Changing personality traits with the help of a digital personality change intervention

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Personality traits predict important life outcomes, such as success in love and work life, well-being, health, and longevity. Given these positive relations to important outcomes, economists, policy makers, and scientists have proposed intervening to change personality traits to promote positive life outcomes. However, nonclinical interventions to change personality traits are lacking so far in large-scale naturalistic populations. This study (n = 1,523) examined the effects of a 3-mo digital personality change intervention using a randomized controlled trial and the smartphone application PEACH (PErsonality coACH). Participants who received the intervention showed greater self-reported changes compared to participants in the waitlist control group who had to wait 1 mo before receiving the intervention. Self-reported changes aligned with intended goals for change and were significant for those desiring to increase on a trait (d = 0.52) and for those desiring to decrease on a trait (d = −0.58). Observers such as friends, family members, or intimate partners also detected significant personality changes in the desired direction for those desiring to increase on a trait (d = 0.35). Observer-reported changes for those desiring to decrease on a trait were not significant (d = −0.22). Moreover, self- and observer-reported changes persisted until 3 mo after the end of the intervention. This work provides the strongest evidence to date that normal personality traits can be changed through intervention in nonclinical samples.

personality change | digital intervention | randomized controlled trial | PEACH

Personality traits predict life outcomes, such as success in love and work, well-being, health, and longevity (1–3). For instance, people with higher conscientiousness show better academic achievement, job performance, physical health, relationship quality, and longevity (4–8). In turn, the economic costs of people with high neuroticism are enormous and exceed those of common mental disorders (9, 10). Importantly, the predictive validity of personality traits is similar in magnitude to factors that are widely accepted as determinants of life success, such as socioeconomic status or cognitive abilities (1, 2, 11, 12).

A large body of evidence has shown that personality traits continue to develop across adulthood, albeit at a slow rate (13–16). This line of longitudinal research suggests that people become more emotionally stable, more confident, agreeable, and conscientious as they age. Moreover, there is empirical evidence showing these changes are consequential and predict important outcomes later in life (17–19).

The fact that personality traits have consequences and are malleable across adulthood raises the question if personality traits can be changed in shorter time periods through nonclinical psychological interventions. The aim of the present study was thus to address this question and to examine whether and how personality traits can be changed with the help of a digital personality change intervention. This aim fits well with recent calls across many professionals, such as psychologists (20–23) as well as economists and policy makers (24–26), to target change in personality traits through nonclinical interventions in order to promote positive life outcomes.

Three lines of research deserve attention as initial guidelines for the present intervention study. The first line of research refers to personality change goals as a prerequisite for intentional personality change. Researchers found that the vast majority of people want to change at least some aspects of their personality (27, 28). However, merely having a personality change goal does not necessarily result in personality change. Although a review of multiple studies suggested that people change in ways that align with their goals across a couple of weeks, albeit with small effect sizes (29), change goals do not always predict actual personality changes (30).

The second line of research addresses clinical interventions with a focus on mental health disorders. Studies provide evidence that personality traits can change as "accompanying effects" of clinical interventions and psychotherapy (31, 32). A recent meta-analytic review of 207 clinical intervention studies found decreases in neuroticism and increases in extraversion as a result of the interventions which were designed to target mental health problems (33). Two main results of this meta-analysis are noteworthy. First, most change in personality traits happens in the first couple of weeks of therapy and plateaus after 8 to 10 wk, which contrasts the rather slow developmental change processes

Significance

Personality traits have consequences and are malleable throughout the lifespan. However, it is unclear if and how personality traits can be changed in desired directions. A 3-mo digital personality change intervention was deployed, and a large-scale randomized controlled trial (n = 1,523) was conducted to examine the effects of intended personality change in a nonclinical sample. The intervention group showed greater changes than the control group, and changes aligned with intended goals for change. Observers also perceived personality changes, but reported changes were less pronounced. Moreover, self- and observer-reported changes persisted until 3 mo after the end of the intervention. These findings provide the strongest evidence to date that normal personality traits can be changed through intervention in nonclinical samples.

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typically seen in longitudinal observational studies (15). Second, the type of therapy employed (e.g., cognitive behavioral, psychoanalytic, or pharmacological) was not strongly associated with the amount of change in personality traits. This suggests that changes in personality traits are not uniquely the result of a specific therapeutic technique from a certain type of therapy but can rather be explained by shared principles (common factors) across different types of clinical therapies (34–36). Building on clinical intervention research, recent conceptual work on personality trait change recognized the potential benefit of focusing on shared principles of clinical change rather than methods driven by specific schools of clinical psychology to target personality traits in nonclinical samples (21, 34, 37–39).

The third line of research focuses on initial nonclinical intervention efforts to examine the processes through which people can intentionally change their personality traits. A few studies have examined the effects of single-intervention components to produce personality change. For instance, one study with a 16-wk intensive longitudinal design demonstrated evidence that generating implementation intentions (specific "if–then" plans) for personality change goals once a week was associated with personality trait changes (40). Another study with a 15-wk intensive longitudinal design examined engagement in behavioral activities as a process of change (41). Actively and successfully implementing behaviors to change oneself appeared to be a successful process to change personality.

So far, only a few studies have focused on intervention approaches that combine multiple components to evoke personality trait change. One study examined the effects of a 10-wk coaching program designed to target personality traits (42, 43). Participation in the face-to-face coaching resulted in significant increases in conscientiousness and extraversion and decreases in neuroticism, and changes in neuroticism and extraversion were even maintained 3 mo after the intervention. A recent study tested the effects of a digital intervention which was specifically designed to target the facets of self-discipline and openness to action via daily text messages (44). The results indicate that people who chose the self-discipline intervention showed greater increases in self-discipline, whereas people who chose the openness to action intervention showed greater increases in openness to action compared to the other group.

Although these three lines of research provide first evidence for personality trait change through intervention, they have considerable limitations. First, these intervention studies typically employed small sample sizes, which provide weak evidence for or against an effect. Second, most studies have solely relied on self-report assessments to measure personality trait change without using other modalities such as observer reports (44). Third, nonclinical efforts to produce personality trait change have typically only used single-intervention techniques such as implementation intentions or behavioral activation and did not simultaneously employ multiple change techniques. Fourth, previous studies have mostly used low-dosage intervention approaches such as one session per week. Fifth, none of the previous nonclinical efforts to target personality traits included a control condition to test whether people who actually want to change a certain personality trait are able to change in desired directions, albeit without receiving any intervention. Finally, it is unclear whether personality

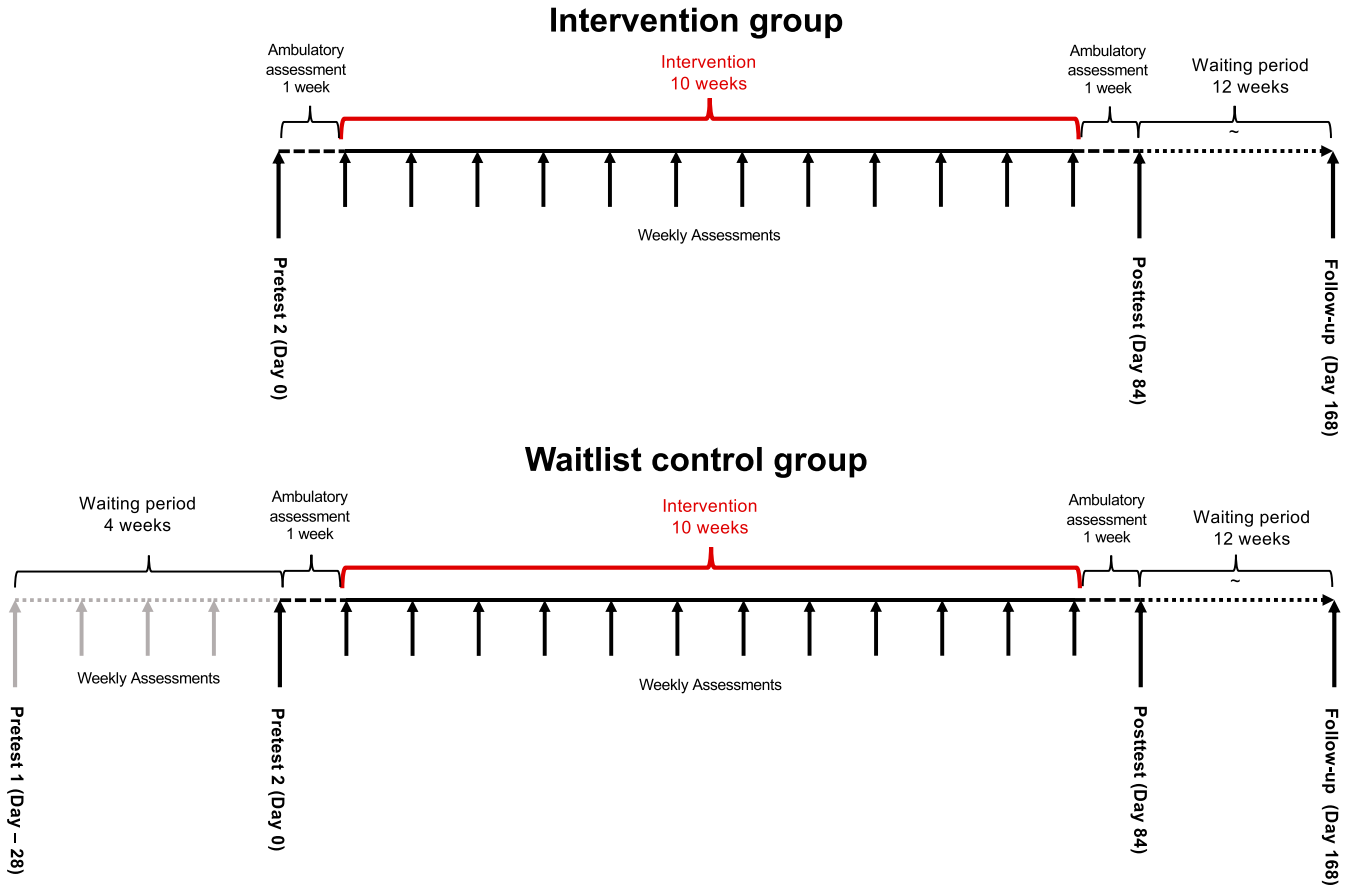

Fig. 1. Study design and procedure. In this study, we focus on the main outcome assessments (i.e., Pretest 1, Pretest 2, Posttest, and Follow-up); Pretest 1 and Pretest 2 included the same measures. Participants in the waitlist control group already selected and indicated their change goals at Pretest 1 before the 1-mo assessment-only period. After this 1-mo waiting period, they received the same intervention as participants in the intervention group.

change evoked through intervention can be maintained after the end of the intervention. The present research aims to address these limitations and to leverage the findings that people are able to change in ways that align with their change goals (29).

The present intervention is based on a recently proposed intervention framework that was derived from psychotherapy research (34). This framework suggests four common factors should be considered when designing personality trait change interventions. First, intervention efforts should actuate discrepancy awareness, which refers to the key idea that desired changes can be most effectively targeted when people are actually aware of a gap between their actual and desired self. Second, the intervention should activate strengths and resources which initiate and maintain positive-feedback circuits and expectations. Third, a personality change intervention should target and increase one's awareness of beliefs, expectations, and motives in order to realize insight. One way to promote insight is to learn how to systematically reflect on thoughts, feelings, and behaviors. Fourth, the intervention should teach people how to practice new behaviors. Put differently, the intervention should help people to learn new skills in everyday life and to gradually increase engagement in new activities and behaviors outside of their comfort zone. The main aim of intervention is to realize all four common change factors to maximize intervention effects (34).

The Present Study

The primary goal of this study was to explore if desired personality trait change is possible through intervention by examining the effectiveness of a 3-mo digital personality change intervention. The digital intervention consisted of the smartphone application PEACH (PErsonality coACH) (45). PEACH is a digital coach that supports people to achieve their personality change goal and delivers microinterventions (specific tools and techniques) to help people modify or change behaviors and experiences as well as to maintain the change process.

We had four specific research questions. First, do personality traits change differently depending on intervention versus waitlist control? To test this first research question, participants were randomized into two treatment groups: the intervention group or the waitlist control group. Participants in the waitlist control group already selected and indicated their change goals before the 1-mo assessment-only period. After this 1-mo waiting period, they received the same intervention as participants in the intervention condition (Fig. 1). We examined if participants in the intervention condition differed from those participants in the control condition with respect to personality trait change. We expected an increase or a decrease in personality traits in the intervention condition and no change in the control condition. Second, do personality traits change in the desired direction? We examined whether and how self-reported changes in personality traits align with the self-selected change goals (i.e., to increase or decrease on one of the Big Five personality traits). We expected a change in the desired direction and a greater change in those personality traits participants wanted to change with the help of the digital intervention. Third, do observers detect personality trait change? We explored whether observers detected changes in the desired direction and whether self-reported personality trait change coincides with observer reports. We expected convergence between self-reports and observer reports in the sense that observers are able to detect personality trait change in the desired direction, albeit with less sensitivity such that the changes noted by others will not be as large (44). Fourth, can personality trait change be maintained? We also explored whether self- and observer-reported trait changes are maintained until follow-up assessment 3 mo after the end of the intervention or whether they revert over time. Based on preliminary work (42, 44), we expected that personality trait changes in the desired direction can be maintained after the end of the intervention.

We used a randomized controlled trial (RCT) design with two treatment groups (i.e., an intervention condition and a 1-mo waitlist control condition) to test the effectiveness of the digital intervention (Fig. 1). The RCT included multiple intensive longitudinal assessments across the 3-mo intervention phase and a follow-up 3 mo postintervention to test the shape of change of the outcome variables. The Big Five personality traits served as outcome variables. In addition to the Big Five self-report measures, we used Big Five observer ratings by close friends, family members, or intimate partners. In this study, we focus on the four main outcome assessments (i.e., Pretest 1, Pretest 2, Posttest, and Follow-up; see Fig. 1) and do not report findings of the process assessments (i.e., ambulatory and weekly assessments). For the analyses, we used two intent-to-treat samples; while the Consenters sample contained all available data, the Starters sample only included participants who actually started with the intervention.

Results

Of all participants who signed up for the intervention, most participants wanted to decrease in neuroticism (26.7%), increase in conscientiousness (26.1%), or increase in extraversion (24.6%). Other change goals were chosen less often. Of all participants, 7.4% wanted to increase in openness, 6.4% decrease in agreeableness, 4.1% increase in agreeableness, 2.6% decrease in conscientiousness, 1.8% decrease in openness, and 0.2% decrease in extraversion (46).

Do Personality Traits Change Differently Depending on Intervention versus Control? In a first step, we tested the effectiveness of the intervention by testing whether change in personality traits significantly differed between the two treatment groups (i.e., the intervention group and the waitlist control group) using the Consenters sample. Descriptive statistics and effect sizes of personality trait change over time in the waitlist control group are shown in *SI Appendix*, Table S1. Multilevel analyses suggest that participants did not show significant changes in the desired direction during the 1-mo assessment-only period before the start of the intervention (*SI Appendix*, Table S2).

To compare changes between the two treatment groups, we conducted a series of multilevel models with time by group interaction effects. For the intervention group, we focused on trait changes from Pretest 2 to Posttest. For the waitlist control group, we focused on trait changes from Pretest 1 to Pretest 2 (Fig. 1). We first collapsed the data across participants who wanted to increase on a trait and across participants who wanted to decrease on a trait. The results suggest that participants of the intervention group reported significantly greater changes in the desired direction ($d = 0.44$ for those desiring to increase and $d = -0.41$ for those desiring to decrease) as compared to their counterparts in the waitlist control group ($d = -0.12$ for those desiring to increase and $d = -0.02$ for those desiring to decrease on a trait). Moreover, we compared the two treatment groups for each change goal individually. Specifically, participants who desired to increase in extraversion, decrease in neuroticism, or increase in conscientiousness showed significantly greater trait changes in the desired direction as compared to their counterparts in the waitlist control group. The results of these multilevel analyses are shown in Table 1. It is important to note that these three change goal groups had the largest samples and therefore provided adequate power to test whether change occurred. Although there was no significant difference between intervention and control group for other change goals with smaller samples, *SI Appendix*, Fig. S1 shows that for the other change goals, participants of the intervention group showed greater changes in the desired direction compared to participants in the waitlist control group. Only participants who desired to increase or

Table 1. Changes over time between treatment groups

Change goal Fixed effects	Increase (n = 948)	Decrease (n = 575)	Increase in extraversion (n = 375)	Decrease in neuroticism (n = 406)	Increase in conscientiousness (n = 379)	Decrease in conscientiousness (n = 40)	Increase in agreeableness (n = 63)	Decrease in agreeableness (n = 98)	Increase in openness (n = 113)	Decrease in openness (n = 28)
Intercept										
Estimate (SE)	2.88*** (0.87)	3.09*** (0.13)	2.80*** (0.13)	3.16*** (0.14)	2.87*** (0.16)	4.11*** (0.40)	3.55*** (0.24)	3.96*** (0.16)	2.90*** (0.27)	3.35*** (0.37)
95% CI	2.71; 3.05	2.89; 3.29	2.54; 3.06	2.89; 3.43	2.62; 3.13	3.30; 4.91	3.08; 4.02	3.65; 4.28	2.37; 3.44	2.60; 4.11
Time										
Estimate (SE)	−0.06 (0.04)	0.01 (0.05)	−0.03 (0.06)	0.03 (0.06)	−0.04 (0.07)	0.04 (0.14)	0.04 (0.15)	−0.11 (0.09)	−0.25 (0.13)	0.41 (0.26)
95% CI	−0.14; 0.03	−0.08; 0.10	−0.16; 0.09	−0.08; 0.14	−0.17; 0.09	−0.25; 0.32	−0.26; 0.37	−0.29; 0.06	−0.50; 0.01	−0.13; 1.07
Group										
Estimate (SE)	0.01 (0.04)	0.04 (0.05)	0.02 (0.07)	0.08 (0.08)	−0.04 (0.06)	−0.12 (0.20)	0.39 (0.14)	−0.02 (0.09)	−0.10 (0.14)	0.07 (0.27)
95% CI	−0.07; 0.09	−0.07; 0.16	−0.11; 0.15	−0.07; 0.24	−0.17; 0.09	−0.52; 0.28	0.11; 0.67	−0.20; 0.15	−0.37; 0.18	−0.48; 0.63
Time by group										
Estimate (SE)	0.26*** (0.05)	−0.24*** (0.06)	0.29*** (0.08)	−0.30*** (0.07)	0.28*** (0.08)	−0.19 (0.16)	0.08 (0.18)	−0.16 (0.12)	0.21 (0.15)	−0.23 (0.30)
95% CI	0.15; 0.35	−0.35; −0.13	0.12; 0.45	−0.44; −0.16	0.12; 0.44	−0.52; 0.16	−0.30; 0.44	−0.40; 0.07	−0.09; 0.52	−0.98; 0.37

Consenters sample; Group: 1 = intervention group; 0 = waitlist control group. Increase: participants with the goals to increase in extraversion, conscientiousness, agreeableness, and openness; Decrease: participants with goals to decrease in neuroticism, conscientiousness, agreeableness, extraversion, and openness. All models are controlled for age, gender, and conversation style. Collapsed data are also controlled for participants' change goals. ***$P < 0.001$.

decrease in openness reported changes in the undesired direction in both the intervention as well as the waitlist control group.

Do Personality Traits Change in the Desired Direction? In a second step, we examined whether self-reported personality traits changed in the desired direction from Pretest to the 3-mo Follow-up, controlling for condition. Descriptive statistics and effect sizes of self-reported personality trait changes over time are shown in *SI Appendix*, Table S3. Again, we first collapsed the data across participants who wanted to increase on a trait and across participants who wanted to decrease on a trait. The results suggest a significant overall increase for participants who wanted to increase (d = 0.52) and a significant overall decrease in participants who wanted to decrease on a trait (d = −0.58). In addition, we examined if participants changed on the trait they desired to change. The results suggest that participants who desired to increase in extraversion (d = 0.58), decrease in neuroticism (d = −0.54), increase in conscientiousness (d = 0.58), increase in agreeableness (d = 1.01), and decrease in agreeableness (d = −0.67) showed significant changes in the desired direction with medium- to large-sized effects over time. No significant changes were found for participants with the goals to decrease in conscientiousness, extraversion, or openness or to increase in openness. The results of the multilevel models are shown in *SI Appendix*, Table S4 for the Starters sample and *SI Appendix*, Table S5 for the Consenters sample. The self-reported personality trait changes are illustrated in Fig. 2.

Furthermore, we tested a series of multilevel models with time by change goal interaction effects. That is, we examined whether participants showed greater changes in personality traits they wanted to change compared to participants who did not want to change the same trait. The interaction effects suggest that participants who desired to increase in extraversion, conscientiousness, or agreeableness or to decrease in neuroticism or agreeableness showed greater changes in these personality traits compared to individuals who did not want to change in the same trait. These results are shown in Table 2 for the Starters sample and *SI Appendix*, Table S6 for the Consenters sample, which mirror the findings for Starters.

Do Observers Detect Personality Trait Change? In a third step, we examined whether observers detected desired personality trait changes. Descriptive statistics and effect sizes for these observer-reported trait changes are shown in *SI Appendix*, Table S7. We first collapsed data across participants who wanted to increase on a trait and across participants who wanted to decrease on a trait to increase power to test whether changes were also seen by others. The results of the multilevel models with the collapsed data across trait domains suggest that observers detected a significant increase from Pretest 2 to Follow-up for participants who wanted to increase on a trait (d = 0.35). Observers did not detect significant decreases in participants who wanted to decrease on a trait (d = −0.22). These aggregate findings are very consistent with prior research that shows observer effect sizes to be about 2/3 to 1/2 the size of self-reports. We also tested whether observers detected desired changes for each trait individually. In terms of statistical significance, observers only detected significant increases in conscientiousness for participants who wanted to increase in conscientiousness and who actually started with the intervention (d = 0.22). It should be noted, though, that the sample sizes for the individual change goals were smaller for the observer reports than the self-reports, which limited the power to detect significant changes. The direction of the effect sizes for desired changes were quite consistent with self-reported change, albeit smaller in magnitude. The results for the multilevel analyses are shown in *SI Appendix*, Table S8 for the Starters sample and *SI Appendix*, Table S9 for the Consenters sample.

We also formally tested whether close associates detected greater changes in the target person's desired direction by running multilevel models with time by change goal interaction effects. Consistent with the univariate findings, close associates only detected greater increases in conscientiousness in participants who wanted to increase in conscientiousness compared to those who did not want to increase in conscientiousness. The remaining time by change goal interaction effects were not significant. The results of these multilevel analyses are shown in *SI Appendix*, Table S10 for the Starters sample and *SI Appendix*, Table S11 for the Consenters sample.

In addition, to investigate whether the direction of observer-reported trait change differed from the direction of self-reported trait change, we conducted multilevel analyses for each change goal individually and added a dummy variable for modality (observer report [1] versus self-report [0]) and a time by modality interaction term to the multilevel models. The findings indicate that self-reported trait changes were more pronounced in the desired direction for individuals who desired to increase in extraversion, decrease in neuroticism, and increase in conscientiousness. For other change goals, the direction of self-reported and observer-reported trait changes did not significantly differ, which suggests that observer-reported trait changes were in the same direction as self-reported changes. These results of the multilevel models are shown in *SI Appendix*, Table S12 for the Starters sample and *SI Appendix*, Table S13 for the Consenters sample. *SI Appendix*, Fig. S2 depicts self- and observer-reported changes over time for each change goal individually. As we used

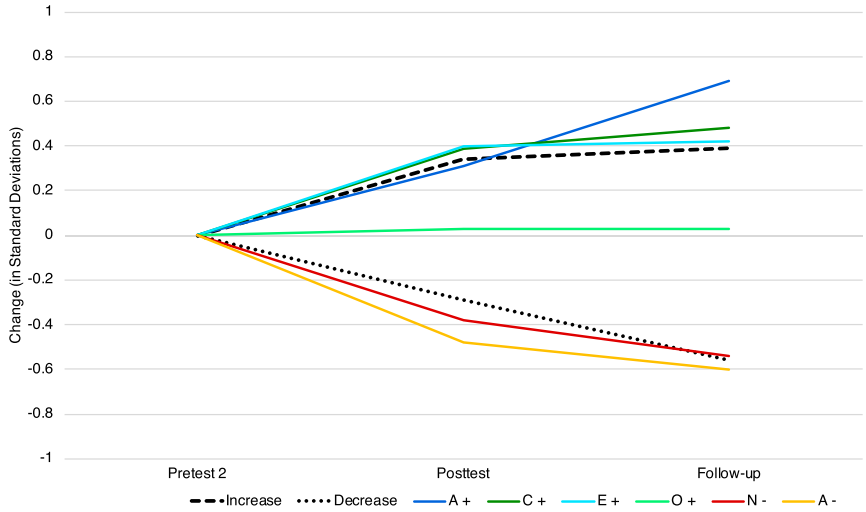

Fig. 2. Change in SD over time in selected personality traits. The *y*-axis is the change in the outcome variable measured in SD units. Estimates for each time point for each outcome were calculated by subtracting the Pretest mean from the mean of the outcome at a specific time point and dividing by the SD of that outcome at Pretest. Positive values indicate an increase in the outcome variable and negative values a decrease in the outcome. Increase: average change in selected traits in participants with the goals to increase in extraversion, conscientiousness, agreeableness, and openness; Decrease: average change in selected traits in participants with goals to decrease in neuroticism, conscientiousness, agreeableness, extraversion, and openness; A+: average change in agreeableness among people who wanted to increase in agreeableness; C+: average change in conscientiousness among people who wanted to increase in conscientiousness; E+: average change in extraversion among people who wanted to increase in extraversion; O+: average change in openness among people who wanted to increase in openness; N−: average change in neuroticism among people who wanted to decrease in neuroticism; and A−: average change in agreeableness among people who wanted to decrease in agreeableness.

the short version of the Big Five Inventory-2 (BFI-2) (47) to assess observer reports, we also analyzed the self versus observer comparison with the 30 common items of the short and full version of the BFI-2 to make the test more comparable. The results of these additional analyses are shown in *SI Appendix*, Table S14. The results mirror the findings of the analyses in which we used the full BFI-2 version for the self-reports.

Can Personality Trait Change Be Maintained? In a fourth step, we tested if self- and observer-reported trait changes were maintained until the Follow-up assessment 3 mo after the end of the intervention. Descriptive statistics and effect sizes of self-reported trait changes after the end of the intervention are shown in *SI Appendix*, Table S3. In terms of self-reports, participants who wanted to increase on a trait maintained their personality trait levels and did not significantly increase or decrease after the end of the intervention ($d = 0.08$). Participants who wanted to decrease in a trait reported another significant decrease on their selected traits after the end of the intervention ($d = -0.29$). We also tested whether self-reported trait changes were maintained for each change goal individually. The results suggest that participants who wanted to decrease in neuroticism showed another significant decrease in neuroticism from Posttest to Follow-up ($d = -0.22$). Participants who wanted to decrease in openness showed a significant increase in openness after the end of the intervention. For the other change goals, self-reported trait levels did not significantly change from Posttest to Follow-up. The results of the multilevel models are shown in *SI Appendix*, Tables S15 for the Starters sample and *SI Appendix*, Table S16 for the Consenters sample.

Moreover, we examined if observer-reported trait changes were maintained. Descriptive statistics and effect sizes of observer-reported trait changes from Posttest to Follow-up are shown in *SI Appendix*, Table S7. Observers detected a significant increase in

Table 2. Change over time in personality traits between change goals

Change goal Fixed effects	Increase in extraversion	Decrease in neuroticism	Increase in conscientiousness	Decrease in conscientiousness	Increase in agreeableness	Decrease in agreeableness	Increase in openness	Decrease in openness
Intercept								
Estimate (SE)	3.18*** (0.09)	2.76*** (0.08)	3.33*** (0.08)	3.21*** (0.09)	3.84*** (0.07)	3.83*** (0.07)	3.38*** (0.09)	3.33*** (0.09)
95% CI	3.01; 3.35	2.60; 2.91	3.17; 3.50	3.03; 3.38	3.71; 3.98	3.69; 3.96	3.20; 3.56	3.15; 3.51
Time								
Estimate (SE)	0.03** (0.01)	−0.04** (0.01)	−0.00 (0.01)	0.04 (0.01)	−0.00 (0.01)	0.01 (0.01)	0.03** (0.01)	0.03** (0.01)
95% CI	0.01; 0.05	−0.07; -0.01	−0.03; 0.02	0.02; 0.06	−0.02; 0.02	−0.00; 0.03	0.01; 0.05	0.01; 0.05
Change goal								
Estimate (SE)	−0.50*** (0.05)	0.56*** (0.05)	−0.66*** (0.05)	0.39** (0.13)	−0.31*** (0.09)	0.24*** (0.07)	−0.44*** (0.08)	0.35* (0.17)
95% CI	−0.60; -0.39	0.48; 0.65	−0.75; -0.57	0.13; 0.66	−1.03; -0.40	0.11; 0.38	−0.61; -0.27	0.01; 0.68
Time by change goal								
Estimate (SE)	0.09*** (0.02)	−0.16*** (0.02)	0.18*** (0.02)	−0.11 (0.06)	0.15*** (0.04)	−0.13*** (0.04)	−0.00 (0.03)	0.02 (0.08)
95% CI	0.05; 0.14	−0.21; −0.12	0.13; 0.22	−0.23; 0.01	0.07; 0.24	−0.21; −0.06	−0.06; 0.06	−0.14; 0.17

Starters sample: $n = 875$. Change goal: 1 = participants who selected this change goal, and 0 = participants who did not select this change goal; controlled for age, gender, treatment group, and conversation style. *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

participants who wanted to increase on a trait ($d = 0.30$). For participants who wanted to decrease on a trait, observer-reported trait levels were maintained and did not significantly change ($d = -0.17$). We also tested whether observer-reported trait changes were maintained for each change goal individually. Observers detected a significant increase in openness for individuals who wanted to increase in openness after the end of the intervention. For the other change goals, observer-reported trait levels did not significantly change. The results of the multilevel models are shown in *SI Appendix*, Tables S17 for the Starters sample and *SI Appendix*, Table S18 for the Consenters sample.

Discussion

This study is a demonstration that self-reported personality trait change is possible with the help of a digital intervention. The results suggest that people maintained their self-reported trait changes until 3 mo after the end of the intervention. These promising findings can be partly attributed to 1) a theory-based intervention framework with the aim to simultaneously realize different common change factors to maximize intervention effects; 2) a smartphone application that accompanied and supported participants to achieve their change goal and delivered a diverse set of evidence-based microinterventions to promote and maintain the change process; 3) the advantage of the digital coaching approach to provide support in a timely, high-dosage, and ecologically attuned manner in participant's daily lives; and 4) last but not least, the basic requirement that participants had to be motivated to work on aspects of their personality.

The present study provides the strongest evidence to date that a nonclinical digital intervention can help people to change Big Five personality traits in a few weeks, which is fast in contrast to the slow developmental change processes typically seen in observational longitudinal studies (15). The study findings suggest that individuals who participated in the intervention showed greater changes than participants in the waitlist control group who did not receive the intervention during the first month. Although participants in the waitlist control group already selected and indicated their change goals before the 1-mo waiting period, they only showed small nonsignificant changes during this time. As such, having the desire to change a certain personality trait and selecting a specific change goal does not necessarily result in actual personality changes. This finding is in line with previous research showing that being motivated to change without having a concrete plan and support to attain the goal does not lead to subsequent change (30). Hence, the intervention, which equipped participants with several tools, helped individuals to channel their desires more efficiently and to work more systematically toward changing their thoughts, feelings, and behaviors.

Our study also suggests that participants showed the most pronounced changes in traits they had selected and in the direction they wanted to change. The finding that participants were able to change the broad Big Five personality traits extends the finding of a recent study which showed that a digital intervention helped participants to change the two narrower personality facets of self-discipline and openness to action in the short term (44). Moreover, the results are in line with personality changes that were found as "accompanying effects" of clinical interventions and psychotherapy (31–33).

Furthermore, observers such as friends, family members, or intimate partners detected significant desired trait changes for participants who wanted to increase on a trait but not for those who wanted to decrease on a trait. Also, observer-reported personality trait changes were smaller in terms of effect sizes and less differentiated compared to the self-reported changes. When testing observer-reported trait changes for each change goal individually, they only detected greater increases in conscientiousness in participants who wanted to increase in conscientiousness compared to those who did not want to increase in conscientiousness. These time-by-change goal interaction effects were not significant for the other change goals. This reduced differentiation may have resulted from lower power in these individual analyses, or it may be the case that observers interpreted positive changes more globally. Measuring whether observers detected personality changes in a short period of time is complex and challenging in many ways. First, cross-sectional correlations between self- and observer reports are typically modest in magnitude (48), as the self and observers have asymmetrical access to thoughts, feelings, and visual information of behaviors in specific situations. This implies that for some personality traits, self-ratings tend to be more accurate, and for others, observer ratings are more accurate (48). Second, personality traits differ in their observability. For example, neuroticism is suggested to be difficult and extraversion easier to observe (48, 49). Third, the timing and frequency of observer assessments may play a crucial role. In the present study, the time lags between the three assessments may not have been appropriate. Observers may need to be assessed more frequently over time to be able to detect personality changes in their target person.

Overall, the present findings add to theory by providing further evidence for plasticity of personality traits. The effects of short-term personality trait change through intervention challenge the common assumption that personality traits are fixed and therefore cannot be changed (50) and fuel the discussion on their degree of plasticity. The results are in line with recent literature suggesting that personality is more amenable to change than previously thought (29, 41) by extending previous work by showing that self- and observer-reported changes can be maintained over several months. Of course, it remains an open question whether these changes persist over longer periods of time such as years and decades or whether they revert after some time.

The present research is limited in ways that should promote future research. First, different measures of personality traits entail different costs and benefits. Self-reports of personality traits predict important outcomes (2, 3), and, especially, they predict outcomes in clinical settings (51). Moreover, individuals have greater insight into their own personality—including the perception of subtle changes therein—than do observers (52). However, self-reports may be biased by social desirability, demand effects, or wishful thinking. As such, participants may have reported personality changes in response of the awareness of being part of an intervention study. Also, although a recent study with emerging adults suggested that personality development does not depend on whether or not individuals believe that their traits can change (53), lay theories about change (54) may have played a role in the context of this personality change intervention such that participants who believed that personality change is possible showed greater self-reported changes than those who think their personality traits are relatively unchangeable. External observers may be less affected by social desirability concerns or experimental demand than self-reports. However, observers may lack motivation to perceive changes in others' personality traits (52) and thus may be slower than the target to update their impressions of the target's personality. Such a process might potentially mask real trait changes—especially over relatively short periods of time. Future personality change intervention studies should take the effects of demand characteristics systematically into account and should include measures of actual behaviors (e.g., savings or work attendance) to address these biases. Also, future studies should investigate whether self- and observer-reported changes are reflected in behavioral indicators captured by smartphone data (55). Second, the entire intervention was delivered via the PEACH smartphone application without any personal contact with participants. It remains unclear how intense and diligently the interventional tasks were completed. A recent study suggests that only individuals who actually completed behavioral challenges were able to attain personality changes (41). In the future, digital personality interventions should

test if individuals who work more diligently toward their goals are better able to achieve them. Third, the intervention included several microinterventions to simultaneously realize different common change factors in order to maximize the intervention effects. From the present findings, it is not clear which mechanisms and intervention components were responsible for the personality trait changes. As the present intervention was delivered through predefined chatbot dialogues, the structure of the intervention with its weekly core themes and the specific microinterventions was the same across participants with the same change goal (45). For example, participants were asked to generate individual if-then plans for each intervention week. Participants could decide themselves if and when they wanted to set themselves more difficult or easier plans. Future microrandomized trials (56) should test for potential effects of order, difficulty, and types of interventional components. Moreover, future studies are needed to better understand the individual pattern of change and how the various change factors are interrelated with the targeted personality trait change. Fourth, it remains unclear from the present study why changes in some personality traits were greater than in others and whether changes in certain personality traits are easier to attain. The self-reports suggest that openness to experience showed the least changes over time. This could be due to the rather broad scope of this trait (57). That is, changes that occur in a specific facet of the openness trait may not generalize as easily to all facets of the trait domain. Also, changes in the normative and more socially acceptable direction (e.g., increases in conscientiousness) may be easier to attain due to additional support from other people. In contrast, changes in the nonnormative direction may not only be less popular as a change goal per se, which limited the power to detect significant changes, but also harder to attain, as the social environment may not necessarily support changes in this direction. However, these ideas need to be tested systematically in future research. Fifth, the present study mainly relied on online advertisements to recruit participants, which resulted in a sample of mostly young adults. Research on personality change goals suggests that they can be found across the entire lifespan (58). As such, future work is needed to replicate personality change intervention studies in other populations such as older adults. Finally, this study shows that desired personality changes can be maintained until 3 mo after the end of the intervention. Future studies should examine whether personality change can be maintained over longer time intervals. Moreover, future research is needed to examine whether and how intended change is related to important outcomes such as success in love and work life, well-being, and health.

Conclusion

Taken together, this research shows that people can actively change their personality traits in desired directions with the help of a digital intervention. The findings provide a challenge for the common misperception that because personality traits are relatively stable, they are therefore unchangeable. Provided that policy makers acknowledge the beneficial effects of personality interventions for the individual and the society as a whole, this digital intervention approach could easily be used as a low-cost and low-threshold prevention tool for a large number of people.

Materials and Methods

This research was conducted according to the Declaration of Helsinki, and the full study protocol was approved by the Ethics Committee of the Philosophical Faculty of the University of Zurich (No. 17.8.4; date of approval: August 31, 2017).

The Smartphone Application PEACH. The smartphone application PEACH was developed to investigate personality change through a digital intervention. The PEACH application was built on the basis of the so-called talk-and-tools paradigm (59). The application offered scalable communication features (the "talk") with the help of a conversational agent (or "chatbot") which imitated a conversation with a human being (60), and the application also offered a broad range of "tools" [microinterventions, e.g., keeping a diary of resources, a reminder for individual implementation intentions, or the delivery of psychoeducation video clips (45)]. In general, the use of this talk-and-tools paradigm cannot only complement and extend existing face-to-face coaching, but it also provides new ways to offer interventions in a scalable fashion where a personal coaching approach is not feasible due to the limited reach, personnel, or budget. The PEACH application allowed us to reach participants in their everyday lives independent of time and place and thus deliver the intervention with a high dosage including two active interactions with the smartphone application each day for 3 mo. Compared to common face-to-face coaching approaches, we could deliver the entire intervention without coaching personnel, which is highly cost effective.

The PEACH application was developed for iOS and Android smartphones. Conversations with the conversational agent included a combination of predefined answers and free-text input to constrain the dialogue along predefined paths and to give participants autonomy where needed (e.g., for the definition of their implementation intentions). With a swipe-to-the-right gesture or via a menu button, participants could open the sidebar of the PEACH application from which they could navigate to the chat channel with the conversational agent, to their personal dashboard, a media library that included psychoeducation video clips, a second chat channel called "support-team" for a traditional WhatsApp-like communication with the study team (e.g., to clarify technical questions and comments), or to a Frequently Asked Questions page. The dashboard was mainly used to give participants individual progress feedback. It provided an overview of the change goal and weekly implementation intention. The dashboard also provided feedback in the form of a traffic light, which indicated whether an individual was able to get closer to the desired change goal (green light), was further away (red light), or if there was no change in any direction (yellow light). Moreover, the dashboard visualized whether and on how many days during the last week participants were able to show their desired behaviors, the latest credit scores (participants could collect credits for each interaction with the application), and the remaining time of the intervention in the form of an hourglass.

The structure of the PEACH intervention included weekly core themes as well as six types of microinterventions that aimed to target and activate the proposed common change factors (34) and thus personality trait change. These six types of microinterventions included individualized implementation intentions (if–then plans), psychoeducation, behavioral activation, self-reflection, resource activation, and individual progress feedback. Further details on the PEACH application and the specific interventional components can be found in the corresponding study protocol (45).

Participants. The flowchart of the study is depicted in *SI Appendix*, Fig. S3. For the analyses, we used two intent-to-treat samples. First, the Consenters sample (n = 1,523 adults, mean $[M]_{Age}$ = 24.99, and 47.7% = female) included all participants who gave informed consent, passed the screening assessment, and filled in the initial Pretest assessment (Pretest 1 for the waitlist control group and Pretest 2 for the intervention group). Second, the Starters sample (n = 875, M_{Age} = 25.66, and 53.8% = female) only included participants who stayed in the study until the intervention actually started, which was 1 wk after Pretest 2 for both the waitlist control and intervention group. Note that the first week after Pretest 2 only included ambulatory assessments but no interventional components (Fig. 1). Descriptive statistics of the Consenters and Starters sample are shown in *SI Appendix*, Table S19.

The focus of this intervention study was explicitly on healthy adults. Inclusion criteria were the following: 18 y or older, ability to read German, owner of a smartphone (Android or iOS) with mobile internet connection, and motivation to change their personality. Exclusion criteria were scores ≥ 14 in the Symptom Checklist [SCL-K11 (61)] and ≥19 in the Depression Scale [ADS-K (62)] and if the person was currently in psychotherapeutic or psychiatric treatment. Also, participants were only considered if they completed the initial Pretest assessment between April 2018 and August 2018. Data collection started in April 2018 and was completed in February 2019. Initial personality trait levels of participants who completed one, two, or all three trait assessments were compared. Overall, these comparisons suggest small differences in terms of effect sizes between those who completed one, two, or three assessments. See *SI Appendix, Appendix A* for these attrition analyses.

Study Design and Procedure. The present study used an RCT design with an intervention and a 1-mo waitlist control condition with repeated assessments over time (Fig. 1). Participants were automatically and randomly assigned into either the intervention group or the waitlist control group. The intervention group was oversampled and included 2/3 of all participants, and the waitlist control group 1/3 of all participants. The allocation into both conditions was computer generated to ensure that the conditions were fully randomized with respect to participants' baseline characteristics (allocation

concealment). Fig. 1 depicts the study procedure. The intervention lasted over 3 mo. Personality trait assessments included a Pretest, a Posttest, and a Follow-up assessment 3 mo after the end of the intervention. Directly after signing up for the study, participants chose one primary change goal for the intervention. More specifically, they could choose whether they want to increase or decrease on one of the Big Five personality traits (except for increases in neuroticism; we did not provide an intervention to become more neurotic). The waitlist control group did not receive any intervention during the first month and received the same 10-wk intervention after this 1-mo waiting period. The rationale for the waitlist control group was to test whether participants already started to change in desired directions albeit without receiving the intervention. At the beginning of the study, all participants were also asked to share a weblink with friends, family members, or their intimate partner to obtain observer reports on their personality change. Observer reports were collected three times at Pretest, Posttest, and Follow-up. Participants were able to forward the link to as many people as they wanted. A more detailed report of the study design, the recruitment process, measures, and sample size calculations can be found in the PEACH study protocol (45).

Self-Report Measures.

Personality change goals. At Pretest, participants had to select one out of nine change goals for the intervention. Change goals included all Big Five traits in both directions except for neuroticism (only decreases were possible). To help participants with the goal selection, they received descriptions of normal characteristics of individuals with high versus low levels in each trait. For example, the description for the goal to increase in extraversion was as follows: "I want to be more extroverted, which means to be more sociable; to have more energy and zest for action; to be less quiet; to be more active and more enterprising; to take the lead more often: to take decisions in groups more often" (ad hoc translation from German). All descriptions of these personality change goals are shown in *SI Appendix*, Table S20. Details on differences between personality change goal groups at Pretest can be found in the article by Stieger et al., 2020 (46).

Personality traits. At Pretest, Posttest, and Follow-up assessment, participants completed the 60-item BFI-2 (47). All items were rated on a scale ranging from strongly disagree (1) to strongly agree (5). Cronbach's alphas ranged across the measurement occasions between 0.86 and 0.88 for conscientiousness, between 0.83 and 0.89 for openness to experience, between 0.87 and 0.88 for extraversion, between 0.81 and 0.88 for neuroticism, and between 0.79 and 0.82 for agreeableness.

Observer Report Measures. Observer reports included the 30-item BFI-2-S (47). Observer reports were assessed at Pretest, Posttest, and Follow-up assessment. Cronbach's alphas for all observers ranged across all measurement occasions between 0.76 and 0.81 for conscientiousness, between 0.59 and 0.68 for openness to experience, between 0.73 and 0.80 for extraversion, between 0.82 and 0.84 for neuroticism, and between 0.77 and 81 for agreeableness. Some participants did not forward the weblink to others, and some observers did not fill out the questionnaire, which led to a smaller sample for participants with observer ratings. Participants had between zero and seven observer ratings (M = 0.66, SD = 1.05) at Pretest, between zero and six observer ratings (M = 0.39, SD = 0.79) at Posttest, and between zero and five observer ratings (M = 0.29, SD = 0.68) at the Follow-up assessment.

Statistical Analysis. For the analyses, we focused on the Consenters sample and the Starters sample. Longitudinal multilevel models (63) and the lme4 package (64) in R (65) were used to investigate the effect of the intervention (63). The data structure included repeated assessments of personality traits (Level 1: Time) nested within participants (Level 2: Person). Based on visual inspection of the data, change models with a linear time term were fitted to be consistent across different analyses and to be able to compare changes in personality traits over time between change goals as well as groups. All models were estimated with maximum likelihood to be able to compare them based on the Akaike Information Criterion and the Bayesian Information Criterion.

Data and R-codes are available on the Open Science Framework (OSF; https://accounts.osf.io/login?service=https://osf.io/g3yfz/).

The effectiveness of the digital personality change intervention was tested with four different approaches. First, to examine whether personality traits changed differently depending on intervention versus waitlist control, we used the Consenters sample, which included all available data provided by participants. Linear conditional models were fitted to test whether participants of the waitlist control group changed in the desired direction during the 1-mo assessment-only period. We collapsed the data across participants who wanted to increase on a trait and across participants who wanted to decrease on a trait to increase the sample size. Moreover, we fitted linear conditional change models to test for the differential effects. These models included a dummy variable for group (1 = intervention group, 0 = waitlist control group) and a time by group interaction term as a Level 2 predictor. We first used the collapsed data to test if participants of the intervention showed greater increases or decreases on their selected traits compared to their counterparts in the waitlist control group. In a second step, we conducted multilevel analyses for each change goal individually. We added age, gender, and conversation style as covariates to all multilevel models to test for the robustness of the results. Also, we added participants' change goals as covariates to the models in which we used the collapsed data.

Second, to examine whether and how self-reported changes in personality traits aligned with the self-selected change goals (i.e., to increase or decrease on one of the Big Five personality traits), we focused on the Starters sample to ensure that participants who were included in the analysis actually started with the intervention. However, as an additional robustness check, we also conducted all multilevel analyses with the Consenters sample. We first used the collapsed data across participants who wanted to increase on a trait and across participants who wanted to decrease in a trait. Linear conditional models were fitted to test for the effects over time. We added age, gender, treatment group, conversation style, and participants' change goals as covariates to the models. In a next step, we conducted these multilevel analyses for each change goal individually and added age, gender, and conversation style as covariates. We also fitted linear conditional change models to test for differential effects between change goals. A dummy variable for change goal (1 = participants who selected this change goal, 0 = participants who did not select this change goal) and a time by change goal interaction term were added as Level 2 predictors to investigate whether personality change over time differed between the change goals. We added age, gender, treatment group, and conversation style as covariates to the multilevel models.

Third, to explore whether observers detected personality changes in the desired direction, we focused on the Starters sample and on observers that provided their ratings on at least two out of three assessments to make sure that observers tracked their target person over time. As an additional robustness check, we also conducted these multilevel analyses with the Consenters sample. As with the self-reports, we ran linear conditional models with the collapsed data as well as with each change goal individually to test for the observer-reported effects over time. Multilevel models with the collapsed samples were controlled for participants' change goals. To test for differential effects between the change goals, dummy variables for change goals (1 = participants who selected this change goal, 0 = participants who did not select this change goal) and time by change goal interaction terms were added to the multilevel model. Moreover, to investigate whether observer-reported trait change differed from self-reported trait change, we conducted multilevel analyses for each change goal individually and added a dummy variable for modality (1 = observer report, 0 = self-report) and a time by modality interaction term to the multilevel models.

Fourth, we examined if self- and observer-reported personality trait change could be maintained after the end of the intervention from Posttest to the Follow-up assessment. For these analyses, we focused on the Starters sample but used the Consenters sample as an additional robustness check. We analyzed linear conditional models with the collapsed data as well as with each change goal individually. Self-reported changes were controlled for age, gender, and conversation style. Multilevel models with the collapsed samples were controlled for participants' change goals.

Data Availability. Anonymized .SAV data have been deposited in OSF (https://osf.io/g3yfz/).

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