MOBILE ENHANCEMENT OF MOTIVATION IN SCHIZOPHRENIA: A PILOT TRIAL OF A PERSONALIZED TEXT-MESSAGE INTERVENTION FOR MOTIVATION DEFICITS

by

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ABSTRACT

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Motivation deficits remain an unmet treatment need in schizophrenia. Recent preclinical research has identified novel mechanisms underlying motivation deficits, namely impaired effort-cost computations and reduced future reward-value representation maintenance, that may serve as more effective treatment targets to improve motivation. The main aim of this study was to test the feasibility and preliminary effectiveness of a translational mechanism-based intervention, MEMS (Mobile Enhancement of Motivation in Schizophrenia), which leverages mobile technology to target these mechanisms with text-messages. Fifty-six participants with a schizophrenia-spectrum disorder were randomized to MEMS (n = 27) or a control condition (n = 29). All participants set recovery goals to complete over eight-weeks. The MEMS group also received personalized, interactive text-messages each weekday to support motivation. Retention and engagement in MEMS was high: 92.6% completed 8 weeks of MEMS, with an 86.1% text-message response rate, and 100% reported that they were satisfied with the text-messages. Compared to the control condition, the MEMS group had significantly greater improvements in interviewer-rated motivation and anticipatory pleasure and obtained significantly more recovery-oriented goals at the end of the 8-week period. There were no significant group differences in performance-based effort-cost computations and future reward-value representations, self-reported motivation, quality of life, functioning, or additional secondary outcomes of positive symptoms, mood symptoms, or neurocognition. Results suggest that MEMS is feasible as a

relatively brief, low-intensity mobile intervention that could effectively improve interviewer-rated motivation, anticipatory pleasure, and recovery goal attainment in those with schizophrenia-spectrum disorders.

INTRODUCTION

Schizophrenia is a severe mental illness (SMI), accounting for over 60 billion dollars in treatment costs and lost wages each year in the U.S. alone.[1] Research suggests that motivation deficits are a key factor affecting functional disability in people with schizophrenia.[2,3] Indeed, motivation reductions have demonstrated cross-sectional and longitudinal links to poorer functioning and quality of life[4-7] and are barriers to obtaining meaningful life goals that can facilitate recovery.[8] Yet motivation deficits remain an unmet clinical need,[9] as most psychosocial and pharmacological interventions have demonstrated limited efficacy in ameliorating these symptoms.[7,10] One barrier in the development of improved treatments to address these symptoms is a limited understanding of the precise mechanisms underlying motivation deficits in people with schizophrenia.

A burgeoning area of preclinical and human behavioral research has identified several reward-processing mechanisms underlying motivation deficits in schizophrenia. Specifically, a recent body of work has found that people with schizophrenia exhibit two related mechanisms that are posited to underlie motivation deficits: 1) impaired effort-cost computations and 2) reduced maintenance of reward-value representations.[11,12] Broadly, effort-cost computations associated with a task or action involve multiple processes, including generating a representation of the perceived effort (or cost such as energy or time) to complete the task, generating a representation of the benefits or rewards linked to completing the task, including identifying the magnitude of the reward and probability of reward receipt,[13] and then integrating this information to evaluate whether the reward is worth the effort.[11] To assess effort-cost computations, researchers have created tasks that assess whether a subject is willing to exert more effort for high versus relatively low magnitude rewards. Initial effort-cost computation

work stemmed primarily from animal model research highlighting the role of mesolimbic dopamine systems in effort-cost computations and in modulating the amount of effort an animal will exert for high versus low magnitude rewards.[14-16] Most notably, Kellendonk and colleagues[17] created an animal model of negative symptoms by genetically altering mice to selectively overexpress striatal D2 receptors (D2R-OE); these mice showed intact hedonic reactions to immediate rewards but impaired effort-cost computations whereby when they were given the option to allocate little or no effort for a low magnitude food reward or exert greater effort (lever presses) for a higher magnitude and preferred food reward, the D2R-OE mice were less willing than control mice to choose to exert greater effort for the preferred reward.[18] Further, these D2R-OE mice also showed reduced sensitivity to a valued future food reward, suggesting that these mice also had difficulty representing the value of future rewards.[18] Together, these results suggest that impaired mesolimbic dopamine systems, which have also been implicated in humans with schizophrenia, may yield specific behavioral mechanisms that contribute to reductions in motivated behavior: effort-cost computations and future reward-value representations.

Building on these preclinical studies, researchers have adapted animal paradigms to assess effort cost-computations in humans. Much of this work has centered around the translational Effort Expenditure for Rewards Task (EEfRT[19]), which asks participants to choose between completing an easy physical effort task that provides low monetary rewards or a relatively harder physical effort task that provides greater monetary rewards on a series of trials. Further, the probability of receiving the monetary rewards if the chosen task is successfully completed varies across trials. On this task, compared to controls, people with schizophrenia are less likely to choose the hard effort option on trials where the rewards and probability of

receiving the rewards are highest[20-24] but select about the same amount[20,24] or even more[22,23] hard effort options than controls on trials with lower reward receipt probability and magnitude. Together, this suggests that people with schizophrenia allocate less effort on maximally rewarding tasks, or in other words, display impaired or inefficient effort-cost computations, especially on trials when it would be most advantageous to put forth more effort. Further, this also suggests that participants with schizophrenia have difficulty translating reward related cues (magnitude, probability) to guide their decisions about when it might be most beneficial to allocate effort. Importantly, several studies have found that greater motivation deficits or negative symptoms are associated with choosing fewer hard tasks on the EEfRT, particularly in the high reward, high probability conditions.[20,22,25] Thus, these studies in humans corroborate findings from the preclinical studies and further suggest that motivational deficits may reflect difficulty integrating information about the cost (i.e., effort) and reward (magnitude, probability) of a task to identify when it is most advantageous to allocate effort.[21,23]

Relatedly, work in people with schizophrenia has also identified that motivational deficits appear to be linked to deficits in representing and maintaining (i.e., 'hold in mind'[26]) mental representations of the value of future rewards over time.[11,12] More specifically, temporally distant rewards such as getting a degree may be more poorly represented and become undervalued, especially compared to more immediate rewards, because of difficulty generating and maintaining internal representations of the value of future rewards needed to guide long-term behavior or goal-attainment.[27] Indeed, many with schizophrenia have difficulty sustaining effort for long-term goals or engagement in vocational or educational training programs,[28,29] especially when the associated rewards are temporally distant (e.g., paycheck, degree). Research has also shown that rewards that are immediately provided impact behavior to a greater degree than

internal representations of rewards in those with schizophrenia.[30] Further, using a delay discounting task, several studies have found that schizophrenia participants discount the value of future rewards more steeply than healthly controls,[27,31-33] suggesting that people with schizophrenia have greater difficulty representing and thus devalue future rewards. Notably, Heerey et al.[27] have also found that greater difficulty representing future rewards (e.g., greater discounting) was related to reduced motivation. Further, others have found that value maintenance even over a brief time period is impaired and associated with reduced motivation in schizophrenia.[26] Thus, motivational impairments in schizophrenia appear to relate to difficulties in identifying and maintaining reward-value representations over time that are needed to guide and support long-term goal-directed behavior.

Although these results provide converging evidence that both impaired effort-cost computations and reduced value representations of future rewards are specific underlying mechanisms that contribute to reduced motivated behavior in animal and human research, work is needed to identify whether targeting these mechanisms in psychosocial treatments will help to ameliorate motivation deficits in people with schizophrenia. Thus, the current study aimed to translate these findings into a novel mechanism-based psychosocial intervention for motivation deficits. Specifically, I aimed to leverage mobile technology to target these mechanisms in real-time, real-world settings. Indeed, effort-cost computations are made throughout a person's daily life (e.g., making favorite meal from scratch versus making a frozen meal version), and mobile interventions can provide real-time services to support adaptative effort-cost computations. Mobile interventions can be used to guide effective effort allocation by helping to cue and reinforce engagement in high-effort but high-reward tasks (e.g., looking/applying for jobs involving animals) that are important to meaningful long term-goals (e.g., becoming a veterinary

technician). Further, mobile interventions can be used to provide frequent reminders to promote and maintain reward-value maintenance associated with different goals in order to guide behavior to support long-term goal attainment.[11] Thus, mobile interventions may provide real-time guidance in a person's naturalistic environment to target both effort-cost computations and maintenance of future reward-value representations in order to improve motivation.

Extant studies have found that mobile interventions are feasible, acceptable, and clinically-promising tools to support a range of outcomes in people with schizophrenia. Participants receiving daily text-messages targeting symptom management and monitoring, medication adherence, and/or socialization have generally reported high levels of satisfaction and utility with text-messages.[34-36] Further, participant retention and response rates to text-messages in seven or 12-week studies with schizophrenia samples have been high,[34,35,37] supporting the feasibility of this approach. Moreover, initial studies have demonstrated that text-message interventions are potentially effective in improving a range of targeted domains, including medication adherence, positive symptoms, and social functioning.[34,37-39]

Despite these promising results, few studies have used mobile interventions to target motivation deficits or other negative symptoms directly. To date, I am aware of only one study that has targeted motivation. Schlosser et al.[40] used a mobile app-based intervention for people with early psychosis and found that the 12-week intervention led to trend improvements in self-reported motivation/pleasure symptoms but no significant changes in clinician-rated negative symptoms, functioning, or quality of life. Further, mobile interventions targeting other domains have found limited effectiveness for improving motivation or negative symptoms more broadly.[34,41] In addition, studies of mobile interventions, particularly text-message interventions, generally have yet to move beyond feasibility studies, and others have pointed to the need for

more rigorous randomized designs.[42] An additional limitation of extant studies is that many provide participants study cell-phones only for the duration of the mobile intervention, which reduces the ecological validity and clinical utility of these findings.

To address these gaps, this study tests the feasibility and initial effectiveness of a mobile text-message intervention, MEMS (Mobile Enhancement of Motivation in Schizophrenia), aimed at improving motivation by targeting effort-cost computations and future reward-value representation maintenance. To more rigorously test the intervention, I used a randomized design to identify whether text-messages would lead to improvements in outcomes above the effects of a group who engaged in a single goal-setting session. I chose goal-setting as the comparator because it is a common method to target motivation in psychosocial interventions.[43,44] I hypothesized that MEMS would lead to greater improvements in primary outcomes of effort-cost computations, value representations of future rewards, clinician-rated and self-reported motivation, and overall goal attainment compared to goal-setting alone. I also explored whether there were group differences in secondary outcomes of quality of life, functioning, neurocognition, and other symptoms (positive, mood, and additional negative symptoms). Further, given that most prior schizophrenia mobile intervention studies provide study cell-phones, I also aimed to test the feasibility of solely using personal mobile phones to deliver text-message interventions, as well as engagement (i.e., response rate), usability, and satisfaction with MEMS.

METHOD

Participants

Participants were recruited from a community mental health center that serves outpatients with SMI. Interested participants were given a study overview and completed a phone screen to identify if they 1) were ≥ 18 years old, 2) had been diagnosed with a schizophrenia-spectrum disorder, 3) owned a mobile phone that could send/receive text-messages, and 4) would permit study staff to send text-messages to their phone. Eligible participants then completed an initial in-person interview after providing informed consent. Diagnoses were confirmed with the Structured Clinical Interview for DSM-5 (SCID-5[45]), and participants were enrolled if they also 1) demonstrated ≥ a fourth grade reading level on the Graded Word List,[46] 2) were in a post-acute illness phase as indexed by no past month inpatient hospitalizations or medication changes; 3) had ≥ moderate motivation deficits according to the Clinical Assessment Interview for Negative Symptoms (CAINS)[47] in at least one domain: motivaiton for family, close friends and romantic relationships, work and school, and/or recreational acitivities. Ineligible participants were compensated $10. Eligible participants completed additional study measures and a goal-setting session where they set recovery-oriented goals to complete over eight weeks. After the goal-setting session, participants were randomized (see supplemental methods for randomization details) to also receive either 1) MEMS or 2) no additional study intervention (referred to hereafter as the control group). Follow-up assessments were completed at the end of the eight-week period. Participants were compensated $40 for completing each assessment and had the opportunity to win an additional $2 to $8.24 on a study task (see below) at both assessments. Following a prior study using personal cell-phones,[35] I reimbursed participants for text-message

costs ($30 per month); however, to ensure that this additional monetary reimbursement was not influencing participant outcomes, both groups received this compensation. Study procedures were approved by the local institutional review board.

Goal-Setting Session

After completing study assessments, all participants engaged in a goal-setting session where they set specific, measurable, achievable, realistic, and timed (SMART[48,49]) recovery goals to complete over eight-weeks. The goal-setting session incorporated techniques from Collaborative Goal Technology (GCT[43]), a systematic, evidence-based recovery goal-setting method focused on identifying the value, importance, and meaning of a goal.[8] See supplemental methods for additional goal-setting details.

MEMS

In line with prior text-message intervention studies,[34,35] the MEMS group received training prior to starting the text-messages with the study interventionist (see supplemental methods for training details).

Participants in MEMS received three sets of text-messages each weekday through TextIt's[50] secure web-based text-messaging service. Text-messages were sent during three specified time blocks: 1) 8:30–10:30 am, 2) 11:30 am–1:30 pm, and 3) 5:30–7:30 pm. Participants were asked to identify when they wanted to start receiving messages in each time block. Participants were informed that the interventionist may have a delayed response to text-messages sent outside the time blocks. Following prior technology-based research with people with SMI,[51] efforts were made to create text-messages that required a low reading level and used

concrete language. Calls to participants were made only if the participant did not reply to any text-messages for three consecutive days.

Throughout an 8-week period, each MEMS participant received text-messages each weekday to reinforce and cue goal completion and to target effort-cost computations and future reward value representation maintenance. Messages occurred in the following order: 1) Reminder of the smaller sub-goal they set to complete that day, inquiry about how much effort they thought the goal would take to complete (scale 1–10), and then positive encouragement; 2) Encouragement that the sub-goal is worth the effort, and reminder of why the goal is valuable to them (based on information from the goal-setting session), and inquiry about when they thought they would complete the goal that day; 3) Assessment of sub-goal completion and how much effort it took to complete the goal (scale 1–10). If they did not complete the sub-goal, participants were asked what might help them reach their sub-goal, and whether the sub-goal could be broken down into smaller steps. If they did complete it, encouragement was provided to reinforce success and support adaptive effort-cost computations (i.e., if they overestimated the effort, then I reinforced that it was less effort then they thought it would be). At the end of each week, feedback indicating progress towards their overall goal was provided.

Measures

Participants were interviewed at baseline and follow-up by trained raters who were blinded to study condition. Brief measure descriptions are below (see supplemental methods for additional measure information).

Primary Outcome Measures.

Interviewer-Rated Motivation. Interviewer-rated motivation was assessed by the aforementioned CAINS four motivation items and the three-item Motivation Index[52] from Heinrich's Quality of Life Scale (QLS[53]). Given that prior work has also found that the single motivation item form the QLS Motivation Index is a valid stand-alone measure of motivation,[54] I also used this item in exploratory analyses.

Subjective Motivation. Subjective motivation was assessed by the 6-item motivation and effort subscale of the self-report Motivation and Pleasure Scale (MAP-SR[55]).

Effort-cost computations. Effort-cost computations were assessed by the aforementioned EEfRT,[19] a 20-minute computerized paradigm consisting of trials where participants choose to complete either an easy or hard task after being informed of the associated monetary rewards for both options and probability of reward receipt.

Value Representations of Future Rewards. Value representations of future rewards were measured using a delay-discounting task[56] where participants choose between either a smaller immediate monetary reward or a larger delayed reward in 27 trials.

MEMS Usability and Satisfaction. MEMS usability and satisfaction was assessed with 14 self-report items based on the Usability, Satisfaction, and Ease of Use questionnaire.[57]

Secondary Outcomes.

Functioning. Functioning was assessed by the 9-item interviewer-rated Strauss-Carpenter Level of Function scale.[58,59]

Quality of Life. Quality of Life was measured by the self-report overall quality of life item from the World Health Organization Quality of Life BREF scale (WHOQOL-BREF[60]).

Neurocognition. Neurocognition was measured using the brief neurocognitive assessment (BNA[61,62]).

Additional Negative Symptoms. Additional negative symptoms were measured with the CAINS. Specifically, I measured anticipatory pleasure (i.e., expected pleasure for the upcoming week), past week pleasure, expressive symptoms, and overall negative symptoms.

Positive and Mood Symptoms. Positive and Mood Symptoms were assessed with the widely-used interviewer-rated Positive and Negative Syndrome Scale (PANSS[63]).

ANALYSES

Although intent-to treat analyses were planned, three people did not complete the study (see below) and follow-up data was not available. For hypothesis testing, I used a full analysis set,[64] including data from all randomized participants with available data, regardless of actual use or adherence to the intervention. After variables were examined to ensure they met statistical assumptions, I first compared both groups on baseline demographics using independent samples t-tests and chi-square tests. Second, to assess MEMS feasibility and engagement, I examined text-message response rates, while descriptive statistics were used to assess responses to MEMS usability and satisfaction questions. Next, I used a series of one-way Analysis of Covariances (ANCOVAs) to assess whether there were group differences (randomized group served as the fixed factor) on primary and secondary outcomes at follow-up after co-varying for the associated baseline outcome level and if necessary, any identified group demographic differences. Given that neurocognition can impact motivation in schizophrenia,[52,65] I re-ran all ANCOVA's controlling for neurocognition; results were nearly identical so are not presented. To compare overall goal attainment between groups, I used independent samples *t*-tests. Finally, to identify whether MEMS engagement (text-message response rate) was related to changes in outcomes, correlations between MEMS response rate and outcome change scores (baseline minus follow-up score) were conducted. Effect sizes were based on Cohen's *d*[66] where 0.20 is small, 0.50 is medium, and 0.80 is large.

RESULTS

Recruitment and Participant Characteristics

One hundred participants were assessed for eligibility and 56 were randomized (27 to MEMS, 29 to control). As seen in the consort diagram (Figure 1), three participants (5.4%) did not complete the study. In the MEMS group, one participant self-withdrew several weeks after starting the text-messages because she obtained a job and did not think she would have time for the text-messages, while another was administratively withdrawn after the participant broke her phone prior to beginning the text-messages and then became unreachable. One participant in the control condition was unreachable at follow-up.

At baseline, groups did not significantly differ on any demographic variable or CAINS motivation (see Table 1). Further, study non-completers (n = 3) and completers (n = 53) did not significantly differ on demographics or CAINS motivation. Across both conditions, participants were predominately African American (n = 39, 69.6%) and male (n = 29, 51.8%). Participants had a mean age of 46.1 (SD = 8.8) and had completed a mean of 11.8 (SD = 2.4) years of school. Most had unlimited text-messaging (n = 54, 96.4%) and had sent text-messages on their personal cell-phone prior to the study (n = 52, 92.9%). Mean chlorpromazine equivalent doses were 513.6 (SD = 472.0), and CAINS motivation deficits were moderate (Mean = 7.6, SD = 2.3).

MEMS Feasibility, Engagement, Usability, and Satisfaction

MEMS Feasibility and Engagement

Over the 8-week text-message period, participants received an average of 207.5 (SD = 62.4) text-messages from the trial interventionist and sent an average of 185.8 (SD = 92.6) text-messages to the interventionist. The average participant response rate was 86.1% (SD = 16.7%).

One participant responded to 18.5% of the text-messages, 3 responded to 63.1% to 73.3%, 9 responded to 80 to 89.4%, and the remaining 12 responded to over 93% of the text-messages.

Usability and Satisfaction

See Table 2 for individual item responses. In terms of usability, 96% (n = 24) of MEMS participants reported they learned the mobile intervention quickly and it was easy to use. Sixteen percent (n = 4) reported difficulties understanding the text-messages and typing their responses, and 12% (n = 3) reported difficulties operating their phone. Regarding satisfaction, all participants reported they were satisfied with the text-messages, and 92% (n = 23) reported that the text-messages were useful and helped them to become more motivated. Ninety-two percent (n = 23) reported that the text-messages helped them to reach their goals and become more productive. Several participants also made unprompted comments via text-messages about how MEMS helped them (See supplemental Table 1).

Preliminary Effectiveness

Primary Outcomes. Consistent with my hypothesis, significant medium-sized group effects were found for CAINS motivation ($F(1, 50) = 4.73$, $p = .03$, $d = -.58$) (see Table 3), with MEMS participants demonstrating greater 8-week motivation than controls after controlling for baseline levels of CAINS motivation. No significant group effects were found for the QLS-Motivation Index ($F(1, 50) = 2.23$, $p = .14$, $d = .41$), but exploratory analyses identified that the MEMS group had greater 8-week scores on the motivation item of the index than the control group after adjusting for pre-test motivation index item scores ($F(1, 50) = 4.59$, $p = .04$, $d = .58$); effect size was medium. As hypothesized, MEMS participants reached significantly more overall goals over eight-weeks than controls ($t(51) = 3.82$, $p < .001$, $d = 1.06$), with a large effect size.

Contrary to hypotheses, no significant group effects were found for subjective motivation ($F(1, 50) = .26$, $p = .61$, $d = -.14$), value representations of future rewards ($F(1, 50) = .96$, $p = .33$, $d = -.27$), or effort-cost computations ($F(1, 50) = .15$, $p = .70$, $d = -.11$); however, several participants demonstrated fixed responses on the EEfRT ($n = 9$) or fixed or inconsistent responses[56,67] on the delay discounting task ($n = 7$) (results were statistically the same when these participants were removed).

Secondary Outcomes

After controlling for baseline levels, follow-up anticipatory pleasure was significantly higher in the MEMS group compared to the control group ($F(1, 50) = 5.93$, $p = .02$, $d = -.66$), with a medium effect size (See supplemental Table 2). There was also a trend towards lower 8-week overall negative symptoms ($F(1, 50) = 3.42$, $p = .07$, $d = -.50$) and higher 8-week pleasure in the past week ($F(1, 50) = 2.87$, $p = .096$, $d = -.46$) in the MEMS relative to the control condition after adjusting for the corresponding baseline score. There were no significant group differences for expressive negative symptoms ($F(1, 50) = .26$, $p = .62$, $d = -.14$), positive symptoms ($F(1, 50) = .02$, $p = .89$, $d = -.04$), mood symptoms ($F(1, 50) = .01$, $p = .94$, $d = -.02$), neurocognition ($F(1, 50) = .12$, $p = .73$, $d = -.10$), quality of life ($F(1, 50) = .08$, $p = .78$, $d = -.07$), or functioning ($F(1, 50) = .11$, $p = .74$, $d = .09$).

MEMS Engagement and Outcome Change

Greater engagement (i.e., a higher text-message response rate) was associated with greater change (i.e., more improvement) in effort-cost computations ($r(23) = -.61$, $p = .001$), overall negative symptoms ($r(23) = .40$, $p = .046$), and anticipatory pleasure ($r(23) = .43$, $p = .03$). No other correlations were significant (See supplemental Table 3).

DISCUSSION

Motivation deficits are a significant unmet treatment need in schizophrenia.[9] The main aim of this study was to test the feasibility and preliminary effectiveness of a translational intervention that leverages mobile technology and recent findings in basic and behavioral schizophrenia research to create a novel, mechanism-based treatment for motivation deficits. These results suggest that not only is MEMS feasible but also is more effective than a single goal-setting session in several domains: interviewer-rated motivation and anticipatory pleasure as well as recovery-oriented goal attainment. Notably, to my knowledge, this study is also the first randomized trial demonstrating the feasibility of solely using participants' personal cell-phones (rather than study provided cell-phones) to deliver a more ecologically valid and interactive text-message intervention to target symptoms in people with schizophrenia.

I also found that the MEMS intervention itself was highly engaging for most participants. Over the 8-week intervention period, the retention rate for the MEMS group was 92.6%, which is higher than rates around 70-80% found in several other text-message intervention studies for schizophrenia.[34,37,39] This is particularly noteworthy given that all participants demonstrated at least moderate baseline motivation deficits. Further, similar to prior text-message intervention studies in schizophrenia,[34,35] the overall mean response rate for MEMS was 86.1%. In addition, all participants reported being satisfied with the text-messages, and almost all participants (96%) reported that the text-messages were useful and helped them to become more motivated, that they learned to use the intervention quickly, and that MEMS was easy to use. Several participants also provided unprompted feedback via text-messages stating that the text-messages were encouraging, motivating, and helpful. Together, these results add to the growing literature

suggesting that text-message interventions are feasible and acceptable for most people with schizophrenia-spectrum disorders.[42,68]

Notably, this study extends prior work by demonstrating that personal cell-phones are a feasible as well as clinically useful conduit for interactive text-messaging interventions. In screening 100 clients, only a few (9%) did not have text-message enabled cell-phones. This largely aligns with recent findings that approximately 72-81.4% of people with a psychotic disorder own a cell-phone.[69,70] Further, all 56 participants who met eligibility criteria prior to randomization had agreed to receive text-messages to their personal cell-phone for 8-weeks, and 92.9% had sent text-messages before the study. Phone service interruptions over the 8-weeks also appeared to be low (based on the MEMS response rate of 86.1%). Finally, although I reimbursed participants for text-message costs, almost all had unlimited text-messaging as part of their service plan, suggesting that reimbursement may not be necessary in future studies. Together, along with a meta-analysis showing that rates of cell-phone ownership among those with SMI appear to be increasing,[69] these findings suggest that it is possible to leverage existing personal cell-phones for mobile interventions. Being able to use existing mobile devices may help to address concerns about ecological validity, scalability, sustainability, and implementation of mobile health text-message interventions in real-world clinical settings.[71-73]

Importantly, this study also builds on feasibility and acceptability studies by using a randomized design with an active control group, to more rigorously test the preliminary effectiveness of MEMS. Results demonstrated that MEMS led to greater improvement in interviewer-rated motivation and anticipatory pleasure as well as recovery-oriented goal attainment compared to a goal-setting alone session, with medium to large effect sizes. These findings are important given that there are few, particularly brief treatments (i.e., less than 18

months) that have demonstrated efficacy for improving the domains of motivation and anticipatory pleasure.

Yet the impact was not universally positive. I found no advantage of MEMS for effort-cost computations, value representations of future rewards, or self-reported motivation. The lack of findings for the performance-based tasks was particularly surprising because these were the targeted mechanisms by which I expected motivation to improve. I speculate that the lack of improvement on both performance-based tasks may be due to near ceiling level or fixed responses at baseline for several participants. Alternatively, it may be that these measures did not effectively represent the constructs that I was targeting in MEMS (e.g., were too different or distal) or that the tasks may have been "too easy" for some participants, particularly in comparison to real-world goal behaviors that often require higher effort than button presses over a longer period of time than a single 20-minute session. Further, in both performance-based tasks, the rewards were monetary and relatively small (particularly in the EEfRT), and the subjective value of money or rewards can vary across people or time-points (i.e., distance from paycheck).[13,74] Further, monetary rewards likely do not facilitate the same motivational response and require a less complex and abstract mental representation than rewards such as pleasure or a sense of accomplishment that are associated with completing real-world goals. Indeed, although I chose these performance-based measures because they have been described as putative objective measures of both effort-cost computations and future reward-value representation maintenance, more recent work has found little overlap between the EEfRT and motivation measures like the CAINS and QLS–Motivation Index,[75] suggesting that they may be measuring disparate constructs. To better assess mechanisms of MEMS improvement and to more precisely identify whether effort-cost computations and future reward-value representation maintenance are

effective treatment targets to enhance motivation, future work could use more recently developed performance-based effort-based decision-making measures, such as effort discounting tasks,[76] which have shown greater concordance with motivation/negative symptom measures.[75]

In terms of secondary outcomes, there were significantly greater improvements in anticipatory pleasure in MEMS compared to the control group (medium effect size). Further, both overall negative symptoms and pleasure in the past week trended towards greater improvement in MEMS relative to the control group. It may be that as participants worked more regularly towards their goals or had more success attaining sub-goals, they also had greater anticipated as well as experienced enjoyment for goal-related activities. Further, the text-message reminders about why the sub-goals were worth the effort and valuable could have helped the participants to more readily represent future rewards (e.g., pleasure) as well as strengthen the mental link between sub-goal completion and future rewards.[30] Alternatively, the reinforcement provided in the text-messages after successful goal attainment could also have led to increased instances of pleasure. Additional work is needed to parse out the mechanisms of improvements. However, there were no significant improvements in the additional secondary outcomes of interviewer-rated symptoms (positive, mood, and expressive symptoms), neurocognition, self-reported quality of life, or interviewer-rated functioning in the MEMS group compared to the goal-setting alone group. This may be due to the low-intensity nature or length of MEMS, which likely limited my ability to detect whether the effects of MEMS would translate into these more distal symptoms or broader, longer-term outcomes such as functioning and quality of life.

I also explored whether greater engagement in MEMS (i.e., a higher text-message response rate) was linked to greater improvements in my primary and secondary outcomes.

Results revealed that greater engagement in MEMS was associated with greater improvement in effort-cost computations, anticipatory pleasure, and overall negative symptoms. In terms of effort-cost computations, this may suggest that only those with higher MEMS engagement saw improvements on this measure. Alternatively, it may also be that the goal-setting session and breaking down overall goals into daily sub-goals helped to improve effort-cost computations in both groups, which obscured the additional benefits of MEMS on effort-cost computations when conducting the group comparisons. Future studies with larger samples may be beneficial in clarifying the impact of MEMS on effort-cost computations. Relatedly, I did not observe that greater MEMS engagement was significantly associated with greater improvements in interviewer-rated motivation; however, the magnitude of the correlations between engagement and interviewer-rated motivation on the CAINS and QLS motivation item was small to medium, suggesting that I may have been underpowered to detect significant effects. On the other hand, given that greater MEMS engagement was associated with greater change in anticipatory pleasure, it may suggest that the content of the text-messages had a relatively stronger impact on anticipatory pleasure rather than on motivation. Future work could examine what level and length of MEMS engagement is needed to produce significant changes in these domains.

Consistent with prior text-message intervention studies,[34,35] these results suggest that MEMS may not be suitable for all people with schizophrenia-spectrum disorders. Even after a text-message training session, I found that a few participants had difficulties typing their responses, operating their phone, and/or understanding the text-messages. Some participants may need additional training in order to better engage with mobile interventions. Similarly, although further work is needed to identify how to best integrate mobile services within current caseloads

and models of care,[71] it may also be that additional, regular support from a community-based clinician may help to reduce difficulties with mobile interventions.

There were also several limitations that should be considered when interpreting these findings. First, although a strength of this study was that I used a randomized design, I was not able to examine whether improvements in the MEMS group were maintained after the intervention period. Second, while the sample size was similar or even larger than many prior text-message studies,[35,37,77] my sample was still relatively small and may have been underpowered to detect some effects. A third limitation is the use of personalized text-messages, which may impede widespread dissemination given the need for clinical personnel. However, more automated approaches could be attempted, and future studies could compare the efficacy of a completely automated approach to this more personalized approach.

In conclusion, this study supports the feasibility and preliminary effectiveness of a translational intervention that uses text-messages to support motivation in real-time, real world-settings among those with schizophrenia-spectrum disorders. Specifically, I found that those who received MEMS had greater improvements in interviewer-rated motivation and anticipatory pleasure compared to a goal-setting alone group. Moreover, MEMS participants successfully obtained significantly more recovery-oriented goals, including obtaining a part-time job, improving familial relationships, becoming healthier through regular exercise, or obtaining independent housing. Importantly, the majority of MEMS participants—all of whom began the study with at least moderate motivation deficits—were highly engaged in the intervention. Together, these findings support the feasibility and utility of leveraging personal cell-phones to deliver a more ecologically valid mobile intervention that may reduce one of the most

debilitating symptoms of schizophrenia and help participants attain more meaningful life-goals that support their recovery.

TABLES

Table 1. Baseline Participant Demographics by Group

	MEMS (n = 27)	Goal-Setting Alone (n = 29)	Test of significance
	n, %	*n*, %	
Diagnosis			X^2 (1) = .25
Schizophrenia	12, 44.4%	11, 37.9%	
Schizoaffective disorder	15, 55.6%	18, 62.1%	
Gender (*n*, % Female)	15, 55.6%	12, 41.4%	X^2 (1) = 1.13
Race			X^2 (2) = .78
African American	18, 66.7%	21, 72.4%	
White	8, 29.6%	6, 20.7%	
Other or multiple races	1, 3.7%	2, 6.9%	
Sent text-messages prior to study	26, 96.3%	26, 89.7%	X^2 (1) = .93
Unlimited text-message plan	26, 96.3%	28, 96.6%	X^2 (1) = .003
	M	*SD*	
Age	46.0 (10.0)	46.3 (7.7)	t (54) = -.12
Education	12.0 (2.7)	11.7 (2.0)	t (54) = .35
Chlorpromazine Equivalent Doses[a]	618.3 (544.6)	416.1 (376.5)	t (54) = 1.63
Length of Illness	24.0 (12.1)	23.4 (10.5)	t (52) = .21
CAINS – Motivation	7.7 (2.6)	7.5 (1.9)	t (54) = .30

Note. CAINS = Clinical Assessment Interview for Negative Symptoms.
[a]Based on[78-80]

Table 2. Usability and Satisfaction for MEMS Participants (n = 25)

	Strongly Disagree	Disagree	Disagree Somewhat	Neutral	Agree Somewhat	Agree	Strongly Agree
Usability items							
I learned to use the mobile intervention quickly.	0	1 (4%)	0	0	4 (16%)	8 (32%)	12 (48%)
The mobile intervention was easy to use.	1 (4%)	0	0	0	1 (4%)	12 (48%)	11 (44%)
The mobile intervention did everything I would expect it to.	0	0	0	3 (12%)	4 (16%)	8 (32%)	10 (40%)
I had difficulties typing my responses.	14 (56%)	3 (12%)	1 (4%)	3 (12%)	2 (8%)	0	2 (8%)
I had difficulties operating my phone.	15 (60%)	4 (16%)	1 (4%)	2 (8%)	1 (4%)	2 (8%)	0
I had difficulties understanding the text messages.	16 (64%)	2 (8%)	2 (8%)	1 (4%)	0	2 (8%)	2 (8%)
The text messages interfered with my daily activities.	17 (68%)	3 (12%)	1 (4%)	2 (8%)	2 (8%)	0	0
Satisfaction items							
The text-messages I recevied were useful.	0	0	0	1 (4%)	1 (4%)	7 (28%)	16 (64%)
I was satisfied with the text-messages I received.[a]	0	0	0	0	2 (8%)	4 (16%)	18 (72%)
I would be interested in participating in similar studies in the future.	0	0	0	0	0	6 (24%)	19 (76%)
I would recommend to others that they should participate in a similar study.	0	0	0	0	2 (8%)	7 (28%)	16 (64%)
The text-messages helped me to reach my goal(s).	0	0	0	2 (8%)	2 (8%)	6 (24%)	15 (60%)
The text-messages helped me to be more productive.	0	0	1 (4%)	1 (4%)	2 (8%)	5 (20%)	16 (64%)
The text-messages helped me become more motivated.[a]	0	0	0	1 (4%)	2 (8%)	7 (28%)	14 (56%)

[a] n = 1 (4%) missing data for this item.

Table 3. Measure Descriptive Statistics and Group Effects for Primary Outcomes

	MEMS		Goal-Setting Alone		F^a	p	d^c
	BL (n = 27)	8-week (n = 25)	BL (n = 29)	8-week (n = 28)			
Measure	M (SD)	M (SD)	M (SD)	M (SD)			
CAINS – Motivation	7.7 (2.6)	6.2 (2.5)	7.5 (1.9)	7.4 (2.7)	4.73	.03	-.58
QLS – Motivation index	8.0 (2.5)	9.6 (3.8)	7.4 (2.8)	8.0 (3.5)	2.23	.14	.41
QLS – Motivation item	2.5 (1.3)	3.6 (1.4)	2.3 (1.1)	2.9 (1.3)	4.59	.04	.58
MAP-SR – Motivation	11.2 (5.4)	11.6 (5.6)	7.9 (5.0)	10.3 (6.5)	.26	.61	-.14
Overall goals obtained - %	–	77.6 (26.7)	–	46.7 (31.6)	3.82[b]	< .001	1.06
Value representation maintenance – % Delayed rewards	35.7 (21.2)	32.7 (19.2)	28.6 (23.0)	30.3 (25.4)	.96	.33	-.27
Effort-Cost Computations - % Hard chosen in 88%, high reward trials	45.9 (32.4)	42.0 (35.5)	36.6 (29.2)	38.9 (36.4)	.15	.70	-.11

Note. Descriptive statistics are simple statistics without co-varying for baseline level of variable; CAINS = Clinical Assessment Interview for Negative Symptoms; MAP-SR = Motivation and Pleasure Self-Report; QLS = Quality of Life Scale.

[a] Results based on those who completed both assessment points.

[b] *t*-value and associated significance test and effect size are reported.

[c] Effect sizes were calculated with adjusted follow-up means and pooled standard deviations for all but goal attainment where effect sizes were based on follow-up means and pooled standard deviations.

FIGURE

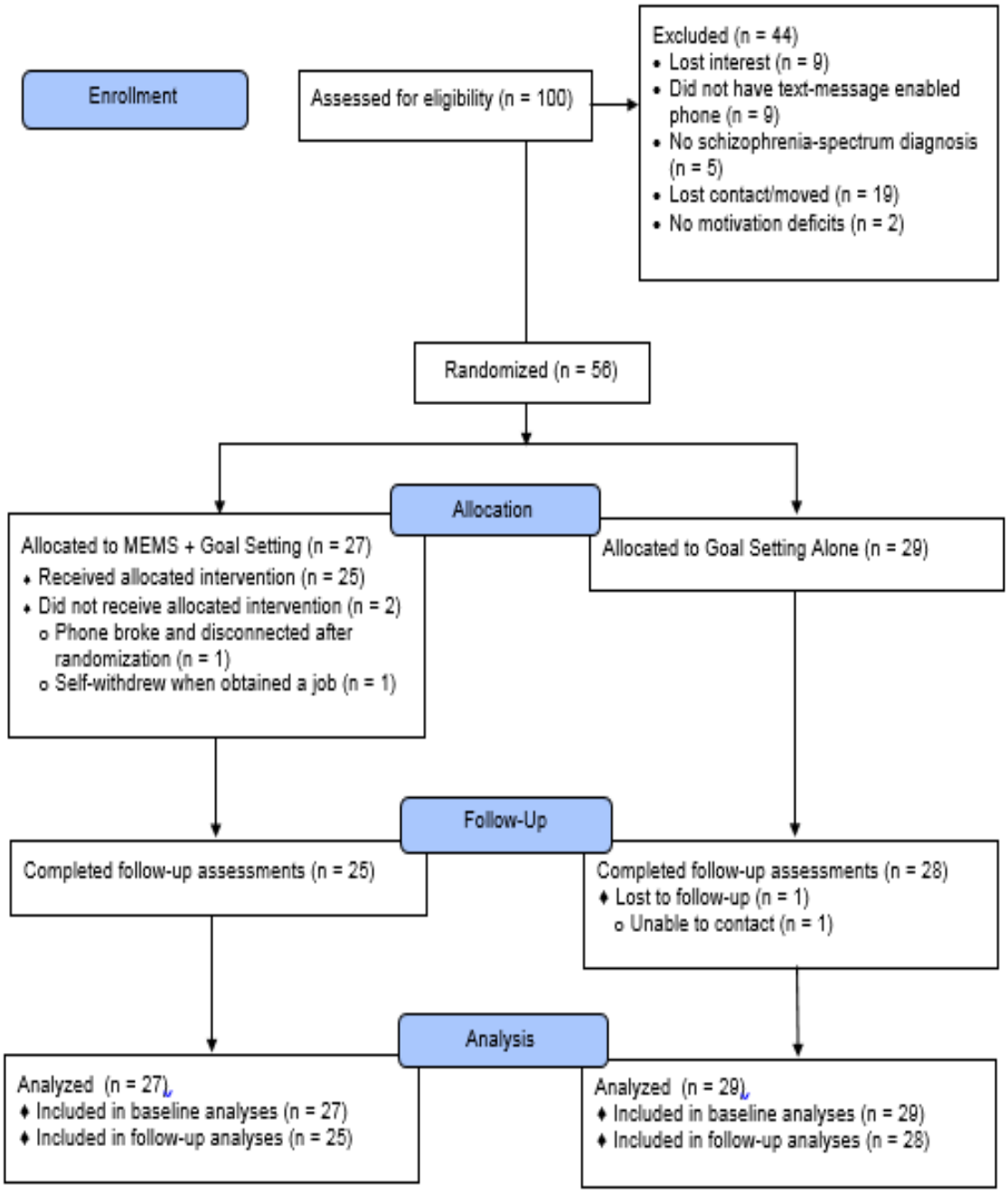

Figure 1. Consort Flow Diagram

APPENDIX A. SUPPLEMENTAL METHODS

RANDOMIZATION. Randomization was conducted using a random number generator in blocks of 10; each block had an equal number of both conditions. Randomization codes were generated by an independent researcher and sealed in envelopes with consecutive numbers; these were opened in ascending order during randomization.

TEXT-MESSAGE TRAINING. First, the limits of text-message confidentiality and ways to improve privacy (e.g., adding an access password) were reviewed. Next, participants were trained to send and receive text-messages and modify relevant settings (e.g., text-message notification volume, text font size) on their personal phone. Participants then engaged in a practice text-messaging session where they drafted and sent a message and opened and read a received message from the study interventionist.

GOAL-SETTING SESSION. Goals could be set in any domain, but participants were first asked if they wanted to make changes in the domains identified as reduced on the CAINS motivation items. Using GCT and information gathered in the assessments, attempts were made to help participants integrate information to accurately identify and assess the value, effort, and probability of attaining an identified goal. Identified goals were translated into a SMART goal, and participants discussed and then rated the value/importance of the goal (rated from 1–10), effort to complete the goal (rated from 1–10), and the participant's confidence in completing the goal (rated 0–100%) (a copy of this information was provided to participants). To further overcome effort-cost computation difficulties, each overall goal was collaboratively broken down into smaller sub-goals to complete each week-day over 8-weeks; sub-goals were written on calendars, and participants were instructed to mark a box in the corner of the calendar to indicate when they completed the sub-goal.

MEASURES

INTERVIEWER-RATED MOTIVATION. The Clinical Assessment Interview for Negative Symptoms (CAINS)[47] motivation items assess motivation over the past week for the domains of family, close friends and romantic relationships, work and school, and recreational activities. The motivation index[53] items assess a person's global degree of motivation to initiate and sustain activities, curiosity in daily life, and sense of purpose or having integrated, realistic life goals over the preceeding four weeks.

SUBJECTIVE MOTIVATION. The Motivation and Pleasure Scale (MAP-SR[55]) motivation and effort subscale items assess perceived motivation and effort over the past week for social, work, school, hobbies, and recreational acitivities.

Effort-Cost Computations. On the Effort Expenditure for Rewards Task (EEfRT[19]), easy task rewards are always $1.00, while hard tasks rewards vary from $1.24-$4.12. The probability of reward receipt if the chosen task is completed varies (but is the same for each trial option), ranging from high (88%), medium (50%), to low (12%). The easy task asks participants to make 30 button presses in 7 seconds using their dominant hand index finger, and the hard task requires 100 button presses in 21 seconds with their non-dominant hand pinky finger. Participants are instructed that earnings from the task are based on two randomly selected tasks. Following prior methods,[23] our main effort-cost computations outcome was the percentage of hard trials selected in the high reward ($\geq$ $3.01) high probability (88%) trials.

VALUE REPRESENTATIONS OF FUTURE REWARDS. On the delay-discounting task,[56] small rewards range from $11-80, while larger delayed rewards range from ($25-85). Delays range from seven to 186 days. As studies have failed to find performance differences between hypothetical and real monetary rewards,[81,82] participants were informed that they would

not receive the rewards but should make their decisions as if the rewards were genuine. Following Myersen et al.,[83] greater ability to represent the value of a future reward was indexed by the percentage of larger delayed rewards selected.

MEMS USABILITY AND SATISFACTION. Items were based on the Usability, Satisfaction, and Ease of Use Questionnaire, which was previously modified to assess the usability and satisfaction of a mobile intervention in a schizophrenia-spectrum sample.[35]

Functioning. The Strauss-Carpenter Level of Function Scale[58,59] contains items that assess social contacts, work, symptoms, and general functioning over the past month.

Quality of life. The World Health Organization Quality of Life Bref scale (WHOQOL-BREF[60]) is based on past 2 weeks.

NEUROCOGNITION. The updated brief neurocognitive assessment (BNA[61,62]) assesses working memory with the letter-number sequencing test[84] and processing speed with the symbol coding subtest from the brief assessment of cognition in schizophrenia (bacs[85]). Following Fervaha et al.,[61] I created an overall BNA standardized z-score based on normative data.

ADDITIONAL NEGATIVE SYMPTOMS. Anticipatory pleasure was measured with the three CAINS items assessing expected pleasure for the upcoming week for the domains of social relationships, work and school, and recreational activities; the CAINS was also used to assess past week pleasure (3 items) for the same domains. Emotion expression and speech were assessed with the four expressive items (facial expression, vocal expression, expressive gestures, quantity of speech). Finally, overall negative symptoms were assessed with the CAINS total score.

POSITIVE AND MOOD SYMPTOMS. I assessed positive and emotional discomfort (mood) symptoms following factor-analytically derived factors[86] on the positive and negative syndrome scale (PANSS[63]).

APPENDIX B. SUPPLEMENTAL TABLES

Supplemental Table 1. Unprompted MEMS Participant Feedback Sent Via Text-Messages

Participant ID	Feedback
108	This has really helped me this study it gave me reason to keep going and not give up.
110	Tu i have never been able tn do this before and all of a sudden i can.
126	I like this study. I wish someone could always work with me on goals like this its helpful.
141	I not only learned but enjoyed this. It makes me better. My goals are getting into focus.
144	Your texts were very helpful motivating me 2 get things done.
148	Thank you very much for everything you have done to encourage me… I think I have learned what I am capable of doing. I just scared of doing it without your morning text-reminders of encouragement….Yet, I know what you are going to say, "NAME, you can do it. That's right: "I can do it."
164	Having the text reminders in the a.m. has been helpful.

Supplemental Table 2. Measure Descriptive Statistics and Group Effects for Secondary Outcomes

	MEMS		Goal-Setting Alone		F^a	p	d^b
	BL (n = 27)	8-week (n = 25)	BL (n = 29)	8-week (n = 28)			
Measure	M (SD)	M (SD)	M (SD)	M (SD)			
CAINS – Anticipatory pleasure	6.8 (3.3)	5.3 (2.5)	7.8 (2.8)	7.2 (2.5)	5.93	.02	-.66
CAINS – Past week pleasure	3.6 (2.3)	2.6 (1.9)	4.0 (2.0)	3.4 (1.4)	2.87	.096	-.46
CAINS – Expressive symptoms	5.1 (3.3)	4.4 (3.9)	6.0 (4.0)	5.2 (3.4)	.26	.62	-.14
CAINS – Overall negative symptoms	23.2 (7.6)	18.4 (8.5)	25.3 (6.0)	23.3 (7.7)	3.42	.07	-.50
PANSS – Positive symptoms	3.2 (.9)	2.7 (1.0)	2.9 (.8)	2.5 (.8)	.02	.89	-.04
PANSS – Mood symptoms	3.3 (1.1)	3.0 (1.2)	3.0 (1.1)	2.9 (1.1)	.01	.94	-.02
BNA – Neurocognition	-1.7 (1.2)	-1.7 (1.0)	-1.8 (1.1)	-1.6 (1.0)	.12	.73	-.10
WHOQOL – Overall QOL	3.4 (1.0)	3.6 (1.0)	3.2 (1.2)	3.6 (1.0)	.08	.78	-.07
Strauss-Carpenter – Functioning	16.9 (5.5)	19.4 (4.5)	17.0 (4.8)	19.0 (4.8)	.11	.74	.09

Note. Descriptive statistics are simple statistics without co-varying for baseline level of variable; BNA = brief neurocognitive assessment; CAINS = Clinical Assessment Interview for Negative Symptoms; PANSS = Positive and Negative Syndrome Scale; WHOQOL = World Health Organization Quality of Life; QLS = Quality of Life Scale; QOL = quality of life.

[a] Results based on those who completed both assessment points.

[c] Effect sizes were calculated with adjusted follow-up means and pooled standard deviations.

Supplemental Table 3. Correlations between MEMS Engagement and Outcome Change (n = 25)

Measure	r
CAINS – Motivation	.20
QLS – Motivation index	-.07
QLS – Motivation item	-.28
MAP-SR – Motivation	-.31
Value Representation Maintenance – % Delayed rewards	-.26
Effort-Cost Computations - % Hard chosen in 88%, high reward trials	-.61**
CAINS – Anticipatory pleasure	.43*
CAINS – Past week pleasure	.21
CAINS – Expressive symptoms	.21
CAINS – Overall negative symptoms	.40*
PANSS – Positive symptoms	-.09
PANSS – Mood symptoms	-.06
BNA – Neurocognition	-.17
WHOQOL – Overall QOL	-.24
Strauss-Carpenter – Functioning	-.09

Note. BNA = Brief Neurocognitive Assessment; CAINS = Clinical Assessment Interview for Negative Symptoms; MAP-SR = Motivation and Pleasure Self-Report PANSS = Positive and Negative Syndrome Scale; WHOQOL = World Health Organization Quality of Life; QLS = Quality of Life Scale; QOL = quality of life.
For CAINS and PANSS, positive correlation = higher response rate associated with greater reduction in symptoms. For other measures, negative correlation = higher response rate is associated with greater improvement in measure.
*p < .05, **p < .01.

REFERENCES

1. Wu EQ, Birnbaum HG, Shi L, Ball DE, Kessler RC, Moulis M, Aggarwal J. The economic burden of schizophrenia in the United States in 2002. *J Clin Psychiatry* 2005.

2. Foussias G, Mann S, Zakzanis K, Van Reekum R, Remington G. Motivational deficits as the central link to functioning in schizophrenia: a pilot study. *Schizophr Res* 2009;115(2-3):333-337.

3. Fervaha G, Foussias G, Agid O, Remington G. Motivational and neurocognitive deficits are central to the prediction of longitudinal functional outcome in schizophrenia. *Acta Psychiatr Scand* 2014;130(4):290-299.

4. Luther L, Firmin RL, Vohs JL, Buck KD, Rand KL, Lysaker PH. Intrinsic motivation as a mediator between metacognition deficits and impaired functioning in psychosis. *B J Clin Psychol* 2016;55(3):332-347.

5. Fervaha G, Agid O, Takeuchi H, Foussias G, Remington G. Clinical determinants of life satisfaction in chronic schizophrenia: data from the CATIE study. *Schizophr Res* 2013;151(1-3):203-208.

6. Foussias G, Mann S, Zakzanis K, van Reekum R, Agid O, Remington G. Prediction of longitudinal functional outcomes in schizophrenia: the impact of baseline motivational deficits. *Schizophr Res* 2011;132(1):24-27.

7. Nakagami E, Hoe M, Brekke JS. The prospective relationships among intrinsic motivation, neurocognition, and psychosocial functioning in schizophrenia. *Schizophr Bull* 2010;36(5):935-948.

8. Clarke SP, Oades LG, Crowe TP, Caputi P, Deane FP. The role of symptom distress and goal attainment in promoting aspects of psychological recovery for consumers with enduring mental illness. *J Mental Health* 2009;18(5):389-397.

9. Marder SR, Galderisi S. The current conceptualization of negative symptoms in schizophrenia. *World Psychiatry* 2017;16(1):14-24.

10. Fusar-Poli P, Papanastasiou E, Stahl D, Rocchetti M, Carpenter W, Shergill S, McGuire P. Treatments of Negative Symptoms in Schizophrenia: Meta-Analysis of 168 Randomized Placebo-Controlled Trials. *Schizophr Bull* Jul 2015;41(4):892-899.

11. Strauss GP, Waltz JA, Gold JM. A review of reward processing and motivational impairment in schizophrenia. *Schizophr Bull* 2013;40(Suppl_2):S107-S116.

12. Gold JM, Waltz JA, Prentice KJ, Morris SE, Heerey EA. Reward processing in schizophrenia: a deficit in the representation of value. *Schizophr Bull* 2008;34(5):835-847.

13. Green MF, Horan WP, Barch DM, Gold JM. Effort-based decision making: a novel approach for assessing motivation in schizophrenia. *Schizophr Bull* 2015;41(5):1035-1044.

14. Salamone JD, Cousins MS, Bucher S. Anhedonia or anergia? Effects of haloperidol and nucleus accumbens dopamine depletion on instrumental response selection in a T-maze cost/benefit procedure. *Behav Brain Res* 1994;65(2):221-229.

15. Assadi SM, Yücel M, Pantelis C. Dopamine modulates neural networks involved in effort-based decision-making. *Neurosci Biobehav Rev* 2009;33(3):383-393.

16. Salamone JD, Correa M, Farrar AM, Nunes EJ, Pardo M. Dopamine, behavioral economics, and effort. *Front Behav Neurosci* 2009;3:13.

17. Kellendonk C, Simpson EH, Polan HJ, Malleret G, Vronskaya S, Winiger V, Moore H, Kandel ER. Transient and selective overexpression of dopamine D2 receptors in the striatum causes persistent abnormalities in prefrontal cortex functioning. *Neuron* 2006;49(4):603-615.

18. Ward RD, Simpson EH, Richards VL, Deo G, Taylor K, Glendinning JI, Kandel ER, Balsam PD. Dissociation of hedonic reaction to reward and incentive motivation in an animal model of the negative symptoms of schizophrenia. *Neuropsychopharmacology* 2012;37(7):1699.

19. Treadway MT, Buckholtz JW, Schwartzman AN, Lambert WE, Zald DH. Worth the 'EEfRT'? The effort expenditure for rewards task as an objective measure of motivation and anhedonia. *PloS one* 2009;4(8):e6598.

20. Barch DM, Treadway MT, Schoen N. Effort, anhedonia, and function in schizophrenia: Reduced effort allocation predicts amotivation and functional impairment. *J Abnorm Psychol* 2014;123(2):387.

21. Treadway MT, Peterman JS, Zald DH, Park S. Impaired effort allocation in patients with schizophrenia. *Schizophr Res* 2015;161(2-3):382-385.

22. Fervaha G, Graff-Guerrero A, Zakzanis KK, Foussias G, Agid O, Remington G. Incentive motivation deficits in schizophrenia reflect effort computation impairments during cost-benefit decision-making. *J Psychiatr Res* 2013;47(11):1590-1596.

23. McCarthy JM, Treadway MT, Bennett ME, Blanchard JJ. Inefficient effort allocation and negative symptoms in individuals with schizophrenia. *Schizophr Res* 2016;170(2-3):278-284.

24. Reddy LF, Horan WP, Barch DM, et al. Effort-based decision-making paradigms for clinical trials in schizophrenia: part 1—psychometric characteristics of 5 paradigms. *Schizophr Bull* 2015;41(5):1045-1054.

25. Horan WP, Reddy LF, Barch DM, et al. Effort-based decision-making paradigms for clinical trials in schizophrenia: part 2—external validity and correlates. *Schizophr Bull* 2015;41(5):1055-1065.

26. Gard DE, Cooper S, Fisher M, Genevsky A, Mikels JA, Vinogradov S. Evidence for an emotion maintenance deficit in schizophrenia. *Psychiatry Res* 2011;187(1-2):24-29.

27. Heerey EA, Matveeva TM, Gold JM. Imagining the future: degraded representations of future rewards and events in schizophrenia. *J Abnorm Psychol* 2011;120(2):483.

28. Harding B, Torres-Harding S, Bond GR, Salyers MP, Rollins AL, Hardin T. Factors associated with early attrition from psychosocial rehabilitation programs. *Community Ment Health J* 2008;44(4):283-288.

29. Kurtz MM, Rose J, Wexler BE. Predictors of participation in community outpatient psychosocial rehabilitation in schizophrenia. *Community Ment Health J* 2011;47(6):622-627.

30. Heerey EA, Gold JM. Patients with schizophrenia demonstrate dissociation between affective experience and motivated behavior. *J Abnorm Psychol* 2007;116(2):268.

31. Heerey EA, Robinson BM, McMahon RP, Gold JM. Delay discounting in schizophrenia. *Cogn. Neuropsychiatry* 2007;12(3):213-221.

32. Linda QY, Lee S, Katchmar N, Satterthwaite TD, Kable JW, Wolf DH. Steeper discounting of delayed rewards in schizophrenia but not first-degree relatives. *Psychiatry Res* 2017;252:303-309.

33. Ahn W-Y, Rass O, Fridberg DJ, et al. Temporal discounting of rewards in patients with bipolar disorder and schizophrenia. *J Abnorm Psychol* 2011;120(4):911.

34. Granholm E, Ben-Zeev D, Link PC, Bradshaw KR, Holden JL. Mobile Assessment and Treatment for Schizophrenia (MATS): a pilot trial of an interactive text-messaging intervention for medication adherence, socialization, and auditory hallucinations. *Schizophr Bull* 2011;38(3):414-425.

35. Ben-Zeev D, Kaiser SM, Krzos I. Remote "hovering" with individuals with psychotic disorders and substance use: feasibility, engagement, and therapeutic alliance with a text-messaging mobile interventionist. *J Dual Diagn* 2014;10(4):197-203.

36. Kannisto KA, Adams CE, Koivunen M, Katajisto J, Välimäki M. Feedback on SMS reminders to encourage adherence among patients taking antipsychotic medication: a cross-sectional survey nested within a randomised trial. *BMJ Open* 2015;5(11):e008574.

37. Pijnenborg G, Withaar F, Brouwer WH, Timmerman M, Van den Bosch R, Evans J. The efficacy of SMS text messages to compensate for the effects of cognitive impairments in schizophrenia. *B J Clin Psychol* 2010;49(2):259-274.

38. Španiel F, Vohlídka P, Kožený J, Novák T, Hrdlička J, Motlová L, Čermák J, Höschl C. The Information Technology Aided Relapse Prevention Programme in Schizophrenia: an extension of a mirror-design follow-up. *International J Clinical Practice* 2008;62(12):1943-1946.

39. Montes JM, Medina E, Gomez-Beneyto M, Maurino J. A short message service (SMS)-based strategy for enhancing adherence to antipsychotic medication in schizophrenia. *Psychiatry Res* 2012;200(2-3):89-95.

40. Schlosser DA, Campellone TR, Truong B, Etter K, Vergani S, Komaiko K, Vinogradov S. Efficacy of PRIME, a mobile app intervention designed to improve motivation in young people with schizophrenia. *Schizophr Bull* 2018;44(5):1010-1020.

41. Ben-Zeev D, Brenner CJ, Begale M, Duffecy J, Mohr DC, Mueser KT. Feasibility, acceptability, and preliminary efficacy of a smartphone intervention for schizophrenia. *Schizophr Bull* 2014;40(6):1244-1253.

42. Naslund JA, Marsch LA, McHugo GJ, Bartels SJ. Emerging mHealth and eHealth interventions for serious mental illness: a review of the literature. *J Ment Health* 2015;24(5):321-332.

43. Clarke SP, Oades LG, Crowe TP, Deane FP. Collaborative goal technology: theory and practice. *Psychiatr Rehabil J* 2006;30(2):129.

44. Substance Abuse and Mental Health Services Administration. *Illness Management and Recovery: Practitioner Guides and Handouts.* HHS Pub. No. SMA-09-4462, Rockville, MD: Center for Mental Health Services, Substance Abuse and Mental Health Services Administration, U.S. Department of Health and Human Services; 2009.

45. First MB, Williams J, Karg RS, Spitzer RL. *User's guide to structured clinical interview for DSM-5 disorders (SCID-5-CV) clinical version*: Arlington, VA: American Psychiatric Publishing; 2015.

46. La Pray M, Ross R. The graded word list: Quick gauge of reading ability. *J Reading* 1969;12(4):305-307.

47. Kring AM, Gur RE, Blanchard JJ, Horan WP, Reise SP. The clinical assessment interview for negative symptoms (CAINS): final development and validation. *A J Psychiatry* 2013;170(2):165-172.

48. Bovend'Eerdt TJ, Botell RE, Wade DT. Writing SMART rehabilitation goals and achieving goal attainment scaling: a practical guide. *Clin Rehabil* 2009;23(4):352-361.

49. Schut H, Stam H. Goals in rehabilitation teamwork. *Disability Rehabil* 1994;16(4):223-226.

50. *TextIt*. http://textit.in. Kigali, Rwanda: Nyaruka and Unicef

51. Rotondi AJ, Eack SM, Hanusa BH, Spring MB, Haas GL. Critical design elements of e-health applications for users with severe mental illness: singular focus, simple architecture, prominent contents, explicit navigation, and inclusive hyperlinks. *Schizophr Bull* 2013;41(2):440-448.

52. Nakagami E, Xie B, Hoe M, Brekke JS. Intrinsic motivation, neurocognition and psychosocial functioning in schizophrenia: testing mediator and moderator effects. *Schizophr Res* 2008;105(1-3):95-104.

53. Heinrichs DW, Hanlon TE, Carpenter WT. The Quality of Life Scale: An Instrument for Rating the Schizophrenic Deficit Syndrome. *Schizophr Bull* 1984;10(3):388-398.

54. Fervaha G, Foussias G, Takeuchi H, Agid O, Remington G. Measuring motivation in people with schizophrenia. *Schizophr Res* 2015;169(1-3):423-426.

55. Llerena K, Park SG, McCarthy JM, Couture SM, Bennett ME, Blanchard JJ. The Motivation and Pleasure Scale–Self-Report (MAP-SR): Reliability and validity of a self-report measure of negative symptoms. *Compre Psychiatry* 2013;54(5):568-574.

56. Kirby KN, Petry NM, Bickel WK. Heroin addicts have higher discount rates for delayed rewards than non-drug-using controls. *J Exp Psychol Gen* 1999;128(1):78.

57. Lund AM. Measuring usability with the use questionnaire. *Usability interface* 2001;8(2):3-6.

58. Strauss JS, Carpenter WT. Prediction of outcome in Schizophrenia: III. Five-year outcome and its predictors. *Arch Gen Psychiatry* 1977;34(2):159-163.

59. Hawk AB, Carpenter WT, Strauss JS. Diagnostic criteria and five-year outcome in schizophrenia: A report from the International Pilot Study of Schizophrenia. *Arch Gen Psychiatry* 1975;32(3):343-347.

60. Skevington SM, Lotfy M, O'Connell KA. The World Health Organization's WHOQOL-BREF quality of life assessment: psychometric properties and results of the international field trial. A report from the WHOQOL group. *Qual Life Res* 2004;13(2):299-310.

61. Fervaha G, Hill C, Agid O, Takeuchi H, Foussias G, Siddiqui I, Kern RS, Remington G. Examination of the validity of the Brief Neurocognitive Assessment (BNA) for schizophrenia. *Schizophr Res* 2015;166(1-3):304-309.

62. Fervaha G, Agid O, Foussias G, Remington G. Toward a more parsimonious assessment of neurocognition in schizophrenia: a 10-minute assessment tool. *J Psychiatr Res* 2014;52:50-56.

63. Kay SR, Fiszbein A, Opfer LA. The positive and negative syndrome scale (PANSS) for schizophrenia. *Schizophr Bull* 1987;13(2):261-276.

64. Guidance E9: Statistical Principles for Clinical Trials, recommended for adoption to the regulatory bodies of the European Union. *International Conference on Harmonisation*. Japan and USA; 1998.

65. Gard DE, Fisher M, Garrett C, Genevsky A, Vinogradov S. Motivation and its relationship to neurocognition, social cognition, and functional outcome in schizophrenia. *Schizophr Res* 2009;115(1):74-81.

66. Cohen J. A Power Primer. *Psychol Bull* 1992;112:155-159.

67. Yu R. Regional white matter volumes correlate with delay discounting. *PloS one* 2012;7(2):e32595.

68. Depp CA, Mausbach B, Granholm E, Cardenas V, Ben-Zeev D, Patterson TL, Lebowitz BD, Jeste DV. Mobile interventions for severe mental illness: design and preliminary data from three approaches. *J Nerv Ment Dis* 2010;198(10):715.

69. Firth J, Cotter J, Torous J, Bucci S, Firth JA, Yung AR. Mobile phone ownership and endorsement of "mHealth" among people with psychosis: a meta-analysis of cross-sectional studies. *Schizophr Bull* 2015;42(2):448-455.

70. Ben-Zeev D, Davis KE, Kaiser S, Krzsos I, Drake RE. Mobile technologies among people with serious mental illness: opportunities for future services. *Administration Policy Ment Health* 2013;40(4):340-343.

71. Mohr DC, Riper H, Schueller SM. A solution-focused research approach to achieve an implementable revolution in digital mental health. *JAMA psychiatry* 2018;75(2):113-114.

72. Tilahun B, Smillie K, Bardosh KL, et al. Identifying Barriers and Facilitators of 13 mHealth Projects in North America and Africa: Protocol for a 5-Year Implementation Science Study. *JMIR Research Protocols* 2018;7(7).

73. Franz-Vasdeki J, Pratt BA, Newsome M, Germann S. Taking mHealth solutions to scale: enabling environments and successful implementation. *J Mobile Technol Med* 2015;4(1):35-38.

74. Goldstein RZ, Tomasi D, Alia-Klein N, Cottone LA, Zhang L, Telang F, Volkow ND. Subjective sensitivity to monetary gradients is associated with frontolimbic activation to reward in cocaine abusers. *Drug Alcohol Depend* 2007;87(2-3):233-240.

75. Luther L, Fischer MW, Firmin RL, Salyers MP. Clarifying the overlap between motivation and negative symptom measures in schizophrenia research: A meta-analysis. *Schizophr Res* 2018.

76. Hartmann MN, Hager OM, Reimann AV, Chumbley JR, Kirschner M, Seifritz E, Tobler PN, Kaiser S. Apathy but not diminished expression in schizophrenia is associated with discounting of monetary rewards by physical effort. *Schizophr Bull* 2015;41(2):503-512.

77. Beebe L, Smith KD, Phillips C. A comparison of telephone and texting interventions for persons with schizophrenia spectrum disorders. *Issues Ment Health Nurs* 2014;35(5):323-329.

78. Practice guideline for the treatment of patients with schizophrenia. American Psychiatric Association. *Am J Psychiatry* Apr 1997;154(4 Suppl):1-63.

79. Woods SW. Chlorpromazine equivalent doses for the newer atypical antipsychotics. *J Clin Psychiatry* Jun 2003;64(6):663-667.

80. Woods SW. Chlorpromazine equivalent doses for atypical antipsychotics: An update. 2011.

81. Bickel WK, Pitcock JA, Yi R, Angtuaco EJ. Congruence of BOLD response across intertemporal choice conditions: fictive and real money gains and losses. *J Neurosci* 2009;29(27):8839-8846.

82. Lagorio CH, Madden GJ. Delay discounting of real and hypothetical rewards III: Steady-state assessments, forced-choice trials, and all real rewards. *Behav Processes* 2005;69(2):173-187.

83. Myerson J, Baumann AA, Green L. Discounting of delayed rewards:(A) theoretical interpretation of the Kirby questionnaire. *Behav Processes* 2014;107:99-105.

84. Gold JM, Carpenter C, Randolph C, Goldberg TE, Weinberger DR. Auditory working memory and Wisconsin Card Sorting Test performance in schizophrenia. *Arch Gen Psychiatry* 1997;54(2):159-165.

85. Keefe RS, Goldberg TE, Harvey PD, Gold JM, Poe MP, Coughenour L. The Brief Assessment of Cognition in Schizophrenia: reliability, sensitivity, and comparison with a standard neurocognitive battery. *Schizophr Res* 2004;68(2-3):283-297.

86. Bell MD, Lysaker PH, Beam-Goulet JL, Milstein RM, Lindenmayer J-P. Five-component model of schizophrenia: assessing the factorial invariance of the positive and negative syndrome scale. *Psychiatry Res* 1994;52(3):295-303.