Developmental Cognitive Neuroscience xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Developmental Cognitive Neuroscience

journal homepage: www.elsevier.com/locate/dcn

Current, future and potential use of mobile and wearable technologies and social media data in the ABCD study to increase understanding of contributors to child health

K.S. Bagot[a,*], S.A. Matthews[b], M. Mason[c], Lindsay M. Squeglia[d], J. Fowler[a], K. Gray[d], M. Herting[e], A. May[a], I. Colrain[f], J. Godino[a], S. Tapert[a], S. Brown[a], K. Patrick[a]

[a] University of California, San Diego, 9500 Gilman Dr., La Jolla, CA, 92093, USA
[b] Penn State University, 507 Oswald Tower, University Park, PA, 16802, USA
[c] University of Tennessee, Henson Hall, 213 Knoxville, Knoxville, TN, 37996-3332, USA
[d] Medical University of South Carolina, 125 Doughty Street, Suite 190, MSC861, Charleston, SC, 29425, USA
[e] University of Southern California, 2011 N Soto St., Los Angeles, CA, 90032, USA
[f] SRI International, 333 Ravenswood Avenue, Menlo Park, CA, 94025, USA

ARTICLE INFO

Keywords:
ABCD
Mobile technology
Wearable sensors
Social media
Child health
Child development

ABSTRACT

Mobile and wearable technologies and novel methods of data collection are innovating health-related research. These technologies and methods allow for multi-system level capture of data across environmental, physiological, behavioral, and psychological domains. In the Adolescent Brain Cognitive Development (ABCD) Study, there is great potential for harnessing the acceptability, accessibility, and functionality of mobile and social technologies for in-vivo data capture to precisely measure factors, and interactions between factors, that contribute to childhood and adolescent neurodevelopment and psychosocial and health outcomes. Here we discuss advances in mobile and wearable technologies and methods of analysis of geospatial, ecologic, social network and behavioral data. Incorporating these technologies into the ABCD study will allow for interdisciplinary research on the effects of place, social interactions, environment, and substance use on health and developmental outcomes in children and adolescents.

1. Introduction

Mobile and wearable technologies, and new methods of data capture that leverage social media, are transforming the way we conduct health-related research. They support the capture of within-person intensive longitudinal high temporal resolution data on environmental, physiologic, behavioral, and psychological factors important to health. They allow deeper understanding of how individuals interact with one another and influence each other's wellbeing. Importantly, this can be accomplished on a multi-scale and multi-system level, including individual, interpersonal, family, school, and community-based influences on health. The complexities of these may be missed via in-lab assessments due to poor recall, diminished salience beyond the time of occurrence, or inability to measure secondary to subjective unawareness (e.g., sleep, air quality). New forms of data captured by mobile devices may lead to new insights into brain development and child health by assessing the multitude of real-time factors that contribute to developmental outcomes.

Mobile phone use is ubiquitous among adolescents. Nearly 75% of adolescents own or have regular access to smartphones, and over 90% of these adolescents access the Internet via smartphones. Seventy-six percent of adolescents use social media, with 71% of these adolescents using more than one social network site (Bagot et al., 2015). Further, minority adolescents are more likely to own smartphones and use apps (Bagot et al., 2015), providing the opportunity to understand factors, including family and culture, which contribute to development in populations that are underrepresented in research and health services. While there are fewer data on commercial wearable device use among children and adolescents, the extant literature suggests that pre-adolescent children find wearing wrist-worn devices such as activity trackers acceptable and are relatively compliant with use (Schaefer et al., 2014). Combined, these technologies and social media represent

* Corresponding author at: Department of Psychiatry, University of California, San Diego, 9500 Gilman Drive, MC 0405, La Jolla, CA, 92093, USA.
E-mail addresses: kbagot@ucsd.edu (K.S. Bagot), sxm27@psu.edu (S.A. Matthews), mmason29@utk.edu (M. Mason), squegli@musc.edu (L.M. Squeglia), fowler@ucsd.edu (J. Fowler), graykm@musc.edu (K. Gray), herting@usc.edu (M. Herting), ian.colrain@sri.com (I. Colrain), jgodino@ucsd.edu (J. Godino), stapert@ucsd.edu (S. Tapert), sandrabrown@ucsd.edu (S. Brown), kpatrick@ucsd.edu (K. Patrick).

https://doi.org/10.1016/j.dcn.2018.03.008
Received 3 April 2017; Received in revised form 15 February 2018; Accepted 18 March 2018

an enormous opportunity to improve how we understand the lives of children and adolescents.

This paper outlines mobile and social technologies and methods that are currently being used with children and families enrolled in the Adolescent Brain Cognitive Development (ABCD) study, and those that will be implemented during participants' early adolescence to augment data collection from other sources such as neuropsychological assessments, biospecimens, and structural and functional neuroimaging data. Linking mobile data with multi-level data that measures contextual place-based variables may provide synergy between traditionally more static, or less temporally dynamic data, and dynamic mobile data. Overall, the plans to capture data as described below will allow for: (a) more precise identification and monitoring of social, emotional, psychological, and behavioral trajectories, (b) in-vivo capture of contributors to substance use and mental health issues and outcomes, and (c) greater understanding of the impact of physical activity, sleep, and environmental exposures on development. Some of the methods outlined here are more established than others, and some may have been used infrequently (if at all) in child and adolescent populations. In addition, the underlying technologies are changing rapidly, and preferences for types of social media–in particular among adolescents–are difficult to predict. Thus, research in this area will require flexibility and adaptability, as there are many challenges in research keeping pace with the rate of change of mobile technologies (Patrick et al., 2016). If successful, we will contribute to the larger body of literature regarding use of these technologies to advance our understanding of contributors of healthy development, and psychosocial, behavioral, and health outcomes in childhood and adolescence.

1.1. Technology currently being used in ABCD

1.1.1. iPads

iPads are currently employed across sites in ABCD to capture clinical, neuropsychological, and self-report data. Parents use the iPads independently to provide historical information about their child, themselves, and their families, while youth use the iPads with the aid of research assistants (RAs). Baseline study sessions begin with RAs administering questions to the youth from the iPads. Surveys of the research assistants on youth and parent feedback, and observations of use by youth and parents suggest that youth are relatively technology-savvy and are able and eager to respond to questionnaires autonomously. Preliminary analyses of feedback data from 3621 youth across sites shows that 88.5% find iPads were easy to use and 82.4% find the iPad games fun. Similarly, parents have provided verbal feedback that the iPads are easy to use, iPad features and accessories such as the ability to zoom in, increase font size, and use an attached external keyboard and/or stylus to help input text are appreciated and increase usability. Overall, entering data into iPads, as opposed to traditional paper and pencil measures, allows for a streamlined data collection process and portability of data collection. Further, direct-data entry minimizes the likelihood of data entry errors, reduces the likelihood of missing data, and expedites the process by which the data are available for public release. These findings are consistent with previous literature that has demonstrated that electronic data capture via tablet is as accurate as traditional paper and pen questionnaires, and allows for immediate review and analysis of data (Walther et al., 2011). Further, there is an increased likelihood of participants reporting sensitive information, with automatic triggers for clinicians when concerning sensitive information is reported (Basch and Goldfarb, 2009).

1.2. Technology currently being piloted in ABCD

1.2.1. Accelerometers

Insufficient or poor quality sleep is associated with alcohol, marijuana, tobacco, and other substance use in adolescents (Roane and Taylor, 2008; Fakier and Wild, 2011). Adolescents with large weekend-weekday differences in sleep duration are also at greater risk for heavy drinking and frequent intoxication (Sivertsen et al., 2015), higher alcohol and marijuana risk taking (O'Brien and Mindell, 2005), and increased marijuana and alcohol use (Pasch et al., 2010). Insomnia and short sleep duration have also been shown to predict depression, and suicidal ideation in adolescents with a > 8-fold increase in odds of depression for those with both insomnia and short sleep duration (Roane and Taylor, 2008; Sivertsen et al., 2015; Roberts et al., 2009). Depressive symptoms also predict insomnia in adolescents (Roberts and Duong, 2013). There is a similar reciprocal relationship between substance use and depression (Leve et al., 2012). However, the reciprocal interaction between sleep problems, substance use, and depression has not been prospectively evaluated in children and adolescents. Further, low levels of physical activity are independently associated with increased risk of mortality, obesity, type 2 diabetes, cardiovascular disease, and some cancers, and there is evidence that the global burden of non-communicable disease attributable to physical inactivity is similar to that of smoking (Lee et al., 2012).

The diversity of biological mechanisms contributing to physical activity and sleep, coupled with difficulties in precise measurement of these complex habitual behaviors, contribute to current challenges in assessing temporal trends and establishing dose-response relationships with physical and mental health. As such, valid measures of physical activity and sleep in-vivo are necessary to determine health outcomes.

Among the most valid and simple to use tools to measure physical activity and sleep are accelerometers (Corder et al., 2007; de Zambotti et al., 2015). These are most often worn on the waist or wrist and are capable of continuously measuring triaxial acceleration at varying frequencies. With the use of algorithms, accelerometers are able to measure the amount of time spent at various levels of activity intensity. Heart rate monitors are typically worn on the chest or wrist and measure direct physiological response of the heart to physical activity via a digitized electrocardiogram signal (chest) or an optical sensor that measures changes in blood volume (wrist). Limitations of accelerometers and heart rate monitors are overcome by combined sensing; heart rate monitors can accurately assess the high intensity physical activity that is the result of upper body movements (e.g., weight lifting) or cycling that accelerometers measure poorly, and accelerometers can accurately assess the low intensity physical activity (e.g. walking) that heart rate monitors measure poorly (Plasqui and Westerterp, 2007; Warren et al., 2010).

Recent advances in microtechnology, data processing, wireless communication, and battery capacity have resulted in the proliferation of low-cost, non-invasive, wrist-worn devices, such as the Fitbit Charge HR 2, Fitbit Surge, Microsoft Band, Apple Watch, etc. These devices include both accelerometers and heart rate monitors, and they are capable of continuously measuring and storing data at a 1 s sampling rate for up to 5 days before needing to be recharged. Wrist-worn devices that measure both acceleration and heart rate have recently been validated against direct observation and indirect calorimetry to provide an objective measure of physical activity (Diaz et al., 2015), and against polysomnography to provide an objective measure of wakefulness and sleep time (de Zambotti et al., 2015; Toon et al., 2016; Mantua et al., 2016; de Zambotti et al., 2016). Such devices infer wakefulness and sleep from the presence or absence of limb movement and an elevated heart rate, and they provide naturalistic measurements of sleep patterns in the home environment at a lower cost than polysomnography.

Because limited data are available about how well consumer-grade devices measure behavioral and physiological parameters in adolescents, a study validating the Fitbit Charge HR for use in children was conducted at University of California San Diego (UCSD) in anticipation of incorporation into ABCD. The validity of physical activity, heart rate and sleep from a consumer-level, multi-sensor, wrist-worn activity tracker in healthy children was assessed. Sixty boys and girls aged 9–10 years were recruited. Participants simultaneously wore a Fitbit Charge HR (contains a triaxial accelerometer, an optical heart rate monitor, an