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Smartphone-based program for enhancing curiosity and its associated virtues: a randomized waitlist-controlled pilot study

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ABSTRACT

This study evaluated a smartphone-based intervention designed to promote dispositional curiosity through daily behavioral activities and ‘mindful curiosity’ practices, which promote an inquiring stance towards everyday experiences. Participants ($N=91$) were randomly assigned to the app intervention (with half further assigned to the mindful curiosity component) or a waitlist control. Pre- and post-tests assessed trait curiosity and several of its correlates, including meaning in life, boredom proneness, and creative behavior. Results revealed that app users, compared to the control group, showed significant increases in perceptual curiosity, meaning in life, and creative behaviors. Follow-up contrasts indicated that while both app user subgroups showed increased creative behaviors, only the group with the additional mindful curiosity component showed significant increases in presence of meaning, mindful awareness, and reduced boredom proneness. These findings suggest that trait curiosity and its benefits can be cultivated through targeted interventions, particularly when combining attitudinal and behavioral strategies.

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Volitional-personality change; dispositional curiosity; personal development; meaning in life; personality

Introduction



Curiosity is a psychological powerhouse that is predictive of an impressive host of character virtues, including intellectual humility, creativity, resilience, gratitude, critical discernment, as well as positive outcomes, including increased academic and professional success, satisfying relationships, and increased meaning in life (M. E. Gross et al., 2019; Kashdan & Steger, 2007; Kashdan et al., 2004; Rawding, 2018; Richman et al., 2005; von Stumm et al., 2011; Zedelius et al., 2022). Although not everyone has the benefit of being naturally high in curiosity, recent psychological research indicates that individuals can develop facets of their character through behavioral interventions that harness habit formation techniques (Hudson et al., 2019; Stieger et al., 2020). The present study sought to test a recently developed intervention designed to promote dispositional curiosity through an evidence-based goal implementation procedure, delivered via a custom Smartphone app. The key components of the intervention are detailed in the following sections.


Behavioral curiosity

Trait curiosity is often conceptualized as an increased tendency to experience states of curiosity (Collins et al.,

2004; Spielberger & Butler, 1971; Spielberger et al., 1976). Indeed, curiosity researchers Silvia and Kashdan (2009) argue that engaging in behaviors and having experiences that elicit salient feelings of interest drive individuals to seek activities that afford similar experiences in the future. With enough frequency, individuals update their mental models of the world to include beliefs about the interestingness of the world and their potential to discover and enjoy such opportunities. This, they argue, provides a framework for understanding how states of curiosity can develop into enduring changes in dispositional curiosity. Consistent with this view, a growing base of research indicates that personality traits may be altered using a ‘bottom-up approach’, namely, increasing the frequency of behaviors that underlie a given trait (Magidson et al., 2014).

Drawing from this, the present study employed a multi-faceted Smartphone-based intervention that included two key forms of behavioral engagement: personalized behavioral goals and behavioral activation tasks, similar to the techniques employed by Stieger et al. (2020) for promoting personality change. To develop personalized goals, participants were asked to develop six concrete activities or behaviors that they were to commit to over the course of the three week

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intervention. Participants received guidance on how to create optimal goals based on their interests and appropriate levels of difficulty. These goals were then transformed into *implementation intentions* using a ‘when-then’ format (Gollwitzer & Sheeran, 2006), in which participants specified both a behavior and its triggering cue; for example, ‘When I am on my lunch break, then I will listen to a new podcast’. This structured goal-setting approach was designed to promote regular curiosity-evoking behaviors as part of participants’ regular daily routine.

The second core behavioral component was behavioral activation (BA) tasks. BA applies principles of reward learning to encourage engagement in novel experiences through well-defined, scheduled daily activities. Successful completion of these easily-achievable activities is thought to reinforce motivation to pursue longer-term goals (Magidson et al., 2014). In our implementation, participants were given ‘daily challenges’; daily activities that encouraged engagement in novel and diverse experiences and were designed based on known empirical and theoretical determinants of curiosity (Daume & Hüttl-Maack, 2020; M. Gross, 2022; Jirout et al., 2022; Silvia & Kashdan, 2009).

Attitudinal curiosity

In addition to forming behavioral habits conducive with curiosity, the intervention explored the impact of cultivating an *attitude* of curiosity. Interest curiosity is associated with an inquiring nature and a general sense of wonderment which manifests as a tendency to ask questions (Stokoe, 2018). Indeed, research in our lab revealed that a novel question-generation procedure, termed the *just ask* paradigm (M. Gross, 2022), effectively promotes interest curiosity. In this paradigm, participants engage in unconstrained question generation during independent reading. In a recent series of studies (M. Gross, 2022), this question-asking strategy was compared to an active control strategy involving summarizing main ideas of text, a standard reading activity in educational settings. Here, the *just ask* paradigm was found to be effective in promoting both questionnaire-based and behavioral manifestations of curiosity (M. Gross, 2022).

The present intervention built off of this research by integrating the *just ask* method with mindfulness techniques in order to enable participants to develop an *enduring* inquisitive mindset, rather than curiosity *for* a specific stimuli or context. In the daily ‘mindful curiosity’ sessions, participants were trained to engage in continuous, open-ended, and non-judgmental inquiry into their immediate experiences with an attitude of open curiosity

(Ding et al., 2014). These practices were designed to cultivate a habit of engagement and exploration using an informal methodology, in order to facilitate seamless incorporation into daily routines. This, in turn, may enable individuals to extend their curiosity beyond academic or learning environments into all areas of life, including routine activities and interpersonal relations.

Self-reflection and progress tracking

Finally, the app targeted several self-regulatory elements to promote retention and solidify habit formation. Drawing on research showing that self-reflection can accelerate the development of new behaviors (Marcovitch et al., 2008), the intervention included a brief daily reflective exercise. The reflective exercises encouraged participants to become aware of the successes and pitfalls inherent in their current strategies and to flexibly adapt their strategies in order to increase the likelihood of success the following day. Another important feature of the app-based intervention was the ability to track progress. The custom app developed for this study allowed participants to visually track their successful days and monitor their ongoing achievement.

Summarized objective

The effectiveness of the Smartphone-based intervention for promoting curiosity was tested in a controlled pilot study ($N = 91$) in which the experimental condition (i.e. app users) was tested against a waitlist control condition. Pre- and post-tests were delivered three weeks apart to assess the impact of app usage on trait-level, or dispositional, forms of curiosity, and associated virtues. It was predicted that use of the app-based intervention would significantly enhance curiosity as well as outcomes that have previously been found in association with it, including creative behaviors and perceptions of meaning in life (e.g. M. E. Gross et al., 2020; Kashdan & Steger, 2007).

While the primary focus of the study was the comparison between app users and the waitlist control group, a secondary aim was to assess the effectiveness of the intervention’s attitudinal component, or ‘mindful curiosity’ sessions, in amplifying the overall effects of the app. To examine this, half of the app users were assigned to complete the daily mindful curiosity task in addition to the behavioral goals (henceforth referred to as *behavior + mindful curiosity* condition), while the other users were only assigned behavioral strategies (henceforth referred to as *behavior-only* condition). This enabled us to examine the

relative contributions of the attitudinal and behavioral components to the intervention's overall effectiveness in secondary analyses.

Method

Design

The study used a 2×2 factorial design with a between-subjects randomized, waitlist-controlled structure. Time (pre- vs. post-intervention) was the within-subjects factor, while condition (app users vs. waitlist control) was the between-subjects factor. This design was used to test the primary effects of a 21-day app-based intervention on dispositional curiosity and its associated benefits. For secondary analyses, the app user group was further divided into those who received the 'mindful curiosity' sessions in addition to the daily behavioral goals (behavior + mindful curiosity), and those who didn't (behavior-only).

Participants

Human Subjects Approval was obtained prior to study commencement from the Institutional Review Board at the University of California, Santa Barbara (Protocol 172-24-0583). Participants were recruited through online platforms and university-wide advertisements soliciting individuals interested in developing their curiosity (see Data Availability Statement for link to registry with recruitment flyer). Of the 110 participants who initially enrolled, 91 (65 female) completed both sessions and were included in the analyses. Participants had a mean age of 20.26 (SD: 3.27). The ethnic makeup of the sample was as follows: 30.8% Caucasian ($N = 28$), 39.6% Asian ($n = 36$), 15.4% Mixed Race ($n = 14$), 5.5% Mexican/Hispanic/Latinx ($n = 5$), 2.2% Pacific Islander ($N = 2$), 2.2% Middle Eastern/West Asian ($N = 2$), 1.1% African American/Black ($N = 1$), 1.1% American Indian or Alaska Native ($N = 1$), and 2.2% Other ($N = 2$). Regarding education, 39.6% were high school graduates ($N = 36$), 45.1% had some college education ($N = 41$), 6.6% were college graduates ($N = 6$), 3.3% had some graduate school experience ($N = 3$), and 5.5% held a graduate degree ($N = 5$). Pre- and post-tests were completed in two lab sessions, 3 weeks apart, and participants were compensated \$25 for their participation.

Measures

Epistemic curiosity

To assess changes in the desire for knowledge and learning, the Epistemic Curiosity Scale (Litman & Spielberger,

2003) was used which has two subscales: interest-based epistemic curiosity and deprivation-based epistemic curiosity. The interest subscale captures general enjoyment in exploring new ideas, e.g. 'I enjoy exploring new ideas', and the deprivation subscale captures the specific motivation to reduce knowledge gaps, e.g. 'Difficult conceptual problems can keep me awake all night thinking about solutions'. Responses were measured on a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The internal consistency for the interest curiosity and deprivation curiosity subscales were reported in the ranges $\alpha = .80-.81$ and $\alpha = .71-.75$, respectively (Litman & Spielberger, 2003).

Perceptual curiosity

The Perceptual Curiosity scale (Collins et al., 2004) was used to assess changes in an individual's tendency to seek out novel sensory experiences or to explore their physical environment. Similarly to the scale for epistemic curiosity, this scale has interest and deprivation subscales. Interest-based perceptual curiosity is characterized by an enjoyment in exploring one's surroundings (e.g. 'I like exploring my surroundings'), and deprivation-based perceptual curiosity refers to a desire to resolve sensory ambiguity (e.g. 'When I smell something new, I try and find out what the odor is coming from'). Response options were on a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Past research indicates good reliability scores for both the interest-based and deprivation-based perceptual curiosity subscales, $\alpha = .73-.78$ and $\alpha = .77-.78$, respectively (Collins et al., 2004).

Boredom proneness

A short Boredom Proneness Scale (BPS; Struk et al., 2017) was used to measure changes in individuals' tendencies towards boredom across different situations. An example item is, 'I find it hard to entertain myself', and responses were given on a 7-point Likert scale ranging from 1 (Strongly Disagree) to 7 (Strongly Agree). Previous research has reported good internal reliability for this scale, with Cronbach's alpha coefficients around $\alpha = .88$ (Struk et al., 2017).

Meaning in life

The Meaning in Life Questionnaire (MLQ; Steger et al., 2006) was used to assess individuals' sense of meaning and purpose in life. The questionnaire consists of 5 questions to assess the presence of meaning in life (e.g. 'My life has a clear sense of purpose') and 5 questions to assess search for meaning in life (e.g. 'I am looking for something that makes my life feel

meaningful'). Responses were given on a 7-point Likert scale, from 1 (Absolutely Untrue) to 7 (Absolutely True). Internal consistency for the meaning in life scale has been reported as high for both the subscales, ranging from $\alpha = .80$ – $.90$ (Steger et al., 2006).

Creative behaviors inventory

The Creative Behavior Inventory – Short form (CBI; Dollinger, 2003) was used to assess the frequency with which individuals engage in creative activities across a range of domains. Participants indicate how often they engage in each activity (e.g. 'Make Cartoons') on a 5-point Likert scale, ranging from 1 (Never) to 5 (More than 3 times). The CBI has shown good internal consistency, with a reported Cronbach's alpha of $\alpha = .84$ (Dollinger, 2003).

Mindful attention and awareness scale (MAAS)

Dispositional mindfulness was assessed using the 15-item Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003). Items on this scale capture present-focused attention and receptive awareness and are reverse-scored, e.g. 'I find it difficult to stay focused on what's happening in the present'. Responses were collected on a 6-point Likert scale, ranging from 1 (Almost Always) to 6 (Almost Never). The MAAS has demonstrated high internal consistency, with Cronbach's alpha values reported at $\alpha = .89$ (Brown & Ryan, 2003).

Materials

The smartphone app

Daily behavioral components. Throughout the intervention, participants in the experimental conditions alternated between selecting one of their six personalized behavioral goals and completing researcher-assigned 'daily challenges' designed to foster curiosity.

Personalized behavioral goals. At the beginning of the intervention, participants created six behavioral goals related to curiosity. Using written instruction and brief instructional videos, they were taught several guiding principles for generating goals in general (e.g. be specific and concrete, choose goals with the right level of difficulty, i.e. desirable difficulty) as well as being given tips specifically related to the goal of being more curiosity (e.g. choose behaviors that involve learning or trying new things). They were guided on how to transform their goals into implementation intentions using a 'when-then' format (e.g. 'When I am on my lunch break, I will listen to a new podcast'). Participants entered these formatted goals into the app (see Figure 1) and were informed that they would select

one of these personalized goals to complete every other day throughout the intervention.

Daily challenges. On alternating days, participants were assigned a researcher-designed 'daily challenge'. These challenges were grouped into three difficulty levels: Curiosity Teaser, Curiosity Booster, and Curiosity Launchpad, allowing participants to tailor their activities based on their available time and energy on a given day, see Figure 2. Each challenge encouraged participants to inquire into their current context, shift their perspectives, break from routine, or engage with their environment in new ways, see examples in Table 1. The 'daily challenge' activities were developed by the first author, with several adapted from an experiential public initiative (July & Fletcher, 2002).

Attitudinal component

Approximately half of the app users were assigned to complete mindful curiosity sessions in addition to their behavioral goal. The app's notifications reminded participants to engage in one of three mindfulness activities each day: mindful eating, mindful walking, or mindful hand washing. Each activity was 4–5 minutes long and designed to help participants become fully present and encourage them to reflect on and ask questions about their current experience (see osf materials for example audio session). For example, during the mindful hand washing session, participants were prompted to explore sensations involved in the activity and ask questions such as, 'Why do certain water temperatures feel more pleasant than others?' or 'How does soap work to kill bacteria?'

Additional measures

In addition to the questionnaire-based measures reported in this study, we also collected eye-tracking data and assessments of mind wandering to address separate research questions that are beyond the scope of the current investigation and will be reported in future publications. A subscale of the Primal Beliefs scale (Clifton et al., 2019) was also included for a subset of participants for exploratory purposes and is not reported here.

Procedures

After providing informed consent, participants completed pre-intervention assessments measuring both epistemic and perceptual forms of curiosity, as well as curiosity-related traits (e.g. creative behavior,

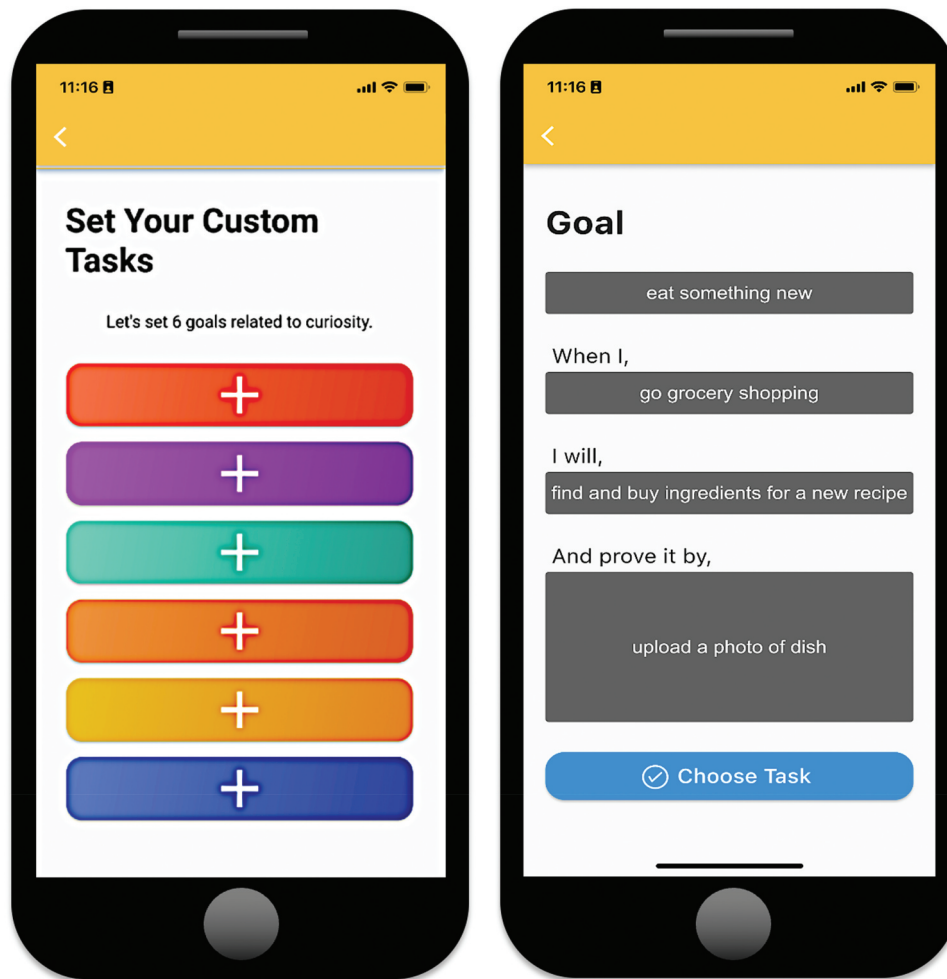


Figure 1. User interface for inputting daily goals. Six behavioral goals were entered one at a time (left). Goals were entered as implementation intentions using the ‘when ... then’ format (right).

boredom proneness, mindfulness, and meaning in life), presented in randomized order. Depending on their condition, participants either received the instruction that the study would start the following day (experimental condition) or that the study was starting on a ‘rolling basis’ and would begin in 21 days. Participants in the experimental group (i.e. app users) were further divided into two subgroups: those who completed mindful curiosity sessions in addition to their behavioral challenges and those who did not. This randomization was determined by participant number: an even-numbered participant ID unlocked the mindfulness component in the app, while odd-numbers did not.

Following the pre-intervention questionnaires, participants completed an onboarding process where they were introduced to the key components of the intervention and core concepts (e.g. ‘what is personality and how can I change it?’) through written content and

instructional videos (2–3 minutes in length). Participants were then guided through the process of downloading the curiosity app, entering their personalized goals, and adjusting phone settings to ensure proper app functionality. Finally, they completed an 8-question comprehension quiz to ensure understanding of key logistical components and study concepts. All pre-intervention questionnaires and onboarding were delivered via Qualtrics. For full onboarding instructions including concept videos, see materials in the osf registry (see Data Availability Statement for link).

Following the pre-test session, participants in experimental (app user) condition received daily notifications from the app to guide them through various tasks and activities designed to promote curiosity. After completing the daily activity each day, participants were prompted to document their experiences by submitting photos, reflections, or written responses to the app. All intervention data were collected through the mobile

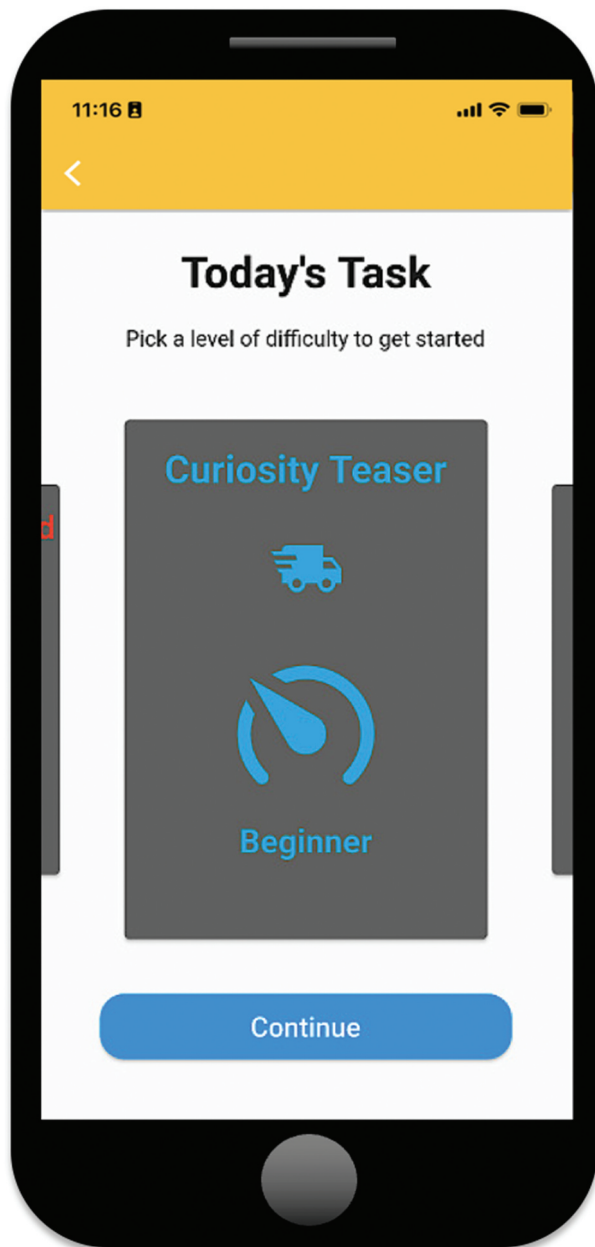


Figure 2. User interface for choosing difficulty level for daily challenges.

app. Participants assigned to the waitlist control group did not receive any intervention during the 21-day period but were given access to the curiosity app after the study's completion. At the end of the intervention, all participants completed a post-test assessment that mirrored the pre-test measures.

Results

Adoption

In the experimental group ($N=55$), 53 participants completed at least one daily task, with an average

Table 1. Example activities for each level of difficulty.

Task Level	Task Information
Curiosity Teaser	<p>Task Title Break your routine</p> <p>Task Description Find a way, no matter how small it is, to transform your usual habits and break from your routine. Here are some ideas: Work outside, switch the order of your morning routine, sit at the other side of the table or sleep on the opposite side of the bed. Small changes like that can change your habitual patterns of thoughts or perspectives.</p> <p>Documentation Write down what you ended up changing and how it made you feel.</p>
Curiosity Booster	<p>Task Title Write a Haiku about THIS moment</p> <p>Task Description Transform your current experience into art by creating a Haiku about THIS moment. A haiku is a three-line poem with seventeen syllables, written in a 5/7/5 syllable count. This simplicity enables the writer to condense the senses, to choose words carefully, to select the perfect moment worth capturing. Haiku can be elegant, funny, or simply profound. There is much to be found in its simplicity.</p> <p>Documentation Upload your haiku.</p>
Curiosity Launchpad	<p>Task Title Question your knowledge</p> <p>Task Description Think of something you have always assumed is true but upon further inspection might not be true at all. Research it online to learn more about it. Be sure to read at least 3 different sources. For example, many people have heard that creative people are 'right-brained'. Is there any truth to this? This is just an example, but choose one relevant to you, something that you yourself hold to be true but are not entirely sure about.</p> <p>Documentation Write up what you thought was true before and how you think about it now.</p>

of 12.91 tasks completed over 21 days ($SD=6.10$, range=0–21). Among those assigned to the behavior+mindful curiosity subgroup ($N=26$), participants completed an average of 9.04 mindfulness sessions ($SD=7.06$; range=0–23), with 23 participants completing at least one session. All participants, including those who completed zero tasks, were included in the analyses using an intention-to-treat approach.

Descriptive statistics

Full descriptive statistics and reliability metrics for trait curiosity variables are presented in Table 2. All measures demonstrated approximately normal distributions. The reliability of both perceptual curiosity subscales was slightly below conventional standards, with Cronbach's alpha coefficients of .67 for the interest-based subscale

Table 2. Descriptive statistics and reliability for trait curiosity questionnaires.

	N	Min	Max	Skewness	Kurtosis	Reliability
Epistemic curiosity: Interest-based	91	1.80	4.00	0.057	-0.83	0.75
Epistemic curiosity: Deprivation-based	91	1.00	4.00	0.35	0.43	0.78
Perceptual curiosity: Interest-based	91	1.60	4.00	-0.074	0.84	0.67
Perceptual curiosity: Deprivation-based	91	1.60	4.00	0.36	-0.52	0.58

Descriptives and reliability statistics provided for pre-intervention (Time 1) measurement. N = number of participants. Reliability was measured using Cronbach's alpha.

and .58 for the deprivation-based subscale. All other curiosity measures exhibited acceptable to good internal consistency.

Full descriptive statistics and reliability for the curiosity-related variables are provided in Table 3. These measures also demonstrated approximately normal distributions with the exception of creative behaviors, which exhibited significant deviations from normality, with kurtosis exceeding acceptable limits (kurtosis = 4.0), indicating a leptokurtic distribution. To address this, a logarithmic transformation was applied, which successfully reduced kurtosis and improved this variables suitability for parametric analyses.

Effects of the app on curiosity

The main research question was whether app users saw greater increases in trait-level curiosity and curiosity-related measures (e.g. meaning in life) from pre-post as compared to those in the waitlist control. Pre- and post-intervention means and standard deviations for each

curiosity measure are shown in Table 4 and for each curiosity-related measure in Table 5.

A series of repeated-measures ANOVAs were performed to determine whether participants in the experimental condition (app users) showed greater changes in curiosity traits from pre-test to post-test compared to those in the waitlist control condition. The primary analysis of interest was therefore the time by condition interaction effect, though main effects are also presented in Table 6 for completeness.

The analysis revealed that while there was no significant time by condition effect for deprivation-based epistemic curiosity, $F(1, 89) = 0.99, p = 0.32, \eta^2 = 0.011$, the change in interest-based epistemic curiosity approached significance, $F(1, 88) = 3.56, p = 0.061, \eta^2 = 0.038$. A significant time by condition effect was observed for perceptual interest curiosity, $F(1, 89) = 5.71, p = 0.019, \eta^2 = 0.060$, and perceptual deprivation curiosity, $F(1, 89) = 4.25, p = 0.042, \eta^2 = 0.046$, indicating that participants in the experimental condition demonstrated significantly greater changes in these traits compared to the control group.

Table 3. Descriptive statistics and reliability for curiosity-related questionnaires.

	N	Min	Max	Skewness	Kurtosis	Reliability
Meaning in life: Presence	91	1.20	7.00	-0.11	-0.33	0.89
Meaning in life: Seeking	91	2.40	7.00	-0.50	-0.18	0.78
Boredom proneness	91	1.00	6.38	0.29	-0.26	0.85
MAAS	91	1.27	5.00	-0.55	0.61	0.85
Creative behaviors	91	1.95	4.05	1.55	4.00 ^a	0.62
Log Creative Behaviors	91	0.67	1.40	0.97	1.80	0.62

Descriptives and reliability statistics provided for pre-intervention (Time 1) measurement. N = number of participants; SD = standard deviation. Reliability was measured using Cronbach's alpha. ^aKurtosis values $>|2|$ indicate substantial non-normality. MAAS is Mindful Attention and Awareness Scale.

Table 4. Pre and post intervention means and standard deviations for curiosity questionnaires.

Condition	Trait	Pre-intervention		Post-intervention	
		M	SD	M	SD
Experimental	Epistemic curiosity: Interest-based	2.95	0.61	3.09	0.53
	Epistemic curiosity: Deprivation-based	2.39	0.69	2.50	0.78
	Perceptual curiosity: Interest-based	2.76	0.62	2.88	0.55
	Perceptual curiosity: Deprivation-based	2.65	0.56	2.73	0.59
Waitlist control	Epistemic curiosity: Interest-based	2.89	0.54	2.87	0.42
	Epistemic curiosity: Deprivation-based	2.23	0.53	2.23	0.56
	Perceptual curiosity: Interest-based	2.91	0.56	2.84	0.47
	Perceptual curiosity: Deprivation-based	2.73	0.54	2.62	0.54

M = Mean; SD = Standard Deviation.

Table 5. Pre and post intervention means and standard deviations for curiosity-related questionnaires.

Condition	Trait	Pre-intervention		Post-intervention	
		M	SD	M	SD
Experimental	Meaning in life: Presence	4.41	1.33	4.75	1.23
	Meaning in life: Seeking	5.39	1.04	5.24	1.03
	Boredom proneness	3.58	1.09	3.31	1.03
	MAAS	3.44	0.70	3.51	0.74
	Creative behaviors (log)	0.91	0.11	0.97	0.14
Waitlist Control (N=36)	Meaning in life: Presence	4.63	1.16	4.53	1.17
	Meaning in life: Seeking	5.18	1.02	5.24	1.28
	Boredom proneness	3.25	1.09	3.27	1.06
	MAAS	3.79	0.63	3.71	0.64
	Creative behaviors (log)	0.93	0.15	0.90	0.12

M = Mean; SD = Standard Deviation. MAAS is Mindful Attention and Awareness Scale.

Table 6. Results of 2 × 2(condition × time) repeated measures ANOVA for curiosity measures.

Trait	Source	SS	F	p	η^2
Epistemic curiosity: Interest-based	condition	0.87	1.76	0.19	.019
	time	0.15	1.70	0.20	0.019
	cond*time	0.33	3.68	0.058	0.040
Epistemic curiosity: Deprivation-based	condition	2.01	2.57	0.11	0.028
	time	0.15	1.27	0.26	0.014
	cond*time	0.13	1.04	0.31	0.012
Perceptual curiosity: Interest-based	condition	0.14	0.26	0.61	0.003
	time	0.029	0.40	0.53	0.004
	cond*time	0.42	5.78	0.018*	0.061
Perceptual curiosity: Deprivation-based	condition	0.005	0.009	0.93	0.00
	time	0.015	0.16	0.69	0.002
	cond*time	0.38	4.21	0.043*	0.045

SS = Sum of Squares; η^2 = partial eta squared. * $p < .05$, ** $p < .01$.

Effects of the app on curiosity-related positive outcomes

A repeated-measures ANOVA was conducted to evaluate changes in positive outcomes associated with curiosity in previous research, such as meaning in life, from pre-test to post-test between the experimental and waitlist control condition. The experimental condition, compared to the control condition, reported increased presence of meaning in life, $F(1, 89) = 7.07$, $p = 0.009$, $\eta^2 = 0.074$, as well as increased creative behavior (log-transformed), $F(1, 89) = 11.28$, $p = 0.001$, $\eta^2 = 0.11$.

In contrast, no significant effect was found for the search for meaning in life, $F(1, 89) = 1.20$, $p = .277$, $\eta^2 = 0.013$, suggesting that the intervention primarily enhanced participants' sense of meaning rather than their pursuit of it. Although the effects on mindful attention and awareness (MAAS) and boredom proneness did not reach statistical significance, both measures indicated marginal improvements in the experimental condition. Specifically, mindful awareness showed a trend toward higher levels, $F(1, 82) = 3.28$, $p = 0.074$, $\eta^2 = 0.035$, while boredom proneness tended to be lower in the experimental group, $F(1, 88) = -2.83$, $p = 0.096$, $\eta^2 = 0.031$; see Table 7 for full statistics.

Contrasts for each experimental group

To further explore the effects of the curiosity app intervention, additional analyses were conducted to compare each of the two versions of the experimental conditions to the control group – the group with and without the 'mindful curiosity' component.

First, descriptives of the curiosity measures and curiosity-related measures for the two subsets of the experimental condition are shown in Tables 8 and 9, respectively.

To examine changes in each outcome variable across all three conditions and time, a linear mixed-effects analysis was used with REML estimation. The model included fixed effects for condition and time (including their interaction) and random intercepts for participants. Effect sizes for the overall model were calculated using bootstrapped partial eta-squared values (1000 iterations) with confidence intervals.

The interaction between condition and time was again of primary interest in this analysis. To examine this, pairwise contrasts were computed using estimated marginal means (EMMs). These contrasts compared the differences between conditions (e.g. behavior-only condition vs waitlist control) across time points (e.g. pre vs. post), as well as the differences between time points within each condition. The contrasts were calculated

Table 7. Results of 2 × 2(condition × time) repeated measures ANOVA for curiosity-related measures.

Trait	Source	SS	F	p	η^2
Creative behaviors (log)	condition	0.016	0.57	0.45	0.006
	time	0.011	1.59	0.21	0.018
	cond*time	0.077	11.28	0.001**	0.11
Meaning in life: presence	condition	1.34×10^{-5}	0.00	0.10	0.00
	time	0.65	2.10	0.15	0.023
	cond*time	2.04	6.63	0.012*	0.069
Meaning in life: seeking	condition	0.45	0.23	0.63	0.003
	time	0.081	0.21	0.65	0.002
	cond*time	0.52	1.33	0.25	0.015
Boredom proneness	condition	1.51	0.76	0.39	0.008
	time	0.64	2.25	0.14	0.025
	cond*time	0.88	3.082	0.083	0.033
MAAS	condition	3.37	3.99	0.049*	0.043
	time	0.001	0.005	0.94	0.00
	cond*time	0.28	2.70	0.10	0.029

SS = Sum of Squares; η^2 = partial eta squared. * $p < .05$, ** $p < .01$. MAAS is Mindful Attention and Awareness Scale.

Table 8. Pre and post intervention means and standard deviations for curiosity questionnaires for experimental conditions.

Condition	Trait	Pre-intervention		Post-intervention	
		M	SD	M	SD
Behavior-only (N=28)	Epistemic curiosity: Interest-based	3.01	0.56	3.14	0.49
	Epistemic curiosity: Deprivation-based	2.31	0.50	2.37	0.70
	Perceptual curiosity: Interest-based	2.71	0.58	2.84	0.55
	Perceptual curiosity: Deprivation-based	2.63	0.46	2.71	0.49
Behavior + Mindful curiosity (N=27)	Epistemic curiosity: Interest-based	2.89	0.66	3.05	0.57
	Epistemic curiosity: Deprivation-based	2.47	0.85	2.64	0.85
	Perceptual curiosity: Interest-based	2.81	0.66	2.93	0.55
	Perceptual curiosity: Deprivation-based	2.67	0.66	2.74	0.68

M = Mean; SD = Standard Deviation.

Table 9. Pre and post intervention means and standard deviations for curiosity-related questionnaires for experimental conditions.

Condition	Trait	Pre-intervention		Post-intervention	
		M	SD	M	SD
Behavior only (N = 28)	Meaning in life: Presence	4.50	1.26	4.66	1.24
	Meaning in life: Seeking	5.34	1.14	5.28	1.08
	Boredom proneness	3.36	1.12	3.20	1.07
	MAAS	3.44	0.83	3.44	0.82
	Creative behaviors (log)	0.91	0.11	0.95	0.12
Behavior + mindful curiosity (N = 27)	Meaning in life: Presence	4.32	1.42	4.84	1.22
	Meaning in life: Seeking	5.44	0.95	5.19	1.00
	Boredom proneness	3.80	1.02	3.43	0.99
	MAAS	3.43	0.56	3.59	0.65
	Creative behaviors (log)	0.91	0.12	0.98	0.17

M = Mean; SD = Standard Deviation. MAAS is Mindful Attention and Awareness Scale.

using the emmeans framework in RStudio (Version 4.4.2), which accounts for the variance structure of the mixed-effects model. Partially standardized effect sizes for each contrast were calculated by dividing the contrast estimates by the model's residual standard deviation (representing within-group variability), with 95% confidence intervals computed using the t-distribution and the model's degrees of freedom.

Given that the primary focus of these follow-up analyses was on the interaction effects, the omnibus main effects – now encompassing three conditions due to the division of the experimental group into two subgroups –

are presented in the supplementary materials to avoid redundancy (see Table S1 and S2). Some interaction effects that were previously significant did not retain significance in this analysis, likely due to reduced statistical power associated with the three-group comparison.

Interaction contrasts by outcome

For interest-based perceptual curiosity, results showed a significant interaction contrast, with the behavior-only condition exhibiting greater improvements from time 1 to time 2 compared to the waitlist control, $t(88) = 2.07$,

$p = 0.042$, $\eta^2 = 0.74$, 95%CI [0.028, 1.44]. While not significant, the behavior + mindful curiosity condition demonstrated a marginally greater increase in interest-based perceptual curiosity relative to the control, $t(88) = 1.94$, $p = 0.055$, $\eta^2 = 0.70$, 95%CI [-0.80, 0.72].

For deprivation-based perceptual curiosity, the behavior-only condition showed marginally greater increases from time 1 to time 2 compared to the control, $t(88) = 1.82$, $p = 0.072$, $\eta^2 = 0.65$, 95%CI [-0.060, 1.36], though this effect did not reach significance for the behavior + mindful curiosity group, $t(88) = 1.59$, $p = 0.12$, $\eta^2 = 0.57$, 95%CI [-0.14, 1.29].

In contrast, the behavior + mindful curiosity condition showed a marginal interaction effect for interest-based epistemic curiosity, $t(88) = 1.72$, $p = 0.090$, $\eta^2 = 0.62$, 95%CI [-0.098, 1.33], whereas the behavior-only group did not show significant changes, $t(88) = 1.41$, $p = 0.16$, $\eta^2 = 0.50$, 95%CI [-0.21, 1.21]. No significant differences were observed for deprivation-based epistemic curiosity for the behavior-only condition, $t(88) = 0.42$, $p = 0.68$, $\eta^2 = 0.15$, 95%CI [-0.56, 0.86], nor the behavior + mindful curiosity condition, $t(88) = 1.20$, $p = 0.23$, $\eta^2 = 0.43$, 95%CI [-0.28, 1.15]. For full statistics, see Table 10.

Next, contrasts between the two experimental conditions against the control, across time, were examined for the curiosity-related outcomes. Here a significantly greater increase, from time 1 to time 2, was observed for the behavior + mindful curiosity group compared to the control for presence of meaning in life, $t(88) = 3.17$, $p = 0.0021$, $\eta^2 = 1.14$, 95%CI [0.43, 1.86], but the interaction contrast of the behavior-only group to the control was not significant. No significant differences were observed for seeking meaning in life for either the behavior + mindful curiosity contrast, $t(88) = -1.45$, $p = 0.15$, $\eta^2 = -0.52$, 95%CI [-1.24, 0.19], or the behavior-only contrast, $t(88) = -0.59$, $p = 0.55$, $\eta^2 = -0.21$, 95%CI [-0.92, 0.50].

Significantly greater increases in creative behaviors (log transformed) were observed across time for both the behavior-only condition compared to the control, $t(88) = 2.45$, $p = 0.016$, $\eta^2 = 0.87$, 95%CI [0.16, 1.58], and the behavior

+ mindful curiosity condition compared to the control, $t(88) = 3.24$, $p = 0.0017$, $\eta^2 = 1.21$, 95%CI [0.45, 1.88].

Comparisons of the interaction effects for boredom proneness revealed a significant difference from time 1 to time 2 for the behavior + mindful condition, $t(88) = -2.00$, $p = 0.048$, $\eta^2 = -0.072$, 95%CI [-1.44, -0.0061], such that there was a larger decrease in the tendency to be bored for the behavior + mindful curiosity condition. However, no significant difference was observed for the behavior-only contrast, $t(88) = -0.092$, $p = 0.36$, $\eta^2 = -0.33$, 95%CI [-1.04, 0.38].

As expected, the behavior + mindful curiosity condition showed greater increases in mindful attention and awareness (MAAS) from time 1 to 2 compared to the control, $t(88) = 2.08$, $p = 0.041$, $\eta^2 = 0.75$, 95%CI [0.033, 1.46], whereas no differences were observed between the behavior-only group compared to the control across time, $t(88) = 0.69$, $p = 0.49$, $\eta^2 = 0.25$, 95%CI [-0.46, 0.95]. For full statistics, see Table 11.

Discussion

Curiosity is a highly beneficial human virtue predictive of a wide array of positive academic, social, and life outcomes. Developing reliable strategies for its enhancement therefore represents an important goal. Here, we demonstrate the potential for a technology-based intervention to promote various facets of curiosity. The observed increases in curiosity were accompanied by additional psychological benefits, including a heightened sense of meaning in life, increased creative behavior, and reduced tendencies toward boredom. These findings highlight the potential value of technology-based interventions for targeting multi-faceted aspects of character development and human flourishing.

The curiosity app was particularly effective in promoting perceptual forms of curiosity. Perceptual curiosity, which is characterized by a motivated desire to explore one's surroundings, parallels the interactive nature of the daily behavioral challenges, many of which

Table 10. Contrast interactions: comparing pre-post changes in curiosity measures between experimental and control conditions.

Trait	Contrast	Estimate	SE	df	t	p	η^2	95% CI
Perceptual curiosity: Interest-based	Behavior-only vs Control	0.20	0.096	88	2.067	0.042*	0.74	[0.028, 1.44]
	Behavior + Mindful curiosity vs Control	0.19	0.097	88	1.94	0.055	0.70	[-0.80, 0.72]
Perceptual curiosity: Deprivation-based	Behavior-only vs Control	0.19	0.107	88	1.82	0.072	0.65	[-0.060, 1.36]
	Behavior + Mindful curiosity vs Control	0.17	0.108	88	1.589	0.116	0.57	[-0.143, 1.29]
Epistemic curiosity: Interest-based	Behavior-only vs Control	0.15	0.107	88	1.41	0.162	0.50	[-0.21, 1.21]
	Behavior + Mindful curiosity vs Control	0.19	0.108	88	1.72	0.090	0.62	[-0.098, 1.33]
Epistemic curiosity: Deprivation-based	Behavior-only vs Control	0.051	0.12	88	0.42	0.68	0.15	[-0.56, 0.86]
	Behavior + Mindful curiosity vs Control	0.15	0.12	88	1.20	0.23	0.43	[-0.28, 1.15]

Estimate = Mean difference between conditions; SE = Standard Error; CI = Confidence Interval for the mean difference. * $p < .05$.

Table 11. Contrast interactions: comparing pre-post changes in Curiosity-related Measures Between Experimental and control conditions.

Trait	Contrast	Estimate	SE	df	t	p	η^2	95% CI
Meaning in life: Presence	Behavior-only vs Control	0.26	0.20	88	1.31	0.19	0.47	[-0.24, 1.17]
	Behavior + Mindful curiosity vs Control	0.62	0.20	88	3.17	0.0021**	1.14	[0.43, 1.86]
Meaning in life: Seeking	Behavior-only vs Control	-0.13	0.22	88	-0.59	0.55	-0.21	[-0.92, 0.50]
	Behavior + Mindful curiosity vs Control	-0.33	0.23	88	-1.45	0.15	-0.52	[-1.24, 0.19]
Boredom proneness	Behavior-only vs Control	-0.18	0.19	88	-0.092	0.36	-0.33	[-1.036, 0.38]
	Behavior + Mindful curiosity vs Control	-0.039	0.19	88	-2.00	0.048*	-0.072	[-1.44, -0.0061]
Creative behaviors (log)	Behavior-only vs Control	0.072	0.030	88	2.45	0.016*	.87	[0.16, 1.58]
	Behavior + Mindful curiosity vs Control	0.096	0.030	88	3.24	0.0017**	1.21	[0.45, 1.88]
MAAS	Behavior-only vs Control	0.078	0.11	88	0.69	0.49	0.25	[-0.46, 0.95]
	Behavior + Mindful curiosity vs Control	0.24	0.11	88	2.08	0.041*	0.75	[0.033, 1.46]

Estimate = Mean difference between conditions; SE = Standard Error; CI = Confidence Interval for the mean difference. * $p < .05$, ** $p < .01$. MAAS is Mindful Attention and Awareness Scale.

encouraged users to seek novel sensory experiences, find hidden beauty in their environment, try new foods or listen to new types of music. More broadly, these results suggest that strategies and interventions that encourage engagement with ones surroundings or diverse forms of sensory interaction may be effective in stimulating perceptual forms of curiosity.

Notably, the effects of the app were strongest on perceptions of meaning in life and creative behaviors, with both experimental conditions showing separable and significant increases relative to the control group. Although many of the daily challenge activities had aesthetic elements, only two of the creative acts listed in the creative behavior inventory were featured in the daily tasks (writing poems and drawing). While these activities may have contributed to the reported increase in creative behaviors, it is also possible that curiosity itself may drive increased creative expression, as suggested by previous research (Hagtvedt et al., 2019; Karwowski, 2012, Silvia et al., 2009; Ren et al., 2024; see also M. E. Gross et al., 2019 for discussion). Consistent with this, the increase in creative behavior was more pronounced in the behavior + mindful curiosity condition, even though the additional mindful curiosity lessons did not include instruction to engage in creative acts. Meaning in life is also often tied to the pursuit of novel experiences and insights (Steger et al., 2006), so the app's provision of complex, novel, and challenging activities may have contributed to the observed increase in users' sense of meaning. Taken together, these results reinforce the notion that curiosity-relevant behaviors may play an important role in promoting several aspects of human flourishing (Litman & Silvia, 2006).

When comparing the effects of the behavior + mindful curiosity condition (i.e. mindful curiosity lessons alongside the behavioral strategies) with the behavior-only condition, several similarities and differences emerged. Both conditions demonstrated marginal effects toward increased interest-based forms of perceptual curiosity, though the behavior-only condition also

saw a significant increase in deprivation-based perceptual curiosity, which reflects a desire to seek out specific sensory information in one's world. Moreover, the behavior + mindful curiosity condition demonstrated a significant increase in both mindful awareness and the presence of meaning in life – effects that were not observed in the behavioral condition alone – while further showing a marginal reduction in boredom proneness. These findings highlight the potential value of integrating attitudinal strategies, such as mindfulness-based practices, into behavioral interventions in order to maximize their psychological impact.

Mindfulness techniques may be beneficial for promoting behavioral change and personal growth by disrupting automatic thought and behavior patterns, while also encouraging open inquiry. These benefits make mindfulness particularly useful for establishing new habits, highlighting its potential value in future volitional-personality change interventions. Beyond its general contributions to habit formation, mindfulness may also work synergistically with curiosity-focused programs. Past research suggests that mindfulness enhances curiosity by helping individuals maintain a present-focused awareness (Kashdan et al., 2009; Brown & Ryan, 2003), allowing individuals to engage with new ideas, experiences, and even their own thoughts and actions, while sustaining a greater level of focus, engagement, and intention. Although mindfulness is widely recognized for improving self-awareness and emotional regulation (Baer et al., 2006), its capacity to promote curiosity, perceptions of meaning, and creative behavior points to a broader role in supporting cognitive flexibility and well-being.

More generally, the current research provides evidence for the plasticity of human personality. Character traits, such as curiosity, openness, and creativity, which have long been conceptualized as fixed aspects of an individual's disposition, may be cultivated through targeted interventions which may have important downstream benefits. Indeed, previous studies have

established correlations between such traits and positive outcomes like personal growth, intellectual engagement, and psychological well-being (Kashdan et al., 2018; Litman, 2008); however, causal evidence from controlled longitudinal studies remains limited.

Our app-based intervention addresses this gap by investigating state-to-trait development, enabling us to examine if and how enabling daily experiences of curiosity can lead to enduring changes in personality-level characteristics and to what degree such shifts are accompanied by further benefits. This approach has the potential to advance understanding of how everyday practices can foster stable personality shifts and potentially establish causal links between personality traits and positive outcomes. The wide-ranging benefits observed in the present curiosity intervention provide initial, suggestive evidence that curiosity may play a role in driving the positive outcomes typically associated with it. By prompting individuals to seek novel experiences, explore new perspectives, and challenge existing beliefs, curiosity may act as an important catalyst for both cognitive and emotional growth. Future research should examine whether curiosity-based interventions can promote flourishing and well-being across various areas of life – from academic contexts to interpersonal relations.

Limitations

Although the initial effects of this smartphone-based curiosity intervention appear promising, several limitations should be acknowledged. First, the use of a waitlist control group, while suitable for this exploratory study, limits our ability to rule out potential confounding factors such as expectancy effects. Future research should include an active control condition to more robustly evaluate the efficacy of this, or similar, interventions. Secondly, due to the exploratory nature of this pilot study, several statistical tests were run without adjusting for multiple comparisons. Although this approach is useful for generating hypotheses in the early stages of research, the results should be interpreted with caution due to the inflated risk of Type 1 errors. For the sake of transparency, we have presented exact p-values and discussed the significance in context.

Thirdly, the reliance on self-report measures may introduce biases related to social desirability or demand characteristics. The addition of objective and ecologically-valid behavioral measures would be a great asset to future research efforts in this area. Fourthly, longitudinal studies with longer follow-up periods are needed

to assess the durability of the intervention's effects, as the 21-day intervention period may not have been long enough to capture long-term benefits. Lastly, though our sample was ethnically diverse, it was mainly composed of young adult students which could limit generalizability. Future studies should include a more diverse group of participants representing multiple age brackets and demographics to improve external validity. Future research in this nascent but growing research area should aim to overcome these limitations in order to further our understanding of how effective smartphone-based interventions are for encouraging curiosity and other virtues.

Concluding remarks

As basic research on volitional personality change advances, practical app-based tools offer immense promise for theoretical and translational impact on personality, health, cognitive, and educational psychology. The app-based curiosity intervention in the present study has particular promise as a scalable means to increase curiosity and therefore benefit from its many downstream benefits, particularly when mindfulness is combined with behaviors designed to promote curiosity. The capability of the program to promote meaningful change in creative behavior and meaning in life further demonstrates its potential for broader applications in improving psychological well-being and cognitive engagement. Future research should explore whether similar strategies can be harnessed for cultivating other impactful personality traits or character virtues.

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Author Contributions

M.E.G. designed and developed the curiosity app; conceptualized and designed the study; led data collection, data preparation, and analysis; secured funding; and drafted the original manuscript. J.W.S. contributed supervision, funding acquisition, and manuscript review and editing.

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Data availability statement

The data that support the findings of this study are openly available in 'curiosity app manuscript materials' at <http://doi.org/10.17605/OSF.IO/BMWPF8>.

Open scholarship



This article has earned the Center for Open Science badge for Open Data. The data are openly accessible at <http://doi.org/10.17605/OSF.IO/BMWPF8>.

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