A Smartphone App for Parental Management of Adolescent Conduct Problems:

Randomized Clinical Trial of iKinnect

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Abstract

Objective: This study evaluates iKinnect, a linked caregiver-teen mobile app system designed to address serious adolescent conduct problems through a focus on key targets of evidence-based treatments for juvenile offending, such as parent expectation setting, monitoring, consistency, and positive reinforcement. Additional gamification and autonomy-supporting features are designed to maximize youth engagement. Digital therapeutics such as mobile apps have great potential to expand access to effective interventions, particularly for youth who engage in serious conduct problems and substance abuse, since most never receive an evidence-based treatment and few apps exist for these concerns.

Methods: This randomized clinical trial used a short-term (12 week) longitudinal design with four time points. Recruited was a U.S. national sample of teens (n = 72, age 13-17, 59.7% male, 68.1% White) receiving services for a serious conduct problem and their primary caregiver. The efficacy of iKinnect, used by parent and teen dyads, was measured against an active control condition, Life360, an app that provided mutual GPS-based location tracking to dyads.

Results: Across 12 weeks of app use, youth who used iKinnect showed significantly greater reductions in alcohol use, marijuana use, school delinquency, status offenses, and general delinquency than did controls. Parents who used iKinnect reported greater improvements in structure/rule clarity and discipline consistency relative to control parents. Teen and parent iKinnect app use and acceptability ratings were high.

Conclusions: Real-world use of iKinnect in future applications can, like other emerging digital health technologies, help to expand the reach of evidence-based interventions to children, youth, and families.

Keywords: Conduct disorder, juvenile offending, externalizing behavior, smartphone app, intervention outcome

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By their 18th birthday, at least 16% of adolescents have been arrested (Brame et al., 2012), 21% have started drinking (Substance Abuse Mental Health Services Administration [SAMHSA], 2019), 16% have used marijuana (SAMHSA, 2019), 9.5% meet criteria for conduct disorder (Nock et al., 2006), and 7% have dropped out of high school prior to graduation (Kena et al., 2015). When these concerns persist, youth with conduct problems are at high risk for multiple adverse long-term outcomes, such as chronic unemployment (Fergusson et al., 2013), adult criminal offending (Loeber et al., 2009), addiction (McCarty et al., 2013), and premature mortality (Border et al., 2018). Although several evidence-based interventions exist to address serious externalizing problems, the vast majority of youth who could benefit never receive one (Kazdin, 2019), not even within juvenile justice settings where most treatment for this population occurs (Fagan et al., 2019). Given these realities, a broader public health approach involving low-cost and scalable evidence-based interventions is needed.

In light of the near ubiquity of adolescent smartphone use, mobile apps and other self-administered digital therapeutics (Carl et al., 2021) have great potential for increasing access to evidence-based interventions and reducing the personal, familial, and societal burden of serious conduct problems. Such technologies could be provided in natural settings (e.g., homes, schools, pediatrician offices) at very low cost. A plethora of mobile apps targeting child and adolescent mental health concerns are now available in the app marketplace, but only a handful include evidence-based intervention content, target known mechanisms of change, or have empirical support for their efficacy (for reviews, see Buttazzoni, Brar, & Minaker, 2021; Hollis et al., 2017; see also Stoll & Pina, 2018). In general, stand-alone (i.e., those used with no or minimal provider assistance) evidence-based digital therapeutics have been shown to be effective in reducing symptoms and improving functioning relative to passive or placebo control interventions, especially for internalizing disorders, with small to moderate

effect sizes; few have been evaluated relative to traditional in-person therapy. Other digital therapeutics designed as adjuncts to traditional treatment used with provider facilitation also generally outperform treatment-as-usual (Hollis et al.).

With regards to evidence-based digital therapeutics designed to address externalizing disorders, two examples are noteworthy. Tantrum Tamers is an app designed to augment Helping the Noncompliant Child (HNC; McMahon & Forehand, 2003), a well-validated parent management training intervention for children (ages 3-8 years old). The app is comprised of HNC-based components. A recent randomized clinical trial (RCT) found parents who used Tantrum Tamers completed HNC in fewer sessions and sustained treatment changes longer than parents receiving only HNC (Jones et al., 2021; Parent et al., 2021). Plan-It Commander is an online "serious game" for pre-adolescents (ages 8-12) with attention-deficit hyperactivity disorder that promotes practice of evidence-based behavioral strategies; an RCT evaluating Plan-it-Commander as a supplement to outpatient treatment indicated improvements in areas such as time management, social skills, and working memory relative to treatment as usual (Bul et al., 2016). Although some apps designed for adults to address substance abuse have been tested in samples that include participants as young as age 18 (Gustafson et al., 2014), we are aware of no digital therapeutics that have been evaluated with adolescents experiencing serious conduct problems.

In considering how a smartphone app might be used to support change in adolescents engaged in problems such as chronic truancy, violence, or criminal offending, a rich body of treatment outcome research points to the need for a parental component. Numerous comprehensive reviews and clearinghouse efforts (e.g., McCart & Sheidow, 2016; Mihalic & Elliott, 2015) and meta-analyses of treatment outcome studies (e.g., Mingebach et al., 2018; van der Stouwe et al., 2014) have concluded that the most effective interventions for adolescent conduct problems involve a robust focus on improving parent management techniques and the parent-teen relationship. Consistent with the risk factor literature (Beauchaine & Hinshaw, 2016), empirically-supported treatments for juvenile offending

such as Functional Family Therapy (FFT; Sexton, 2019), Multisystemic Therapy (MST; Henggeler, 2011), and Treatment Foster Care-Oregon (TFC-O; Chamberlain, 2003) all seek to improve caregiver skills in setting clear expectations, monitoring youth whereabouts and activities, and providing consistent disciplinary and positive (e.g., praise) responses to youth behavior. Although FFT, MST, and TFC-O all have achieved the highest standards of evidence (e.g., "model programs" in Blueprints for Healthy Youth Development; Mihalic & Elliott, 2015), only FFT and MST focus exclusively on building the skills of natural caregivers. And, although treatment process research has linked elements of FFT with positive outcomes for youth who abuse substances (e.g., Ozechowki, 2014), only MST has identified change mechanisms that account for its success with juvenile offenders. Specifically, Huey et al. (2000) found that MST led to improved parental monitoring and family cohesion which, in turn, led to decreased youth associations with deviant peers and reductions in criminality. Another study found that increases in parental monitoring and discipline consistency, along with decreases in youth deviant peer affiliation, accounted for MST effects for youth engaged in juvenile drug court (Schaeffer et al., 2010).

Given its effectiveness and appropriateness for the target population, MST guided the design of iKinnect, a paired mobile app system that supports caregivers (in delivering) and youth (in receiving) evidence-based techniques to reduce youth serious conduct problems. Like iKinnect, MST is designed for adolescents ages 13-18, the developmental period when youths' autonomy is increasing but caregiver support is still critical. MST is based on Bronfenbrenner's (1979) social-ecological model, which maintains that youth behavior is largely determined by the functioning of the multiple systems (i.e., family, school, peer, and neighborhood) in which the youth is embedded. MST contends that caregivers are the key agents of youth change and that barriers to effective parenting (e.g., low social support, low confidence) must be addressed. The MST logic model suggests that improved parent management and increased parent-teen warmth leads to better youth functioning with peers (i.e., fewer deviant peer and more prosocial peer associations), in school (i.e., better attendance and behavior), and in the

community (i.e., less access to deviant settings, increased prosocial activities) which, in turn, reduces serious conduct problems and substance use (Henggeler, 2011).

Using user-centered design (UCD) processes led by mobile app design and UCD experts, iKinnect was iteratively developed with extensive testing and feedback from target end-users (i.e., youth with conduct problems and their caregivers) over a two-year period to ensure usability, acceptability, and clinical relevance (see Schaeffer et al., 2022). MST experts, consultants, and providers also gave feedback throughout development to ensure app congruence with MST principles. The resulting linked parent-teen app system interacts throughout the day to help parents monitor youth activities and respond consistently with tangible (i.e., reward points) and relational (i.e., praise and acknowledgment) rewards for appropriate behavior. The teen version supports positive behavior through structure, reminders, and rewards, and uses autonomy-supporting and gamification to enhance engagement. Our goal was to create a digital therapeutic that could be used by families of a teen with a serious conduct problem receiving no or only minimal formal services, in an effort to maximize the reach of these evidence-based features.

This study reports findings from a short-term longitudinal randomized clinical trial (RCT) that examines the effectiveness of caregiver and teen use of iKinnect relative to an active control condition, use of Life360, an app that allows users to know family members' whereabouts on demand through GPS-based tracking. A nationally-recruited U.S. sample of teens receiving services for a serious conduct problem and their primary caregiver participated, with randomization occurring at the dyad level. Across 12 weeks, caregiver-teen dyads used their assigned app as desired and participated in assessments at four time points examining a range of youth externalizing behaviors, parent distress indicators, and parent management techniques. We hypothesized that relative to dyads who used Life 360, youth who used iKinnect would show greater declines in externalizing behaviors. We also hypothesized that caregivers who used iKinnect would report decreasing levels of stress, helplessness, and lack of control

in parenting their teen than would caregivers using Life360, since iKinnect gives caregivers ideas and an organizing framework for addressing conduct problems. We further hypothesized that because iKinnect directly assists caregivers in setting expectations, monitoring compliance, and consistently responding, caregivers in this arm would show greater improvements in these parenting skills.

Method

Sample

Participants were youth with a current serious conduct problem (n = 72) ages 13 to 18 (M = 14.7, SD = 1.3) and their primary caregiver (n = 72). Most (59.7%) youth participants identified as male. The youth sample racial composition was 68.1% White, 15.3% Black, 12.5% mixed race, 1.4% Asian/Pacific Islander, 1.4% American Indian/Alaskan Native, and 1.4% Other; 19.4% also identified as Hispanic. The majority (81.9%) were enrolled in school, 26.4% had been arrested previously, and 16.7% were previously incarcerated. All participating caregivers identified as female (age M = 39.1; SD = 6.8) and had on average 2.7 children (including the target youth) in their household (SD = 1.2). Because 97.3% of caregivers were the youth's biological or adoptive parent, the term "parent" will be used hereafter. Parents were 77.8% White, 12.5% Black, 6.9% mixed race, 1.4% Asian/Pacific Islander, and 1.4% American Indian/Alaskan Native; 11.1% also identified as Hispanic. Socioeconomically, 50% of parents reported their highest level of educational attainment as high school or lower, 37.5% were unemployed, and 61.1% reported an income < $50,000. Most parents (93.0%) reported their current technology use as "high" on a 3-point scale (low, medium, high). Dyads were primarily recruited through social media (79.2%), with the remainder through a service provider. Participants randomized to receive iKinnect were significantly more likely to have learned of the study through social media, but the two study arms otherwise did not differ on any youth or parent demographic characteristic (see Table 1).

Eligibility and Recruitment

All participants were required to be English speaking (iKinnect was only available in English) and own an Android or iOS smartphone with a data plan. Youth eligibility criteria included being between the ages of 13 and 18, residing with the linked parent at least five days a week, and currently experiencing a clinically significant conduct problem, defined as one of the following: (a) history of arrest, or (b) receiving a T score of 64 or higher (92nd percentile) on the 10-item *Child Behavior Checklist Externalizing Behavior Screening Scale* (Achenbach & Rescorla, 2001; Petersen et al., 2016; raw score threshold = 6 or higher on the measure's range of 0-20). To address stakeholder concerns that an untested app would be insufficient support for families of a teen with a clinically significant conduct problem, all youth also had to have received behavioral health or probation services for their conduct problem within the past month. No exclusion criteria were established for youth. Parents were eligible to participate if they were at least 18 years old and were a primary caregiver of the participating youth. In light of concerns that involvement in child protective services could impede a parent's ability to use a parenting app, and that parents with a recent incident of child maltreatment could misuse the app, dyads with an open CPS case were excluded from participation.

Recruitment occurred two ways, through providers and using Facebook advertisements. First, advertisements about the study were distributed nationally, to several county-level juvenile justice systems and to several multi-state organizations known to provide outpatient and home-based treatment to high numbers of youth with serious conduct problems. In serving youth with conduct problems, most of the providers offered both standard outpatient treatment services and intensive evidence-based treatments (i.e., FFT or MST); most opted to advertise the study to both populations. Staff were asked to tell parents they worked with about the opportunity and to provide a link to the study website. In the other recruitment strategy, study information was circulated on Facebook using purchased advertisements strategically targeted to parents who followed pages relating to parenting or teen behavior problems, and ads included a link to the study website.

Figure 1 presents the Consort diagram. In total, 551 dyads expressed interest in participating in the study by providing contact information at a secure study website. Of these, 522 dyads completed an initial screening interview; many were deemed ineligible, most commonly due to the youth not currently receiving services (42.3%), a phone or app issue (17.5%; e.g., no data plan, already using Life360), the youth being subthreshold on conduct problem severity (9.8%), or multiple different reasons for screening out (12.0%). Of 196 eligible dyads, 120 were lost after screening or otherwise did not provide consent. Of the 76 parents who consented, 73 youth also provided assent, and one dyad dropped out after consent/assent but before baseline assessment and randomization. Ultimately, 72 caregiver-youth dyads were randomized to condition (iKinnect=38 dyads; Life360=34 dyads).

Interventions

iKinnect

iKinnect is a native app built for both Android and iOS. Linked parent-teen features functioned under all possible phone operating system combinations (i.e., Android-iOS, iOS-iOS, etc.).

Parent version. Clinical targets of the MST treatment approach informed features for the parent version of iKinnect. Parent app features included: (a) *Guided Game Plan Set-Up***.** The iKinnect game plan operationalizes the MST goal for parents to set clear and developmentally-appropriate expectations for youth behavior, particularly those relating to improved school functioning and avoidance of deviant peers, activities, and settings. At the start of app use, parents are guided through a set-up module where they define their expectations (their *game plan*) for what youth should do (their activities) and where they should or shouldn't be (locations) by selecting from five pre-defined expectation categories and one open-ended (i.e., parent articulates required tasks not covered by existing categories) option (see Table 2). Parents build a game plan calendar for their youth's expected activities (e.g., go to school Monday-Friday from 8:00am to 3:30pm; complete homework daily), which are then depicted graphically in the app as *challenge cards* (one card per rule) (b) *Reward Store*. Consistent with the MST technique

for parents to acknowledge positive teen behavior, as part of initial set-up, parents are guided through how to establish real-world rewards (e.g., extended curfew on Friday night, access to video games) the youth can earn with points they accumulate in the app for completing an expected activity. (c) *Geofencing***.** Geofencing helps with parental monitoring, a key component of MST. Parents set geofencing boundaries for location-based required activities (e.g., school, back at home for curfew), for "acceptable" additional locations the youth may be during unscheduled times (e.g., Aunt's house, community center, church), and for off-limits locations the youth is expected to avoid (e.g., abandoned lot, home of an older associate). (d) *Automatic Notifications and Alerts***.** Once the game plan is established, the paired mobile app system automatically tracks the youth's whereabouts using the youth's phone GPS and alerts parents if the youth is at the location of the expected scheduled activity (confirmation notifications) or has entered an off-limits location (alerts). When their teen does do the expected activity, iKinnect prompts parents to reinforce the desired behavior (e.g., respond with a personal text or emoji) in real time. When the youth is not at an expected location or is outside the geofence range of acceptable locations, when alerted, parents are also coached to check in and support their youth to get back on track. In alignment with MST techniques, notifications and alerts were designed to enhance parental monitoring, consistent responding, and warm/supportive responding. (e) *On-Demand Find My Teen.* Parents can easily locate their youth in real-time with a single click. (f) *Approval of challenge completion*. Parents receive prompts to verify whether youth expectations for challenges that are not location-based (e.g., take medication, do homework) have or have not occurred and, if the expectation is met, allocate points to the youth. (g) *Modeling Videos.* Five brief parent skills training videos demonstrate additional MST-consistent skills for challenging teen situations: intervening in real time when your youth is in a high-risk situation, staying firm when your teen protests, using non-phone-based monitoring techniques such as talking with your teen, verbally expressing gratitude and warmth to a teen, and calming down after an upsetting exchange.

Teen version. Three primary features define the youth version of iKinnect: (a) *Game Plan.* Youth can easily see and review their game plans (daily parental expectations) for where (location) they are supposed to be when (time of day), and how they are to conduct themselves. Each parental expectation is depicted in the game plan as a *challenge card.* (b) *Reminders and Alerts.* Like calendar notifications, youth are reminded about upcoming events (e.g., "leave for school in 15 minutes") and other daily challenges they are expected to meet to achieve daily rewards. For geofence-linked rules, iKinnect issues an alert when the youth is not where they are expected to be and coaches the youth to change behavior by reminding them of consequences and rewards. (c) *Rewards.* Using gamification techniques (e.g., increasing points for streaks, leveling up), youth see their points accumulate in real time as they perform tasks. Points can be exchanged for parent-selected prizes, which appear in a *reward store*.

In addition to primary features, three additional functions were designed to enhance teen engagement and autonomy. First, youth can accept or reject parent expectations at the time they receive them, and "cards" are not "in play" until they are accepted. When a card is rejected, parents receive a notice to talk with their teen as to why the expectation is important, and parents can resend (re-request) cards at any time. Second, youth can proactively send parents an alert (e.g., "homework now complete") when a particular required task is complete to prompt them to authorize points. Finally, teens can request specific rewards from the reward store when they have sufficient points.

Life360

Life 360 is a popular commercially-available app that allows family members to track the location of their loved ones on demand in real time. Both parents and teens in this arm installed and used the free version of Life360. Whereas the iKinnect *Find My Teen* feature only allowed parents to track teen whereabouts, Life360 also allowed teens to know the locations of their parent.

Procedures

Study procedures were approved by Behavioral Health Research Collective as well as the

university's Institutional Review Board. A Certificate of Confidentiality was secured at the project's start. Enrollment was on a first come, first serve basis and was open from June 2018 through April 2019. Persons interested in participating contacted the research team using a secure website, dedicated voicemail box, or email address. Screening and informed consent/assent procedures were conducted as phone meetings with the researcher were held separately with the parent and youth; both members had to provide consent or assent for the dyad to be accepted into the study. Separate parent and teen phone appointments also were scheduled to conduct the baseline and all subsequent assessments. All assessment measures were collected using Survey Monkey while a research assistant stayed on the phone call to answer questions and, when necessary or requested, read items aloud.

For allocation to study arms, a minimization random assignment procedure (White & Freedman, 1978) was used where youth were matched on: (1) History of juvenile justice system involvement (no history of juvenile justice involvement, current or past involvement, but no history of out-of-home placement, or past history of juvenile justice involvement with out-of-home placement); (2) youth age at time of consent (13-14 years; 15-16 years; or 17-18 years); and (3) youth intervention involvement (in juvenile justice probation services only; in treatment, but not evidence-based; or receiving an evidence-based intervention). As caregivers were yoked to youth, their assignment was automatically determined. Participants learned their study condition immediately after the second dyad member completed the baseline assessment. A research team member then guided each participant in how to download and activate their respective app (for iKinnect, parents and teens were given a unique access code). Given our ultimate goal to develop an app that could have the widest possible reach and be provided outside of any formal intervention context, parents and youth were not given any training or suggestions for how to use iKinnect. Participants in both study arms were instructed simply to use their app as they wished for the 12-week study duration and were informed that research assistants were available by telephone, text, and email for the study's entirety to answer technical questions.

Parents and youth repeated the same assessment battery at 4, 8, and 12 weeks post-baseline using the same procedures, and were encouraged to participate independent of whether they had used their assigned app. Research assistants were aware of participant condition when conducting follow-up assessments. Participants were compensated for each assessment and were incentivized with an increasing payment structure and a bonus for completing all assessments. Total possible compensation was $240 for caregivers and $140 for youth for a maximum of $380 per family.

Measures

With the exception of indicators of app acceptability and iKinnect use (week 12 only), all measures were administered at each time point and used a past two weeks reporting period. For most constructs, both parents and teens provided ratings. Other constructs involved only the parent (i.e., parent distress) or youth (i.e., alcohol use, marijuana use, and delinquent behaviors) perspectives.

App Acceptability and Use

System Usability Scale (SUS; Brooke, 1996)*.* The SUS, which measured the usability and acceptability of each mobile phone app (Life 360 or iKinnect) to the parent and teen, was administered only at the Week 12 assessment. The scale was comprised of 10 items each with a 5-point response scale (1=Strongly Disagree; 5=Strongly Agree). An example item is, "I thought the research app (iKinnect or Life360) was easy to use." Items were summed with higher scores indicated greater acceptability.

iKinnect use. Data pertaining to actual use of the assigned app was available only for dyads in the iKinnect condition and were taken directly from the app server. iKinnect usage was examined for 94 days after the date that the dyad was randomized, corresponding to the 12-week study period (84 days) plus an additional 10 days to account for variability in when participants met with research staff for guidance on app installation. Indicators available included number and types of rules set by parents, degree to which youth met daily challenges, youth points earned, and use of reward store.

Youth Problem Behaviors

Alcohol and marijuana use. Two items from the substance frequency scale of the Global

Appraisal of Individual Needs (GAIN-Q3; Dennis et al., 2003) were used to assess youth alcohol and

marijuana use: During the past 2 weeks, on how many days have you "used any kind of alcohol?" and

"used marijuana, hashish, blunts, or THC?" Data were recorded as counts. The GAIN-Q3 has been used

extensively with adolescents (Davis et al., 2016; Godley et al., 2008). Equivalent items for other drug

categories could not be examined due to zero frequencies at all time points.

Self-Report of Delinquency (SRD; Elliott et al., 1990). The 26-item SRD is a widely-used measure

that asks youth to report how many times in the past two weeks they engaged in a number of

delinquent and illegal behaviors. Total numbers of times were tallied for all items for the *general*

delinquency scale. In addition, two subscales, *status offenses* (e.g., ran away from home, purchased

alcohol, truant) and *school delinquency* (e.g., cheated on tests, damaged school property, got

suspended) were examined. Other available SRD subscales (i.e., minor theft and robbery) could not be

examined due to zero frequencies at all time points.

Aggressive and rule breaking behaviors. Parents and youth responded to items relating to the

two externalizing behavior subscales available through the Child Behavior Checklist (CBCL) and the

Youth Self Report (YSR) of the Achenbach System of Empirically Based Assessment (ASEBA; Achenbach &

Rescorla, 2003). Each subscale item relating to *aggressive behavior* (19 items; e.g., "gets in fights;"

"attacks people") and *rule breaking* (17 items; e.g., "sets fires;" "steals outside of the home") had three

possible responses (0=Not True; 1=Somewhat or sometimes true; 2=Very true or often true). Internal

consistencies were strong for both subscales across all time points and respondents (aggression, parent

α = .90 - .93, youth α = .86-.90; rule-breaking, parent α = .83 - .90, youth α = .77-.84).

Parent Distress

Perceived Stress. The Perceived Stress Scale (PSS; Cohen, 1988) is a 10-item measure of parents'

overall stress within the last two weeks. An example item is, "how often have you felt that you were

unable to control the important things in your life? (0=Never; 4=Very Often)." All 10 items were summed for a total score, with higher scores indicating higher perceived stress. Internal consistency across timepoints was strong (α =.78-.83).

Parent Locus of Control (PLC; Campis et al., 1986). The PLC measures parents' feelings of *helplessness* (10 items; e.g., "What I do has little effect on my teen's behavior") and *lack of control* (10 items; e.g., "I allow my teen to get away with things") using five-point scales (1=Strongly Disagree; 5=Strongly Agree). For each scale, items were summed, with higher sums indicating greater helplessness (α = .72-.82) and greater lack of control (α = .85-.89).

Parenting Behaviors

Both parents and teens reported on aspects of parenting behavior. Scales from the Parents as Social Context Questionnaire (PSCQ; E. Skinner et al., 2005) were used as measures of household rule clarity (on the PSCQ, "chaos") and parents use of coercion. Measures relating to the parent's monitoring and supervision of the teen, discipline consistency, and use of rewards were taken from subscales of the Loeber Parenting Scale (Loeber et al., 1991), widely used in studies of juvenile offenders.

Rule clarity. This scale was comprised of five parent items (e.g., "I change the rules a lot at home") and four youth items (e.g., "My parent keeps changing the rules on me")(both reverse scored). Parents and teens responded to items using a four-point scale (1=Less True; 4=More True); respondent's scores were summed separately. Higher scores indicate more clarity. Internal consistency across timepoints was acceptable (parent α = .65-.84; youth α = .75-.89).

Coercion. The coercion scale was comprised of 5 items for parents (e.g., "To get my child to do something, I have to yell at him/her") and 4 items for youth (e.g., "My parents think there is only one right way to do things - their way"), each with a four-point response scale (1=Less True; 4=More True). High scores indicate more coercion. Internal consistency across timepoints was strong (parent α = .79-.83; youth α = .83-.88).

Parental monitoring and supervision. The parent version (8 items) includes items such as "Do you know who the companions of your teen are when he/she is not home?" The youth version (10 items) includes items such as "Does your parent know where you are when you are away from home?" Response scales vary depending on the nature of the item but all involve 3- to 4-point Likert scales (e.g., 1=almost never, 2 = sometimes, 3 = sometimes). Items were summed with higher scores indicating greater monitoring. Internal consistency across time was strong (parent α = .81-.84; youth α = .89-.91).

Discipline consistency. The parent version (8 items) includes items such as "If a punishment has been decided upon, can your teen change it by explanations, arguments, or excuses?" An example youth-version (9 items) item is "Does your parent sometimes punish you for something and at other times not punish you for the same thing?" Response scales involved Likert scales (3 or 4 levels) that were summed, with higher scores indicating greater parental monitoring. Internal consistency across timepoints was strong (parent α = .71-.80; youth α = .63-.75).

Use of rewards. Parent and teen versions of the use of rewards scale involved 9 fully parallel items with wording tailored to the respondent. The stem for all items for parents [youth] was "In the past two weeks when your teen [you] did something that you [your parent] liked or approved of, how often did you [he/she]..." An example item is, "say something nice about it, praise, or give approval?" Items used a 3-point Likert response scale (1=almost never, 2 = sometimes, 3 = sometimes). Internal consistency across timepoints was adequate (parent α = .58-.69; youth α = .78-.86).

Data Analysis

Analyses were intent-to-treat and so included data from dyads with complete data as well as those who did not finish the study or who had missing data for other reasons. Latent growth curve modeling (LGM) and Mplus Version 8 (Muthén & Muthén, 2017) were used to examine change over time and intervention effects. Statistical models included data from all four time points: pre-treatment (baseline), and at 4, 8, and 12 weeks post-baseline. Outcome measures of aggression, rule

breaking, parent distress, and parenting skill were modeled using continuous variable LGMs. For count outcomes (alcohol use, marijuana use, and delinquency), several linkage functions were explored (i.e., Poisson, zero-inflated Poisson, and negative binomials), and the Poisson linkage function was determined to be the best fit for all. Parent and teen reports were analyzed separately.

For all outcomes, models with different assumptions about the nature of change over time (e.g., intercept-only vs. linear change) and other parameter specifications (e.g., fixed vs. freely-estimated residual variances) were tested. Specifications that significantly improved model fit were retained. In all cases, the linear function was retained with intervention condition examined as a predictor of intercept and slope. To increase model fit, potentially relevant covariates also were considered as predictors; those that further improved model fit were retained. For all outcomes, covariates were youth race (white/nonwhite), age, sex (male/female; no other statuses observed), juvenile justice system involvement (yes/no), and recruitment pathway (Facebook vs, other-unknown); for parent-reported outcomes, covariates also included parent age. Final absolute fit index scores for continuous outcomes were adequate using both the Comparative Fit Index (CFI; see Table 3) and the Root Mean Square Error of Approximation (RMSAS; range .000 to .046). Because there are no criteria for judging the absolute fit of count-based LGMs, the Baysian Information Criterion (BIC) and the Yuan-Bentler chi-square difference test for nested models were used to compare the relative fit of models with different assumptions, and best fitting models were retained.

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Results

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iKinnect App Usage

All parents who received iKinnect used the game plan feature (made at least one rule), with great variability in how many rules parents set (range 1-22 rules, *M* = 4.33, *SD* = 4.2). As expected, most rules (57.2% of all rules) were set within the first week of iKinnect usage, although a sizeable portion (22.7%) were set during the second and third months of the study, suggesting consistent and ongoing

parental engagement with the tool. On average, teens had at least one rule active on 44.9 days out of 94

total study days (range 3-89 days, SD = 23.8). As shown in Table 2, parental rules set (challenge cards)

were most commonly related to going to school and completing a required task (e.g., homework,

chores). Overall, 95% of teens earned at least some points, and youth met expectations on average

about 60% of the time (see Table 2).

App Satisfaction and Usability

Parent users of iKinnect and of Life360 were equally satisfied with the usability of their app, M =

84.7 vs. M = 78.0, respectively, $F(1, 71)$ = 3.49, p = .065. Youth ratings for the two apps also did not

differ, Life360 M = 74.4 (SD = 18.6) vs. iKinnect M = 69.3 (SD = 18.2), $F(1, 71)$ = 1.12, p = .295. Among

youth iKinnect users, satisfaction ratings did not differ across age groups (13-14 M = 70.6, 15-16 M =

70.6, 17-18 M = 81.7, ns), sexes (Female M = 71.8, Male M = 72.0, ns), racial groups (Youth of Color M =

73.6, White Youth M = 71.5, ns), and JJ status (involved never M = 74.2 vs. current/in past, M = 72.1, ns).

Change in Clinical Outcomes Across 12 Weeks

Youth problem behaviors. As shown in Table 3, across 12 weeks of app use, there were

significant across-condition linear changes in some youth problem behaviors, including youth-reported

marijuana use and school delinquency (increases), and in youth- and parent-reported aggression

(decreases). Relative to those using Life360, youth who used iKinnect showed significant decreases over

time in alcohol use, general delinquency, and status offenses, and significantly lower increases over time

in marijuana use and school delinquency, with medium to large effect sizes ranging from d = .54 to d =

.84 (Cohen, 1998). Intervention condition was not related to change for youth- or parent-reported

aggression and rule breaking.

Parent distress and parenting behaviors. Across time, parents reported significantly decreasing

across-condition levels of perceived stress, helplessness, and feelings of low control in their parenting.

Parents also reported significant across-condition decreases in their monitoring and supervision of the

teen across 12 weeks, whereas youth reported a significant increase. Both parents and youth also reported significant declines in parents' use of coercive discipline. Although the effects of iKinnect on these outcomes were in predicted directions, none were significant. Parents who used iKinnect reported significant increases in discipline consistency and in rule clarity/structure (small and medium effects).

Between-Groups Differences at 12-Weeks

To better understand the benefits of iKinnect after 12 weeks of use, models corresponding to outcomes showing significant change over time were re-parameterized such that the 12-week time point was estimated as the intercept in growth models. The effect of condition regressed on intercept served as the test of interest. As shown in Table 4, intervention effects remained significant for each outcome, with effect sizes ranging from d = .32 (small) to d = .95 (large; Cohen, 1998). In terms of clinical significance, in the preceding 2 weeks (scale reporting period), on average, youth in the iKinnect arm used alcohol on 1.05 fewer days and marijuana on 1.04 fewer days than did comparison youth, corresponding to 18-40% less use, and engaged in 24-43% fewer delinquent behaviors.

<div align="center">

Discussion

</div>

iKinnect is the first smartphone app built to address serious adolescent conduct problems, designed to help caregivers achieve clinical tasks that are a central focus of empirically-supported approaches such as MST (i.e., setting expectations for youth behavior, monitoring compliance, and providing consistent and appropriate responses). Findings from this RCT lend support to the efficacy of iKinnect for this population. Compared to youth using Life360, youth who used iKinnect engaged in significantly less alcohol use, marijuana use, school delinquency, general delinquency, and status offenses across 12 weeks of app use, resulting in 18-43% lower problem behavior involvement by the final time point. Effect sizes for these outcomes were in the medium to large range. These promising results were obtained with youth whose conduct problems were severe (92nd percentile or higher on a CBCL-based screener). If replicated in future research, these findings have substantial public health and

safety implications, given the high rates of youth substance misuse, school dropout, and criminality.

These promising results on the ultimate youth outcomes of interest (i.e., reductions in serious

conduct problems) are likely linked to concurrent improvements in parents' behavior. Consistent with

hypotheses, parents who used iKinnect, relative to parents who used a location-monitoring only app,

reported significantly greater improvements in the clarity and structure of their rules and in the

consistency of their discipline techniques. Extensive risk factor research has shown that unclear parental

expectations and inconsistent discipline have both direct and indirect (through their impact on youth

deviant peer associations) effects on both onset and progression of youth conduct problems (Lansford

et al., 2003; Stanger et al., 2004). Moreover, in two dismantling studies, reductions in youth antisocial

behavior and in youth drug use following completion of TFC-O were mediated by improvements in

parent discipline practices (Eddy & Chamberlain, 2000; Henderson et al., 2009).

iKinnect places a strong emphasis on improving these aspects of parenting behavior. Upon initial

use of the app, parents are guided to think through what expectations they'd like to set for their teen,

with pre-defined categories (challenge card options) listed as a menu to guide ideas. Once set, parents

are reminded in real time (through automated app notifications) to be consistent in their responses,

either by congratulating a teen who has done well (e.g., to send a heart emoji through the app) or by

contacting a teen who might be about to stray off course (with a "call teen now" button). iKinnect also

provided a way for teens to hold their parents accountable by allowing them to self-report their

compliance with expectations that were not automatically verifiable through GPS (i.e., "required task"

cards) and by requesting specific agreed-upon rewards when they had sufficient points.

In terms of parent behaviors, it is interesting that in both study arms, teens reported

experiencing increases in monitoring and supervision behaviors, and both teens and parents reported

declines in coercive parenting techniques. Parents in both arms also reported significant decreases in

stress, feelings of helplessness, and sense of being out of control in their parenting. Without a no-

intervention comparison group, it is not possible to know whether these significant changes were related to the passage of time, other services families may have been receiving, or other factors (e.g., regression to the mean). Nevertheless, a testable hypothesis for future research is whether on-demand GPS monitoring in and of itself is helpful to families with a teen engaged in conduct problems. However, based on present study results, it appears that reductions in coercion and improvements in monitoring alone may be insufficient to ultimately change problematic teen behaviors such as delinquency and substance use. The findings from this study suggest that improvements in parents' communication of clear expectations and in their consistency in responding to teen behavior are likely also necessary.

Limitations and Future Directions

Several limitations are noteworthy. First, our outcome measures were limited to youth and parent self-report. Additional indicators (e.g., school grades, arrests) of improvements in youth behavior from other sources (e.g., teachers, arrest records) should be considered in future studies of iKinnect over a longer time window. Second, the sample (N = 72) was relatively small and underpowered to detect small effects. The sample was also heterogenous with regards to types of conduct problems; although this heterogeneity potentially supports the app's generalizability, further research is needed to understand iKinnect's effectiveness with particular clinical subgroups such as juvenile offenders or youth with substance use disorders. Similarly, although intervention effects analyses included youth race, age, and sex as covariates (when statistically significant), the small sample size prohibited a deeper understanding (e.g., moderator or split-sample analyses) of whether effects were equivalent across these groups. The majority of our sample (68% of youth, 78% of parents) self-identified as White, which may limit the generalizability of findings to families who identify with other racial/ethnic groups. Relatedly, at this early stage of iKinnect development and evaluation, the app does not yet exist in other languages, limiting its potential reach. Further app development and additional rigorous evaluation studies with more diverse samples are needed to address these concerns.

Despite these limitations, the present study suggests that iKinnect may be beneficial in helping curb adolescent conduct problems and extending the reach of evidence-based techniques to a wider range of youth and families. iKinnect joins the small but growing list of high-quality digital health therapeutics, including apps, serious games, immersive environments, and wearables, that are designed for children and adolescents experiencing mental health concerns (Stoll & Pina, 2018). iKinnect is unique in its focus on severe adolescent externalizing behavior, linked caregiver-teen functionality, and high customizability, allowing parents to tailor their approach to individual youth needs and to dynamically change expectations over time. The unique interactive functionality of iKinnect may someday serve as a platform for delivery of other evidence-based practices for which a strong parental component is warranted. For example, work is underway to expand iKinnect by adding features that coach parents in teen suicide prevention techniques, such as limiting youth access to lethal means, regularly assessing teen emotional state, and supporting teen to use suicide prevention skills.

The need to close the "treatment gap" and provide effective interventions to a much higher proportion of children and adolescents with behavioral health needs is urgent, particularly for those conditions with high prevalence rates and far-ranging human and financial costs like serious conduct problems. iKinnect could be valuable in a variety of contexts, either as a supplement to a youth's treatment, a way to sustain gains after treatment termination, as a stand-alone tool independent of treatment, and in any number of preventative or early intervention settings. For example, iKinnect could be a first-line intervention in several large public youth-serving systems, such as in juvenile justice, targeting diversion or re-entry populations, or in school systems, targeting students with truancy or disciplinary concerns. We are also exploring using parent-to-parent peer support specialists as conduits for iKinnect in innovative dissemination settings such as large employers or pediatrician offices. With nearly ubiquitous smartphone ownership among teens and their caregivers, the timing is right for technologies such as iKinnect to play a significant role in addressing adolescent mental health needs.

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Table 1

Participant Characteristics by Study Group

Characteristic	Frequencies		χ^2	p
	iKinnect (n = 34)	Life360 (n = 38)		
Youth gender (% male)	55.9	63.2	0.40	.530
Youth race (% each)			2.37	.652
White	64.7	71.1		
Black	14.7	15.8		
American Indian	2.9	---		
Asian or Pacific Islander	---	2.6		
More than one race/Other	14.7	10.5		
Youth ethnicity (% Hispanic/Latinx)	26.5	13.2	2.03	.154
Youth education level (% each)			11.33	.125
Completed 5th grade	---	5.3		
Completed 6th grade	20.6	2.6		
Completed 7th grade	17.6	26.3		
Completed 8th grade	23.5	15.8		
Completed 9th grade	23.5	23.7		
Completed 10th grade	5.9	18.4		
Completed 11th grade	5.9	5.3		
High school graduate	---	2.6		
Youth regular school (% attending)	82.4	81.6	0.01	.932
Youth history of arrest (% yes)	29.4	23.7	0.30	.604
Youth history of detention (% yes)	20.6	13.2	0.71	.299
Parent gender (% female)	100	100		
Parent role (% each)			2.85	.416
Biological parent	94.1	89.5		
Adoptive parent	2.9	7.9		
Stepparent	2.9	---		
Other	---	2.6		
Parent race (% each)			2.38	.666
White	76.5	78.9		
Black	11.8	13.2		
American Indian	2.9	---		
Asian or Pacific Islander	---	2.6		
More than one race/Other	8.8	5.3		
Parent ethnicity (% Hispanic/Latinx)	14.7	7.9	0.84	.359
Parent relationship status (% each)			2.85	.416
Sole adult in household	44.1	26.4		
Living with partner, not youth's parent	23.6	42.2		
Living with youth's other parent	29.4	26.3		
Other	2.9	5.3		

(table continues)

| | Frequencies | | | |
Characteristic	iKinnect (*n* = 34)	Life360 (*n* = 38)	χ^2	*p*
Parent education level (% each)			8.48	.292
Partial high school	2.9	7.9		
High school graduate	47.1	52.6		
2-year college degree	17.6	13.2		
4-year college degree	26.5	13.2		
Masters degree	---	10.5		
Doctoral (PhD, MD, or other)	2.9	2.6		
Other	2.9	---		
Parent employed (% yes)	50	73.7	4.30	.038
Annual household income (% each)			3.18	.786
Less than 10,000	8.8	10.5		
10,001 – 20,000	17.6	7.9		
20,001 – 30,000	14.7	28.9		
30,001 – 40,000	8.8	7.9		
40,001 – 50,000	8.8	7.9		
50,001 – 60,000	14.7	13.2		
60,000 and above	26.5	23.7		
Parent use of computers and smartphones [b]				
Minimum: Uses "only occasionally"	0.0	2.7	1.88	.391
Medium: Uses "sometimes"	2.9	8.1		
High: Uses "very often in my free time"	97.1	89.2		
Family recruitment source (% each)			8.19	.017
Social media	88.2	71.1		
Other	5.9	28.9		
Unknown	5.9	---		
	Means (SDs)		*F*	*p*
Youth age (in years)	14.6 (1.3)	14.7 (1.3)	0.16	.695
Conduct problems screening score[a]	12.7 (4.5)	11.3 (4.6)	1.67	.201
Parent age (in years)	39.4 (7.0)	38.8 (6.7)	0.04	.704
Number of other children in household	1.8 (1.4)	1.6 (1.0)	1.0	.410

[a] Based on the 10-item *Child Behavior Checklist Externalizing Behavior Screening Scale* (Achenbach & Rescorla, 2001; Petersen, Bates, Dodge, Lansford, & Pettit, 2016). A score of 6 corresponds to a T score of 64 (92nd percentile) on this scale (possible range 0 – 20).

[b] Based on parents' response to the question, "Rate your current level of computer and smartphone use" asked as part of the baseline assessment.

Table 2

iKinnect App Usage by Parents and Teens Across 12 Weeks

Parental Expectations Set "Challenge Cards"	% of parents setting rule (card)	% of youth achieving highest card level	Cards played per family M(SD)	Days card active M(SD)[a]	% of days youth successful M(SD)
Go to school	65.0	34.6	0.80 (0.7)	24.6 (14.6)	72.0 (10.1)
Do a required task	60.0	45.8	2.58 (3.9)	144.8 (158.8)	47.0 (18.2)
Curfew	37.5	40.0	0.45 (0.6)	38.5 (28.2)	73.0 (8.7)
Go to a required activity	27.5	54.5	0.45 (0.8)	18.1 (15.3)	90.0 (9.9)
Avoid off-limits locations [b]	2.8	---	0.03 (0.2)	---	---
Avoid off-limits people [b]	2.8	---	0.03 (0.2)	---	---
Overall [c]	100.0	52.5	4.33 (4.2)	122.3 (136.1)	60.0 (17.6)

[a] The study lasted for 94 days. Values greater than 94 indicate instances in which multiples cards were active (multiple rules were in place) on the same day.

[b] Category of parental expectation was set by only two parents; insufficient data to report

[c] All expectations (cards) combined.

Table 3

Latent Growth Model Results for Youth (Y)- and Parent (P)-Reported Outcomes Across 12 Weeks of App Use (N = 72)

Outcomes	Intercept		Across Condition Change (Slope)			Between Condition Change (Intervention on slope)				Model Fit	
	Est	SE	Est	SE	*p*	Est	SE	*p*	*d*	BIC	CFI [a]
Youth Problem Behaviors											
Alcohol use (Y)	10.80	1.02	-1.18	0.64	.062	-0.43	0.19	.027	.54	165.34	---
Marijuana use (Y)	-0.93	0.53	1.02	0.35	.003	-0.36	0.10	.000	.78	427.24	---
School delinquency (Y)	2.94	0.18	0.49	0.23	.033	-0.34	0.11	.002	.69	1005.71	---
General delinquency (Y)	4.38	0.13	0.02	0.15	.875	-0.30	0.09	.001	.84	1680.42	---
Status offenses (Y)	4.28	1.26	0.38	0.33	.253	-0.78	0.24	.001	.72	650.56	---
YSR aggression (Y)	16.84	2.78	-2.42	0.93	.009	-0.22	0.59	.711	---	1575.63	1.00
CBCL aggression (P)	20.60	0.98	-4.24	1.51	.005	-1.70	1.10	.120	---	1704.25	0.96
YSR rule breaking (Y)	7.58	2.23	-0.93	0.80	.247	0.12	0.45	.797	---	1445.99	1.00
CBCL rule breaking (P)	10.35	0.61	0.74	0.59	.213	-0.57	0.34	.093	---	1514.27	0.93
Parent Distress											
Perceived Stress (P)	14.23	3.06	-1.21	0.34	.000	-0.36	0.56	.515	---	1624.14	0.99
Helpless (P)	21.04	1.36	-0.90	0.27	.001	-0.06	0.41	.884	---	1492.47	0.99
Out of control (P)	28.46	2.20	-2.19	0.39	.000	-0.02	.617	.975	---	1619.37	1.00

(table continues)

Outcomes	Intercept		Across Condition Change (Slope)			Between Condition Change (Intervention on slope)				Model Fit	
	Est	SE	Est	SE	p	Est	SE	p	d	BIC	CFI [a]
Parenting Behaviors											
Rule clarity and structure (P)	17.29	0.39	-0.13	0.26	.611	0.67	0.29	.021	.51	1216.77	0.98
Rule clarity and structure (Y)	12.02	0.32	0.67	0.38	.078	-0.12	0.23	.620	---	1192.40	1.00
Coercion (P)	13.11	0.43	-0.69	0.18	.000	-0.13	0.27	.632	---	1301.84	1.00
Coercion (Y)	9.72	0.26	-0.79	0.27	.004	-0.08	0.20	.693	---	1096.64	1.00
Monitoring/supervision (P)	27.71	0.66	-1.18	0.14	.000	0.26	.017	.120	---	1061.52	1.00
Monitoring/supervision (Y)	26.98	0.53	0.99	0.50	.049	0.21	0.38	.587	---	1340.95	1.00
Discipline consistency (P)	13.37	0.51	-0.10	0.13	.440	0.24	0.12	.044	.22	967.27	1.00
Discipline consistency (Y)	15.53	0.32	0.34	0.36	.351	0.11	0.22	.620	---	1135.48	1.00
Use of rewards (P)	21.48	0.35	0.12	0.13	.340	0.33	0.19	.078	---	1236.87	1.00
Use of rewards (Y)	18.15	0.43	-0.16	0.56	.775	0.20	0.29	.502	---	1291.87	0.99

Note. For all outcomes, models measured change across 4 time points (baseline and at 4, 8, and 12 weeks post-baseline), and the response period was past two weeks. All models involving count variables used the Poisson linkage function. Parameters relating to the effects of covariates on intercepts and slopes were estimated when the parameter for a particular covariate improved model fit. Covariates varied across outcomes and parameters, but included youth race, age, sex, juvenile justice system involvement (yes/no), and recruitment strategy (Facebook vs. other); for parent-reported outcomes, parent age was also considered. Condition was coded dichotomously, iKinnect app = 1, Life360 app = 0. Est = estimate; SE = standard error; d = effect size (provided only for significant intervention effects); BIC = Bayesian Information Criterion; CFI = Comparative Fit Index. The parameter S on Condition indicates the intervention effect. All analyses were intent-to-treat. *N* = 72.
[a] CFI is not available for outcomes involving counts.

Table 4

Differences Between Study Arms at the Final (12 Week) Timepoint for all Significant Outcomes (N = 72)

Outcomes	Intercept at 12 weeks		Between-Condition Difference At 12 weeks[a]		
	Est	SE	Est	SE	Cohen's d
Youth Problem Behaviors					
Alcohol use (Y)	5.91	0.18	-1.05	0.19	.95
Marijuana use (Y)	2.61	0.54	-1.04	0.21	.45
School delinquency (Y)	1.48	0.44	-0.64	0.20	.33
General delinquency (Y)	1.90	0.10	-0.45	0.17	.53
Status offenses (Y)	2.06	0.74	-0.71	0.18	.63
Parenting Behaviors					
Rule clarity and structure (P)	16.38	0.39	0.91	.54	.32
Discipline consistency (P)	11.77	0.34	0.98	.46	.44

Note. Condition was coded dichotomously, iKinnect app = 1, Life360 app = 0. Est = estimate; SE = standard error; *d* = effect size. All analyses were intent-to-treat. *N* = 72.

[a]Between-condition comparisons are based on reparameterizations of the growth models reported in Table 3 in which the intercept was estimated using the week 12 timepoint, and the intervention effect was condition regressed on the intercept.

Figure 1 Consort Diagram