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Pop, Ioana; Dinkelacker, Jannis

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ORIGINAL RESEARCH PAPER

Microdosing psychedelics – Does it have an impact on emodiversity?

IOANA POP* and JANNIS DINKELACKER

Sociology Department, Tilburg University, PO BOX 90153, 5000, LE Tilburg, The Netherlands

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ABSTRACT

Background and aims: Previous research has proposed that microdosing, i.e., the repeated use of sub-threshold doses of serotonergic hallucinogens, has an impact on mood by increasing emotional awareness. We propose that increased emotional awareness could translate into higher emodiversity, a balanced experience of emotions in which emotions are experienced with more similarity in intensity and duration. We examine the effect of microdosing, the day after, as well as the cumulative effect of microdosing on overall, positive and negative emodiversity. *Methods:* We use data collected over a period of 28 days sampled between February to June 2020 from 18 users that already had an active practice of microdosing at the start of the data collection. We assessed emotional states using ESM methods, i.e., signal-contingent sampling with triggers sent 5 times a day. The working dataset has a number of 224 observations days. We used mixed effects models to test our hypotheses. *Results:* When taking into account the level of average affect, we found that during microdosing days positive and overall emodiversity were significantly lower. No evidence was found for a mediating role of the level of average affect. Higher cumulative instances of microdosing were not related to any of the emodiversity indexes. Participants experienced more "awe, wonder, or amazement", "ashamed, humiliated, or disgraced" as well as less "joyful, glad, or happy" emotions during microdosing days. *Conclusion:* A microdosing practice may increase the centrality of certain emotions on microdosing days, resulting in a decrease in emotional diversity.

KEYWORDS

microdosing, emodiversity, experience sampling methods

INTRODUCTION

Microdosing refers to the practice of using serotonergic hallucinogens, also coined under the name of psychedelics (e.g., LSD and psilocybin mushrooms), by repeatedly ingesting doses that do not reach the threshold for perceptual alterations with the purpose of improving wellbeing, emotional state, and cognitive function (Kuypers et al., 2019). The interest in this practice is not new, and research on the effects of various doses of psychedelics on a variety of outcomes dates back to the mid 50's and 60's (Passie, 2019). However, it is only recently, building on the influential work by Fadiman (2011) and the coverage by mainstream mass-media (Leonard, 2015) that this practice has received particular attention both from the scientific field and the general public.

Research that has evaluated the practice of microdosing is situated at the intersection of several dichotomies: the dichotomy of therapeutic vs enhancement effects, between qualitative vs quantitative methodologies, observational vs experimental designs, and retrospective vs prospective studies (Ona & Bouso, 2020). When examining the effects reported, three recent qualitative studies reported alleviation of depressive and anxiety symptoms, better pain management, increase in creativity, energy levels or focus (Andersson & Kjellgren, 2019; Anderson, Petranker, Rosenbaum, et al., 2019; Johnstad, 2018). However, scholars have warned that qualitative and observational studies tend to paint a positive view of the range of effects and underscore potential negative effects (Hutten, Mason, Dolder, & Kuypers, 2019).

*Corresponding author.
E-mail: i.a.pop@tilburguniversity.edu

When turning to the few studies that employ quantitative methods, use an experimental design, more precise measurements of expected effects, or collect data on multiple points in time, they present a rather fragmented picture of results. Still, their findings are difficult to integrate because of the differences in design, samples and measures that they use (for an overview of the literature, see Kuypers et al., 2019; Ona & Bouso, 2020; Polito & Liknaitzky, 2022).

Presented with mixed findings, this study proposes to advance the field in several ways. First, after examining seemingly inconsistent evidence from previous research, evidence that we will spell out in the following section of the paper, in combination with novel insights on psychological functioning and sources of wellbeing (Quoidbach et al., 2014), we propose emodiversity as a potential outcome of the practice of microdosing. Second, we use self-collected data over a period of 28 days in combination with a novel method of data collection, i.e., Experience Sampling Methods (ESM) (Myin-Germeys & Kuppens, 2021) using an app and daily prompts at various points during the day. The repeated measurements set up of the data allow us to employ methods of analysis that more strictly control for confounding variables.

Third, by collecting information over a longer period of time allows us to make a distinction between *acute*, i.e., effects that manifest during the day when participants have ingested a microdose, and *cumulative* effects, i.e., effects that are related to the number of occasions of ingesting the drug. These definitions are mirroring the ones proposed by Passie (2019), who talks about acute and chronic effects. While this difference is discussed in the literature, it is seldom made explicit and examined in practice. Examples of prospective studies that examined acute and effects over time of microdosing are Polito and Stevenson (2019) and Dressler, Bright, and Polito (2021).

To sum up, the research questions that guide our study is: to what extent does the microdosing practice have *acute* and *cumulative* effects on (overall, positive and negative) emodiversity. In order to answer this question we have used data collected over a period of 28 days sampled between February to June 2020 from 18 users that already had an active practice of microdosing at the start of the data collection.

Microdosing and emodiversity

Anecdotal accounts as well as (mainly qualitative) research strongly emphasize the positive effects of microdosing practice on mood. For instance, Anderson, Petranker, Christopher, et al. (2019) report that 26 percent of their sample of 278 respondents indicate improved mood, i.e., happiness, wellbeing, peace or calm, as the most noticeable effect of their microdosing practice. Johnstad (2018), in a qualitative study of 21 males also reports an improvement in everyday life functioning, e.g., more emotional balance, calm, less brain-fog as well as decrease levels of depression and anxiety.

Two studies that employ a prospective design with repeated measurements within respondents and largely used measures of wellbeing provide support for the results derived from qualitative research. Polito and Stevenson (2019) collected data from 98 participants, with measurements at baseline and daily prompts over a period of 42 days. Their study showed significant differences in wellbeing measures between the microdosing day and baseline or the days without ingestion of the psychedelic substance, providing thus support for the *acute effects* of the practice. When they examined the change in time in the various outcomes over the period studied, they found that depression and anxiety levels have significantly decreased, mind wandering was reduced, and absorption and neuroticism have increased.

A subsequent study by Dressler et al. (2021) included 76 participants that had complete information in two time points, 31 days apart. Contrary to the results from Polito and Stevenson (2019), they found that neuroticism significantly *decreased* during the period studied. They proposed that alexithymia, i.e., a measure of how much emotional insight a person has in terms of being able to identify, describe and express one's feelings, might be an explanation for the change in neuroticism. Alexithymia was positively correlated with the level of neuroticism at the start of the measurement period and the study also reports that previous microdosing duration was correlated with lower levels of neuroticism. These correlations suggest that a longer experience with microdosing practice relates with higher levels of emotional awareness.

Based on the above, a reasonable expectation is that individuals that microdose are more aware of their emotional life, being able to more easily identify and describe both positive and negative emotions. Following up on this conclusion, we make the link with the concept of emodiversity. Mirroring biodiversity, emodiversity has been conceptualized as "the richness (how many specific emotions are experienced) and evenness (the extent to which specific emotions are experienced in the same proportion) in the human emotional ecosystem" (Quoidbach et al., 2014, p. 2058). If engaging in the microdosing practice is linked to increased emotional awareness, it seems plausible to conclude that the users will be more aware of a larger variety of emotions throughout the day. This would result in a higher level of emodiversity across positive, negative and also overall emotions.

Turning to the postulated relationship between microdosing and emotional awareness, it is uncertain how such an effect would manifest. One possibility is for this effect to solely depend on the ingestion of the substance, i.e., purely an acute effect during the microdosing day. Additionally, anecdotal accounts suggest that a weaker effect could also be experienced during the following day (microdose.nl, 2021). Another possibility is that with each microdosing opportunity the users become better and better at identifying and expressing their feelings, i.e., they are training their emotional awareness. In this case, we would also observe a cumulative effect of microdosing on increasing emodiversity, depending on the number of microdosing days that the participant had from the start of the observation period until

a particular measurement day. With more opportunities to train emotional awareness, users could report a wider range of emotions or a higher intensity, which would translate in higher emodiversity scores.

The above arguments suggest that microdosing practice could have acute effects of increasing the level of positive, negative and overall emodiversity, the strongest effect during the day when the psychedelic substance is ingested, followed by a weaker effect the day after (*H1*). Next, the cumulation of microdosing days is expected to relate to higher level of negative and positive emodiversity (*H2*).

METHODS

The data collection

Prospective data was collected from 18 respondents over a period of 28 days. Participants were enrolled when they had an active practice of microdosing at the time of enrollment. The data collection started on February 20, 2020 and until March 5th we recruited six students enrolled at the university of the researchers. The situation around the COVID-19 pandemic have forced a reassessment of the recruitment strategy by including respondents located at other universities and abroad, students and not-students population. The second wave of data collection started in May 12, 2020 and the last participant was enrolled in the study the same year on May 21st. Participants were incentivized with a gift card and a report on their own data.

At baseline (day 0), we collected information on demographics, history of substance use as well as other measures not relevant for the current study. Starting with day 1 until day 28, we assessed emotional states using ESM methods, i.e., signal-contingent sampling with triggers sent 5 times a day, every three hours between 10 am and 10 pm. During the first week, each day was sampled, during week 2 and 3, we sampled every other day (e.g., days 8, 10, 12 and 14), and during week 4, we sampled 3 days (days 23, 27 and 28). This was done in order to reduce participation burden. Participants were instructed to provide as much data as possible, allowing them to submit additional surveys both during days with and without triggers. We used EthicaData app (EthicaData, 2020), an application that is used in the field and is approved by the Ethics Review Board of the researchers 'university in terms of compliance with GDPR regulations.

Participants were instructed to report which emotions they have felt since they have filled out the last questionnaire or, for the first trigger in the day, from the period since they woke up. The basis for the questionnaire that was administered was the modified differential emotion scale (mDes) originally used by Fredrickson, Tugade, Waugh, and Larkin (2003). This original scale's psychometric properties were validated in another Greek sample of respondents (Galanakis, Stalikas, Pezirkianidis, & Karakasidou, 2016). The participants were asked "Thinking about yourself and how you felt today", since the last time you filled in this questionnaire, to what extent did you generally feel: "Amused, fun-loving, or silly", "Awe, wonder, or amazement", "Grateful, appreciative, or thankful", "Hopeful, optimistic, or encouraged", "Interested, alert, or curious", "Joyful, glad, or happy", "Love, closeness, or trust", "Proud, confident, or self-assured", "Angry, irritated, or annoyed", "Ashamed, humiliated, or disgraced", "Contemptuous, scornful, or disdainful", "Disgust, distaste, or revulsion", "Embarrassed, self-conscious, or blushing", "Guilty, repentant, or blameworthy", "Sad, downhearted, or unhappy", "Scared, fearful, or afraid", "Serene, content, or peaceful", "Stressed, nervous, or overwhelmed", "Sympathetic, concerned, compassionate". Following Quoidbach et al. (2018), the responses were recorded on a 21-point Likert scale ranging from 0 "Never" to 21 "All the time", in order to improve weighting of the two components of emotional diversity, evenness and richness.

Emodiversity

We used the formula proposed by Quoidbach et al. (2014) in order to calculate the *overall*, *positive* and *negative emodiversity* scores in a day. In this formula, *i* represents the number of emotions included, S is equal to the *sum of scores* (the richness) for the included emotions and P represents the proportion of each emotion in S:

$$\sum_{i=1}^{S} = (P_i \times lnP_i)$$

A higher score indicates higher emodiversity. For our analyses, we deleted the raw records with missing information on all emotions which resulted in a working sample with 18 respondents and 313 observation. In this sample, overall emodiversity ranged from 0 to 2.89 with a mean of 2.21, positive emodiversity ranged from 0 to 2.20 with a mean of 1.98 and negative emodiversity ranged from 0 to 2.19 with a mean of 1.06.

Microdosing practice

Microdosing practice was measured by an indicator variable differentiating between the microdosing day "I have taken a dose today" (MD 0), the day after "I have taken a dose yesterday" (MD 1), and "no dose today or yesterday" (MD no). We asked respondents each day to record whether they microdose that day, a day before or 2 days before. Using this information, we imputed missing values when that was possible. For the days when that was not possible and in order to avoid reducing the sample size we introduced in the analysis a dummy variable (MD not known). From the 313 observations in the sample with valid information for the emodiversity indexes, 26.2 percent were MD 0 days, 21.73 percent MD 1, 30.99 percent MD no and 21.09 percent MD not known.

Cumulative instances of microdosing was measured by computing the cumulative previous instances of MD 0. For example, for a sequence of 4 days when in the first day the participants have taken a microdose, in day 2 and day 3 they did not and in day 4 yes, this variable recorded 1, 1, 1, 2.

A similar procedure was used by van Deurzen and Bekker (2018) in their analysis of the relationship between health and cumulative spells of atypical employment.

Analytical strategy

In order to test our hypotheses we used a mixed effects model with observation points (level 1) nested in individuals (level 2) and only the intercept estimated as a random effect. Daily overall, negative and positive emodiversity were the dependent variables and the MD 0 and MD 1 were the independent variable of interest. We included a series of control variables. *Gender* was measured by an indicator variable differentiating between men (ref.) and women ($n = 3$). *Age* of the participant was introduced as a continuous variable. 17 of the participants were between the age 19 to 30 and one participant was 57 at the time of data collection. *Average positive* and *negative affect* was calculated for each day across the items capturing the emotions of participants. In order to control for potential systematic differences between daily activities during weekdays, we added the *days of the week* as indicator variables in our models (Saturday was ref). We also added an indicator variable differentiating between the period before and after March 5th 2020 in order to account for the two *waves of data collection* that were a result of the pandemic. In order to address possible habituation effects due to participants getting used to fill in the surveys (Eisele et al., 2022), we included dummies for the observation days.

In Model 1 we estimated the effect of MD 0 and MD 1 and of the control variables except the average positive and negative affect, measures introduced in Model 2. Model 3 and 4 replicated these steps, replacing MD 0 and MD 1 with the measure of cumulative instances of microdosing.

RESULTS

We start with some exploratory analyses. In our working dataset, the minimum number of days of observation for a participant was 5 and the maximum was 30. Following up from the sampling design, all 18 participants had previous experience with microdosing before the beginning of the data collection and have used microdosing for a minimum of 1 time, a maximum of 9 and an average of 5 times between their first and last observation day.

Table 1 presents the correlation matrix for the emodiversity indexes and the average positive and negative affect.

The correlation between the positive and the negative emodiversity was moderately strong (0.40). The positive emodiversity index was moderately and positively correlated with both average positive and negative affect (0.43 and 0.23) while the negative emodiversity was very strongly correlated with average negative affect (0.76) and negatively and weakly correlated with positive emodiversity (−0.21).

Paired samples *t*-test showed that the average positive emodiversity was significantly higher than the average negative emodiversity (1.98 vs 1.01). ANOVA analyses did not show significant differences in the average of the emodiversity indexes between microdosing days and none of the emodiversity indexes was correlated with the measure of cumulative instance of microdosing.

Table 1. Correlation matrix of emodiversity indexes and average positive and negative affect

	PE	NE	E	AP	AN
Positive emodiversity (PE)	1				
Negative emodiversity (NE)	**0.40**	1			
Overall emodiversity (E)	**0.83**	**0.80**	1		
Average positive affect (AP)	**0.43**	**−0.21**	**0.12**	1	
Average negative affect (AN)	**0.22**	**0.76**	**0.62**	**−0.16**	1

Note: Bold effects are significant for $P < 0.05$

We turn to the formal tests of our analyses, main results presented in Table 2. We first estimated a null model for each measure of emodiversity and calculated the intraclass correlation. 56, 70 and 77 percent from the variation in positive, negative and overall emodiversity respectively was situated between participants. This suggests that differences in especially negative emodiversity are more linked to individual characteristics and not to characteristics linked to the days of observation.

When we examined the differences in emodiversity between microdosing days in models where the average positive and negative affect was not included, we did not find any significant differences (Model 1). However, when we controlled for the average positive and negative affect, we found that during the days where participants took a microdose the positive and the overall emodiversity were significantly lower. These results are contrary to what we expected.

We further explored whether the average positive and negative affect played the role of a mediator, i.e., if emotional awareness is higher, it is possible that during microdosing days emotions could be felt more fully and have higher intensity. This was however not the case (results not presented in tables). Since S, i.e., the range of emotions in the emodiversity index, is by calculation colinear to the average affect measure, this implies that between microdosing days it was not the range of emotions that was impacted. We further explored whether certain emotions became more prominent between microdosing days and we regressed each of the calculated P*i*, i.e., the proportion of S made up of a particular emotion, on our independent level variables included in Model 1. We found that during the day when participants took a microdose, the proportion represented by “awe, wonder, or amazement” and “ashamed, humiliated, or disgraced” was significantly higher among the positive and negative emotions respectively, while the proportion of “joyful, glad, or happy” was significantly lower among the positive emotions.

Turning to the effect of cumulative instances of microdosing on emodiversity, in the model where the average positive and negative affect was not included we found a significant and positive effect on positive emodiversity

Table 2. The acute effect of microdosing on the positive, negative and overall emodiversity. Results from mixed effects models

	Positive emodiversity				Negative emodiversity				Overall emodiversity			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
MD 0	−0.03 (0.05)	**−0.08** (0.04)			0.05 (0.07)	0.01 (0.06)			−0.03 (0.04)	**−0.08** (0.03)		
MD 1	−0.05 (0.05)	−0.01 (0.04)			0.11 (0.07)	0.10 (0.06)			−0.02 (0.04)	0.01 (0.04)		
CM			**0.07** (0.03)	0.04 (0.03)			−0.07 (0.06)	−0.05 (0.04)			0.02 (0.03)	0.00 (0.03)
Average positive affect		**0.08** (0.01)		**0.07** (0.01)		−0.01 (0.01)		−0.01 (0.01)		**0.06** (0.01)		**0.06** (0.01)
Average negative affect		0.02 (0.02)		0.01 (0.02)		**0.22** (0.02)		**0.21** (0.02)		**0.11** (0.01)		**0.10** (0.01)
Between-person variance	0.06 (0.03)	0.08 (0.03)	0.06 (0.02)	0.08 (0.03)	0.42 (0.15)	0.26 (0.09)	0.41 (0.14)	0.25 (0.09)	0.13 (0.05)	0.13 (0.05)	0.13 (0.04)	0.13 (0.04)
Within-person variance	0.07 (0.00)	0.05 (0.00)	0.07 (0.01)	0.05 (0.00)	0.14 (0.01)	0.10 (0.01)	0.14 (0.03)	0.10 (0.01)	0.06 (0.01)	0.04 (0.00)	0.06 (0.01)	0.04 (0.00)
N individuals = 18. N observations = 224												

Note: Effects with standard errors in parentheses. Bold effects are significant for $P < 0.05$.
All models included control variables for gender, age, day of the week, data collection phase, and dummies for the observation day. MD 0: I took a microdose today. MD 1: I took a microdose yesterday. MD no: I did not take a microdose yesterday or the day before (ref.). CM: cumulative microdosing instances.

index. However, when we controlled for the average positive and negative affect, this effect turned to be not significant.

As such, based on the above presented results, we did not find support for H1 or H2.

DISCUSSION

Based on our analyses using ESM data collection protocol covering an interval of 28 days and 18 participants we derive the following take away messages. First, in line with recent arguments in the literature stating that engaging in the microdosing practice could increase emotional awareness, we expected to find that during days when a microdose was ingested as well as with more cumulative instances of microdosing the level of emodiversity across both positive and negative emotions, and subsequently also overall emodiversity, to be higher. Still, this was not the case. Surprisingly, during a microdosing day, and when the average level of positive and negative affect was accounted for, we found that levels of positive emodiversity as well as overall emodiversity were lower.

Ours is a puzzling finding as it seems to be contrary to the qualitative literature that reports improvement in mood as result of the microdosing practice (Anderson, Petranker, Christopher, et al., 2019; Johnstad, 2018). This apparent contradiction can be the results of how the emodiversity index is calculated such as that it increases when a wider range of emotions are experienced and when these emotions are more even within the human emotional ecosystem. If microdosing impacts the intensity or duration of only a small number of positive emotions this could explain the reduction in positive emodiversity. This seems to be suggested by previous research, e.g., the participants in the study by Johnstad (2018) report more calm, peace, contemplative mood and emotional balance.

When we pursued this possibility, we found that the range of emotions was not impacted, but that certain emotions stood out, i.e., among the positive valence emotions, during microdosing days the proportion represented by "awe, wonder, or amazement" was significantly higher while the proportion of "joyful, glad, or happy" was significantly lower. Similarly, among the negative valence emotions, during microdosing days the proportion represented by "ashamed, humiliated, or disgraced" was significantly higher. That "awe, wonder, or amazement" was found to take a more prominent place during microdosing days among positive emotions is in line with results from a recent experimental study (van Elk et al., 2021). However, the results regarding the decrease prevalence of "joyful, glad, or happy" among the positive emotions and the increased prevalence of "ashamed, humiliated, or disgraced" among negative emotions, are surprising. We abstain from speculating why this was the case. We believe that the way of advancing our understanding of how microdosing could impact emotions is by thoroughly articulating the psychological as well as neurological mechanisms underlying these effects and this task cannot be properly addressed within the scope of this paper.

We add a note on our use of the emodiversity indexes. Usually, research in the field uses the overall emodiversity index (Ong, Benson, Zautra, & Ram, 2018; Quoidbach et al., 2014) and rarely the two components are examined separately (Werner-Seidler et al., 2020). Our results show that this approach is valuable, i.e., we have expected an increase in emodiversity during microdosing days and our results showed otherwise but only for positive and subsequently also for overall emodiversity.

Our study's main limitation is the enrollment of only a small amount of participants. Still, our methodology allowed for rich sampling due to our longitudinal design over 28 days and such, the use of ESM methods have proved successful in terms of retention and response rates. Furthermore, sampling through a smartphone may allow for the most ecologically valid assessment that creates new opportunities of data collection that can capture more fine-grained effects of microdosing. However, a cautionary note regards our outcome of interest, i.e., a rich emotional life, whose measurement may be the biggest obstacle in compliance. Furthermore, previous research has shown that ESM studies have a habituation period (Eisele et al., 2022), i.e., participants could respond differently throughout the study period of investigation because of getting used to the items presented and also because of the intensive nature of data collection. In our sampling strategy we allowed for breaks in between the observations days and in our analyses we introduced dummies for the observation days, actions meant to address such concerns.

In addition to the above, we have not measured emotional awareness formally, and we were unable to examine the theoretical mechanism suggested by literature, i.e., emotional awareness could increase during microdosing days or with more instances of microdosing, and this in turn could impact the level of emotional diversity. As such, this mechanism requires further investigation. Addressing the above limitations with a stricter design, i.e., participants with no prior experience of microdosing, as well as a double blinded procedure and dose control, and including measures of emotional awareness and expectations (Eisele et al., 2022; Kaertner et al., 2021), would allow a deeper understanding of how the microdosing practice impacts the human emotional ecosystem.

This said, our study has made clear that there is merit to examining emodiversity in relation to the microdosing practice. However, the relationship needs to be investigated separately across the positive and negative emotions. Furthermore, we found evidence for only some emotions, with both positive and negative valence, taking a central role during microdosing days. Our findings emphasize the need to make a move towards a robust theory and research of how the microdosing practice could differently impact particular emotions.

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