in cannabis use makes it important to understand the potential influence of chronic use on attentional control and other executive functions (EFs). Because cannabis is often used to reduce stress, and because stress can constrain attentional control and EFs, the primary goal of this study was to determine the joint effect of acute stress and chronic cannabis use on specific EFs.

Methods: Thirty-nine cannabis users and 40 non-users were assigned to either a stress or no stress version of the Maastricht Acute Stress Test. Participants then completed two cognitive tasks that involve EFs: (1) task switching, and (2) a novel Flexible Attentional Control Task. These two tasks provided assessments of vigilant attention, inhibitory control, top-down attentional control, and cognitive flexibility. Salivary cortisol was assessed throughout the study.

Results: Reaction time indices showed an interaction between stress and cannabis use on top-down attentional control ($p = 0.036$, $n_p^2 = 0.059$). Follow-up tests showed that cannabis users relied less on top-down attentional control than did non-users in the no stress version. Despite not relying on top-down control, the cannabis users showed no overall performance deficits on the tasks.

Conclusions: Chronic cannabis users performed cognitive tasks involving EFs as well as non-users while not employing cognitive control processes that are typical for such tasks. These results indicate alterations in cognitive processing in cannabis users, but such alterations do not necessarily lead to global performance deficits.

1. Introduction

Cannabis is the most commonly used illicit drug in the United States (Center for Behavioral Health Statistics and Quality, 2015), and chronic use is prevalent, particularly among young adults (Haberstick et al., 2014). With increasing ease of access due to legalization in many American states, chronic use of cannabis has the potential to influence many activities of daily living, such as those that involve organization and direction of goals and work performance. Because of this potential influence, it is important to better understand the effects of chronic cannabis use on cognitive processes related to attentional control and other executive functions (EFs) that are involved in the regulation of behavior generally and that are directly affected by substance use behavior (Giancola and Tarter, 1999; Verdejo-García et al., 2006; Pentz et al., 2016).

When evaluating effects of cannabis use on cognition, consideration should be given to factors that motivate cannabis use. One of the most common reasons given for cannabis use is stress reduction. Motives related to managing stress have often been linked to both frequency of cannabis use and dependence (McKay et al., 1992; Chabrol et al., 2004; Hyman and Sinha, 2009). Acute stress has been found to increase cannabis cravings in some studies, particularly cravings to use cannabis for coping purposes (Buckner et al., 2016). Thus, for many people, stress appears to play a role in both initiation and maintenance of chronic use. Additionally, recent work has shown a blunted stress response in chronic cannabis users, as assessed by subjective stress ratings and salivary cortisol (Cuttler et al., 2017). Although there is substantial interest in the literature on the effects of cannabis use (e.g., Pope et al., 2001; Pattij et al., 2008; Fontes et al., 2011) and stress (Starcke et al., 2016; Shields et al., 2016; Robinson et al., 2015) on EFs, there have

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been no experiments directly examining possible interactive effects of cannabis use and stress on attentional control or other EFs.

When EFs are diminished, such as in substance dependent individuals (Tanabe et al., 2007), those with traumatic brain injuries (Mangeot et al., 2002), and some older adults (Dodge et al., 2011), the inability to engage in goal-directed behavior can impair social relationships, decision making in risky contexts, and creative problem solving (Mangeot et al., 2002; Roca et al., 2010; Tanabe et al., 2007). Despite a common assumption that chronic cannabis use is detrimental to EFs, evidence is equivocal (e.g., Broyd et al., 2016; Pope et al., 2001). The lack of consistent association between cannabis use and EFs may stem from the fact that EFs are a collection of at least partly dissociable functions that include attentional control, cognitive flexibility, and inhibition (e.g., Stuss and Alexander, 2007; Miyake et al., 2000). Different tasks used to study EFs load on different abilities and these abilities can be sensitive to different factors (e.g., Clarke et al., 2005; Phillips et al., 2002; Shields et al., 2015).

A recent review on the effects of cannabis use on cognition established that attentional control is one of the functions most consistently decreased by both acute and chronic cannabis use (Broyd et al., 2016), but there are insufficient data to draw definitive conclusions (Broyd et al., 2016; Volkow et al., 2016). Similarly, detrimental effects of chronic cannabis use have been reported for cognitive flexibility, an executive function involved in shifting strategies as the environmental context changes (Lane et al., 2007; Fontes et al., 2011). However, other studies report finding no differences between chronic users and non-users on measures such as attentional control (Pope et al., 2001), cognitive flexibility, and memory span (Fisk and Montgomery, 2008), and one study examining medical marijuana users before and after initiation of use showed improvement on some EF measures (Gruber et al., 2016).

Evidence for effects of acute stress on EFs is also inconsistent. Working memory efficiency, inhibitory control, and top-down attentional control have all been reported to decrease under stressful conditions (Luethi et al., 2009; Starcke et al., 2016; Sänger et al., 2014). Moreover, in some cases, acute stress decreased self-reported ability to use attentional control in a goal-directed manner (Putman et al., 2014). However, acute stress has been reported to impair cognitive flexibility, (Alexander et al., 2007; Hillier et al., 2006; Plessow et al., 2011), enhance cognitive flexibility (e.g., Delahaye et al., 2015), or have no effect (Dierolf et al., 2016). Thus, while stress can act as a detriment to some forms of cognition, it can also facilitate or have no influence depending on the specific tasks employed.

In the current study, we employed a pair of tasks that are designed to assess multiple, distinct EF indices (vigilant attention, inhibitory control, top-down attentional control, and cognitive flexibility) within a short temporal window. We used this approach to evaluate the extent to which chronic cannabis use and stress interact to produce deficits in specific domains of EF. In this study, we evaluated two distinct possibilities. First, chronic cannabis use may interact with acute stress to exacerbate impairments in various EFs. Alternatively, acute stress may differentially impact chronic cannabis users and non-users to produce different types of effects on EFs in these two groups. Given the recent finding that chronic cannabis use is associated with decreased reactivity to acute stress (Cuttler et al., 2017), chronic cannabis use could dampen the stress response that ordinarily impairs performance of some EFs. Thus, we predicted that this blunted stress response in chronic cannabis users would confer an advantage over non-users in aspects of EF that are particularly vulnerable to the deleterious effects of acute stress.

2. Method

2.1. Participants

Participants were first screened for psychological disorders, the use of psychoactive medications, medical and neurological conditions, concussions, head injury involving a loss of consciousness for more than two minutes, learning disabilities, heavy drinking (defined as alcohol use four or more days per week), and illicit drug use in the past six months. Eighty-seven adult volunteers passed this initial screening and completed the study,[1] with eight removed from final analysis (four for using cannabis on the day of testing, three for technical problems with the study equipment, and one for falling asleep repeatedly during testing), leaving 79 total participants. In this final sample, 40 participants were classified as non-users, and 39 participants were classified as cannabis users. To be eligible for the study, participants in the non-user group had to have used cannabis 10 or fewer times in their lifetime and never in the past year. Participants in the cannabis users group had to use cannabis daily or near-daily (a minimum of 3 times per week) for a minimum of one year. All participants were paid $25 for their time. Participant characteristics are reported in Table 1.

Table 1
Sample characteristics.

	Cannabis User group		Cannabis Non-user group	
	Stress (n = 19)	No Stress (n = 20)	Stress (n = 20)	No stress (n = 20)
Age	25.85 (6.19)	25.35 (8.71)	27.25 (10.4)	25.25 (5.57)
Sex (frequency)	F-7; M-12	F-5; M-15	F-13; M-7	F-11; M-9
Days/month using cannabis	27.21 (5.36)	26.70 (4.98)	–	–
Years using cannabis	7.88 (5.88)	7.03 (3.05)	–	–
Age of first cannabis use	16.89 (3.34)	15.97 (5.45)	–	–

Note: All tests to evaluate potential group differences in these variables were non-significant. Results presented are *M* (*SD*) unless otherwise noted. Individuals were screened for psychological disorders, the use of psychoactive medications, medical and neurological conditions, concussions, head injury involving a loss of consciousness for more than two minutes, learning disabilities, heavy drinking (defined as alcohol use four or more days per week), and non-cannabis illicit drug use in the past six months.

All cannabis users reported using cannabis for over a year, with the average being 7.4 years. A large majority (87.1%) reported using either once a day or more than once a day. Cannabis use was confirmed using NarcoCheck (Saint-Victor, France) pre-dosage THC tests. Most non-user participants (77.5%) reported never using cannabis, with the remaining participants reporting using over one year ago. Of those, five had used 1–5 times total and four had used 6–10 times total.

2.2. Materials

2.2.1. Cannabis questionnaire

Cannabis consumption was assessed with the Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory (DFAQ-CU; Cuttler and Spradlin, 2017)

2.2.2. Maastricht acute stress test (MAST)

MAST procedures were taken from the protocol described in Smeets et al., 2012. In the Stress version, participants were required to alternate between five trials of placing their hand in ice cold water (M = 36.3°F, SD = 1.38) for unpredictable lengths of time that ranged from 45 to 90 seconds and counting backwards from 2043 by 17 as quickly as possible. They were given negative feedback and required to start again when they made a mistake, and were told that they would be video recorded to analyze facial expressions later. A webcam was placed in front of participants, and the image was projected onto a

[1] The participants described here completed other measures, as reported in Cuttler et al. (2017). Included there were measures assessing cannabis withdrawal and cravings, subjective stress, and the Perceived Stress Scale. These measures have already been presented in full, and thus will not be discussed further here.