# The influence of recreational drug use on experiences of the passage of time

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Abstract

Background: Laboratory research suggests that alcohol, marijuana, cocaine and MDMA influence the processing of time. Anecdotal reports of recreational drug use also often include descriptions of changes in the speed of the passage of time. Despite this, little is known about how and why recreational drug use influences the passage of time.

Aim: To examine retrospective self-reports of the passage of time during a previous instance of alcohol, cannabis, cocaine or MDMA use. To establish the effect of substance use frequency, substance dose, anxiety, depression and stress on the passage of time.

Method: Using an online questionnaire, passage of time judgments were collected for the current day as well as recent instances of alcohol, cocaine, marijuana or MDMA use. Measures of affect, typical substance use frequency and substance use amount were taken.

Results: Time was remembered as passing significantly more quickly than normal during alcohol, cocaine and MDMA use. Marijuana was associated with time passing more slowly than normal. Regression analysis revealed that drug induced distortions to the passage of time use were not predicted by drug use frequency, dose, depression, anxiety or stress. Furthermore, comparison of recreational drug users and non-users did not indicate any long-term effects of drug use on the passage of time.

Conclusions: The results suggest that whilst distortions to the passage of time are a common feature of drug use, their causes are complex.

*Introduction*

In the UK, the recreational use of substances such as alcohol, marijuana, cocaine and MDMA is common. In 2020, 9.4% of adults aged 16-59 reported using one or more illegal drugs in the past year with the figure rising to 21% for people aged 16-24 (ONS, 2020). Recreational drug and alcohol use are known to have a significant acute and chronic impact on cognitive (Durmon & Verkes, 2006; Kroon, Kuhns & Cousijn, 2021; Ranganathan & D'Souza, 2006; Roberts, Jones & Montgomery, 2016; Spronk, van Wel, Rameakers & Verkes, 2013) and emotional processing (de Wit & Sayette, 2018; Miller, Bershad & de Wit, 2015) altering the way in which users perceive the world around them.

Anecdotal accounts suggest that one commonly experienced consequence of recreational drug use is distortion to the speed at which time feels like it is passing, with users often reporting that time feels like it is passing more quickly or slowly than normal whilst under the influence of drugs and alcohol (Wearden et al., 2014; Taylor 2020). However, despite widespread anecdotal reports of altered time experience during recreational drug use, research into this phenomenon is relatively scarce. This is because to date, the effect of substance use on temporal processing has been largely limited to laboratory settings (Marinho et al., 2018; Meck, 1996).

Developing an understanding of the impact of recreational drug use on the experience of the passage of time during real-world activity is important because it may help to improve understanding of the factors which are influential in the development and maintenance of substance use disorders. In a recent review, Paasche, Weibel, Wittmann and Lalanne, (2019) proposed that changes in time experience as a result of substance use may play a role in substance use disorders. They note that a critical variable in the development and maintenance of substance use disorders is increased impulsivity. As one way to characterise impulsivity is as the ability (or not) to delay actions for a period of time, temporal processing may be critical to the experience and regulation of impulsivity. It is therefore possible that changes in temporal processing may contribute to substance use disorders via their impact on impulsivity. This suggestion is biologically plausible, as noted by Paasche et al (2019), impulsivity and time perception share similar neural bases, with striatal and prefrontal areas being implicated in both processes. There is also supportive behavioural evidence showing that altered time perception in substance users may be related their increased impulsivity and impaired ability to delay gratification (Wittmann & Paulus, 2016). However, because research in this area is scarce, Paasche et al., (2019) highlight the need to further examination of how temporal experience is altered during substance use. The current study therefore sought to explore how experiences of the passage of time were influenced by the recreational use of alcohol, marijuana, cocaine and MDMA.

*Laboratory studies of timing*

Laboratory based research has consistently demonstrated that substance administration has a significant impact on our ability to accurately perceive the duration of short (< minute) events (see

Paasche for review, 2019). The administration of alcohol (Lapp et al., 1994; Ogden et al., 2011, Rammsayer & Vogel, 1992, Terry et al., 2009, Tinklenberg et al., 1976), marijuana (Hicks et al. 1984; Mathew et al. 1998; McDonald et al. 2003, Muro et al., 2021; Tinklenberg et al, 1976, Sewell et al., 2013), cocaine (Cheng et al., 2006; Cheng et al., 2007; Mattell et al., 2004), methamphetamine (Buhusi & Meck, 2002; Cheng et al., 2007; Matell et al., 2006; Meck et al., 2012; Zhang et al., 2019), ketamine (Coull et al., 2011; Cheng et al., 2007; Cheng et al., 2006; Moore et al., 2013) and nicotine (Daniels et al., 2015; Hinton & Meck, 1996) have all been shown to alter temporal processing. The effects of these drugs are varied, whilst methamphetamine and cocaine are consistently shown to speed up time, the effects of alcohol (see Ogden et al., 2011 for discussion), nicotine (Ashare & Kable, 2013) and marijuana administration (see Atakan et al., 2012 for review) are less consistent.

There is also some evidence that chronic substance use may have a long-term impact on temporal processing with cocaine and methamphetamine dependent individuals displaying impaired timing ability even in the absence of current drug use (Wittmann et al., 2007). However, long-term impairment of time perception was not always observed in chronic marijuana users (Sewell et al., 2013 and see Atakan et al., 2012 for review) and was present only for male nicotine users (Ashare & Kable, 2013).

The primary mechanism by which drug administration is thought to affect time perception is through its effect on neural dopamine. The administration of dopaminergic agonists is consistently associated with time passing more quickly than normal whereas the administration of dopaminergic antagonists is consistently associated with time passing more slowly than normal (see Meck, 1996 for review). Dopaminergic drugs are thought to impact on timing because areas such as the prefrontal cortex and striatum, which are activated during timing, are all densely innervated with dopamine receptors (Meck, 1996). Changes in dopamine levels in these areas are therefore thought to alter the way in which the brain processes time (Meck, 1996).

Although dopaminergic changes can explain why the processing of the duration of short (< minute) events is altered by drug use, how and why time experience in the real world is affected by recreational drug use remains unclear. This is in part due to obvious limitations on studying recreational drug users experience of the passage of time during the use of what are often illegal substances. As a result, it is unclear whether the effects observed in tightly controlled laboratory experiments are replicated in the complex real-world environment.

*Real-world temporal experience*

During normal daily life people often make judgements about the speed at which time appears to be passing (Wearden, 2016). These judgements, termed passage of time judgements, reflect the subjective speed at which time feels like it is passing in comparison with normal i.e. more quickly than normal, more slowly than normal or as normal (Wearden, 2016). Passage of time judgments are thought

to be a distinct form of temporal judgement because studies of concurrent passage of time judgments and duration estimates are rarely correlated (Droit-Volet & Wearden, 2016). Consequently, different cognitive and neural mechanisms are therefore thought to underpin the two types of judgment. It is therefore important to understand the impact of recreational drug use on passage of time judgements in their own right.

The idea that recreational drug use distorts the passage of time is not new. Thomas De Quincey and Aldous Huxley described significant changes in their experience of the speed of the passage of time following opium, mescaline and LSD use in Confessions of an Opium Eater and The Doors of perception. More recent research does however appear to confirm their observations in a broader range of contemporary recreational substances (Ogden & Montgomery, 2012; Wearden et al., 2014). Wearden et al., (2014) used an online questionnaire to explore experiences of the passage of time during recreational drug use. Analysis of 203 retrospective narrative accounts of the experience of the passage time during recreational substance use suggested that distortions to the passage of time following the recreational use of drugs such as alcohol, cannabis, cocaine, MDMA and ketamine were common. Indeed, 66% of participants reported that distortions to time were more common during drug use than during other periods in life. As in lab-based studies, alcohol and cocaine were consistently associated with the sensation of time passing more quickly than normal (Wearden et al., 2014). Interestingly however, although marijuana use was associated with distortion to the passage of time, participants reported that time was equally likely to feel like it had sped up or slowed down (Wearden et al., 2014).

Although Wearden et al., (2014) provides initial evidence that recreational drug use affects the speed at which time is experienced to pass, many aspects of drug-induced distortions to time remain unstudied. For example, it is presently unclear how the frequency of substance use and size of typical dose consumed influence the passage of time during real-world activity. Furthermore, it is unclear how affective factors such as depression and anxiety may influence the impact of recreational drug use on the experience of time.

The current study sought to address these gaps in understanding by exploring retrospective experiences of the passage of time during recent recreational usage of alcohol, marijuana, cocaine and MDMA and examining how the experience of time was related to frequency of substance use, typical dose, depression, anxiety and stress. Based on the findings of Wearden et al., (2014) it was expected that widespread distortion to the passage of time would be reported following recreational drug use in comparison to normal (i.e. when sober). Systematic changes in the direction of distortion to time were expected for difference substances. Specifically, based on the findings of laboratory research, time was expected to be experienced as passing more quickly than normal following alcohol, cocaine and MDMA use because of their direct and indirect effects on dopamine. For marijuana, although previous research has demonstrated inconsistent effects, 70% of papers report a slowing of time during marijuana use

(Atakan et al., 2012). It was therefore expected that time would pass more slowly than normal following marijuana use than when sober.

For all substances, it was expected that the passage of time during substance use would be predicted by the typical dose, with greater typical doses being associated with greater distortion to the passage of time. Use frequency was also anticipated to be a predictor of the passage of time, however the directionality of this effect was unclear. One possibility is that greater use frequency would be associated with greater distortion to time as a result of greater long-term changes in cognition and neuroplasticity associated with more frequent recreational drug use (Robinson & Kolb, 2004). However an alternative possibility is that greater frequency of use would be associated with fewer distortions to the passage of time due to greater levels of drug tolerance. Finally, because depression, anxiety and stress have previously been associated with slowing's of the passage of time (Ogden, 2020, 2021) it was anticipated that greater levels of depression, anxiety and stress would be predictive of greater slowing of the passage of time.

## Method

### *Participants*

One hundred and thirty-six participants were recruited using opportunity sampling from social media platforms such as snapchat, WhatsApp, twitter, and Sona. Participants were aged 18-57 years (M = 24.92 SD= 9.56), 58 were male. Participants were required to be substance free for 24 hours prior to participation. Table 1 shows a summary of number of users in the previous 6 months, the average frequency of use and the average amount of use for each substance. All participants gave informed consent. The study was approved by Liverpool John Moores University School of Psychology Ethics Committee and was conducted in accordance with the Declaration of Helsinki.

Table 1: Average frequency of use, mean usage quantity and number of users for alcohol, cannabis, cocaine and MDMA.

| Substance | N used in the last 6 months | Mean usage (SD) | Average frequency of use | % |
|---|---|---|---|---|
| Alcohol | 110 | 10.06 (6.83) units in which one unit is equal to 10ml or 8g of pure alcohol. | Daily | 2.70 |
| | | | More than once a week | 30.90 |
| | | | Weekly | 26.40 |
| | | | Fortnightly | 12.70 |
| | | | Monthly | 13.60 |
| | | | Less than once a month | 13.60 |
| Marijuana | 68 | 1.92 (2.80) grams | Daily | 26.00 |
| | | | More than once a week | 13.00 |
| | | | Weekly | 9.10 |
| | | | Fortnightly | 3.90 |

| | | | | |
|---|---|---|---|---|
| | | | Monthly | 6.50 |
| | | | Less than once a month | 41.60 |
| Cocaine | 48 | 0.74 (0.77) grams | Daily | 0.00 |
| | | | More than once a week | 2.00 |
| | | | Weekly | 8.00 |
| | | | Fortnightly | 6.00 |
| | | | Monthly | 12.00 |
| | | | Less than once a month | 72.00 |
| MDMA | 51 | 489.12 (395.85) mg | Daily | 0.00 |
| | | | More than once a week | 2.10 |
| | | | Weekly | 0.00 |
| | | | Fortnightly | 4.10 |
| | | | Monthly | 12.20 |
| | | | Less than once a month | 81.60 |

*Measures*

Participants completed an online questionnaire distributed through Qualtrics.com. The questionnaire recorded demographic information (age and gender), the passage of time, substance use and depression, anxiety and stress.

*The passage of time*

Participants were asked to rate their experience of the subjective speed of time in comparison to normal using a 7 point likert scale; 1. Extremely slow, 2. somewhat slower, 3. a little slower, 4. as normal, 5. a little faster, 6. somewhat faster, 7 extremely fast. Participants rated their experience of the passage of time 1) today, and when they last used 2) alcohol, 3) marijuana, 4) cocaine and 5) MDMA. For example, "Thinking of the last time you used alcohol, how quickly did you feel like time was passing in comparison to normal?" Participants, selected NA if they had no experience of taking a substance.

*Substance use*

Two questions were used to measure the frequency and quantity of use for each of four substances studied: alcohol, marijuana, cocaine and MDMA use in the last 6 months.

For each substance participants first indicated whether they had used the substance in the last 6 months (Y/N). Users then rated their (1) frequency of use using the following scale: 1 never, 2 less than once a month, 3 monthly, 4 fortnightly, 5 weekly, 6 more than once a week, 7 daily and (2) average quantity used in a typical session. For alcohol, estimates were provided in units for alcohol, in grams for marijuana and in number of pills or grams for MDMA. Quantity estimates for MDMA which were provided as a number of pills were converted into milligrams using average purity levels identified in recent European analyses (Couchman et al., 2019; DIMS, 2020, Vrolijk & Smit-Rigter2021)

*Depression, Anxiety and Stress*

The DASS-21 (Lovibond & Lovibond, 1995) is a short version of the 42-item Depression Anxiety Stress Scales, which measures depression, anxiety, and stress. The 21-item questionnaire contains three, seven item subscales measuring depression, anxiety and stress. Responses are provided by indicating the severity with which each item reflected the participants experience: (1) did not apply to me at all; (2) applied to me to some degree; (3) applied to me to a considerable degree; and (4) applied to me very much. Cronbach's alpha for the 21 item DASS questionnaire was 0.93.

*Procedure*

Participants completed the online questionnaire using mobile phones or tablets. Participants were provided with an information sheet and gave informed consent prior to participation. The questionnaire

took approximately 5 minutes to complete. Participants were provided with links to drug and alcohol support services upon completion.

*Data analysis*

Because the passage of time judgement was an ordinal scale, non-parametric analyses were conducted. Mann Whitney U tests were used to establish differences in passage of time during the day (POTJ-day) between users and non-users of each substance. Wilcoxon matched pairs tests were used to establish differences between time experience when sober in comparison with when using alcohol, marijuana, cocaine and MDMA. Spearman's correlations were used to establish the relationship between the passage of time during substance use, substance use frequency and quantity, depression, anxiety and stress. Finally, ordinal regression was used to assess the predictive value of substance use frequency, quantity, depression, anxiety and stress on the passage of time separately for each substance.

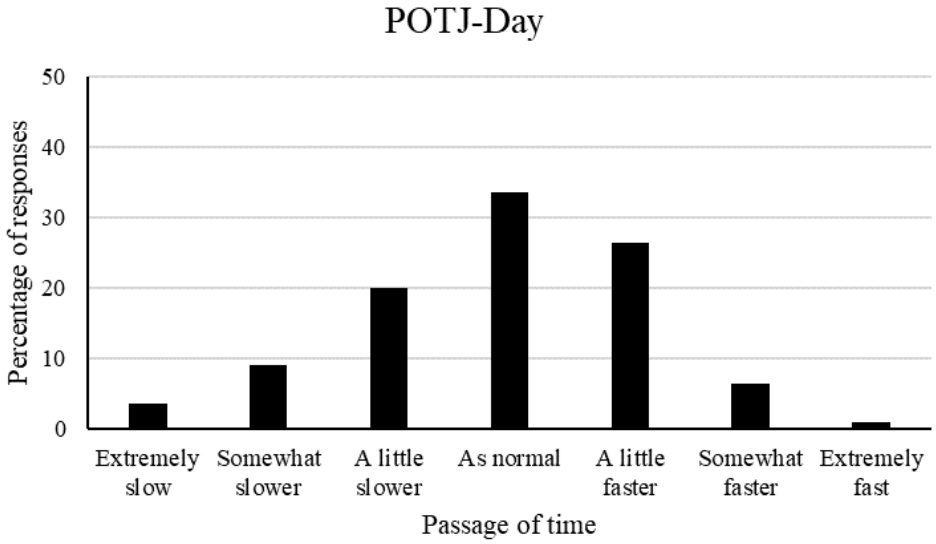
## Results

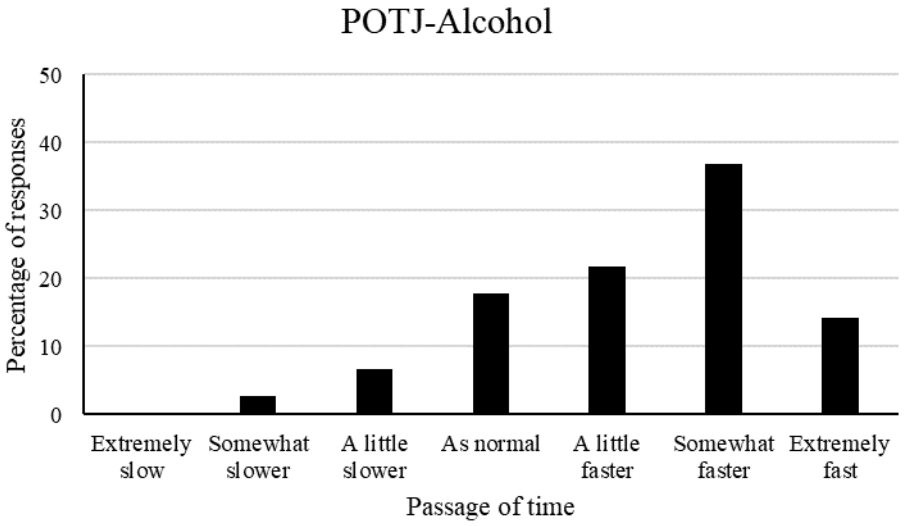
Data from 23 participants was excluded because they did not complete all aspects of the questionnaire. The initial analysis presented is based on the responses of participants who reported using the specified substance at least once in the 6 months prior to questionnaire completion. The users vs non-users analysis is based on a comparison of participants who had and had not used each of the specified substances in the last 6 months.

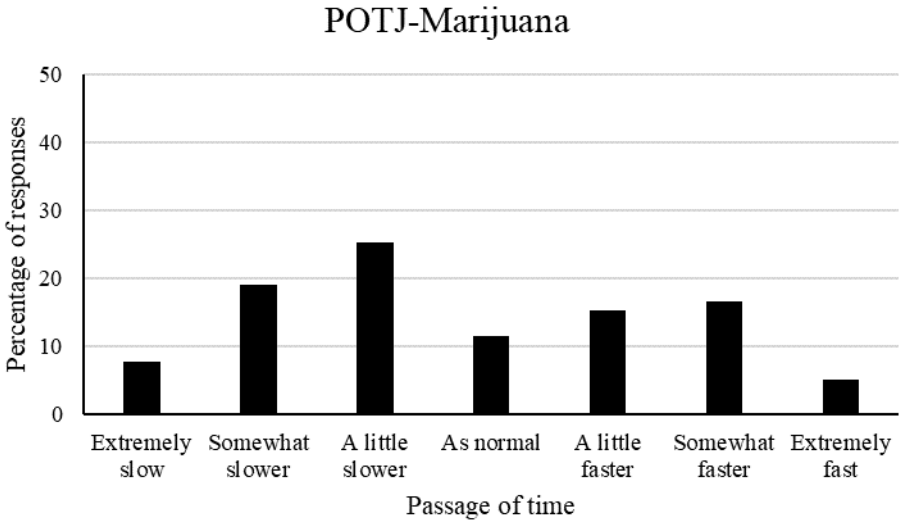
Figure 1 shows histograms of the percentage of responses for the passage of time judgments for the day when sober, following alcohol consumption, marijuana consumption, cocaine consumption and MDMA consumption. Examination of Figure 1 suggests that whilst the passage of time day (POTJ-day) histogram has the highest proportion of responses at "as normal", for the passage of time (POTJ) alcohol, cocaine and MDMA the response distribution indicates that time was experienced as passing more quickly than normal following the use of those substances. For marijuana whilst very few participants reported experiencing time as passing as normal, time was equally likely to be distorted to pass more quickly or more slowly than normal.

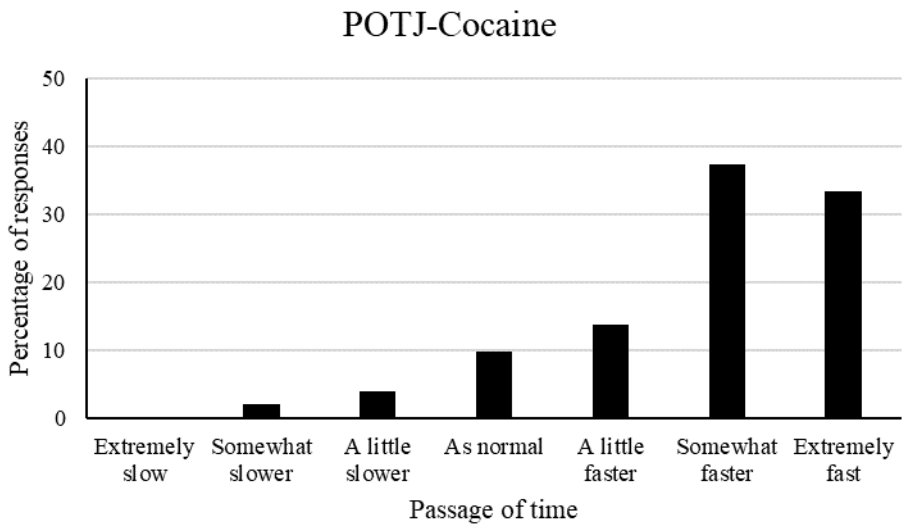
These suggestions were confirmed by statistical analysis. Time was remembered as passing significantly quicker than when sober following alcohol ($Z = 6.20$, $p < .001$), cocaine ($Z = 5.30$, $p < .001$) and MDMA ($Z = 3.70$, $p < .001$) use. There was no significant difference in which the speed at which time passes when sober to when using marijuana ($Z = 1.12$, $p = .26$). However, follow up analysis of passage of time judgments following marijuana use using chi square revealed that a greater than expected number of participants reported experiencing time as passing slower than normal and fewer than expected reported that time passed as normal $X^2 (6) = 15.90$, $p = .01$.

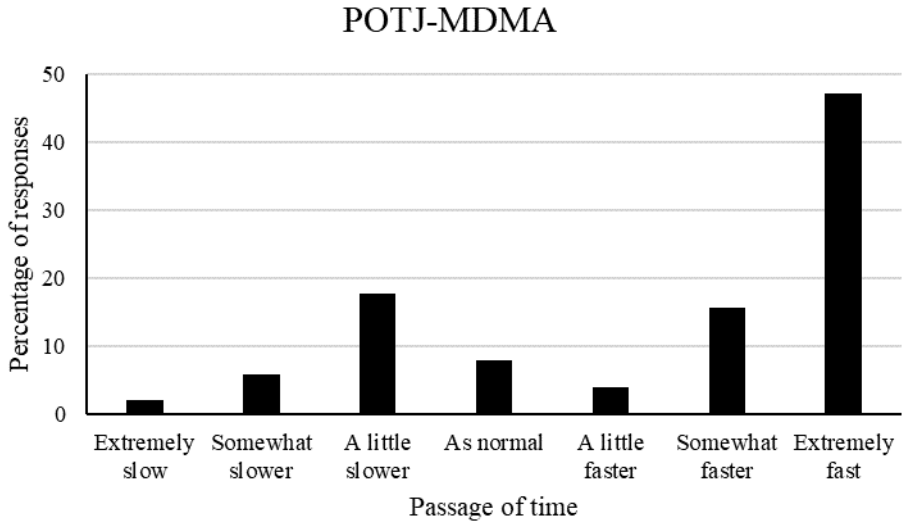
Figure 1: Experiences of the passage of time as a function of substance used.






*Predictors of distortions to the passage of time*

*Alcohol*

There were no significant relationships between passage of time judgments for a period of alcohol consumption and the frequency with which alcohol was typically used ($r$ = .01, $p$ = .97), the average amount of alcohol consumed ($r$ = .08, $p$ = .45), depression ($r$ = .05, $p$ = .58), anxiety ($r$ = .05, $p$ = .59) or stress ($r$ = .02, $p$ = .83).

Ordinal regression with proportional odds with predictor variables of age, gender, depression, anxiety, stress, alcohol use frequency and alcohol use amount was conducted to explore the predictive factors in the experience of the passage of time following alcohol consumption. No significant model fit was observed $\chi^2(7) = 5.73$, $p$ = .57.

*Marijuana*

There were no significant relationships between passage of time judgments for a period of marijuana consumption and the frequency with which marijuana was typically used ($r$ = -.20, $p$ = .08), the average amount of marijuana consumed ($r$ = -.01, $p$ = .95), depression ($r$ = -.03, $p$ = .83), anxiety ($r$ = -.04, $p$ = .72) or stress ($r$ = -.17, $p$ = .13).

Ordinal regression with proportional odds with predictor variables of age, gender, depression, anxiety, stress, marijuana use frequency and marijuana use amount was conducted to explore the predictive factors in the experience of the passage of time following marijuana consumption. No significant model fit was observed $\chi^2(7) = 6.19$, $p$ = .52.

*Cocaine*

There were no significant relationships between passage of time judgments for a period of cocaine consumption and the frequency with which cocaine was typically used ($r$ = -.23, $p$ = .11), the average amount of cocaine consumed ($r$ = .01, $p$ = .98), depression ($r$ = -.04, $p$ = .81), anxiety ($r$ = .04, $p$ = .77) or stress ($r$ = -.13, $p$ = .35).

Ordinal regression with proportional odds with predictor variables of age, gender, depression, anxiety, stress, cocaine use frequency and cocaine use amount was conducted to explore the predictive factors in the experience of the passage of time following cocaine consumption. No significant model fit was observed $\chi^2(7) = 4.65$, $p$ = .70.

*MDMA*

There was a significant positive relationship between the frequency of MDMA use and the passage of time during MDMA use ($r$ = .49, $p$ < .001). There were no significant relationships between passage of time judgments the average amount of MDMA consumed ($r$ = .07, $p$ = .67), depression ($r$ = .19, $p$ = .17), anxiety ($r$ = .12, $p$ = .41) or stress ($r$ = .14, $p$ = .33).

Ordinal regression with proportional odds with predictor variables of age, gender, depression, anxiety, stress, MDMA use frequency and MDMA use amount was conducted to explore the predictive factors in the experience of the passage of time following MDMA consumption. No significant model fit was observed $\chi^2(7) = 4.03$, $p$ = .78.

*Users vs non-users*

To establish whether there was an effect of being a substance user on the normal day-to-day experience of the passage of time, responses to the passage of time day (POTJ-day) question were compared for users and non-users of marijuana, cocaine and MDMA using Mann Whitney U tests. There was no significant difference in POTJ-day responses for users and non-user of marijuana ($U$ = 959.50, $p$ = .70), cocaine ($U$ = 559.00, $p$ = .62), and MDMA ($U$ =609.50, $p$ = .66). There do not therefore appear to be effects of prior drug use on the experience of the passage of time when not currently under

the influence of a substance. It was not possible to compare the POTJ-day for alcohol users and non-users because only 3 participants reported no previous use of alcohol.

## Discussion

The current study sought to explore the effects of the recreational use of alcohol, marijuana, cocaine and MDMA on experiences of the passage of time. Furthermore, the study sought to establish whether substance use frequency, typical dose amount, depression, anxiety and stress were related to experiences of the passage of time. The results show that distortions to the passage of time were frequently recalled following recreational drug use. Time was consistently experienced as feeling like it was passing more quickly than normal following recreational alcohol, cocaine and MDMA use. Following marijuana use, time distortion was also common, with very few participants reporting that time passed as normal. The directionality of distortion to time was not however universal, although a slowing of time was more common following marijuana use. These findings confirm suggestions made in Wearden et al., (2014) that recreational drug use is associated with the experience of distortion to the passage of time. They also suggest that the effects of drug administration on time experience are not limited to laboratory studies of the perception of short durations. Therefore, despite differing cognitive and neural bases, drug administration has the capacity to alter the processing and experience of short and long durations in lab and real-world environments.

Contrary to expectations, substance use frequency, typical dose, depression, anxiety and stress were not significant predictors of the passage of time for any substance. Greater substance dose and substance use frequency were primarily expected to be associated with greater distortion to the passage of time because they would have greater influence on neural dopamine levels, cognition and affective processing. Indeed greater substance doses are associated with greater distortions to time processing in the lab (Meck et al., 2012) and greater levels of cognitive and emotional impairment (e.g. Vonmoos et al., 2014). The absence of an effect of dose and use frequency may therefore suggest that the dopaminergic, cognitive and affective changes as a result of the recreational use of alcohol, cocaine, marijuana and MDMA are not critical factors in the subjective speed of the passage of time during their use. However, an alternative possibility is that inaccurate estimates of use and dose coupled with a lack of measurement of purity obscured their influence on the passage of time. Estimates of drug and alcohol consumption (frequency and dose) are often inaccurate (Harrison, 1997), in part because of forgetting and social desirability bias. Furthermore, even when estimates are accurate, they fail to take into account variability in substance purity. It is therefore possible that more accurate measurement of consumption and purity would be predictive of the speed of the passage of time. Future studies should therefore seek to measure recreational drug and alcohol use and the passage of time in "real-time" with objective measures of dosage and purity rather than retrospectively.

The absence of an effect of affective state on temporal experience contradicts previous studies which have demonstrated a relationship between anxiety, depression and stress and experiences of the passage of time (Ogden, 2020, 2021). This therefore suggests that trait mood characteristics (i.e. depression, anxiety and stress) do not contribute towards distortions to the passage of time during recreational drug use. This may be because one consequence of recreational drug use is a change in mood during intoxication (see Baker et al., 2006 for discussion). The measures of affect taken in the current study were not therefore necessarily representative of the affective state during the period of recreational drug use in which the passage of time judgement was based. Wearden et al., (2014) noted that affective state during drug use appeared to be associated with temporal distortions during drug use. It is therefore possible that affective state during recreational drug use would be predictive of experiences of the passage of time. This seems particularly plausible for the speeding up of time observed with cocaine and alcohol because both are associated with increased positive affect (Baylen & Rosenberg, 2006; Breiter et al., 1997) which is itself associated with a faster passage of time (Droit-Volet & Wearden, 2016; Ogden 2020, 2021). Future research should explore this possibility.

Interestingly, although the passage of time was experienced as different during drug use than when sober, there was no evidence that recreational drug use itself altered temporal experience when sober. This is because comparisons of the speed at which time passed when sober (POTJ-day) between users and non-users did not differ for any drug. The absence of an effect of "off drug" changes in time experience perhaps indicates that long-term drug induced changes in time experience may not in themselves to contribute to the development and maintenance of substance use disorders. This raises the possibility that the proposed relationship between changes in temporal processing through drug use (Paasche et al., 2019) and changes in impulsivity which contribute to drug (Wittman & Paulus, 2016), use may be complex. However, it is plausible that changes in the passage of time during drug use itself may still influence substance use behaviour. For alcohol, cocaine and MDMA, a speeding up of time may result in greater amounts of substance consumption during a period of drug use. This is because time passing more quickly than normal may cause a user to believe that it is longer since their previous dose than it actually was, resulting in more frequent dosing. More frequent dosing may result in greater levels of drug consumption which in turn may increase the likelihood of dependency developing. These effects are of course speculative at present and further research exploring the relationship between the passage of time during drug use and dose frequency is required to confirm these suggestions.

Limitations

It should be noted that a relatively small number of participants reported regular use of cocaine and MDMA. Although the distortions to time reported by these participants were reasonably heterogeneous, caution should be taken when generalising the experiences reported during the use of these substances to other populations. In particular, it is possible that the analysis of the predictors of

temporal experience and the long-term effects of MDMA and cocaine use on temporal experience lacked sufficient power. Future research should therefore seek to explore the impact of recreational drug use in these populations on a much broader scale.

It should also be noted that the passage of time judgments reported in this study are retrospective interpretations rather than objective reports of experience. Participants were not judging their experience of time during substance use, but instead reflecting on their memory of a previous experience. Although the passage of time judgments reported in this study were collected using a modified version of a previously published passage of time questionnaire (Ogden, 2020, 2021), it is possible that the retrospective nature of the judgments altered the way in which time was remembered as passing. Furthermore it is possible that impaired memory function as a consequence of substance use impaired or altered recollections of the passage of time, reducing the reliability of the current findings. Future research should therefore seek to explore how the passage of time changes during active recreational substance use.

## Conclusions

The findings of this study confirm previous suggestions that recreational drug use has a significant impact on users' experience of the passage of time. Time was remembered as passing more quickly than normal during periods of alcohol, cocaine and MDMA use. Time was rarely experienced as passing normally following marijuana use and was instead more likely to be experienced as passing slowly. Although the absence of long term effects of recreational drug use on the passage when sober suggest that drug induced changes in time experience are unlikely to contribute to the development and addictive behaviours, it is plausible that changes in time experience during substance use itself contribute to greater amounts of use in a given session. However, to fully understand the role of the drug induced changes in the passage of time in the development of addiction, further research conducted during substance use itself is required.

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