TRAC9 Impact on Residential Addiction Treatment Outcomes

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Key Findings

TRAC9 is a digital therapeutic system and measurement based care system that enhances residential addiction treatment through systematic symptom monitoring. This analysis examined outcomes from 97,960 treatment episodes to quantify the incremental benefit of TRAC9 utilization.

Active utilization of TRAC9 features, therapist data review and patient cue exposure exercises, was associated with substantial improvements beyond standard residential care with passive monitoring. Patients receiving treatment with optimal TRAC9 utilization achieved 82% greater symptom improvement compared to those with minimal system engagement (23.80 vs 13.08 GRS points, $p < 0.001$). This enhanced symptom improvement translated to reduced relapse risk, with optimal utilization associated with a 6.6 percentage point absolute risk reduction (42.1% to 35.5%) in one-year post-discharge substance use.

While standard residential treatment with basic monitoring provides the foundation of recovery (reducing relapse risk from approximately 50% untreated to approximately 42%), TRAC9's therapeutic features offer meaningful optimization. The visual cue exposure component showed particularly strong effects, contributing more to outcomes than therapist review alone. These findings suggest structured cue exposure therapy may address a critical gap in traditional addiction treatment.

Scenario	Therapist Review	Visual Cue Exposure	GRS Improvement	Relative Benefit	1-Year Relapse
Untreated	No	No	0.0	0	50.2%
No utilization	0%	No	13.08	Baseline	42.1%
Optimal utilization	100%	Yes	23.80	82%	35.5%

METHODS

The TRAC9 system assesses nine core domains of addiction recovery using primarily public-domain instruments, either in original form or with minor adaptations for the addiction context. The five symptom domains include: Anxiety (Penn State Worry Questionnaire), Depression (CES-D), Stress (Perceived Stress Scale), Verbal Craving (substance-specific questionnaires adapted by drug of choice), and Visual Craving (Cue exposure, serving as assessment and treatment). Commitment (Commitment to Sobriety Scale), Optimism (Life Orientation Test-Revised), Quality of Life in Addiction Recovery, and Spirituality (Religious Background and Behavior Questionnaire, God changed to Higher Power). Together, these nine domains form the Global Recovery Scale (GRS), with visual craving uniquely employing image-based cue-exposure while the remaining eight domains (GRSx) utilize traditional questionnaire formats (e.g., Likert).

RESULTS

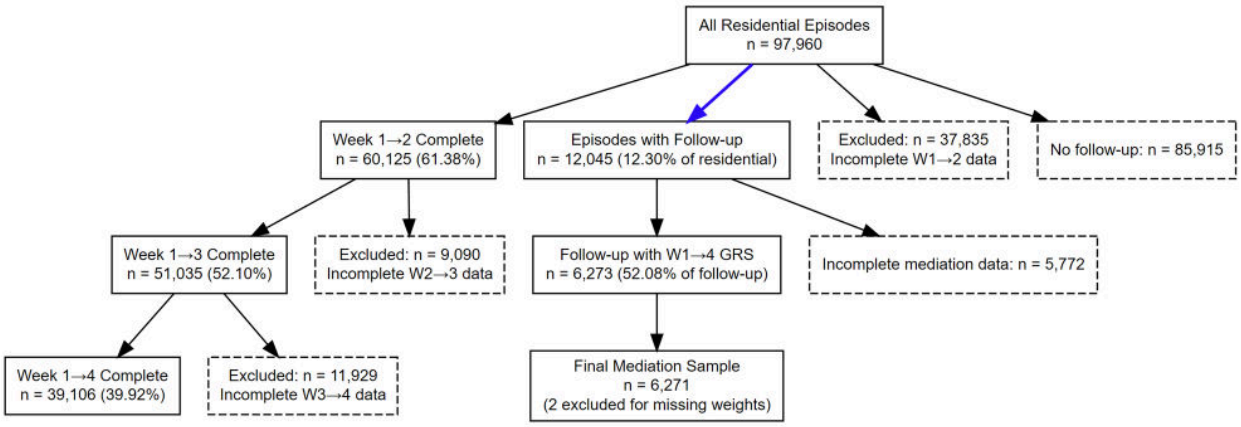
ANALYSIS 1: TREATMENT ENGAGEMENT AND WITHIN-TREATMENT OUTCOMES

Sample Characteristics

A total of 97,960 residential treatment episodes for substance use disorder were examined for the current study. While the a priori hypotheses focused exclusively on changes from Week 1 to 4 in treatment, changes across all weeks are reported for full transparency. Of the total residential episodes, 60,125 (61.38%) had complete Week 1 to 2 data, 51,035 (52.10%) had complete Week 1 to 3 data, and 39,106 (39.92%) had complete Week 1 to 4 GRS scores necessary for the primary analysis.

Table 1 presents demographic and clinical characteristics across all analysis timepoints. The primary analysis sample (Week 1 to 4, n = 39,106) had a mean age of 41.73 years (SD = 12.27) and was predominantly male (69.86%) and White (80.26%). The mean baseline GRS score was 55.61 (SD = 14.82). Importantly, selection effects were observed across timepoints: median length of stay increased from 23 days in the full residential sample to 30 days in the Week 1 to 4 sample, while the proportion completing standard discharge increased from 77.43% to 95.29%. This selection toward treatment completers reflects the natural consequence of requiring later assessment points. Demographics remained stable across timepoints, suggesting the selection primarily affected retention rather than patient characteristics.

Engagement with the Trac9 progress monitoring system was high across all samples. In the primary analysis sample, the mean clinician review rate was 76.17% (SD = 30.80%), with 48.76% of patients experiencing complete therapist fidelity to the review protocol throughout their treatment.



Preliminary Outcome Analysis

The association between Trac9 engagement and treatment outcomes was evaluated using linear regression models predicting GRS change from Week 1 to 4. In the unadjusted model, each unit increase in review rate (from 0 to 1.00) was associated with 3.69 additional GRS points of improvement (95% CI: 3.22-4.15, $p<0.001$), representing a 24.49% enhancement over baseline improvement of 15.07 points.

After adjusting for baseline GRS severity, the association remained robust with a coefficient of 3.21 (95% CI: 2.80-3.61, $p<0.001$). This model explained 25.00% of the variance in treatment outcomes ($R^2 = 0.250$), with the addition of baseline severity substantially improving model fit ($\Delta R^2 = 0.244$, $F = 12{,}768$, $p<0.001$). The effect size was large (Cohen's $f^2 = 0.333$), indicating clinically meaningful improvement.

Further adjustment for discharge status minimally altered the engagement coefficient ($\beta = 3.14$, 95% CI: 2.73-3.54, $p<0.001$) with negligible improvement in model fit ($\Delta R^2 = 0.003$), indicating that the beneficial association of Trac9 engagement persisted across all discharge types. Model diagnostics confirmed assumptions were met (VIF < 1.01 for all predictors), though heteroscedasticity was present (Breusch-Pagan $\chi^2 = 2610.61$, $p<0.001$).

For patients whose therapists had a 76.17% review rate, the expected additional benefit from Trac9 engagement was approximately 2.45 GRS points beyond standard treatment effects. Complete engagement (100% review rate) versus no engagement (0% review rate) was associated with a 3.21-point greater improvement in functional outcomes.

Trajectory of Treatment Effects

To examine when the benefits of Trac9 engagement emerged and how they evolved during treatment, we analyzed GRS changes at multiple timepoints. The engagement effect was significant by Week 2, with each unit increase in review rate associated with 1.10 additional GRS points of improvement (95% CI: 0.83-1.37, $p<0.001$) after adjusting for baseline severity. This early effect represented a 14.90% enhancement over standard treatment.

The magnitude of benefit increased linearly over time. By Week 3, the adjusted coefficient approximately doubled to 2.22 (95% CI: 1.88-2.56, p<0.001), representing a 19.90% boost. The effect continued to grow through Week 4, reaching the maximum observed benefit of 3.21 points (24.49% enhancement), as reported in the primary analysis.

This dose-response pattern, with coefficients of 1.10, 2.22, and 3.21 at Weeks 2, 3, and 4 respectively, suggests that sustained engagement with progress monitoring materials was associated with progressively greater improvements throughout the treatment episode. The roughly linear increase (approximately 1.1 points per week) indicates a steady accumulation of therapeutic benefit from ongoing interaction with the Trac9 system.

ANALYSIS 2: MEDIATED PATHWAYS FROM ENGAGEMENT TO RELAPSE PREVENTION

Follow-up Sample Characteristics

Of the 97,960 residential treatment episodes in the dataset, 12,045 (12.30%) had voluntary follow-up data available through the post-discharge monitoring system. Among these, 6,271 episodes had both complete Week 1 to 4 GRS data and follow-up assessments necessary for the mediation analysis, representing 52.06% of episodes with any follow-up data. Two cases were excluded at the modeling stage due to missing weights.

Table 3 presents the demographic and clinical characteristics of the follow-up subsample. The follow-up cohort was demographically similar to the primary analysis sample. Clinically, the follow-up cohort demonstrated a baseline GRS of 55.80 (SD = 15.10), treatment duration with a median of 28.00 days (IQR 19.00-32.00), and mean engagement rate of 73.10% (SD = 32.00%). This subsample achieved a mean GRS improvement of 19.41 points (SD = 14.38) from Week 1 to 4. The primary outcome, one-year relapse rate, was 35.26% (n = 2,211).

Selection Bias Adjustment

To address potential selection bias from differential follow-up participation, we employed inverse probability weighting. A propensity model predicting follow-up participation included baseline GRS, Week 1-4 improvement, engagement rate, treatment duration, age, gender, and race. The model achieved a C-statistic of 0.599. After stabilization and trimming at the 1st and 99th percentiles (weight range: 0.600-2.219), the weights had a mean of 0.997 and SD of 0.304, yielding an effective sample size of 91.50%. Post-weighting, standardized mean differences for all covariates were <0.010 (maximum 0.004), indicating excellent covariate balance. Two cases were excluded at the modeling stage due to missing weights, leaving an analysis sample of n = 6,271.

Mediation Analysis

We examined whether engagement influenced relapse through its effect on symptom improvement using causal mediation analysis with 5,000 bootstrap replications (analysis sample n = 6,271). Models incorporated inverse probability weights to adjust for selection bias and included baseline severity, treatment duration, age, gender, and race as covariates. The treatment contrast compared complete engagement (100% review rate) to no engagement (0% review rate).

The mediator model indicated that complete versus no engagement increased total GRS improvement by 3.67 points (SE = 0.52, $p < 0.001$), with a significant engagement × baseline severity interaction ($\beta = -0.09$, SE = 0.03, $p = 0.006$), consistent with stronger effects at lower baseline severity. The outcome model showed that each 1-point increase in GRS improvement was associated with 2.10% lower odds of relapse (OR = 0.979, 95% CI: 0.974-0.983, $p < 0.001$), while the direct effect of engagement was non-significant ($\beta = -0.04$, SE = 0.09, $p = 0.622$). The mediator-model estimate (3.67 points) corresponds to the same 0-to-1 contrast as the primary analysis (3.69 points), with minor differences attributable to IPW and the interaction term.

Moderated Mediation Results

The indirect effect of engagement on relapse through symptom improvement varied by baseline severity. At the 25th percentile of baseline GRS (45.30 points), the average causal mediation effect (ACME) was -0.023 (95% CI: -0.032 to -0.015, $p < 0.001$), indicating that full engagement reduced relapse probability by 2.30 percentage points via improved symptoms. This effect attenuated with increasing baseline severity: at the median (GRS = 55.60), ACME = -0.018 (95% CI: -0.025 to -0.013, $p < 0.001$), and at the 75th percentile (GRS = 66.50), ACME = -0.013 (95% CI: -0.020 to -0.008, $p < 0.001$).

The difference between low and high baseline severity corresponded to an absolute ACME difference of 0.0095, representing a 42.04% attenuation from low to high severity. Direct effects were non-significant across severity strata, as were total effects, indicating that engagement operated primarily through the symptom-improvement pathway.

Each 10-point increase in GRS improvement was associated with 19.12% lower odds of relapse (OR = 0.809). For the subsample's mean improvement of 19.41 points, the associated odds reduction was 33.76% (OR = 0.662).

Summary

Patient engagement with progress monitoring materials reduced relapse risk primarily through enhancing symptom improvement during treatment. This mediation pathway was significant across all baseline severity levels, though the effect was strongest for patients with lower initial symptom severity (ACME = -0.023 at the 25th percentile, $p < 0.001$). The absence of significant direct effects indicates that engagement's protective influence operates specifically through functional improvement rather than alternative mechanisms. These findings support targeting engagement interventions particularly toward patients with lower baseline severity while recognizing benefits across the severity spectrum.

ANALYSIS 3: VISUAL CUE EXPOSURE AS A CATALYST FOR SYMPTOM IMPROVEMENT

Visual cue exposure has long been used as an active therapeutic technique in addiction treatment, grounded in learning and extinction principles and supported by several decades of clinical investigation. Building on that tradition and on our prior analyses establishing an engagement-to-improvement-to-relapse pathway, this tertiary analysis investigates whether improvement following visual cue exposure contributes uniquely to broader recovery. Specifically, we examine whether changes in visual cue reactivity are associated with greater improvement on the adapted main factor of 8 non-visual Global Recovery Scale domains (GRSx), whether this association is independent of therapist review rate (our measure of ongoing clinical engagement), and whether any association between visual cue exposure and

relapse is accounted for by changes in GRSx. Our aim is to distinguish the role of visual cue exposure as a treatment component from general engagement effects, and to clarify the pathway through which it influences clinical outcomes.

This tertiary analysis draws on two prespecified analytic frames. First, to isolate general engagement effects independent of visual cue exposure measurement, we used the full residential cohort with complete data on GRSx change and therapist review rate. Second, to evaluate the contribution of visual cue exposure (VIS), we used the VIS-complete cohort with paired baseline and week 4 visual cue scores and relapse follow-up.

Methods

We tested whether improvement in visual cue exposure (VIS) predicts gains across the non-visual domains of the Global Recovery Scale (GRSx) independent of therapist review. The outcome was change in GRSx from Week 1 to Week 4. The key predictor was change in VIS from baseline to Week 4 (higher values indicate improvement). Therapist engagement was indexed by review rate (0 to 1), reported per 10 percent increments. Covariates were baseline symptom severity (GRS Week 1 score, centered within each analysis subset), age (years), gender, race, and treatment duration (days).

Analyses used complete data for all variables. Episodes showing zero VIS at both baseline and Week 4, treated as likely data-entry placeholders, were excluded from primary VIS analyses (n = 7,069; 20.71 percent) and included in sensitivity analyses. VIS effects are reported per 10 points; Review effects per 10 percent.

Models were estimated with ordinary least squares, were unweighted, and used heteroscedasticity-robust (HC1) standard errors after heteroscedasticity was detected by the Breusch–Pagan test. For model comparisons, Review-only, VIS-only, and Joint (Review + VIS) models were fit on the same sample with complete VIS data.

RESULTS

Review rate predicts symptom improvement (full residential sample, complete cases)

N = 34,128. Review rate was positively associated with change in GRSx (coefficient = 3.36, SE = 0.22, 95% CI [2.94, 3.79], t = 15.60, P < .001). Each 10 percent increase in Review corresponded to a 0.34-point improvement in GRSx (95% CI [0.29, 0.38]). Model fit: R^2 = 0.2288, adjusted R^2 = 0.2286. See Table 3 for the full effect estimate and confidence interval for Review.

VIS predicts symptom improvement

Excluding 7,069 zero-zero VIS episodes (20.71 percent) yielded N = 27,059. VIS improvement strongly predicted change in GRSx (coefficient = 0.19, SE = 0.003, 95% CI [0.18, 0.20], t = 57.97, P < .001). Each 10-point VIS improvement corresponded to a 1.90-point improvement in GRSx (95% CI [1.84, 1.97]). Model fit: R^2 = 0.3069, adjusted R^2 = 0.3066. A complete summary of the VIS effect per 10 points is reported in Table 3

Joint model including Review and VIS

N = 27,059. Both predictors were independently associated with change in GRSx. Review: coefficient = 3.16 (SE = 0.23, 95% CI [2.70, 3.62], t = 13.47, P < .001), equal to 0.32 points per 10 percent Review (95% CI [0.27, 0.36]). VIS: coefficient = 0.19 (SE = 0.003, 95% CI [0.18, 0.20], t = 57.67, P < .001), equal to 1.89 points per 10-point VIS improvement (95% CI [1.83, 1.95]). Model fit: R^2 = 0.3112, adjusted R^2 = 0.3109. Coefficients for Review (per 10 percent) and VIS (per 10 points) in the joint model are presented in Table 3.

Model comparisons and diagnostics

When fit on identical rows (N = 27,059), model comparison favored the joint specification. AICs were 216,917.91 for Review-only, 213,432.11 for VIS-only, and 213,265.34 for the joint model. Adding VIS to Review significantly improved fit (F(1, 27046) = 3910.98, P < .001), increasing R^2 by 0.0996. Adding Review to VIS also improved fit (F(1, 27046) = 169.22, P < .001), though the R^2 increment was smaller (0.0043). Model fit indices (AIC) and nested F-tests are summarized in Table 4.

Sensitivity and magnitude

Including the 7,069 zero-zero VIS episodes (N = 34,128) attenuated the VIS effect from 1.89 to 1.64 per 10 points (95% CI [1.57, 1.70]), a 13.49 percent reduction, supporting exclusion of these records in the primary analyses. In the primary joint model, the VIS effect was approximately six times larger than the Review effect (1.89 vs 0.32 per 10 percent). Both the primary and sensitivity VIS effects are tabulated in Table 3.

Table 1. Demographic Characteristics by Analysis Sample

		All Residential	Week 1-2	Week 1-3	Week 1-4
Population	N	97,960	60,125	51,035	39,106
Age	M	41.44	41.51	41.65	41.73
	SD	12.26	12.19	12.20	12.27
Gender	Male	68.36%	68.94%	69.32%	69.86%
	Female	31.37%	30.81%	30.43%	29.89%
	Other	0.27%	0.25%	0.25%	0.25%
Race	White	78.80%	80.07%	80.27%	80.26%
	Black	10.29%	10.69%	10.66%	10.72%
	Other	6.72%	6.63%	6.52%	6.48%
	Indigenous	1.41%	1.42%	1.40%	1.44%
	Asian	0.69%	0.74%	0.73%	0.73%
	NH/PI	0.31%	0.31%	0.30%	0.28%
	Missing	1.77%	0.14%	0.13%	0.10%

Table 2. Clinical Characteristics by Analysis Sample

		All Residential	Week 1-2	Week 1-3	Week 1-4
Baseline GRS	N	97,960	60,125	51,035	39,106
	M	56.79	56.60	56.29	55.61
	SD	15.15	15.10	14.97	14.82
Length of Stay	M	24.41	28.89	31.88	35.47
	SD	19.81	18.01	17.83	17.99
Discharge Type	Successful	77.43%	86.86%	91.87%	95.29%
	Against Medical Advice (AMA)	13.56%	6.93%	3.84%	2.13%
	Administrative	4.17%	3.15%	2.27%	1.42%
	Transfer	3.35%	3.07%	2.02%	1.17%
Review	M	73.79%	77.35%	76.74%	76.17%
	SD	35.72	30.62	30.63	30.80

Table 3. Effects of therapist review and visual cue exposure on change in GRSx

Predictor	Coefficient (SE)	95% CI	t	p	Effect per unit
Review (per 10%)	3.36 (0.22)	[2.94, 3.79]	15.6	< .001	0.34 points
VIS (per 10 points)	0.19 (0.00)	[0.18, 0.20]	57.97	< .001	1.90 points
Review (joint, per 10%)	3.16 (0.23)	[2.70, 3.62]	13.47	< .001	0.32 points
VIS (joint, per 10 points)	0.19 (0.00)	[0.18, 0.20]	57.67	< .001	1.89 points

Table 4. Model comparisons of review-only, VIS-only, and joint models

Model	AIC	R^2	Adj R^2
Review-only	216917.91	0.2116	
VIS-only	213432.11	0.3069	
Joint	213265.34	0.3112	0.3109