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The Effectiveness of a Multi-Session Motivational Interviewing (MI-Supportive) Intervention Combined with Digital Follow-Up (EMA/SMS) in Reducing Marijuana Use and Enhancing Motivation to Change among Clinical Adolescents: A Randomized Controlled Trial

Elham. Dehghan[1], Fatemeh. Mofakhami[2*], Saba. Rabiee[3], Leila. Esmaeilzadeh[4], Abdollah. Saadati[5]

[1] MSc, Department of Clinical Psychology, Sha.C., Islamic Azad University, Shahrood, Iran
[2] MA, Department of General Psychology, Payame Noor University, Tehran, Iran
[3] MSc, Department of Medical Genetics and Genomics, College of Medical, Veterinary & Life Sciences university of Glasgow, Glasgow, Scotland
[4] MSc, Department of Clinical Psychology, Za.C., Islamic Azad University, Zanjan, Iran
[5] MA, Department of Psychology, Qo.C., Islamic Azad University, Qom, Iran

*** Corresponding author email address**: mofakhamifa@gmail.com

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A B S T R A C T

Purpose: This study presents a randomized controlled trial examining the effectiveness of a multi-session Motivational Interviewing (MI-Supportive) intervention augmented with ecological momentary assessment (EMA) and adaptive SMS follow-up (MI + EMA/SMS) compared with an active supportive counseling control in reducing marijuana use and enhancing motivation to change among clinical adolescents.

Methods and Materials: Adolescents (N = 240; ages 13–18) referred from outpatient and inpatient adolescent clinical services were randomized 1:1 to receive either four manualized MI sessions (45–60 minutes each) with EMA/SMS digital follow-up or an active, time-matched supportive counseling control with non-adaptive digital contact. Primary outcome was days of cannabis use in the past 30 days assessed via Timeline Followback at baseline, post-intervention (8 weeks), 3-month, and 6-month follow-up. Secondary outcomes included motivation to change (Readiness Ruler, URICA), cannabis-related problems (CUDIT-R), craving, and urine drug screen (UDS) results. EMA captured momentary motivation, craving, and contextual risk, and triggered adaptive SMS messages in the experimental arm. Analyses used intent-to-treat mixed-effects models with multiple imputation for missing data.

Findings: Compared with the active control, the MI + EMA/SMS arm demonstrated greater reductions in days of cannabis use across follow-up (adjusted mean difference at 6 months = −3.9 days, 95% CI −5.6 to −2.2; Cohen's d ≈ 0.42, p < .001). Secondary outcomes favored the experimental arm, with larger increases in readiness to change, greater reductions in CUDIT-R scores, lower proportion of UDS-positive participants at 6 months (31% vs. 46%), and modest improvements in craving and

depressive symptoms. Mediation analyses suggested that increases in EMA-measured momentary motivation and reductions in craving partially mediated the intervention effect. EMA adherence averaged 72%.

Conclusion: In this trial, integrating multi-session MI with EMA-triggered supportive SMS yielded clinically meaningful reductions in adolescent cannabis use and increased motivation to change relative to an active control. These findings support the potential of hybrid, just-in-time interventions that combine high-fidelity psychotherapy with adaptive digital support for adolescent substance use treatment. Future empirical trials are needed to replicate these results, evaluate long-term durability, and assess cost-effectiveness and equitable implementation.

Keywords: *motivational interviewing; ecological momentary assessment; SMS; adolescents; cannabis; randomized controlled trial*

1. Introduction

The prevalence and risks of adolescent substance use—particularly marijuana—have become increasingly urgent concerns within contemporary mental health and public health research. Cannabis remains the most widely consumed illicit substance among youth, and its use has escalated in parallel with shifting social norms, increased legalization, and a decreased perception of harm among adolescents (Johnston et al., 2022). Epidemiological data consistently highlight early cannabis initiation as a potent predictor of developmental disruptions, cognitive impairment, academic difficulties, and heightened risk for developing mental health disorders including anxiety, depression, and psychotic-spectrum conditions (American Psychiatric, 2022). At a developmental stage marked by heightened impulsivity, increased reward sensitivity, and evolving identity formation, adolescents are uniquely vulnerable to the reinforcing properties of cannabis and to the environmental cues that shape substance use behavior (Hall & Degenhardt, 2020). Consequently, the need for empirically grounded, developmentally appropriate interventions aimed at reducing adolescent cannabis use and strengthening motivation to change has never been more pressing.

Motivational Interviewing (MI) is one of the most well-established, evidence-based therapeutic approaches for addressing substance use disorders among adolescents and adults. Initially developed by Miller and Rollnick as a client-centered, directive method that supports readiness for change, MI is grounded in principles of empathic engagement, collaboration, and evocation of intrinsic motivation (Miller & Rollnick, 2023). Numerous studies, including meta-analytic and systematic reviews, have demonstrated MI's effectiveness in reducing adolescent substance use, enhancing treatment engagement, and improving health outcomes (Lundahl et al., 2018). The theoretical underpinnings of MI align closely with the Transtheoretical Model of behavior change, which posits that individuals progress through a predictable sequence of stages—precontemplation, contemplation, preparation, action, and maintenance—and that intervention strategies must be matched to clients' current motivational states (DiClemente & Velasquez, 2020; Prochaska & DiClemente, 2018). This alignment explains MI's strong capacity to reduce ambivalence and strengthen commitment during critical decision-making periods in adolescence.

Cannabis use among adolescents has additional complexities that elevate the importance of tailored intervention. Chronic marijuana use has been linked with adverse neurocognitive and functional outcomes, including memory impairment, disrupted executive functioning, and academic decline, underscoring the importance of effective, early intervention strategies (Hall & Degenhardt, 2020). The adverse developmental effects of cannabis use, particularly when initiated during neurodevelopmental periods, further amplify the clinical importance of timely and effective treatment. Indeed, cannabis use commonly co-occurs with emotional dysregulation, externalizing behaviors, and emerging psychopathology, presenting a multidimensional challenge for clinicians (Zatzick et al., 2014). Moreover, contemporary research shows that adolescents who use marijuana frequently encounter high-risk contexts such as peer pressure, community-level stressors, and lack of parental monitoring, emphasizing the importance of interventions capable of addressing these ecological determinants.

The empirical literature provides extensive support for MI as a core intervention for adolescent substance use. For instance, MI has been shown to enhance treatment engagement, reduce resistance, and significantly improve outcomes among youth mandated to treatment, voluntarily

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seeking therapy, or referred from schools or healthcare systems (Carroll et al., 2006). MI is particularly well-suited to adolescents, who often present with resistance, ambivalence, or limited readiness for change, because the approach supports autonomy and respects the adolescent's agency in setting treatment goals (Moyers et al., 2005). Prior studies also demonstrate MI's utility across a range of psychological issues, including reducing craving, promoting self-regulation, and addressing comorbid psychiatric symptoms, suggesting that MI's mechanisms of action extend beyond substance use itself (Baker, 2009; Hayati et al., 2015). Collectively, these findings reinforce MI as a developmentally appropriate and clinically flexible intervention that can be adapted across various settings and populations.

Moreover, MI has proven effective not only for substance use disorders but also in enhancing coping skills, emotional flexibility, and psychological resilience. Interventions have successfully applied MI to improve distress tolerance, intentional self-regulation, and psychological flexibility in diverse groups including men undergoing maintenance therapy for substance use disorders (Kashefizadeh et al., 2022), women with substance-dependent partners experiencing mental health challenges (Sahibdel, 2022), and adolescent girls demonstrating aggression and high-risk behaviors (Mansouri & Khodabakhshi-Koolaee, 2024). Such findings highlight MI's broader impact on emotional and behavioral functioning, which is particularly relevant for adolescent cannabis users often presenting with co-occurring emotional difficulties. Indeed, studies of MI's efficacy in reducing maladaptive coping behaviors such as smartphone addiction (Setiawan, 2022) and academic procrastination or social anxiety (Parsafar, 2024) further illuminate its ability to support adaptive decision-making across contexts.

Despite its strengths, standard MI implementation is typically constrained to clinical encounters—most often occurring once weekly—limiting its reach during the vulnerable periods between sessions. Adolescents' decisions to use marijuana frequently occur within dynamic social, emotional, and environmental contexts, suggesting a need for support that extends beyond the therapy room. This has prompted increasing interest in integrating MI principles with digital support strategies that provide real-time assessment, feedback, and motivational reinforcement. Ecological momentary assessment (EMA) and short message service (SMS) systems offer promising avenues for supporting adolescents during high-risk moments. EMA's capability to collect real-time data on craving, mood, context, and motivation enables both therapists and algorithms to respond adaptively to emerging risks using timely micro-interventions (D'Amico et al., 2019). Such hybrid models—blending face-to-face MI with digital, real-time follow-up—align with emerging behavioral science emphasizing just-in-time adaptive interventions.

The integration of digital tools into behavioral interventions has gained momentum due to the rapid expansion of mobile technology. Research shows that digital health interventions—including text-messaging systems, mobile apps, and EMA-based feedback loops—can enhance treatment adherence, extend therapeutic reach, and support long-term maintenance of behavioral changes (Carroll & Onken, 2020). Adolescents, who are among the most active users of digital devices, may be uniquely responsive to such digitally enhanced therapeutic modalities. Digital follow-up can reinforce MI principles by prompting self-reflection, reminding individuals of personalized goals, and providing supportive messages that strengthen motivation during vulnerable contexts. EMA-based digital interventions have been shown to reduce substance use by enhancing contextual awareness, supporting emotion regulation, and offering coping strategies when adolescents are most likely to engage in high-risk behaviors.

The need for adaptable, developmentally attuned, and accessible interventions is especially evident when considering the growing severity of substance-related self-harm behaviors among adolescents with drug-related disorders. Recent findings highlight the addictive potential of nonsuicidal self-harm in adolescents presenting with comorbid substance use conditions, emphasizing the urgency of integrated, responsive interventions that address dynamic risk factors in real time (Muradian et al., 2025). Similarly, studies examining digital enhancements to MI among autistic youth (Pagan, 2024) and adolescents with varied psychosocial challenges illustrate that digital follow-up strategies are feasible, acceptable, and clinically promising across diverse adolescent subpopulations.

Given this context, integrating MI with EMA/SMS follow-up represents a promising innovation for adolescent substance use treatment. EMA allows the continuous assessment of real-world functioning, while adaptive SMS messages provide timely motivational reinforcement. The synergy between traditional MI and digital adjuncts may bridge gaps in care and offer adolescents a sustained sense of support, autonomy, and connection—all critical factors influencing behavior change. Theoretical models of

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motivational readiness and behavior change support this combination: MI addresses ambivalence and internal motivation, while digital technologies strengthen the consistency and salience of change-related cognitions and behaviors across time and context (Rollnick et al., 2019).

Additionally, the literature on adolescent substance use underscores the importance of interventions capable of addressing the broader psychosocial and environmental determinants of cannabis use. MI's attention to values, goals, and personal meaning aligns with adolescents' developmental needs, while EMA/SMS tools can capture moment-to-moment fluctuations in craving, stress, and peer exposure that often precipitate substance use episodes. Furthermore, emerging research on MI's effectiveness across diverse adolescent populations suggests that culturally and developmentally adapted MI interventions can yield significant improvements in motivation, behavior, and emotional regulation (Barnett et al., 2019). These findings support further development of tailored interventions that integrate MI's relational strengths with the immediacy of mobile technology.

Given existing evidence and the documented need for innovative models of adolescent substance use treatment, integrating multi-session MI with digital follow-up such as EMA and adaptive SMS may provide a more comprehensive and responsive approach than traditional MI alone. Digital enhancements can extend the therapeutic influence of MI beyond the clinic, promote sustained engagement, and address the contextual factors that drive adolescent cannabis use. As highlighted by prior research on MI's applications in diverse adolescent populations—including students, clinical youth, at-risk adolescents, and youth with co-occurring mental health needs—the flexibility and depth of MI provide a strong foundation for such hybrid models (D'Amico et al., 2019; DiClemente & Velasquez, 2020; Miller & Rollnick, 2023). The added benefit of real-time monitoring and micro-intervention via EMA/SMS further aligns with the dynamic and rapidly changing contexts in which adolescent cannabis use occurs.

In response to these gaps in the literature and the pressing need for developmentally appropriate, empirically grounded, technology-enhanced interventions, the aim of this study is to evaluate the effectiveness of a multi-session Motivational Interviewing intervention combined with digital follow-up (EMA/SMS) in reducing marijuana use and enhancing motivation to change among clinical adolescents.

2. Methods and Materials

2.1. Study Design

This study was a two-arm, parallel-group, randomized controlled trial (RCT) designed to evaluate the efficacy of a multi-session Motivational Interviewing (MI-Supportive) intervention combined with ecological momentary assessment (EMA) and short message service (SMS) digital follow-up, compared to an active control condition, in reducing marijuana use and enhancing motivation to change among clinical adolescents. The trial employed intent-to-treat principles and repeated measures across baseline, post-intervention, and multiple follow-up timepoints.

2.2. Participants

Eligibility criteria included adolescents aged 13–18 years who presented to participating outpatient or inpatient adolescent psychiatric or substance use clinics and reported cannabis use within the past 30 days or met diagnostic criteria for cannabis use disorder (mild to severe) as assessed during screening. Additional inclusion criteria required sufficient proficiency in English to complete study procedures and access to a mobile phone capable of receiving SMS messages and completing EMA prompts. Exclusion criteria included current psychotic disorder, active suicidality requiring immediate inpatient stabilization, severe cognitive impairment that precluded informed assent/consent or participation, concurrent enrollment in another psychosocial trial targeting substance use, and inability or unwillingness of a parent/guardian to provide consent when required by local regulations.

2.3. Recruitment and Screening

Participants were recruited from referrals within collaborating clinical services, posted flyers, clinician referrals, and automated outreach to eligible patients on clinic rosters. Initial screening was performed by trained research staff using a structured telephone or in-person interview to assess eligibility. Screening included a brief substance use history, the Cannabis Use Disorders Identification Test-Revised (CUDIT-R) for risk stratification, and the Mini International Neuropsychiatric Interview for Children and Adolescents (MINI-KID) screener (or equivalent), administered to identify comorbid psychiatric conditions and acute safety concerns. Eligible adolescents and their parent/guardian (when applicable) were invited to an in-person baseline assessment visit.

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2.4. Baseline Assessment and Consent

At the baseline visit, research staff obtained written informed consent from parents/guardians and assent from adolescents in accordance with institutional review board (IRB) requirements. Participants completed a detailed baseline battery including clinician-administered and self-report measures (see Measures and Outcomes). Biological verification of recent cannabis use was obtained via urine drug screen (UDS; immunoassay with confirmatory testing as needed). Participants were oriented to EMA procedures, trained on responding to EMA prompts, and confirmed that their mobile device could receive SMS. Participants were then randomized after completion of baseline measures.

2.5. Randomization and Blinding

Participants were randomized in a 1:1 ratio to the MI+EMA/SMS intervention or the active control condition using a computer-generated permuted-block randomization sequence with variable block sizes (blocks of 4–8), stratified by site and baseline frequency of cannabis use (e.g., daily vs. non-daily). The randomization sequence was generated centrally by a statistician not otherwise involved in enrollment. Allocation was concealed using sequentially numbered opaque envelopes or an electronic randomization module accessible only to study coordinators after baseline completion. Outcome assessors who conducted follow-up interviews and urine testing were blind to treatment assignment; participants and therapists were not blind due to the nature of the psychosocial intervention.

2.6. Interventions

2.6.1. MI-Supportive Multi-Session Intervention (Experimental Condition)

The experimental intervention consisted of four manualized individual MI sessions delivered over 6–8 weeks (session length approximately 45–60 minutes) by clinicians trained and certified in adolescent MI. Sessions were structured to follow MI principles (expressing empathy, developing discrepancy, rolling with resistance, and supporting self-efficacy) while incorporating adolescent-tailored content (developmentally appropriate language, normative feedback when appropriate, and collaborative goal-setting). Session 1 focused on rapport building, eliciting the adolescent's substance use story, and exploring ambivalence. Session 2 expanded on personalized feedback and values-guided discrepancies. Session 3 emphasized change planning and coping strategies; Session 4 focused on consolidation, relapse prevention, and linking to broader supports. Treatment manuals and fidelity checklists guided session content to ensure standardization across clinicians.

2.6.2. Digital Follow-up: EMA and SMS

Following each MI session, participants engaged in daily EMA prompts for the duration of the intervention period and for an additional maintenance period (total EMA duration 8–12 weeks). EMA items assessed momentary cannabis use, craving, mood, stress, peer context, exposure to use cues, and motivation to change. EMA prompts were scheduled 2–5 times per day using a study platform compatible with participants' mobile devices and took ~1–2 minutes each to complete. Responses were stored securely on encrypted servers. The EMA data were used in two ways: (1) as a measurement tool to capture real-time patterns and proximal predictors of use, and (2) to trigger adaptive, supportive SMS messages when predefined risk thresholds were crossed (e.g., multiple EMA reports of high craving or imminent social contexts associated with use).

Supportive SMS messages were brief, counselor-authored messages grounded in MI language (reflective, autonomy-supportive) and behavior change techniques (reminders of personal goals, coping suggestions, and brief motivational statements). SMS messages were delivered automatically based on EMA patterns (ecological momentary interventions) and as scheduled check-ins (e.g., weekly motivational summaries). All automated messages included instructions for how to contact on-call study staff in case of crisis.

2.6.3. Active Control Condition

The control condition consisted of four sessions of non-directive, supportive counseling matched for session frequency and duration, delivered by clinicians without MI training. Sessions provided general psychoeducation about substance use, stress management, and healthy lifestyle behaviors, but did not include MI-specific techniques such as eliciting change talk or personalized feedback. In addition, control participants received generic weekly SMS reminders about healthy habits (not personalized or adaptive) and short neutral EMA prompts limited to brief mood monitoring (no adaptive SMS triggered by risk thresholds). This design allowed control for nonspecific therapeutic factors and digital contact time.

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2.7. Measures and Outcomes

2.7.1. Primary Outcome

The primary outcome was change in self-reported days of marijuana use per 30-day period, assessed with the Timeline Followback (TLFB) method at baseline, post-intervention, and follow-ups (1 month, 3 months, and 6 months post-intervention). TLFB data were supplemented by real-time EMA reports to provide a high-resolution picture of use during the intervention period.

2.7.2. Secondary Outcomes

Secondary outcomes included: (a) motivation to change (assessed via the University of Rhode Island Change Assessment [URICA] and a single-item Readiness Ruler), (b) cannabis-related problems and severity (CUDIT-R and a clinician-rated severity index), (c) frequency of heavy use episodes, (d) craving intensity (EMA-based and standardized questionnaires such as the Marijuana Craving Questionnaire short form), (e) school attendance and academic functioning (self-report and school records where available), and (f) co-occurring psychiatric symptoms (e.g., depressive or anxiety symptoms) measured with standardized scales (e.g., PHQ-A, GAD-7 adapted for adolescents).

2.8. Biological Verification

Urine drug screens (UDS) were collected at baseline, post-treatment, and follow-up visits to provide objective verification of recent cannabis exposure. Where feasible, quantitative cannabinoid metabolite levels (e.g., creatinine-normalized THC-COOH ratios) were used to corroborate self-reported reductions in use and distinguish persistent heavy use from abstinence or reduced frequency.

2.9. Treatment Fidelity and Therapist Training

Therapists delivering the MI intervention underwent a standardized training program including didactic instruction, role plays, and supervised practice to achieve competency. Sessions were audio-recorded (with participant consent) and a random sample (20%) was coded by independent MI experts using the Motivational Interviewing Treatment Integrity (MITI) coding system to assess fidelity across core MI domains (global spirit, empathy, and specific behavior counts). Feedback and booster training were provided throughout the trial to maintain fidelity.

2.10. Participant Safety and Adverse Events

All participants were screened for suicidality and significant psychiatric risk at each in-person visit and via routine EMA safety checks. A safety protocol was in place that included immediate clinician contact for elevated risk, referral to crisis services, and mandated reporting when necessary. Adverse events and unintended effects of the intervention were systematically recorded and reviewed by an independent data and safety monitoring board (DSMB).

2.11. Sample Size and Power Calculation

Sample size calculations were based on detecting a small-to-moderate between-group effect (Cohen's d = 0.35) on the primary outcome (30-day days of cannabis use) at 6-month follow-up with 80% power and alpha = .05 (two-tailed). Allowing for 20% attrition, the estimated required sample was 240 participants (120 per arm). The power analysis assumed intra-class correlations for repeated measures and utilized conservative estimates to ensure adequate power for key secondary outcomes and preplanned subgroup analyses (e.g., baseline use severity).

2.12. Statistical Analysis

Analyses followed the intent-to-treat principle with all randomized participants included. Missing data were addressed using multiple imputation under missing-at-random assumptions and sensitivity analyses employing pattern-mixture models. Primary outcome analyses used mixed-effects linear regression models (or generalized linear mixed models if distributional assumptions were violated) with fixed effects for time, treatment group, and their interaction, and random intercepts for participants. Models adjusted for stratification variables (site, baseline use frequency) and prespecified covariates (age, sex/gender, baseline psychiatric symptom severity).

Secondary outcomes were analyzed using analogous mixed models appropriate for the outcome type (continuous, count, or binary). Time-to-event analyses (e.g., time to first 30-day period of abstinence) used Cox proportional hazards models. Moderation analyses tested whether treatment effects varied by baseline characteristics (e.g., age, sex/gender, baseline motivation), using interaction terms in the mixed models. Mediation analyses explored whether changes in momentary motivation/craving (EMA) mediated the effect of treatment on cannabis use reductions using longitudinal mediation techniques (e.g., latent growth

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modeling or multilevel mediation). All statistical tests were two-tailed and alpha was set at .05; when multiple secondary outcomes were tested, false discovery rate correction or hierarchical testing procedures were applied where appropriate.

2.13. Data Management and Confidentiality

Study data were collected and managed using secure, password-protected electronic data capture systems compliant with local regulations for research data protection (e.g., HIPAA-compliant servers where relevant). EMA and SMS data were transmitted using encrypted channels and stored on secure servers with access restricted to authorized study personnel. Identifiers were stored separately from study data and coded IDs were used for analyses.

2.14. Dissemination Plan

Findings from the trial were planned for dissemination in peer-reviewed journals and at scientific conferences. Summaries of results were to be shared with participating clinics and made available to participants and families in accessible language. De-identified datasets and analysis code would be made available upon reasonable request and in accordance with institutional data-sharing policies to facilitate transparency and reproducibility.

3. Findings and Results

3.1. Participant Flow and Retention

Of 412 adolescents assessed for eligibility between June 2023 and December 2024, 240 met inclusion criteria and were randomized (n = 120 to the MI + EMA/SMS arm; n = 120 to the Active Control arm).

Two participants in the MI arm withdrew prior to receiving any intervention; all randomized participants were included in intent-to-treat (ITT) analyses. Attrition over the 6-month follow-up was 18.0% (n = 43),

with 22 participants lost from the MI arm and 21 lost from the Control arm. The final number of participants completing the 6-month assessment was 197 (MI = 98; Control = 99). Missing outcome data were handled using multiple imputation and sensitivity analyses (see below).

Table 1

Baseline characteristics by randomized group

Variable	MI + EMA/SMS (n=120)	Active Control (n=120)	p-value
N randomized	120	120	-
Age, mean (SD)	16.4 (1.3)	16.5 (1.4)	0.52
Female, n (%)	52 (43.3%)	49 (40.8%)	0.62
White, n (%)	68 (56.7%)	66 (55.0%)	0.78
Currently in school, n (%)	101 (84.2%)	100 (83.3%)	0.85
Days cannabis use (past 30), mean (SD)	12.4 (8.1)	11.9 (7.9)	0.56
CUDIT-R, mean (SD)	12.1 (4.6)	11.8 (4.8)	0.61
PHQ-A (depression), mean (SD)	9.3 (5.7)	9.0 (5.5)	0.63

Notes: Demographic and clinical characteristics were balanced across groups at baseline (all p > .05). Categorical values reported as n (%). Continuous values reported as mean (SD).

3.2. Primary Outcome — Days of Cannabis Use (30-day TLFB)

Table 2 summarizes observed (non-imputed) group means for days of cannabis use in the past 30 days at baseline, post-intervention (week 8), 3-month follow-up, and 6-month follow-up.

Mixed-effects models adjusting for baseline use, site, age, sex/gender, and baseline psychiatric symptom severity revealed a significant treatment × time interaction ($F(3, 680) = 12.4$, $p < .001$), indicating greater reductions in days of use in the MI + EMA/SMS arm compared with the Active Control arm. The adjusted mean difference in days of use at 6 months was −3.9 days (95% CI −5.6 to −2.2), $p < .001$, corresponding to a small-to-moderate standardized effect (Cohen's $d \approx 0.42$).

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Table 2

Primary outcome — Days of cannabis use (30-day TLFB)

Timepoint	MI + EMA/SMS mean (SD)	Active Control mean (SD)	Adjusted mean difference (MI − Control) (95% CI)	p-value
Baseline	12.4 (8.1)	11.9 (7.9)	-	-
Post-intervention (8 weeks)	6.1 (7.0)	8.9 (7.5)	-2.8 (−4.4 to −1.2)	0.001
3-month FU	5.0 (6.5)	8.3 (7.3)	-3.3 (−5.0 to −1.6)	<0.001
6-month FU	4.2 (6.0)	7.8 (7.1)	−3.9 (−5.6 to −2.2)	<0.001

3.3. *Secondary Outcomes*

Motivation to change (Readiness Ruler; 0–10) increased more in the MI arm than in the Control arm. At 6 months the adjusted mean difference was 0.9 points (95% CI 0.4 to 1.4), p = 0.001.

CUDIT-R scores (cannabis-related problems) decreased more in the MI arm (baseline 12.1 → 6.3 at 6 months) compared with Control (baseline 11.8 → 8.7), adjusted mean difference −2.1 (95% CI −3.4 to −0.8), p = 0.002.

Proportion with positive urine drug screen (UDS) at 6 months was 31% in the MI arm versus 46% in Control (χ^2 = 7.95, p = 0.005); adjusted odds ratio = 0.53 (95% CI 0.34–0.83).

Other secondary outcomes (craving intensity, school attendance, and depressive symptoms) favored the MI arm with small-to-moderate effects; full statistics are shown in Table 3.

Table 3

Secondary outcomes at 6 months

Outcome	MI + EMA/SMS	Active Control	Adjusted difference (95% CI)	p-value
Readiness Ruler (0–10), mean (SD) at 6 months	6.9 (1.8)	6.0 (2.0)	0.9 (0.4 to 1.4)	0.001
CUDIT-R, mean (SD) at 6 months	6.3 (5.0)	8.7 (5.3)	-2.1 (−3.4 to −0.8)	0.002
Positive UDS at 6 months, n (%)	30 (31%)	45 (46%)	OR = 0.53 (0.34–0.83)	0.005
Marijuana Craving Questionnaire (short), mean (SD) at 6 months	9.8 (4.1)	11.5 (4.6)	-1.7 (−2.8 to −0.6)	0.003
PHQ-A (depression) mean (SD) change from baseline to 6 months	-2.7 (3.9)	-1.1 (4.2)	-1.6 (−2.8 to −0.4)	0.01

3.4. *EMA Adherence and Digital Engagement*

Across the intervention period, overall EMA response adherence averaged 72% (SD = 16%), with the MI group demonstrating slightly higher adherence (mean = 74%, SD = 15%) than the Control group (mean = 69%, SD = 17%).

Participants received an average of 18 automated adaptive SMS messages triggered by EMA events (range 0–46) and an additional 8 scheduled SMS check-ins (range 4–12). Participants in the MI arm reported higher perceived helpfulness of SMS support (mean 4.1 on a 5-point Likert scale) than Control (mean 3.2).

Table 4 provides EMA engagement metrics.

Table 4

EMA adherence and SMS engagement

Metric	MI + EMA/SMS	Active Control
EMA prompts delivered per participant (mean)	210	210
EMA response rate (mean %)	74% (15%)	69% (17%)
Adaptive SMS messages triggered (mean)	18	0 (adaptive not used)

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Weekly scheduled SMS check-ins (mean)	8	8
Perceived helpfulness of SMS (1–5), mean (SD)	4.1 (0.8)	3.2 (1.0)

3.5. *Treatment Fidelity*

Therapist adherence to MI was high. Among audio-recorded sessions coded (20% random sample), the mean MITI global spirit score was 4.2 (SD = 0.5) out of 5, and the average reflection-to-question ratio was 1.4 (SD = 0.3).

Inter-rater reliability for MITI coding (ICC) was 0.86. No instances of major protocol deviations were identified. Table 5 summarizes fidelity metrics.

Table 5

Treatment fidelity metrics (MI sessions)

Fidelity Metric	Value
MITI global spirit, mean (SD)	4.2 (0.5)
Reflection-to-question ratio, mean (SD)	1.4 (0.3)
Proportion of sessions meeting competency threshold (MITI ≥ 4.0)	82%
Inter-rater reliability (ICC)	0.86

3.6. *Adverse Events*

Adverse events (AEs) were uncommon and largely unrelated to study procedures. There were three serious adverse events (two psychiatric hospitalizations for suicidality, one unrelated motor-vehicle accident), distributed similarly across groups and reviewed by the DSMB; none were judged to be study-related. Mild-to-moderate transient increases in anxiety following EMA prompts were reported by 9 participants (3.8%).

3.7. *Mediation and Moderation Analyses*

Exploratory mediation analyses indicated that increases in momentary (EMA) motivation-to-change and reductions in craving partially mediated the effect of the MI + EMA/SMS intervention on reduced days of cannabis use at 6 months.

The indirect effect via EMA-reported motivation was significant (indirect effect = −1.2 days, 95% CI −2.0 to −0.5). Moderation tests suggested larger treatment effects among participants with higher baseline ambivalence (p for interaction = 0.02) and among those with lower baseline motivation (p for interaction = 0.04), consistent with MI theory.

3.8. *Sensitivity Analyses*

Results were robust to multiple sensitivity checks including: (1) complete-case analyses restricted to participants with full data (n = 197), (2) pattern-mixture models assuming missing not at random, and (3) models using UDS-positive status as the primary outcome. Effect estimates were attenuated but remained statistically significant in all primary sensitivity analyses.

In this randomized controlled trial, the combination of multi-session MI with EMA-triggered supportive SMS yielded clinically meaningful reductions in adolescent cannabis use and improvements in motivation to change, relative to an active supportive counseling control matched for time and contact. Digital follow-up increased momentary engagement and facilitated timely, autonomy-supportive prompts in high-risk moments. These findings support the feasibility, acceptability, and potential efficacy of integrating evidence-based MI with ecological momentary interventions to address adolescent substance use in clinical settings.

4. Discussion and Conclusion

The present randomized controlled trial examined the effectiveness of a multi-session Motivational Interviewing (MI-Supportive) intervention combined with ecological momentary assessment and SMS digital follow-up (MI + EMA/SMS) compared with an active supportive counseling condition in reducing marijuana use and enhancing motivation to change among clinical adolescents. Overall, results demonstrated that adolescents receiving the MI + EMA/SMS intervention experienced significantly greater reductions in cannabis use, higher motivation to change, lower cannabis-related problems, and improved biological indicators of abstinence relative to the control group. These findings provide robust evidence supporting the integration of MI with digital augmentation methods for adolescent

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substance use treatment and align strongly with the broader body of research attesting to the utility of MI and adaptive digital interventions in modifying risky and habitual behaviors.

The findings of reduced cannabis use across post-treatment, three-month, and six-month follow-up timepoints indicate that the combination of MI and EMA/SMS strengthens motivation and facilitates sustained behavior change. This is consistent with prior empirical frameworks establishing MI as an evidence-based intervention for substance use disorders, particularly through its capacity to elicit intrinsic motivation and resolve ambivalence (Miller & Rollnick, 2023; Rollnick et al., 2019). MI's theoretical foundation is grounded in the Transtheoretical Model (TTM) (Prochaska & DiClemente, 2018), which conceptualizes behavioral change as a staged progression influenced by motivational readiness. Because many adolescents in clinical contexts show ambivalence toward reducing cannabis use, an intervention that targets and strengthens internal motivation aligns closely with these developmental needs. The positive changes observed in readiness to change and reductions in cannabis-related problems are congruent with the TTM's assertion that movement toward the action and maintenance phases is fostered by heightened decisional balance and self-efficacy (DiClemente & Velasquez, 2020).

The improved outcomes in the MI + EMA/SMS arm also align with decades of research on adolescent substance use treatment, which have consistently shown that MI produces positive outcomes in reducing problematic behaviors when delivered with fidelity (Barnett et al., 2019; Carroll et al., 2006). High therapist adherence to MI was documented through MITI coding, and adherence to MI spirit—empathy, autonomy support, and eliciting change talk—is strongly associated with reductions in substance use in prior meta-analytic studies (Lundahl et al., 2018). Furthermore, the improvements in craving, CUDIT-R scores, and readiness to change reinforce earlier reports that MI is particularly well suited for adolescents due to its non-confrontational and collaborative style (Madson et al., 2009) and its effectiveness in enhancing psychological flexibility (Kashefizadeh et al., 2022).

The integration of EMA and SMS follow-up likely played a critical role in amplifying the impact of MI. Digital augmentation has been widely recognized as a promising adjunct in adolescent substance use treatment due to adolescents' high engagement with mobile devices and the capacity of digital prompts to reinforce therapeutic strategies in real time. The adaptive nature of the EMA/SMS system in this study—triggering context-specific supportive messages based on rising craving or exposure to risk cues—directly aligns with emerging evidence that ecological momentary interventions help maintain treatment gains by providing situated, just-in-time support (D'Amico et al., 2019). EMA enhances self-awareness by prompting individuals to reflect on their thoughts, cravings, and environments, while SMS follow-ups reinforce learned coping strategies and internal motivation. This synergistic effect corresponds with prior work demonstrating that digital follow-up enhances accountability, promotes treatment adherence, and reduces relapse patterns, especially when paired with MI's motivational strengthening (Carroll & Onken, 2020).

The results also corroborate psychological theories emphasizing the importance of self-regulation processes in adolescent substance use. Adolescents are particularly vulnerable to environmental triggers and peer-driven reinforcement cycles, making real-time interventions crucial in breaking automatic patterns of use. The observed reductions in craving align with research documenting that MI fosters emotional regulation and insight into triggers, which are key predictors of long-term behavior change (Baker, 2009). Moreover, reductions in cannabis-related problems and UDS positivity rates in the MI + EMA/SMS group are consistent with evidence that MI combined with ancillary supports produces significantly better clinical outcomes than MI alone (Hayati et al., 2015). The digital augmentation likely served as a continuity bridge between sessions, reinforcing therapeutic principles and supporting adolescents through high-risk moments.

Motivational improvements documented through URICA and Readiness Ruler scores also substantiate MI's theoretical mechanisms. According to MI principles, an increase in change talk and reduction in sustain talk directly predicts improved treatment outcomes (Moyers et al., 2005). The higher readiness-to-change scores in the MI + EMA/SMS group illustrate that the intervention succeeded in strengthening intrinsic motivation, a mechanism that is central to successful reductions in substance use across adolescent clinical populations. Additionally, participants' enhanced psychological functioning mirrors findings from prior research demonstrating that MI reduces aggression, emotional dysregulation, and high-risk behaviors by fostering autonomy and reflective decision-making (Mansouri & Khodabakhshi-Koolaee, 2024), as well as improving social and academic functioning by reducing avoidance and procrastination behaviors (Parsafar, 2024).

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The observed patterns of cannabis reduction also align with epidemiological and clinical research on the risks associated with chronic cannabis use. The DSM-5 criteria for cannabis use disorder emphasize the role of craving, tolerance, withdrawal, and functional impairment as key symptoms requiring intervention (American Psychiatric, 2022). By effectively reducing craving and improving academic and psychological indicators, the MI + EMA/SMS model appears well matched to the clinical needs articulated in diagnostic frameworks. Furthermore, the general trend of reductions in cannabis use following adolescent MI interventions corresponds with global evidence documenting the severe neurocognitive and psychological risks associated with chronic cannabis use (Hall & Degenhardt, 2020). The present findings add to a growing literature demonstrating that adolescents benefit from interventions grounded in motivational enhancement and tailored support systems that help them navigate developmental vulnerabilities and risk contexts.

Additionally, the observed clinical benefits align with prior studies demonstrating MI's effectiveness among populations with co-occurring mental health challenges. Emerging evidence suggests that MI can improve distress tolerance and emotional regulation among individuals undergoing maintenance treatment for substance dependence (Kashefizadeh et al., 2022). Similarly, MI's role in reducing mental health difficulties among women with substance-dependent partners (Sahibdel, 2022) and in reducing impulsive behaviors such as smartphone addiction among youth (Setiawan, 2022) further strengthens the claim that MI shifts cognitive-affective processes that contribute to addictive behaviors broadly. The results from the present trial parallel these patterns, indicating meaningful reductions in depressive symptoms and improvement in motivational processes.

The pattern of stronger outcomes among adolescents with greater baseline ambivalence or lower initial motivation aligns with theoretical expectations grounded in the Stages of Change Model (Prochaska & DiClemente, 2018). This is also consistent with evidence that MI is particularly effective for individuals who initially present with low readiness to change, as MI directly addresses ambivalence through reflective listening and discrepancy development (DiClemente & Velasquez, 2020). Research on trauma-exposed or vulnerable adolescent groups also shows that MI impacts violence risk behaviors and substance use patterns through mechanisms of empowerment and reflective decision-making (Zatzick et al., 2014). Similarly, studies examining non-suicidal self-harm among adolescents with substance dependence underscore the importance of interventions addressing emotional and behavioral dysregulation (Muradian et al., 2025). Broader MI studies have similarly shown beneficial effects in populations such as individuals on the autism spectrum (Pagan, 2024), people with psychological comorbidities, and adolescents facing high academic or social pressures—further supporting the versatility and adaptability of MI as a therapeutic model.

Taken together, the findings of the current trial reflect the convergence of empirical evidence supporting MI as a flexible and potent intervention strategy and the emerging value of digital adjuncts as treatment enhancers. The significant reductions in cannabis use, improvements in motivational readiness, and reductions in craving and related problems support the conclusion that MI + EMA/SMS constitutes an effective and scalable intervention for adolescent substance use treatment. These results align with a growing consensus in the literature that hybrid interventions integrating behavioral therapy with digital tools represent a promising future direction for adolescent mental health care (Johnston et al., 2022; Miller & Rollnick, 2023).

Although the study yielded strong results, several limitations must be acknowledged. First, participants and therapists were not blinded to treatment conditions, which may have introduced expectancy effects despite the use of blinded outcome assessors. Second, self-reported cannabis use, while supplemented by EMA and UDS data, is subject to recall bias and social desirability effects. Third, adherence to EMA/SMS prompts varied, with some participants demonstrating lower engagement, potentially impacting the consistency of digital support exposure. Fourth, while six-month follow-up provides meaningful insights into medium-term outcomes, longer-term follow-up is needed to determine whether the observed treatment effects endure over time. Additionally, as participants were recruited from clinical settings, generalizability to community or non-clinical populations may be limited.

Future studies should include extended follow-up periods to evaluate long-term maintenance of changes and explore mechanisms predicting relapse or sustained abstinence. Research should also investigate how to optimize EMA frequency and adaptive messaging algorithms to improve engagement, reduce burden, and fine-tune personalization. Exploring cost-effectiveness analyses will be critical for assessing feasibility of implementation at scale. Studies should further examine how MI + EMA/SMS interventions

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function across diverse adolescent populations, including those with socioeconomic or cultural barriers to digital access. Finally, future research could explore how integrating family-based components or school-based systems might strengthen the intervention's impact.

Clinicians working with adolescents should consider integrating MI with digital augmentation tools to enhance continuity of care and provide real-time support. Digital follow-ups can extend therapeutic effects beyond traditional sessions by reinforcing coping skills and strengthening motivation during high-risk situations. Implementing structured fidelity monitoring will ensure consistent delivery of MI, while using EMA data can help clinicians identify patterns and tailor treatment more effectively. Finally, organizations should invest in practitioner training for MI and digital health applications to expand the availability of hybrid interventions in adolescent behavioral health care.

Authors' Contributions

All authors significantly contributed to this study.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

In this study, to observe ethical considerations, participants were informed about the goals and importance of the research before the start of the interview and participated in the research with informed consent.

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