

Mystical experiences occasioned by the hallucinogen psilocybin lead to increases in the personality domain of openness

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Abstract

A large body of evidence, including longitudinal analyses of personality change, suggests that core personality traits are predominantly stable after age 30. To our knowledge, no study has demonstrated changes in personality in healthy adults after an experimentally manipulated discrete event. Intriguingly, double-blind controlled studies have shown that the classic hallucinogen psilocybin occasions personally and spiritually significant mystical experiences that predict long-term changes in behaviors, attitudes and values. In the present report we assessed the effect of psilocybin on changes in the five broad domains of personality – Neuroticism, Extroversion, Openness, Agreeableness, and Conscientiousness. Consistent with participant claims of hallucinogen-occasioned increases in aesthetic appreciation, imagination, and creativity, we found significant increases in Openness following a high-dose psilocybin session. In participants who had mystical experiences during their psilocybin session, Openness remained significantly higher than baseline more than 1 year after the session. The findings suggest a specific role for psilocybin and mystical-type experiences in adult personality change.

Keywords

Hallucinogen, mystical experience, openness, personality, psilocybin, psychedelic

Introduction

Psilocybin and other classic hallucinogens with actions mediated at the 5-HT_{2A} receptor site (Glennon et al., 1984; Nichols, 2004) produce a unique profile of subjective effects including robust changes in perception, cognition, affect, volition, and somaesthesia (Isbell, 1959; Rosenberg et al., 1964; Wolbach et al., 1962). In early trials of hallucinogens administered under supportive conditions, 50–80% of participants claimed lasting beneficial changes in personality, values, attitudes and behavior (McGlothlin and Arnold, 1971; Metzner and Editors, 1963). Some of the most frequent subjective reports included greater appreciation of music, art and nature, greater tolerance of others, and increased creativity and imagination (McGlothlin et al., 1967). Consistent with these findings, Studerus et al. (2011) recently reported that nearly 40% of participants in several laboratory studies of psilocybin claimed positive long-term changes in aesthetic experience and in their relationship with the environment (i.e. nature) following their psilocybin sessions.

The long-term positive impact of hallucinogens may depend on their ability to occasion profound insights and mystical-type experiences (Doblin, 1991; Pahnke, 1963). The core features of *mystical experience*, as defined by Stace (1960) and Hood (2003), are feelings of unity and interconnectedness with all people and things, a sense of sacredness, feelings of peace and joy, a sense of transcending normal time

and space, ineffability, and an intuitive belief that the experience is a source of objective truth about the nature of reality. Because such experiences appear to enable individuals to transcend their usual patterns of thinking, feeling, and acting, it is plausible that they could occasion changes in core dimensions of personality. In support of this, a double-blind controlled study by Griffiths et al. (2006, 2008) demonstrated that a single psilocybin session occasioned mystical experiences associated with positive changes in behaviors, attitudes and values more than a year later. Moreover, independent ratings from participants' romantic partners, coworkers, and friends corroborated the first-person reports. These findings suggest fundamental changes in personal concerns, goals, and identity, which are considered to be important dimensions of personality (e.g. in the framework described in McAdams, 1995). However, the impact

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of psilocybin-occasioned mystical experience on core personality traits is unknown.

There is general agreement that personality traits are relatively enduring styles of thinking, feeling, and acting (McCrae and Costa, 1997). The most widely accepted model of personality structure is the five-factor model, which describes five broad domains of personality, each encompassing many related traits: Neuroticism, Extroversion, Openness, Agreeableness and Conscientiousness (Digman, 1990; McCrae, 2009). Many studies have confirmed that these personality factors are heritable (Bouchard et al., 1990) and reliable across cultures, suggesting a universal human personality structure that is rooted in biology (McCrae and Costa, 1997). Longitudinal studies have shown that individual personality is predominantly stable across the lifespan. Although there are mean-level personality changes after age 30, these shifts are typically gradual and subtle (1–2 *T*-score points per decade; Terracciano et al., 2005).

Despite the relatively stable nature of personality, researchers have hypothesized that significant life events could change adult personality quite dramatically. Studies investigating individual differences in personality trait change have found that certain life experiences are associated with changes in adult personality (see review in Roberts and Mroczek, 2008). For example, personality changes have been associated with divorce (e.g. increases in Extroversion and Openness in women, Costa et al., 2000), remarriage (e.g. decreases in Neuroticism in men, Mroczek and Spiro, 2003), and career success (e.g. decreases in Conscientiousness in individuals who were fired versus promoted, Costa et al., 2000). However, such correlational studies cannot address the causal link between particular events and subsequent personality change.

Relatively little research has investigated personality change in the laboratory, likely because events that might be expected to change personality are difficult to create under experimental (i.e. randomized or assigned) conditions. Some studies have shown changes in personality after experimental treatment interventions in patients, such as several weeks of antidepressant medication (e.g. Costa et al., 2005) and intensive outpatient counseling for substance abuse rehabilitation (Piedmont, 2001). Personality changes have also been shown in healthy adults after 3 months of intensive contemplative training in attention and emotion regulation (Sahdra et al., 2011). These personality changes, as well as socioemotional and behavioral improvements, were maintained several months after completion of training, suggesting possible long-term benefits.

To our knowledge, no study has prospectively demonstrated personality change in healthy adults after an experimentally manipulated discrete event. Although it has been speculated that treatment with classic hallucinogens could be a method for occasioning dramatic and rapid personality change (Unger, 1964), a controlled study of LSD in healthy volunteers failed to find significant changes in a large battery of empirical measures of personality, aesthetic sensitivity, and creativity 6 months after LSD sessions (McGlothlin et al., 1967). Nevertheless, these investigators confirmed the subjective claims of long-term change frequently reported in uncontrolled trials.

The subjective claims of hallucinogen-occasioned long-term changes (McGlothlin and Arnold, 1971; McGlothlin et al., 1967; Metzner and Editors, 1963; Studerus et al., 2011) appear to align with the modern personality construct of Openness, which encompasses aesthetic appreciation and sensitivity, imagination and fantasy, and broad-minded tolerance of others' viewpoints and values. The present report combines data from two double-blind controlled studies of psilocybin (Griffiths et al., 2006, 2011) to analyze changes in Openness and the other four broad personality domains using the NEO Personality Inventory (Costa and McCrae, 1992). Personality change was assessed 1–2 months after a high-dose psilocybin session and again more than 1 year later to determine the persistence of personality change. Consistent with previous results indicating a correlation between mystical experiences during the session and long-term spiritual significance and personal meaning attribution (Griffiths et al., 2008), we hypothesized that mystical experiences during the psilocybin session would lead to enduring increases in Openness.

Methods

Participants

Recruitment methods and screening procedures were similar across the two studies. Participants were recruited from the local community by flyers announcing 'a study of states of consciousness brought about by psilocybin, a naturally occurring psychoactive substance used sacramentally in some cultures'. The first phase of screening involved a scripted telephone interview, which was used to pre-screen for the major inclusion/exclusion criteria. Common reasons for not passing the telephone screen included distance from study site, extensive prior hallucinogen use, and inability to make the time commitment required for participation. Individuals who passed the telephone screen (approximately 20% of those screened) were evaluated in person for inclusion/exclusion criteria and medical and psychiatric health, as described previously for human research with classic hallucinogens (Johnson et al., 2008). The inclusion/exclusion criteria were similar across the two studies, although participants in Study 2 were permitted to have limited prior experience with hallucinogens (Griffiths et al., 2011). The single participant in Study 2 who had prior lifetime experience with psilocybin was excluded from the present analyses. In addition, one participant in Study 1 (Griffiths et al., 2006) had incomplete personality data and was excluded. Thus, the present analyses included 52 hallucinogen-naïve participants (Table 1). Participants were generally well educated (54% had postgraduate degrees) and spiritually active (90% regularly participated in religious services, discussion groups, prayer, or meditation).

Participants did not receive monetary compensation but generally reported being motivated by curiosity about the effects of psilocybin and the opportunity for extensive self-reflection. The Institutional Review Board of the Johns Hopkins University School of Medicine approved the studies, and all participants gave their informed consent before participation.

Psilocybin sessions

Dose conditions. Participants completed 2–5 8-h drug sessions, with consecutive sessions separated by at least 3 weeks. Participants were informed that they would receive a ‘moderate or high dose’ of psilocybin during one of their drug sessions, but neither the participant nor the session monitors knew when this session would occur. In Study 1 (Griffiths et al., 2006), each participant received psilocybin (30 mg/70 kg body weight) on one session and an active control drug, methylphenidate (40 mg/70 kg), on the other one or two sessions. In Study 2 (Griffiths et al., 2011), each participant received four doses of psilocybin (5, 10, 20 and 30 mg/70 kg) in ascending or descending order (50% random assignment) across four sessions, with a fifth placebo session quasi-randomly inserted in the sequence. In the present report, we analyzed mystical experiences and changes in personality associated with the high-dose (30 mg/70 kg) psilocybin session.

Session protocol. Participants received extensive preparation and met with session monitors for at least 8 h on several different occasions prior to their first drug session, in line with recommendations for hallucinogen research (Johnson et al., 2008). The drug was orally administered in capsule form with 100 mL water at the beginning of each session. During the session, participants were encouraged to lie down on a couch, use an eye mask to block external visual distraction, wear headphones through which a music program was played, and focus their attention on their inner experiences.

Measures

NEO Personality Inventory (NEO-PI). Personality was assessed at screening, 1–2 months after each drug session, and approximately 14 months after the last drug session

using a computer-based version of the revised NEO-PI (Costa and McCrae, 1992). This 240-item instrument measures the five factors of personality and the six facets that define each factor. The facets of Openness are Fantasy (e.g. ‘I have a very active imagination’), Aesthetics (e.g. ‘I am intrigued by patterns I find in art and nature’), Feelings (e.g. ‘I experience a wide range of emotions and feelings’), Ideas (e.g. ‘I often enjoy playing with theories or abstract ideas’), Values (e.g. ‘I consider myself broad-minded and tolerant of other people’s lifestyles’), and Actions (e.g. ‘I think it’s interesting to learn and develop new hobbies’). Items were answered on a 5-point scale ranging from *strongly disagree* to *strongly agree*, and raw scores were standardized as *T* scores ($M = 50$, $SD = 10$) using the combined-sex norms reported in the NEO-PI-R manual.

States of Consciousness Questionnaire (SOCQ). Mystical-type phenomena during the drug sessions were assessed using 43 mystical experience items embedded within a 100-item instrument, the States of Consciousness Questionnaire (SOCQ), which assesses phenomenological content during altered states of consciousness (Griffiths et al., 2006). The mystical experience items have been shown to be sensitive to the effects of psilocybin (Doblin, 1991; Griffiths et al., 2006, 2011; Pahnke, 1963;) and other hallucinogens (Richards et al., 1977; Turek et al., 1974). The SOCQ was administered after each session (approximately 7 h after capsule administration). Items were answered on a 6-point scale ranging from 0 (*none, not at all*) to 5 (*extreme, more than ever before in my life and stronger than 4*). Data on each of the following six subscales were expressed as percentage of maximum possible score: unity; transcendence of time and space; ineffability and paradoxicality; sacredness; noetic quality; and positive mood. Consistent with previous research (Griffiths et al., 2006), a ‘complete mystical experience’ was defined as having a score of 60% or higher on each subscale. A total score was also calculated as the mean across all items in the six subscales.

Table 1. Demographic and Personality Variables at Screening

	Study 1	Study 2
Age at study entry (years)	46 (24–64)	46 (29–62)
Sex	14 M, 21 F	8 M, 9 F
Education	4.2 (2–5)	4.0 (2–5)
Mysticism Scale - Lifetime	215 (184–283)	216 (124–282)
NEO Personality Inventory		
Neuroticism	41.8 (26.4–64.6)	46.1 (19.3–61.3)
Extroversion	55.3 (31.3–76.4)	52.1 (34.0–78.0)
Openness	65.4 (42.1–80.3)	62.7 (45.6–83.8)
Agreeableness	55.7 (41.0–75.1)	55.1 (37.2–72.6)
Conscientiousness	51.0 (22.7–80.6)	51.7 (32.9–72.1)

The table presents mean values (with ranges in parentheses) for hallucinogen-naïve participants with complete personality data ($n = 35$ in Study 1; $n = 17$ in Study 2). Educational achievement was scored on the following scale: 1 = high school diploma; 2 = some college; 3 = college degree; 4 = some graduate study; 5 = graduate degree. Mystical experiences across the lifetime were quantified as total score on the Hood Mysticism Scale at screening (Hood et al., 2001). Personality was assessed using a computer-based version of the revised NEO Personality Inventory (Costa and McCrae, 1992). No significant study-group differences in demographic or personality variables were evident at screening (p -values > 0.10).

Mysticism Scale. The Mysticism Scale was originally developed to assess mystical experiences across the lifetime and has been validated in several studies, including cross-culturally (Hood, 1975, 2003; Hood et al., 2001). Items were answered on a 9-point scale ranging from -4 (*this description is extremely not true of my own experience*) to +4 (*this description is extremely true of my own experience*). Total score (sum across 32 items) was used to quantify lifetime mystical experiences at screening (see Table 1). In addition, a modified version of the Mysticism Scale was used to assess mystical effects during the drug sessions. Participants completed the experience-specific version approximately 7 h after capsule administration and answered the items in reference to their experiences since receiving the capsule that morning.

APZ. The APZ is a 72-item yes/no questionnaire designed to assess altered states of consciousness, including those produced by hallucinogens (Dittrich, 1998). The three scales

on the APZ are OSE ('oceanic boundlessness'; this scale assesses phenomena such as unity, bliss, and transcendence of time and space); VUS ('visionary restructuring'; this scale assesses visual pseudo-hallucinations, illusions, and synaesthesias); and AIA ('dread of ego dissolution'; this scale assesses dysphoric feelings such as anxiety, fear, and feeling trapped). Data on each scale were expressed as percentage of maximum possible score.

Analysis

We combined data from two double-blind psilocybin studies to achieve greater statistical power to detect personality change at the group level and to examine personality change in sub-groups of individuals who differed in mystical-type psilocybin effects. Because Study 2 involved multiple doses of psilocybin in addition to the single high dose used in Study 1, it was not possible to completely isolate the high-dose session in Study 2. However, the session protocol implemented in Study 2 was identical to that used in Study 1. Furthermore, changes in personality following the high-dose session were always assessed within 1–2 months of the high-dose session and before any subsequent session.

We hypothesized that mystical experiences during the psilocybin session, as measured by the SOCQ, would lead to increases in Openness. We investigated this prediction using three analysis approaches (all analyses were conducted in SPSS version 18.0). First, we used multivariate repeated measures analysis of variance (ANOVA) to analyze changes in Openness and the other four NEO-PI factors (Neuroticism, Extroversion, Agreeableness, and Conscientiousness) from screening to post-test (1–2 months after the high-dose psilocybin session). After confirming that Openness changed significantly following the high-dose session, we calculated Pearson's linear correlations between changes in Openness and session-day measures (the SOCQ, the Mysticism Scale, the OSE, the VUS, and the AIA). We then confirmed via regression analysis that mystical experience, as measured by the SOCQ, was a significant predictor of changes in Openness. Specifically, we conducted a series of linear regression analyses that tested the predictive power of the SOCQ above and beyond the predictive power of the four questionnaire measures that also correlated with Openness change (the Mysticism Scale, the OSE, the VUS, and the AIA). In each of four models (one model for each questionnaire), we tested the following predictors of Openness at post-test in a stepwise manner: 1) Openness at screening, 2) an alternate questionnaire measure (e.g. total score on the Mysticism Scale), and 3) mystical score on the SOCQ. We hypothesized that mystical score on the SOCQ (Step 3) would explain significantly more variability in Openness than each of the alternate questionnaire measures (Step 2), as indicated by significant estimates of *R*-squared change from Step 2 to Step 3.

Finally, we compared Openness change in participants who met the criteria for having had a complete mystical experience during their high-dose session ($n=30$) with participants who did not meet the criteria ($n=22$). We used the 'complete mystical experience' classification (60% on each subscale of the SOCQ) rather than data-driven classification

(e.g. median split) for several reasons. First, median split analyses have been associated with reductions of power and effect size (MacCallum et al., 2002). Second, classification based on subscale scores takes into account the breadth of mystical-type effects, which total score does not. For example, a participant could have a high total score while not endorsing many sacredness items. Finally, designating participants who met the criteria for a complete mystical experience allowed a comparison with previous studies (Griffiths et al., 2006, 2008, 2011; Pahnke, 1963; Richards et al., 1977).

Results

Changes in personality following the psilocybin session

Consistent with our hypothesis, the repeated measures ANOVA showed that Openness increased significantly from screening to post-test ($M=+2.8$, $F(1, 51)=5.47$, $p=0.023$, $\eta_p^2=0.10$). Moreover, because participants received the high dose on different sessions, it was possible to conduct a comparison analysis of changes in Openness following the first session in the subgroup of participants who did not receive a high dose of psilocybin on that session ($n=30$ participants received inactive placebo, methylphenidate, or 5 mg/70 kg of psilocybin on their first session). There were no significant changes in Openness after the first session in this subgroup ($F(1, 29)=0.52$, $p=0.48$). Finally, with regard to changes in the other four personality factors after the high-dose session, there were no significant changes from screening to post-test in Neuroticism ($M=-0.5$; $F(1, 51)=0.24$, $p=0.62$), Extroversion ($M=+0.8$; $F(1, 51)=0.79$, $p=0.38$), Agreeableness ($M=+1.7$; $F(1, 51)=2.31$, $p=0.16$), or Conscientiousness ($M=-0.9$; $F(1, 51)=1.22$, $p=0.28$), and test–retest correlations were high across assessments ($r_s=0.61$ – 0.84). Taken together, these results indicate predominantly stable personality traits with specific increases in Openness following the high-dose session.

Relationship between session-day effects and changes in Openness

We hypothesized that individual differences in mystical experience during the psilocybin session, as measured by the SOCQ, would be related to individual differences in Openness change. There was considerable variability in mystical-type effects during the high-dose session, with nearly the full range of possible scores (range: 0.03–1.00) represented across the six subscales of mystical experience. Consistent with our hypothesis, mystical experience (mean score across all of the items in the six subscales) correlated significantly with increases in Openness ($r=0.42$, $p=0.002$; Figure 1). Importantly, mystical experience did not correlate significantly with screening levels of Openness ($r=0.12$, $p=0.41$) or its facets; the highest correlation was with Feelings ($r=0.24$, $p=0.09$).

Changes in Openness were also correlated with scores on the Mysticism Scale ($r=0.33$, $p=0.017$), the OSE ($r=0.44$,

$p=0.001$), the VUS ($r=0.41$, $p=0.003$), and the AIA ($r=0.31$, $p=0.024$). The significant relationships shown by Pearson's linear correlations were also shown by Spearman's rank order correlations between change in Openness and the SOCQ ($r_s=0.47$, $p<0.001$), the Mysticism Scale ($r_s=0.40$, $p=0.003$), the OSE ($r_s=0.45$, $p=0.001$), the VUS ($r_s=0.47$, $p<0.001$), and the AIA ($r_s=0.33$, $p=0.018$). However, a series of stepwise regression analyses showed that the SOCQ explained significantly more variability in Openness change than the Mysticism Scale (R -squared change = 0.046, $p=0.033$), the OSE (R -squared change = 0.047, $p=0.031$), the VUS (R -squared change = 0.042, $p=0.036$), and the AIA (R -squared change = 0.12, $p=0.001$).

Effect of mystical experience on changes in Openness

We further examined the relationship between mystical experience and increases in Openness by comparing participants who met the criteria for having had a complete mystical experience during their high-dose session ($n=30$) with participants who did not meet the criteria ($n=22$). ANOVA revealed a significant interaction between time (screening vs. post-test) and group (complete mystical experience vs. no complete mystical experience) ($F(1, 50)=9.32$, $p=0.004$, $\eta_p^2=0.16$). Follow-up t -tests confirmed that the complete mystical experience group showed significant increases in Openness from screening to post-test ($M=+5.7$; $t(29)=3.44$, $p=0.002$) while the other group did not ($M=-1.2$; $t(21)=0.87$, $p=0.39$) (Figure 2). Five of the six

facets of Openness showed this same pattern when examined individually: the interaction between time and group was significant for Fantasy ($p=0.029$, $\eta_p^2=0.09$), Aesthetics ($p=0.010$, $\eta_p^2=0.13$), Feelings ($p=0.038$, $\eta_p^2=0.08$), Ideas ($p=0.014$, $\eta_p^2=0.11$), and Values ($p=0.036$, $\eta_p^2=0.09$), but not Actions ($p=0.19$). Follow-up t -tests for the five facets showing significance confirmed that the complete mystical experience group increased in these facets while the other group did not (Figure 3).

Follow-up

The persistence of increases in Openness was assessed at a follow-up assessment conducted more than 1 year after the high-dose session ($M=16$ months). In participants who had a complete mystical experience ($n=30$), Openness levels at follow-up decreased slightly from post-test but did not differ significantly from Openness levels at post-test ($p=0.12$) and remained significantly higher than at screening ($M=+4.2$; $F(1, 29)=4.17$, $p=0.050$, $\eta_p^2=0.13$). In contrast, participants who did not have a complete mystical experience ($n=21$) had nearly identical Openness levels at follow-up and screening ($M=-0.3$; $p=0.86$).^{1,2}

Discussion

We observed significant increases in Openness after a high-dose psilocybin session that were larger in magnitude than changes in personality typically observed in healthy adults over decades of life experience (Terracciano et al., 2005).

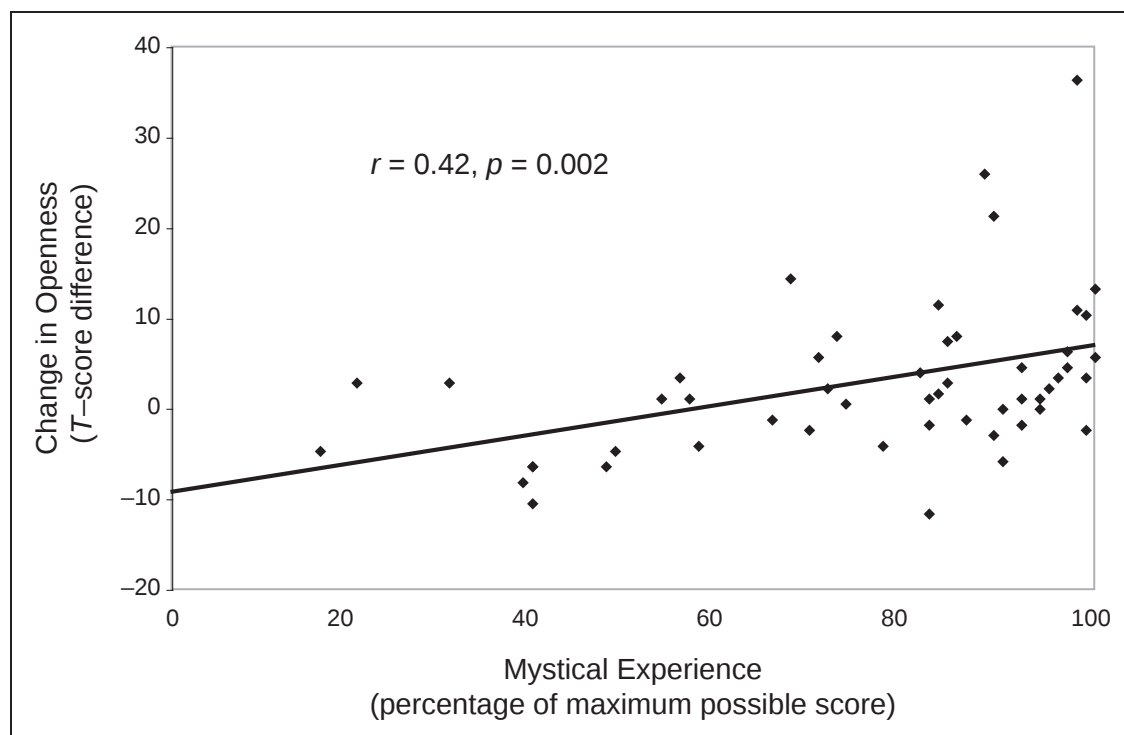


Figure 1. Change in Openness from screening to post-test as a function of mystical experience during the high-dose psilocybin session ($n=52$). Data points show individual experimental data; a linear regression line has been fit to those data.

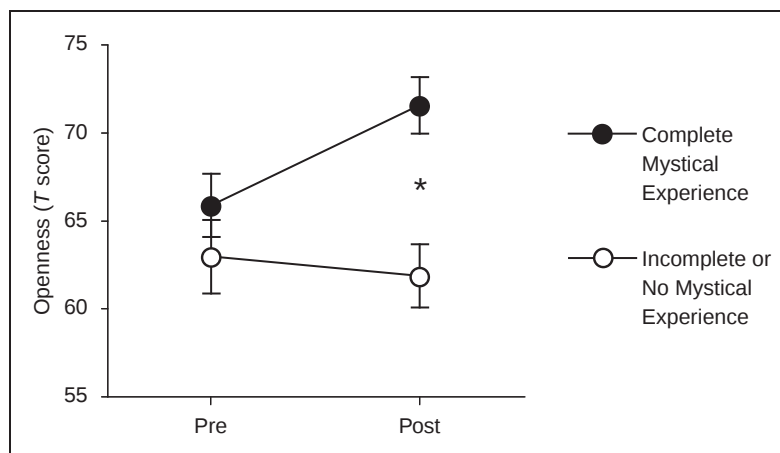


Figure 2. Changes in Openness after psilocybin in participants who did and did not have mystical experiences. Figure shows Openness *T* scores at screening (Pre) and post-test (Post) in participants who had a complete mystical experience ($n = 30$; filled symbols) and those who had an incomplete or no mystical experience ($n = 22$; open symbols). Data points are means; bars show ± 1 SEM; asterisk indicates a significant difference ($p < 0.001$) at the post-psilocybin assessment. Screening levels of Openness and its facets did not differ between participants who met the criteria for having had a complete mystical experience and those who did not (p -values > 0.10).

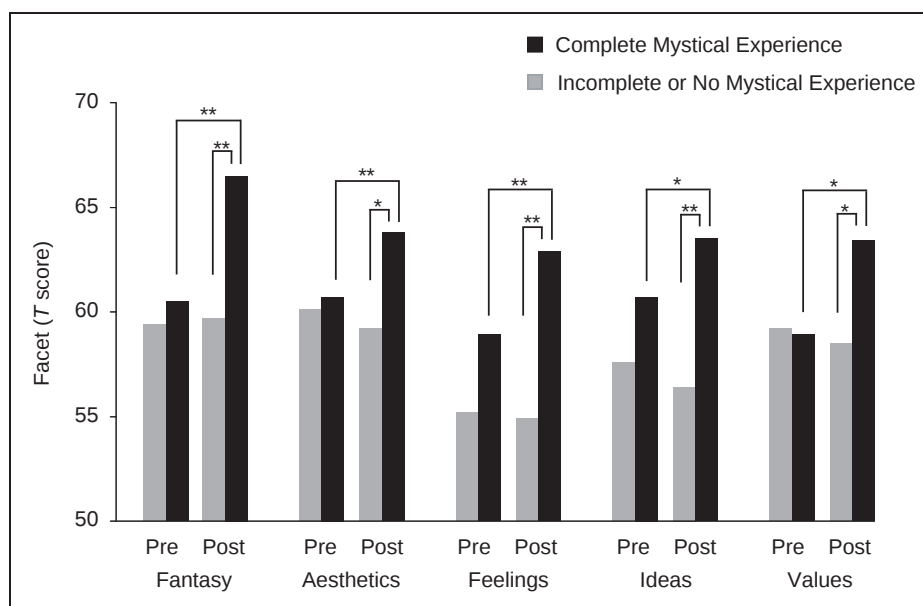


Figure 3. Changes in five facets of Openness after psilocybin in participants who did and did not have mystical experiences. Figure shows facet *T* scores (Fantasy, Aesthetics, Feelings, Ideas and Values) at screening (Pre) and post-test (Post) in participants who had complete mystical experiences (black bars) and those who did not (grey bars). Bars show means; brackets indicate statistical differences (* $p < 0.05$, ** $p < 0.01$).

Moreover, in participants who met criteria for having had a complete mystical experience during their psilocybin session, Openness remained significantly higher than baseline more than 1 year after the session. This is the first study to demonstrate changes in personality in healthy adults after an experimentally manipulated discrete event. To our knowledge, the only other experimental (i.e. randomized) intervention reported to change healthy adults' personality involved hundreds of hours of solitary meditation over the course of 3 months (Sahdra et al., 2011). The present findings are suggestive of lasting change in core personality traits. However, it

will be important to replicate these results in larger groups of individuals with diverse baseline personality profiles.

It is informative to compare the magnitude of Openness change observed in the present study with previous findings of longitudinal personality change. During normal aging, Openness typically *decreases* linearly at a rate of approximately 1 *T*-score point per decade (see Figure 4 in Terracciano et al., 2005). In comparison, participants in the present study who had a complete mystical experience during their psilocybin session increased more than 4 *T*-score points from screening to follow-up. Notably, this increase is larger

than increases in Openness seen in individuals treated successfully with antidepressant medication (see Figure 1 in Costa et al., 2005) and intensive outpatient counseling for substance abuse (see Table 1 in Piedmont, 2001).

Openness includes a relatively broad range of intercorrelated traits covering aesthetic appreciation and sensitivity, fantasy and imagination, awareness of feelings in self and others, and intellectual engagement. People with high levels of Openness are 'permeable to new ideas and experiences' and 'motivated to enlarge their experience into novel territory' (DeYoung et al., 2005). Openness is strongly associated with creativity (Silvia et al., 2009), and some of its facets (Ideas, Values) are correlated with general fluid intelligence and cognitive ability (DeYoung et al., 2005, 2009). Although the present study did not directly investigate the corollary benefits of increased Openness, significant increases in nearly all of the facet scores indicate the potential for improvements in aesthetic and cognitive domains.

Very few controlled studies have attempted to characterize the effects of classic hallucinogens on aesthetic and creative outcomes. One previous well-controlled study of LSD (McGlothlin et al., 1967) found evidence for short-term improvements on measures of artistic ability (e.g. figure drawings), aesthetic sensitivity (e.g. compatibility between participant and expert ratings of paintings), and creativity (e.g. generating alternate uses for a common object). However, they failed to find significant improvements in creativity or aesthetic measures at a 6-month follow-up. Notably, the McGlothlin study included graduate students who were paid for participation, generally showed little interest in LSD, and received minimal preparation and support for the LSD sessions. In contrast, the present study included unpaid community volunteers who were motivated by curiosity about the effects of psilocybin and received extensive interpersonal preparation and support for the psilocybin sessions. It is likely that differences in participant motivation and preparation contributed to different long-term outcomes following hallucinogen sessions. In addition, nearly all of the participants in the present study regularly engaged in spiritual activities such as religious services, prayer, and meditation. It is possible that such individuals are particularly sensitive to the mystical-type effects of psilocybin, which were predictive of increases in Openness.

Cross-sectional methods have been used to examine differences in personality, attitudes and values between regular hallucinogen users and controls. A study in Brazil by Grob et al. (1996) found that individuals who used the hallucinogenic plant ayahuasca as a spiritual sacrament had lower trait levels of excitability, disorderliness and impulsivity, and higher trait levels of confidence, gregariousness and optimism compared with community members who did not use ayahuasca. Lerner and Lyvers (2006) found that individuals who used hallucinogens valued spirituality, concern for others, concern for the environment (i.e. nature), and creativity more highly than individuals who used other illicit drugs (e.g. marijuana, amphetamine, heroin). Although the findings are suggestive of personality changes that might be associated with hallucinogen exposure, it is not possible to isolate the effects of hallucinogens per se because of the self-selection bias that may confound results

of cross-sectional studies. Longitudinal studies will be required to replicate hallucinogen-related changes in personality, attitudes, and values.

The NEO-PI is one of the most widely used measures of personality in modern psychology. Nevertheless, it is useful to consider alternate methods of classifying personality. For example, the Temperament and Character Inventory (TCI) measures personality as a combination of *temperament* or automatic responses to emotional stimuli and *character* or self-aware concepts that are associated with voluntary intentions and attitudes (see review in Cloninger, 1994). The TCI scales are considered distinct from the factors in the NEO-PI. However, a factor analysis showed that TCI scales loaded on the five NEO-PI factors (McCrae et al., 2001). In particular, the Self-Transcendence scale of the TCI loaded on Openness, effectively representing 'openness to spiritual experience' (McCrae, 2009). Given the connection between mystical experience and increases in Openness observed in the present study, it is likely that Self-Transcendence might also increase following a high-dose psilocybin session.

In contrast to the numerous questionnaires available for assessing personality, very few questionnaire measures have been developed to assess mystical experiences. Despite the generally infrequent use of the SOCQ, it has been used effectively along with the more widely used and validated Mysticism Scale (Hood, 2003) to characterize hallucinogen effects (Griffiths et al., 2006, 2008, 2011). Although a psychometric validation of the SOCQ has not been published, data from a study in our laboratory involving several hundred respondents indicate that the mystical items in the SOCQ have a reliable factor structure and that the factor scores differentiate self-reported mystical experiences from otherwise profound positive experiences. In the present study, the SOCQ was a better predictor of changes in Openness than other questionnaire measures of mystical effects (e.g. the Mysticism Scale) and positively experienced hallucinogen effects (e.g. the OSE). Overall, these results suggest a specific role for the SOCQ in quantifying mystical experiences and predicting personality change, although it will be necessary to continue to examine the sensitivity and validity of the SOCQ in characterizing the mystical-type effects of psilocybin and other classic hallucinogens.

The findings have important implications for the application of psilocybin and classic hallucinogens in clinical psychiatry. Recent reviews have suggested that hallucinogens could have positive effects on the outcomes of clinical disorders, particularly anxiety and mood disorders (Griffiths and Grob, 2010; Vollenweider and Kometer, 2010). Clinical work along these lines was initiated in the 1950s and suggested possible improvements after hallucinogen treatment in individuals with terminal cancer (Grob et al., 2011; Kast, 1967; Richards et al., 1977) and substance dependence (Halpern, 1996; Mangini, 1998; Terrill et al., 1964). Although there is still much to learn about the mechanisms by which hallucinogens might produce positive changes, the increases in Openness observed in the present study indicate novel avenues of future research into the biological and psychological mechanisms of psilocybin treatment.

It will also be important in future treatment studies to examine the effects of psilocybin and mystical experience on

changes in maladaptive personality traits. For example, although we did not observe decreases in mean Neuroticism (feeling tense, anxious, moody, or insecure), which was nearly 1 *SD* below normal at baseline, reductions in Neuroticism have been observed in patients undergoing treatment for depression (Costa et al., 2005) and substance abuse (Piedmont, 2001). Similarly, reductions in Neuroticism might accompany reductions in anxiety and depressed mood following psilocybin treatment in patient populations (e.g. individuals with advanced-stage cancer; Grob et al., 2011). In addition, although the present study focused on personality change following a single high-dose session, it is possible that multiple sessions would be associated with changes in additional domains besides Openness.

In conclusion, the present results indicate that a high dose of psilocybin administered under supportive conditions produced increases in Openness, consistent with participants' subjective claims of the long-term effects of hallucinogens. Importantly, participants who had a complete mystical experience during their high-dose session, but not others, showed enduring increases in Openness, suggesting that other mystical experiences could occasion similar change. Qualitative research has documented sudden and dramatic positive changes in attitudes, values and behaviors following spontaneous mystical or spiritual experiences (Miller, 2004; Paloutzian et al., 1999). Further, correlational research has highlighted a role for spirituality in addiction recovery (Kelly et al., 2011) and in coping with life-threatening illnesses such as cancer (McCoubrie and Davies, 2006), which may account for the potential efficacy of psilocybin in the aforementioned treatment of addictions and cancer distress. Future research should continue to investigate the conditions – both pharmacological and non-pharmacological – that might occasion mystical experiences, as well as describe their potential long-term consequences.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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Notes

1. The overall pattern of results was similar between Study 1 and Study 2. In participants who had a complete mystical experience, there were no differences between the studies in Openness change ($p=0.11$) or in Openness at screening ($p=0.28$), post-test ($p=0.69$) or follow-up ($p=0.36$).
2. Three participants in Study 2 met the criteria for a complete mystical experience during their 20 mg/70 kg (i.e. moderately high dose) psilocybin session but not during their

30 mg/70 kg (i.e. high dose) session. Including these participants in the 'complete mystical experience' group ($n=33$) did not change the reported results.

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