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# Attitudes and Interest in Technology-Based Treatment and the Remote Monitoring of Smoking among Adolescents and Emerging Adults

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**Introduction:** Despite the public health relevance of smoking in adolescents and emerging adults, this group remains understudied and underserved. High technology utilisation among this group may be harnessed as a tool for better understanding of smoking, yet little is known regarding the acceptability of mobile health (mHealth) integration.
**Methods:** Participants (ages 14–21 years) enrolled in a smoking cessation clinical trial provided feedback on their technology utilisation, perceptions, and attitudes; and interest in remote monitoring for smoking. Characteristics that predicted greater technology acceptability for smoking treatment were also explored.
**Results:** Participants ($N = 87$) averaged 19 years old and were mostly male (67%). Technology utilisation was high for smart phone ownership (93%), Internet use (98%), and social media use (94%). Despite this, only one-third of participants had ever searched the Internet for cessation tips or counselling (33%). Participants showed interest in mHealth-enabled treatment (48%) and felt that it could be somewhat helpful (83%). Heavier smokers had more favourable attitudes toward technology-based treatment, as did those with smartphones and unlimited data.
**Conclusions:** Our results demonstrate high technology utilisation, favourable attitudes towards technology, and minimal concerns. Technology integration among this population should be pursued, though in a tailored fashion, to accomplish the goal of providing maximally effective, just-in-time interventions.

## Introduction

Cigarette smoking remains the leading cause of preventable death in the United States (US)(Centers for Disease Control and Prevention, 2008) with the majority of adult smokers starting prior to age 18 years (U.S. Department of Health & Human, 2012; U.S. Department of Health Human Services, 2014). Tobacco use in adolescence reliably predicts being a smoker as an adult (Chassin, Presson, Sherman, & Edwards, 1990), supporting the need for focused research and improved cessation efforts targeting adolescent and emerging adult smokers. Recent data show that current (i.e., past month) use of cigarettes among high school students was approximately 9.2% (Grades 9–12) in the US (Arrazola et al., 2015). Grade-specific estimates of past month cigarette use were shown to be similar (7.2% for 10$^{th}$ and 13.6% for 12$^{th}$ grade students) (Johnston, O'Malley, Meiech, Bachman, & Schulenberg, 2015). Among young adults aged 18–24 years, past month cigarette use is estimated at 18.7% (Jamal et al., 2014). Over half (57%) of adolescent and emerging adult smokers have intentions of quitting (Tworek et al., 2014), and 50–77% have made serious, past-year quit attempts (Bancej, O'Loughlin, Platt, Paradis, & Gervais, 2007; Eaton et al., 2012; Hollis, Polen, Lichtenstein, &

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Whitlock, 2003; Tworek et al., 2014). However, only 4–6% of unassisted quit attempts among this population are shown to be successful (Centers for Disease Control and Prevention, 2006; Chassin, Presson, Pitts, & Sherman, 2000; Stanton, McClelland, Elwood, Ferry, & Silva, 1996; Sussman, Lichtman, Ritt, & Pallonen, 1999; Zhu, Sun, Billings, Choi, & Malarcher, 1999), and use of evidence-based treatments and pharmacotherapy is only slightly better (Gray et al., 2011; Gray, Carpenter, Lewis, Klintworth, & Upadhyaya, 2012; Killen et al., 2004; Stanton & Grimshaw, 2013; Sussman, Sun, & Dent, 2006). These findings illustrate that young smokers are motivated to quit but do not engage in or with effective cessation support.

mHealth technology is uniquely suited to address research and treatment gaps within this population, and offers advantages to understand smoking outside of the clinical or research environment in several ways. First, young smokers often face challenges in attending clinic visits, which contributes to study drop-out and missing data. Diminished availability of outcome data leads to inadequately powered trials that continue to constrain the treatment literature (Backinger et al., 2003; Skara & Sussman, 2003; Sussman, 2002). Second, mHealth technology allows for data collection in real-time and in ecologically valid settings, thus providing a more detailed and accurate understanding of smoking. Work in this area began with ecological momentary assessment (EMA), procedures, and outcomes of which are now well established in the field (Shiffman, 2005; Shiffman, Stone, & Hufford, 2008). Additional innovations now allow for the remote collection and monitoring of carbon monoxide (CO) (Dallery & Glenn, 2005; Hertzberg et al., 2013; Meredith et al., 2014), and the detection of individual puffs through proxies of use, such as arm movements and respiration (Ali et al., 2012; Raiff, Karataş, McClure, Pompili, & Walls, 2014; Sazonov, Lopez-Meyer, & Tiffany, 2013). Remote monitoring offers the opportunity to study health processes at a more granular level, and with the possibility of unobtrusive sensing that may minimise respondent burden and allow for dynamic, interactive approaches. Third, mHealth technology holds the potential to contribute to the delivery, availability, and fidelity of treatment to smokers attempting to quit. Work has been proposed or conducted incorporating mHealth methodology into smoking treatment as a means to engage the individual and provide support in real-time. This has been done through text messaging (Whittaker et al., 2012) and ecological momentary interventions (Heron & Smyth, 2010). Also, work is ongoing to incorporate several features of monitoring and intervention delivery at critical moments in the natural environment (McClernon & Roy Choudhury, 2013). The eventual goal of much of this work is to improve the efficacy and reach of interventions that can be delivered in real-time to improve the likelihood of long-term abstinence.

Adolescents and emerging adults are ideally suited for technology integration into research, and show greater technology utilisation compared to other age groups (Lenhert, Ling, Campbell, & Purcell, 2010; Zickuhr, 2011). Among young adults (ages 18–29 years), 85% are smartphone users, and of these, approximately 15% report that smartphones are their primary means to online access (Pew Research Center, 2015). For those between the ages of 12–17 years, smartphone use was approximately 47% in 2013 (Madden, Lenhert, Duggan, Cortesi, & Gasser, 2013). Virtually all smartphones are already equipped with features, capabilities, and the necessary computing power to serve as a platform for monitoring technology and intervention delivery.

While high rates of technology utilisation among this population may be harnessed as a tool for better understanding of smoking and delivery of treatment, little is known regarding the acceptability and feasibility of mHealth integration to study smoking. Assessing attitudes, interest, and concerns among this target population is critical prior to implementation of mHealth techniques. Identification of characteristics that may predict greater acceptability of mHealth methods and platforms may facilitate the development of acceptable, tailored smoking cessation, and relapse prevention tools among sub-groups. Therefore, this study aimed to characterise a broad array of usage, attitudes, and perceptions related to technology-based treatment and the remote monitoring of smoking among adolescent and emerging adult daily cigarette smokers. The survey used in this report was intentionally broad and covered the areas of; the remote assessment of behaviour, remote collection of smoking biomarkers (i.e., breath CO), and the remote delivery of treatment for smoking. Specifically, this study aimed to; (1) characterise technology use among this group; (2) assess perceptions, attitudes, and interest in remote monitoring for smoking research and treatment and remote biomarker collection, and (3) determine characteristics that predicted greater acceptability technology for smoking research and treatment.

## Methods

### Participants

Participants enrolled in a 12-week smoking cessation pharmacotherapy clinical trial (NCT01509547; PI Gray) were approached to complete a questionnaire, typically during the randomisation study visit. Participants eligible for the parent study were daily smokers (≥5 cigarettes per day over the past 6 months) between the ages of 14–21 years who were interested in making a quit attempt, and had at least one failed quit attempt in their lifetime. Participants were excluded if they had any unstable psychiatric or medical disorder, had any history with suicidal ideation or attempts, were pregnant or breastfeeding, or taking other smoking cessation medications. No additional inclusion or exclusion criteria were implemented for this survey. Administration of the technology questionnaire took place from December 2012 through January 2015



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(study recruitment for the parent trial is still ongoing). All procedures were approved by the Institutional Review Board at the Medical University of South Carolina.

### Measures

Since we know of no validated surveys to assess smoking-specific technology attitudes, perceptions, and acceptability, a 46 item survey was developed locally. Participants were asked about their use of various forms of technology (mobile phones, Internet, computer, email, social media; 21 items), their interest and concerns regarding the use of technology for the remote monitoring of smoking, remote biomarker collection through breath CO, and treatment delivery (15 items), and the perceived ease of remotely monitoring their smoking and CO (10 items). Among the questions pertaining to interest, concerns, and perceived ease of technology-based treatment, questions, and response options were closed-ended. Response options for these items are listed as part of Table 3 below.

Several demographic and smoking-related measures were collected as well. Demographic questions assessed age, gender, education, income, race, and ethnicity. Several smoking measures were also included. A 30-day Timeline Follow-Back (TLFB) (Sobell, Sobell, Leo, & Cancilla, 1988) to assess cigarettes per day was conducted at screening, which has been validated among adolescent smokers (Lewis-Esquerre et al., 2005). Smoking history questions assessed years of regular smoking, age of first cigarette, and number of serious quit attempts. Breath CO and urine cotinine at screening were collected, as well as the modified Fagerström Tolerance Questionnaire (mFTQ) (Prokhorov et al., 2000) and questions to assess the participants' readiness and confidence to quit smoking. Readiness and confidence questions were locally developed and were on a 10-point Likert scale (i.e., 'On a scale of 1–10, with 1 being not ready and 10 being extremely ready, how ready are you to quit smoking?').

### Statistical Analyses

The survey was administered to 87 participants enrolled in the parent study. Standard descriptive statistics were used to summarise demographic and smoking characteristics. Means and standard deviation are presented for continuous characteristics, while frequency distributions are presented for categorical characteristics. Since this questionnaire constituted an exploratory analysis, possible correlates of favourable technology attitudes and interest were selected from baseline demographic and smoking characteristics as well as technology utilisation responses (i.e., gender, race, current and past smoking characteristics, smartphone use, and unlimited data). Binary outcome items (yes, no) were analysed using logistic regression and ordinal outcomes (Not helpful → Very helpful) were analysed using ordinal logistic regression. Categorical outcomes that were not ordinal (yes, no, not sure) were analysed using generalised logistic regression. For all ordinal logit models, the proportional odds assumption was tested and when proportional odds could not be verified, the data were analysed using generalised logit models. Items with small cell counts ($\leq 5$) had categories collapsed into logical groups. Results from logistic regression models are presented as odds ratios and associated 95% confidence intervals [OR (95% CI)]. All statistical analyses were performed using the SAS System version 9.3.

## Results

### Demographic and Smoking Characteristics

Of the 87 participants who completed the questionnaire, the average (SD) age was 18.9 (1.4) years, and the sample was primarily male (58/87; 67%), Caucasian (64/87; 74%), and approximately 68% had graduated from high school (59/87). On average, participants smoked 11.7 (7.6) cigarettes per day, had breath CO readings of 14.2 parts per million (ppm) (8.4) at screening, and urinary cotinine values ($n = 60$) of 1,047 ng/ml (619). Nicotine dependence scores averaged 4.4 (1.7) and nearly a quarter of the participants reported substantial nicotine dependence (mFTQ$\geq$6). Participants had been regularly smoking since age 16.2 (1.7) years and more than half lived with another smoker (49/87; 56%). Participants were generally motivated to quit smoking, with readiness and confidence scores (on a 10-point scale) averaging 7.7 (1.8) and 7.0 (2.4) respectively.

### Technology Utilisation

Technology use characteristics are shown in Table 1. As expected for this study sample, technology use was high. Nearly all of the study participants endorsed owning a mobile phone (82/87; 94%) and those who did not own a mobile phone had access to one on a regular basis. All but one participant had the ability to send and receive short message service (SMS) text messages and 93% of participants had smartphones with internet capabilities (81/87). Over half of the study participants reported unlimited data on their mobile phones (45/87; 52%) and the majority reported having yearly contracts (44/87; 51%) and having never changed their mobile phone number (48/87; 55%).

Computer, Internet, email, and social media use was also high in this sample. The majority of participants reported using the Internet (85/87; 98%), email (72/87; 83%), and social media (82/87; 94%) on a weekly basis. The most frequently endorsed social media sites used by participants were Facebook (81/87; 93%), Instagram (35/87; 40%), and Twitter (30/87; 35%). Weekly computer use was the least utilised (67/87; 77%), and 65% of participants reported that their mobile phone is the most frequent way that they access the Internet (55/87).

### Perceived Ease of Remotely Monitoring Smoking

When participants were asked about the perceived ease of using a remote monitoring technology system to report on their smoking (consisting of remote breath CO



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**Table 1**
Technology use characteristics

| Mobile Phone Use | % ($N = 87$) | N ($N = 87$) |
|---|---|---|
| Mobile phone ownership | 94.3 | 82 |
| Regular access to a mobile phone (do not own) | 100 | 5 |
| Type of Contract | | |
| Pay-as-you-go | 10.3 | 9 |
| Monthly | 39.1 | 34 |
| Yearly | 50.6 | 44 |
| Regular phone access > 3 years | 78.1 | 68 |
| Changed Mobile Number (past year) | | |
| Never | 55.2 | 48 |
| 1 time | 14.9 | 13 |
| 2 times | 18.4 | 16 |
| 3 or more times | 11.5 | 10 |
| SMS text message capabilities (send and receive) | 98.9 | 86 |
| Internet access on phone - Yes | 93.1 | 81 |
| Unlimited data - Yes | 51.7 | 45 |
| Uses for Mobile Phone (5 most common listed) | | |
| Text | 97.7 | 85 |
| Phone calls | 97.7 | 85 |
| Social media | 85.1 | 74 |
| Music | 85.1 | 74 |
| Applications (apps) | 79.3 | 69 |
| Email | 70.1 | 61 |
| Computer/Internet/Email Use | % or Mean ($N = 87$) | $N$ or SD ($N = 87$) |
| Weekly internet use -% | 97.7 | 85 |
| Days/week internet use - mean | 6.5 | 1.3 |
| Sources of Internet Access | | |
| Mobile phone -% | 64.7 | 55 |
| Home computer -% | 29.4 | 25 |
| Other (family/friend cell phone/public library/school) -% | 5.9 | 5 |
| Weekly computer use -% | 77.0 | 67 |
| Weekly email use -% | 82.8 | 72 |
| Days/week email use - Mean | 5.3 | 2 |
| Weekly social media use -% | 94.3 | 82 |
| Days/week social media use - mean | 5.7 | 1.7 |
| Family/friends on social media -% | 83.6 | 19.4 |
| Most Frequently Endorsed Social Media Sites | | |
| Facebook -% | 93.1 | 81 |
| Instagram -% | 40.2 | 35 |
| Twitter -% | 34.5 | 30 |

monitoring), they were generally favourable in their responses. Responses on the perceived ease of use of remote monitoring technology are shown in Table 2 as median ratings and percentage distributions of scores for 10-point scale items and percentage distribution for 4-point scale items. Some items were reverse scored and are noted in the table. Specifically, participants responded favourably to being able to carry necessary devices with them on a daily basis and to return study devices. Privacy concerns were relatively low with a median score of 4 (out of 10),



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**Table 2**
Perceived ease of using remote monitoring technology

| 10-point Scale Items | Median | 1–3 -% | 4–6 -% | 7–10 -% |
|---|---|---|---|---|
| Likely to report each cigarette smoked in real time (could not do this ➔ could definitely do this) | 7 | 20 | 24 | 56 |
| Accuracy of remembering cigarettes smoked at the end of the day (not accurate ➔ accurate) | 7 | 9 | 33 | 57 |
| Ease of carrying two devices (CO monitor and phone) (very difficult ➔ very easy) | 6 | 13 | 41 | 46 |
| Concerned about privacy (not at all concerned ➔ very concerned)* | 4 | 48 | 28 | 24 |
| Concerned about confidentiality (not at all concerned ➔ very concerned)* | 6 | 44 | 36 | 21 |
| Would return study devices (would not return ➔ definitely return) | 10 | 1 | 5 | 94 |
| 4-point Scale Items | Not at all likely -% | Somewhat likely -% | Moderately likely -% | Definitely likely -% |
| Able to complete 2–3 remote sessions per day | 10 | 23 | 33 | 34 |
| Able to respond immediately to sessions when prompted | 19 | 35 | 29 | 17 |
| Carry devices at all times | 12 | 26 | 26 | 36 |
| Find a private space to complete sessions | 13 | 25 | 30 | 32 |

*Notes:* * indicates reverse scoring for that item on the 1–10 scale.

while confidentiality concerns were slightly higher (6 out of 10). Participants also endorsed the likelihood of being able to complete remote sessions in a timely fashion, and in a private space.

#### Attitudes and Interest in Technology for Smoking

Responses regarding attitudes, interest, and concerns with technology for smoking are shown in Table 3. Despite high rates of mobile phone, Internet, email, and computer use, only 33% (29/87) reported that they had ever searched for smoking cessation resources online, and even fewer had ever used health related or self-help applications (apps) on their phones (24/87; 28%). About a quarter of the participants stated that they had no interest in using computer-based smoking cessation counselling (21/87; 24%) and 20% of participants expressed no interest in receiving mobile-phone based cessation counselling (18/87). Nearly half of the sample (42/87; 48%) endorsed being interested in mobile-phone counselling, with far fewer being interested in computer-based counselling (25/87; 29%).

A large percentage of participants felt that mobile phones could be at least somewhat helpful in getting support during a quit attempt (73/87; 84%), and also felt that a quit smoking app may help to motivate them (81/87; 93%). Despite this, about half of the sample still preferred face-to-face counselling exclusively for quitting smoking (44/87; 51%), and most felt that treatment delivered through the Internet would be less effective than in-person treatment (54/87; 62%), though most also reported that Internet-delivered treatment would be more convenient (46/87; 53%). About half of the sample said that they had no concerns regarding technology-based treatment for smoking cessation (43/87; 50%) and remote monitoring of their smoking (52/87; 60%). The most frequent concern for technology-based treatment was that it wouldn't help them to quit (22/87; 25%).

#### Predictors of Technology Acceptability

Demographic, smoking, and technology characteristics were explored as potential predictors of more favourable acceptability towards technology-based smoking treatment. Several results suggest that smokers with greater nicotine dependence and/or use history were more favourable towards technology integration. First, those with greater dependence (mFTQ scores) were more likely to endorse Internet-delivered treatment as being more effective than in-person treatment (OR = 1.35; 95% CI = 1.05–1.74; $p = 0.021$). Second, those who had started smoking regularly at a younger age were more likely to have used health-related apps (OR = 1.39; 95% CI = 1.01–1.91; $p = 0.043$) and were more likely to report computer-based counselling as potentially helpful (OR = 1.45; CI = 1.04–2.03; $p = 0.029$). Third, smokers with higher CO values (indicative of higher intensity of smoking) were more likely to endorse greater interest in technology-based treatment (OR = 1.08; 95% CI = 1.01–1.16; $p = 0.045$;



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**Table 3**
Attitudes and interest in technology for smoking

| Previous Tech Use | % ($N = 87$) | *N* |
|---|---|---|
| Used health or self-help apps on mobile device - Yes | 27.6 | 24 |
| Used the internet for smoking cessation counselling, treatment, tips - Yes | 33.3 | 29 |
| Interest in Tech | | |
| Interest in Computer-Based Smoking Cessation Counselling | | |
| Yes | 28.8 | 25 |
| No | 24.1 | 21 |
| Not sure | 47.1 | 41 |
| Interest in Mobile Phone-Based Smoking Cessation Counselling | | |
| Yes | 48.3 | 42 |
| No | 20.7 | 18 |
| Not sure | 31.0 | 27 |
| Smoking Treatment through Mobile Phone or Internet – How Interested? | | |
| Not at all | 25.3 | 22 |
| A little interested | 33.3 | 29 |
| Moderately interested | 32.2 | 28 |
| Very interested | 9.2 | 8 |
| Attitudes and Acceptability | | |
| Computer-Based Smoking Cessation – How Helpful? | | |
| Not at all | 18.4 | 16 |
| A little helpful | 45.9 | 40 |
| Moderately helpful | 29.9 | 26 |
| Very helpful | 5.8 | 5 |
| Mobile Phone-Based Smoking Cessation – How Helpful? | | |
| Not at all | 16.1 | 14 |
| A little helpful | 23.0 | 20 |
| Moderately helpful | 39.1 | 34 |
| Very helpful | 21.8 | 19 |
| Quit Smoking App – How Motivating? | | |
| Not at all | 18.4 | 16 |
| A little motivating | 29.9 | 26 |
| Moderately motivating | 34.5 | 30 |
| Very motivating | 17.2 | 15 |
| Smoking Cessation Counselling Preference | | |
| Computer only | 10.3 | 9 |
| Face-to-face only | 50.6 | 44 |
| Both computer and face-to-face | 27.6 | 24 |
| No counselling | 11.5 | 10 |
| Internet-Delivered Treatment vs. In-Person Treatment – How Effective? | | |
| Less effective | 62.1 | 54 |
| Same | 27.6 | 24 |
| More effective | 10.3 | 9 |
| Internet-Delivered Treatment vs. In-Person Treatment – How Convenient? | | |
| Less convenient | 23.0 | 20 |



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**Table 3**
Continued

| Previous Tech Use | % ($N = 87$) | $N$ |
|---|---|---|
| Same | 24.1 | 21 |
| More convenient | 52.9 | 46 |
| Comfort with Research Staff Monitoring Your Smoking through Submitted Videos | | |
| Sounds very cool | 19.5 | 17 |
| Sounds ok | 41.4 | 36 |
| Don't know | 27.6 | 24 |
| Sounds bad | 8.0 | 7 |
| Sounds awful | 3.5 | 3 |
| Comfort with Physician Monitoring Your Smoking through Submitted Videos | | |
| Sounds very cool | 11.5 | 10 |
| Sounds ok | 36.8 | 32 |
| Don't know | 28.7 | 25 |
| Sounds bad | 14.9 | 13 |
| Sounds awful | 8.1 | 7 |
| Tech Concerns | | |
| Technology-based Treatment Concerns | | |
| Too difficult to access | 5.8 | 5 |
| Too complicated | 9.2 | 8 |
| Too much time | 14.9 | 13 |
| Not confidential enough | 12.6 | 11 |
| Won't help me quit | 25.3 | 22 |
| Might be embarrassing | 14.9 | 13 |
| Other | 2.3 | 2 |
| No concerns | 49.4 | 43 |
| Remote Monitoring Concerns | | |
| Too difficult to access | 2.3 | 2 |
| Too complicated | 6.9 | 6 |
| Too much time | 16.1 | 14 |
| Not confidential enough | 18.4 | 16 |
| Invasion of privacy | 11.5 | 10 |
| Might be embarrassing | 13.8 | 12 |
| Other | 1.2 | 1 |
| No concerns | 59.8 | 52 |

$p = 0.037$). In contrast, those with an earlier age of first cigarette use were less likely to endorse Internet-delivered treatment as being more effective than in-person treatment (OR = 0.83; 95% CI = 0.69–0.99; $p = 0.037$). Demographically, Caucasian participants were more likely to endorse that Internet-based treatment would be more convenient compared to non-Caucasian participants ($p = 0.025$). Participants who owned smartphones and had unlimited data on their phones were both (a) more likely to endorse interest in computer-based cessation (OR = 3.33; 95% CI = 1.22–9.13; $p = 0.019$), more likely to feel that cell phones could be useful when quitting smoking (OR = 14.2; 95% CI = 2.30–87.8; $p = 0.004$) and (b) endorse smoking apps as motivating (OR = 11.5; 95% CI = 1.89–69.9; $p = 0.008$).

## Discussion

The purpose of this study was to assess technology utilisation, perceptions, attitudes, comfort, and interest in remote monitoring and technology-based systems for



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smoking among a treatment-seeking, nicotine dependent sample of adolescents and emerging adults. Exploratory analyses identified potential characteristics that may predict greater acceptability of technology integration. Generally, technology utilisation was high for these participants in all forms, which would suggest that they are ideal candidates for technology integration into research and treatment focused on smoking cessation. Despite this, use of technology in the form of apps or Internet searches for information, treatment or tips to quit smoking was low. Participants expressed moderately high interest for technology-based systems for smoking. Results also showed that those with smartphones, unlimited data, greater nicotine dependence, and smoking severity viewed technology-based treatment more favourably, with the only exception being for those with a younger age of first cigarette use. It should be noted, however, that predictive analyses were exploratory and significant relationships are interpreted with caution.

These results seem to favour the development and use of mobile-based tools or systems to study and treat smoking. Among this study sample, participants were more interested in mobile-based cessation compared to computer-based programs. This is not surprising given that for many participants, primary access to the Internet was through mobile devices. Also, this study sample showed consistency in mobile phone use and low rates of changing phone numbers. This may suggest that a younger population is less likely to use pay-as-you-go phones that would result in frequent phone number changes, which is a limitation to mobile-based systems. However, it is possible that many study participants may have still been part of a family mobile phone plan, thus contributing to the stability of their mobile access and number. Given that mobile phones are so prevalent among adolescents and young adults, remote monitoring systems that can be incorporated or delivered through mobile platforms are highly desirable, and may help to reduce the burden associated with study participation, data collection, biomarker collection and analysis, and treatment delivery.

This survey study was part of a larger smoking cessation clinical trial (NCT01509547; PI Gray), and as such, participants were motivated to quit smoking and had experienced a failed quit attempt. Even though these participants were treatment-seeking, unfavourable, or ambivalent ratings regarding technology-based treatment were still present. For example, 20% and 25% of the sample had no interest in mobile- or computer-based counselling for smoking, respectively. Many more participants said they were 'not sure' if they were interested in mobile- (31%) or computer-based counselling (47%), suggesting that this sub-sample is unlikely to engage with technology-based treatment strategies. Additionally, 25% of the sample felt that technology-based treatment wouldn't help them to quit, which was the most commonly endorsed concern regarding technology-based treatment. These results could have several explanations. First, this may be due to the particular wording of the questions and a lack of concrete examples of the systems being described. Perhaps, demonstrating a technology-based system to a user would provide more meaningful measures of acceptability and interest. Second, these data may reflect perceptions that participants have regarding how effective technology-based resources are to quit smoking. Many currently available online and mobile resources are not necessarily evidence-based, which may contribute to perceptions of inefficacy. For example, content analyses of iPhone and Android apps reveal low adherence to evidence-based strategies for quitting smoking (Abroms, Lee Westmaas, Bontemps-Jones, Ramani, & Mellerson, 2013; Abroms, Padmanabhan, Thaweethai, & Phillips, 2011; Bennett et al., 2014), though several apps use strategies to promote behavioural self-monitoring in the form of tracking cigarettes smoked (Bennett et al., 2014). Encouraging adolescents and emerging adults to track and monitor their smoking may be a useful component of a comprehensive intervention or part of in-person treatment, but may not be efficacious independently. It is possible that the self-monitoring of behaviour would allow for the collection and use of data specific to the individual that could be used in treatment to encourage and track smoking reduction, understand, and avoid triggers, etc. Even in instances where mobile app efficacy is established for smoking cessation among this population, usability and acceptability of these apps will remain a hurdle in their dissemination. It will be essential in the development and evaluation of apps to monitor use and determine which components are most liked and helpful. Also, mobile apps should be developed to be as personalised for the individual as possible, in order to increase efficacy and engagement.

The integration of technology into research and treatment holds great potential as the landscape of novel tobacco products and other substance use changes. Previous work has been done to remotely monitor cigarette smoking through self-report, biochemical verification, and monitoring systems that detect proxies of smoking (Ali et al., 2012; Dallery & Glenn, 2005; Dallery, Raiff, & Grabinski, 2013; Raiff et al., 2014; Sazonov et al., 2013; Shiffman et al., 2008). Technology integration should be pursued to incorporate measures of other tobacco and drug use into remote monitoring systems. This is justified, given that cigarette smoking continues to decline in young smokers (Arrazola et al., 2015; Johnston et al., 2015), while the use of other products are on the rise. For example, use of electronic cigarette (e-cigs) and vaping are consistently on the rise in a younger population (Arrazola et al., 2015; Johnston et al., 2015). For feasibility purposes, remote monitoring and intervention delivery may only be focused on one particular tobacco product, but this may not be sufficient since novel products are gaining popularity at a rapid pace. Research must focus on how best to quantify, monitor, and treat use of novel tobacco products,



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while potentially incorporating remote methods into this work.

There were several limitations to the current study that should be noted. First, this was a relatively small and homogenous convenience sample of participants that may not generalise widely or be adequately representative. Specifically in terms of motivation to quit smoking, our results cannot necessarily generalise to unmotivated smokers. It will be essential for technology-based treatment systems to attempt to engage unmotivated smokers in order to increase their motivation and confidence in quitting. It is likely that an unmotivated smoker may be even more ambivalent regarding technology-based treatment than our current sample, but this is an important group of young smokers that must not be overlooked with these treatment strategies. Another limitation is that the questions asked of participants were not validated and only queried interest in mostly hypothetical technology-based systems. The responses, therefore, may not translate to actual use of these systems or compliance with their requirements. Hypothetical acceptability was favourable though, providing justification for the pursuit of technology-based systems for this group.

Adolescent and emerging adult smokers are ideally suited for mHealth integration, and our results reveal that this population has high technology utilisation and generally favourable attitudes towards remote monitoring and technology-based systems. The greatest barriers demonstrated in this study were specific to ambivalence towards technology-based systems and the perception that those resources may not be effective. Modifying perceptions regarding lack of efficacy is important to address if these systems are to be used with this target population. We also found some evidence that technology acceptability may vary based on certain characteristics, and this should be carefully considered prior to implementation. Technology integration may need to be tailored to meet smokers where they are in terms of technology use, motivation to quit, and what they perceive as most helpful in their quit attempt. Adolescent and emerging adult smokers tend to be accepting of new technology outlets, and this integration should be pursued to accomplish the goal of providing maximally effective and just-in-time smoking cessation interventions to promote long-term abstinence.

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## Conflict of Interest

None.

## Ethical Standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

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