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Increasing Physical Activity in Adolescents Diagnosed with Autism Spectrum Disorders Using Progressive Goal Setting, Self-Monitoring, Feedback, and Reinforcement

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Increasing Physical Activity in Adolescents Diagnosed with Autism Spectrum Disorders

Using Progressive Goal Setting, Self-Monitoring, Feedback, and Reinforcement

by

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Abstract

Insufficient physical activity (PA) is prevalent amongst adolescents, particularly those diagnosed with autism spectrum disorders. According to the World Health Organization (2020), globally, 81% of adolescents do not meet the recommended levels of PA. Whole-day interventions (i.e., interventions implemented throughout the day) can effectively increase PA levels holistically throughout the day, in line with PA guidelines. However, research remains scarce regarding the effectiveness of whole-day interventions (i.e., interventions implemented throughout the day) for increasing PA levels in individuals diagnosed with ASD. The present study evaluated the use of a multicomponent intervention package comprising progressive goal setting, self-monitoring, feedback, and reinforcement, implemented by the parent to increase whole-day step count in two adolescents diagnosed with ASD. The participants increased their daily step counts to 14,000 steps by the conclusion of the study, thus meeting or exceeding PA guidelines. Perceived social validity was high among both parent and participants, and behavioral outcomes point to high social validity among participants. The implications of the findings are discussed in this paper.

Keywords: physical activity, adolescents, autism spectrum disorders, whole-day intervention

Table of Contents

Chapter Page

List of Tables

Table Page

List of Figures

Figure Page

Chapter I: Introduction

Physical activity (PA) can be defined as the production of any bodily movement (e.g., during activities of daily living, leisure, or as part of an individual's occupation), that results in energy expenditure (World Health Organization [WHO], 2020). PA can be categorized as light- (e.g., walking at a leisurely pace), moderate- (e.g., walking briskly), or vigorous-intensity (e.g., running). PA confers numerous health benefits across the lifespan, including improved physical fitness, cardiometabolic health, bone health, sleep quality, cognitive outcomes, mental health, and reduced adiposity (WHO, 2020). Despite the significant health benefits of PA, globally, 81% of adolescents do not meet the recommended levels of PA (WHO, 2020), with increasing prevalence of insufficient PA (Guthold et al., 2020).

The prevalence of insufficient PA is even greater amongst individuals diagnosed with autism spectrum disorders (ASD) (Jones et al., 2017; McCoy et al., 2016; McCoy & Morgan, 2020). McCoy and Morgan (2020) found adolescents diagnosed with ASD were 41% more likely to be overweight and 84% more likely to be obese compared to their typically developing peers. Several reasons have been posited for the lower PA levels in individuals diagnosed with ASD, including motor skill impairments, social skills deficits, behavioral problems, lack of interest, or lack of time and resources (Pan et al., 2011; Srinivasan et al., 2014). Individuals living with disabilities, including adolescents diagnosed with ASD, can derive many of the same health benefits as described above (WHO, 2020). The WHO (2020) recommends that adolescents living with disabilities should engage in at least an average of 60 min of moderate- to vigorous-intensity PA (MVPA) per day, and vigorous-intensity PA and PA that incorporates muscle and bone strengthening at least thrice per week, similar to their typically developing peers. In addition, should these goals prove too challenging, the WHO recommends engaging in some PA is better than none. Thus, it is important to identify and implement effective interventions to increase PA levels in adolescents diagnosed with ASD, on which there is a paucity of research to date.

Measures of Physical Activity

Given the wide variation in PA topographies, success in designing and implementing effective programs for increasing PA requires the development of objective and valid measures of PA. Advances in healthcare technology continually present behavior analysts with new tools to measure and promote health behaviors (Dallery et al., 2015). Presently, healthcare technology offers ready access to various aspects regarding an individual's health information, including activity levels, activity patterns, weight, sleep quality, and blood oxygen levels. This health information can be obtained unobtrusively and efficiently through electronic measurements that yield a permanent product that can be accessed later, circumventing the need for an observer. Healthcare technology opens new avenues for measuring behaviors (e.g., whole-day step totals) that can be instructive in designing and implementing effective interventions (e.g., whole-day interventions).

There are several measures currently being used to assessed PA. Four common measures of PA include direct observation, heart rate monitoring, pedometry, and accelerometry.

Direct Observation

Direct observation typically involves having trained observers record PA behavior as they occur and code them into specific categories. When observers are trained and follow clear systems that have been psychometrically validated, direct observation can provide valid and reliable measures of PA behavior (Loprinzi & Cardinal, 2011).

One early application of direct observation to the study of PA is the Children's Activity Rating Scale (CARS) (Baranowski et al., 1992; DuRant et al., 1993). CARS provides information regarding PA intensity levels in children. Using CARS, an observer rates the intensity of PA on a scale of one through five, with one representing sedentary activity levels and five representing vigorous activity levels. As CARS involves measuring behaviors with a rating scale, it is not a true direct observation in the behavioral tradition. An example of a direct observation system that is conceptually systematic is the Behaviors of Eating and Activity for Children's Health Evaluation System (BEACHES) (McKenzie et al., 1991), in which observers code, in addition to PA intensity levels, relevant contextual factors including location of activity, and presence of others in the environment using a momentary time-sampling method. Another system, the System for Observing Play and Leisure Activity in Youth (SOPLAY) (McKenzie et al., 2000) allows observers to capture PA at the group level. Using SOPLAY, observers code PA intensity levels for a group of children, and contextual factors, including accessibility of target areas, and the provision of supervision, organized activities, and equipment. More recently, the Observational System for Recording Activity in Children–Preschool/Home (OSRAC-P/OSRAC-H) (Brown et al., 2006; McIver et al., 2009), was developed to further capture relevant contextual factors. With the OSRAC systems, observers code, in addition to PA intensity levels and topography of behaviors, contextual factors including locations, activity contexts, activity initiation, prompts, and engagement from other individuals.

In allowing researchers to assess behaviors as they occur, direct observation has two main advantages over other measures. First, it provides researchers with contextual information, allowing them to identify variables that influence PA (Loprinzi & Cardinal, 2011; McIver et al., 2009). Second, it provides researchers with information about PA behaviors themselves, including the topography of the PA (e.g., running vs. swimming) and intensity of PA (e.g., jogging at a leisurely pace vs. sprinting). A key disadvantage of direct observation is that it is time-intensive, requiring training of observers who must be present to record and code the behavior (although this can be somewhat mitigated by using video recordings). As such, direct observation is often limited to specific durations and settings, and is not suitable for molar assessments of PA under free-living (whole day) conditions.

Heart Rate Monitoring

Heart rate monitoring as a measure of PA involves recording the number of heart beats per minute. Heart rate is traditionally derived from electrocardiography recordings, and more recently, derived from optical blood flow measurements using photoplethysmography techniques (Mühlen et al., 2021; Stahl et al., 2016). Measurements of heart rate can be used in two ways as a measure of PA. First, heart rate can be used to calculate energy expenditure from engaging in PA in conjunction with other participant characteristics such as height, weight, age, and sex (Donaldson & Normand, 2009). Second, heart rate can be used to derive measurements of PA intensity. According to the Centers for Disease Control and Prevention (CDC, 2020) guidelines, moderate-intensity PA involves raising the heart rate to between 64% and 76% of an individual's estimated maximum heart rate, which is derived by subtracting the individual's age from 220. Vigorous-intensity PA involves raising the heart rate to between 77% and 93% of an individual's maximum heart rate.

An inherent advantage of heart rate monitoring is that it is an inexpensive and unobtrusive method for measuring PA (Loprinzi & Cardinal, 2011), making it suitable for assessments of PA under free-living (whole day) conditions. Additionally, measurements can be obtained remotely via an electronic recording, without the presence of an observer. It does not, however, yield contextual information and information about PA topography. While the validity and reliability of heart rate monitoring technology has improved in recent years (Fuller et al., 2020), heart rate measurements remain susceptible to measurement errors, as heart rate can be affected by variables unrelated to PA (Butte et al., 2012). Nevertheless, a number of recent studies have examined the utility of heart rate as a measurement of PA (Eckard et al., 2019; Rosado et al., 2021; Van Camp et al., 2021).

Pedometry

Another cost-efficient and unobtrusive method for measuring PA is the use of a pedometer, a device that is typically worn at the hip and used to measure the number of steps taken by the wearer. Similar to heart rate monitors, pedometers can obtain and store behavioral measurements, making them suitable for free-living assessments of PA. Pedometers have been demonstrated to be valid and reliable (Butte et al., 2012; Loprinzi & Cardinal, 2011), and the measurement of step count using pedometers has been widely used in behavioral interventions targeting PA (e.g., Andrade et al., 2014; Normand, 2008; Valbuena et al., 2019). One limitation of pedometric measurements of step count is that certain PAs that do not involve stepping (e.g., riding bicycles, weightlifting, yoga) are not readily detected. Contextual information, topography and intensity of PA, are also not provided by pedometers.

With the prevalence of pedometers as an assessment and intervention tool for increasing PA, considerable attention has also been given to the health benefits of increasing step count. In addition, taking steps is topographically simple and can be achieved through walking. This represents a lower barrier for engaging in PA for individuals who have been inactive for an extended duration, or who have less experience with topographically complex forms of PA (Page et al., 2020). With PA guidelines shifting towards MVPA-based outcomes (CDC, 2020; WHO, 2020), attempts have been made to translate step counts to MVPA (e.g., Adams et al., 2013; Tudor-Locke et al., 2011; Tudor-Locke et al., 2019). For adolescents (ages 12–17), 60 min of MVPA can be translated, on average, to 11,500 to 14,000 daily steps for both boys and girls (Adams et al., 2013).

Accelerometry

Accelerometry serves as an alternative technology to pedometry for step-count based measurements of PA. Accelerometers are devices that are typically worn on the hip or wrist that measure acceleration in one or more planes. In addition to the advantages of pedometers, accelerometers are also capable of capturing intensity of PA (i.e., moving fast or slow) and vertical movements (e.g., squats, jumps). While not a new technology, technical advances in accelometry technology have resulted in increased validity and reliability of measurements (Fuller et al., 2020; Sharp et al., 2017), resulting in the increased adoption of accelerometers in recent research (e.g., Hayes & Van Camp, 2015; Kurti & Dallery, 2013; Valbuena et al., 2015). The increased adoption of accelerometers is not limited to research studies, with many consumer wearables (e.g., Fitbit, Apple Watch) today equipped with built-in accelerometers to measure step count. While accelerometers offer more information than pedometers, they share the same limitation as pedometers of not providing topographical or contextual information regarding PA.

Behavioral Interventions to Increase Physical Activity

Session-Based Interventions

Several interventions have been examined in the context of increasing PA levels in populations with disabilities within researcher-prescribed sessions (i.e., session-based interventions). Session-based interventions are implemented in discrete time periods (e.g., fixed activity time), with the general aim of increasing PA levels during these specific time periods.

In one study, Valbuena et al. (2019) evaluated the effectiveness of self-monitoring and monetary reinforcement in increasing the rate of walking in five adults (ages 36–51) diagnosed with intellectual disability. Participants wore pedometers and participated in 1-hr sessions conducted at a life skills development facility attended by the participants on weekdays. The researchers assessed rate of walking (steps/min) during baseline and intervention using an ABAB design. During baseline, participants wore their pedometers sealed to prevent self-monitoring, and were not provided with instructions, feedback, or consequences. During intervention, participants wore their pedometers unsealed and received 0.25 USD from the researchers for every 1,000 steps they walked during the session. Additionally, the researchers trained one staff member from the facility to implement the intervention after the rate of walking was stable in the second intervention phase. The intervention resulted in increases in step count for all five participants in the first intervention phase, and four out of five participants in the second intervention phase. The intervention was implemented with high fidelity by the staff member, and both participants and staff member perceived the intervention to be effective and acceptable. The results were notable in that two participants averaged above 100 steps/min for most of the intervention sessions, and two participants averaged above 100 steps/min for approximately half the intervention sessions, a step count rate indicative of MVPA (Tudor-Locke et al., 2019), in line with PA guidelines.

Bassette et al. (2018) evaluated the effectiveness of a package intervention comprising an exercise app (Exercise Buddy), a least-to-most prompt hierarchy, incremental increases in criteria, and reinforcement to increase PA in three adolescents (ages 18–21) diagnosed with ASD. The Exercise Buddy app included various exercises with video models, of which four exercises (i.e., squat, hip extension, dumbbell lateral raise, and dumbbell push-up row) were selected by the researchers as dependent measures in the study. The study was implemented across multiple settings, beginning with a teaching trial setting (e.g., home living room), then to a fixed community setting (i.e., a local YMCA), then to the participant's preferred community setting (e.g., personal training facility). The study was conducted using a concurrent multiple-probe design across participants. During baseline, participants were shown pictures of the target exercises and asked to perform 10 reps of the exercises. The researchers provided access to preferred activities (selected through verbal requests prior to the sessions) or monetary reinforcement for task compliance. During intervention phases, participants viewed the video models on the Exercise Buddy app and were asked to perform the exercise. The researchers provided least-to-most prompts if steps were not independently completed. Participants were initially required to complete 2 reps of each exercise, with incremental increases until participants completed 10 reps of each exercise. All participants demonstrated increased independence in performing the PA targets across all settings. Participants also indicated that they liked using the app, and parents or caregivers indicated that the app was effective and that they planned to have their child continue exercising. While the Exercise Buddy app was received favorably by participants and caregivers, the inclusion of other intervention components makes it difficult to evaluate the effectiveness of the app in promoting PA and further research is warranted.

In a recent study, Hanashiro-Parson and Miltenberger (2021) compared the effectiveness of token reinforcement and monetary reinforcement to increase rate of walking (steps/min) in five young adults (ages 18–23) diagnosed with intellectual disability. Sessions were conducted for an hour each day on weekdays at a group home where the participants resided. Participants wore pedometers during the sessions through which they were able to view their step count across all phases of the study. An ABAB design was used to evaluate if reinforcement (token reinforcement and monetary reinforcement) increased rate of walking, and an alternating treatment design was used to compare the effectiveness of token reinforcement and monetary reinforcement. During baseline, the researchers did not provide any feedback or consequence for walking. During intervention, participants received either 0.25 USD or a token for each 1,000 steps they took. Tokens could be exchanged for preferred food, drinks, or tangibles at the end of each session. In the first intervention phase, token reinforcement and monetary reinforcement were used in alternate sessions. In the second intervention phase, participants chose between the two reinforcement contingencies prior to the start of each session. Both monetary reinforcement and token reinforcement were effective at increasing rate of walking for all participants. When choice of reinforcement was provided, two participants demonstrated a clear preference for token reinforcement, one participant demonstrated a clear preference for monetary reinforcement, and two participant produced less discriminated responding. Regardless, all participants' rate of walking increased to a similar or greater level than the first intervention phase. Additionally, all participants indicated that they enjoyed participating in the study, and the intervention was perceived to be to be acceptable and feasible by the group home staff.

While increasing PA during structured sessions might contribute to the recommended levels of PA, PA levels outside of session time are generally disregarded in session-based interventions. Herein lies a potential issue—participants might be producing high PA levels during sessions, but are sedentary at other times, contrary to the recommendations that the amount of time spent throughout the day engaging in sedentary behavior should be limited and replaced with PA where possible (WHO, 2020).

Whole-Day Interventions

In contrast to session-based interventions, whole-day interventions aim to encourage individuals to incorporate more PA and reduce sedentary behavior throughout the entire day. To that end, in line with PA guidelines (WHO, 2020), whole-day interventions might more effectively allow for monitoring of and arranging for holistic increases in PA levels.

Given its advantages, whole-day interventions are commonly used with typically developing adult populations (e.g., Kurti & Dallery, 2013; Normand, 2008; Valbuena et al., 2015). However, several challenges are faced in the application of whole-day interventions to adolescents diagnosed with ASD. First, whole-day interventions require tolerance of delayed reinforcement contingencies, with the individual having to produce the desired behavior for an extended duration before contacting reinforcement, typically with one-week intervals between reinforcement delivery. Adolescents diagnosed with ASD may not have developed appropriate responding to delayed contingencies found in whole-day interventions. Second, whole-day interventions typically (but not always, see Zarate et al., 2019, for an exception) involve aspects of self-monitoring and goal setting, whereby the participant observes their own behavior, evaluates their behavior against a standard (i.e., an established intervention goal), and attempts to bring their behavior in line with the standard. Similarly, adolescents diagnosed with ASD may not necessarily have a sufficient repertoire of these complex skills, which diminishes the effectiveness of interventions that rely on these mechanisms to effect behavior change. Third, identifying effective and appropriate reinforcers can prove difficult, especially when delayed reinforcement contingencies are in effect. For some adults, reinforcement can be found in the outcomes of engaging in PA, for example, in losing or maintaining weight (e.g., Donaldson & Normand, 2009; Valbuena et al., 2015), or increasing fitness (e.g., Wack et al., 2014). While money often functions as an effective generalized conditioned reinforcer for many adults (e.g., Andrade et al., 2014; Kurti & Dallery, 2013; Washington et al., 2016), the costs might limit the feasibility of the interventions, particularly for whole-day interventions which demand more sustained increases in behavior than session-based interventions. The use of money as a generalized conditioned reinforcer with adolescents may also be viewed as less socially acceptable.

To the researcher's knowledge, no study has examined a whole-day intervention for increasing PA levels in adolescents diagnosed with ASD. Nonetheless, some attempts have been made to evaluate the effectiveness of whole-day interventions in increasing PA in young individuals or individuals diagnosed with ASD (Ek et al., 2016; Kuhl et al., 2015; LaLonde et al., 2014).

LaLonde et al. (2014) evaluated the effectiveness of goal setting and reinforcement for increasing daily step count in five young adults (ages 21–26) diagnosed with ASD. A multiple baseline across participants with changing criterion design was used to increase daily step count progressively, and withdrawals were included for four of five participants.

The study was conducted at a young adult training program for six hours a day on weekdays from 8:00 am to 2:00 pm. During baseline, participants wore Fitbit accelerometers sealed to prevent self-monitoring, and received prizes for wearing their Fitbit devices. During intervention, the Fitbit devices were unsealed to allow self-monitoring and the researchers gave participants step count goals each morning. An initial goal was proposed as a 10% increase from baseline step count, and a new goal (10% increase) were given each time goals were met on two consecutive days. Participants recorded their daily step count each day and earned a prize if they met their goals. Prizes comprised preferred items selected by the participants on a trip to local stores beforehand. Daily step count increased to 10,000 or more steps by the end of the first intervention phase for all participants. Additionally, all participants indicated that they liked wearing the Fitbit device and would like to participate in the intervention again and the teacher indicated that the treatment was acceptable and effective. LaLonde et al. (2014) demonstrate an effective intervention for increasing daily step count in young adults diagnosed with ASD in a transitional school setting, wherein participants had a substantial amount of discretionary time with which they could allocate to walking. Further research is warranted on the effectiveness of the intervention in other settings, and extending assessment of PA outside of time attending programs to the entire day.

In another study, Kuhl et al. (2015) evaluated the effectiveness of two interdependent group contingencies in increasing daily step count in 30 typically developing third-grade students in two classrooms. The study was conducted using a withdrawal (ABACX) design, with X representing the more effective intervention. Participants wore pedometers throughout the day from Monday through Thursday except when sleeping, showering, or swimming. During baseline, pedometers were sealed to prevent self-monitoring. Following baseline, each classroom received one intervention initially, then the other intervention, with the order counterbalanced across the classrooms. In one intervention, the researchers assigned cumulative total step count goals to the students, calculated based on an increase of 1,500 steps from the aggregated mean daily step count of the class during baseline. In the other intervention, participants were given individual daily goals, calculated based on an increase of 1,500 steps from their individual mean daily step count during baseline. The researcher provided daily praise to participants who met their goals (e.g., “Nice job, you met your goal!”), and encouragement for participants who did not meet their goals (e.g., “Keep trying!”). Students also recorded their daily step count in an activity diary. If 80% of students met their daily goals on all four days (Monday through Thursday), the entire class earned extra recess time on Fridays. Both interdependent group contingencies increased step counts, with individual goals producing greater increases in step count across both classes (more than 4,800 steps and 5,000 steps respectively). One factor that might have contributed to the greater increase for the individual goals contingency was the addition of individual feedback, which was not present for the cumulative goals contingency. This hypothesis is supported by data indicating a slight decrease in step count following the fading of feedback to every two or four days. As social validity was not assessed, it is unclear whether teachers and students found the intervention acceptable, feasible, or effective. Overall, Kuhl et al. (2015) presents a promising intervention in interdependent group contingencies to increase whole-day PA levels in children.

Ek et al. (2016) implemented a multicomponent intervention comprising goal setting, self-monitoring, feedback, and reinforcement to increase step count in five typically developing children (ages 8–11) with BMIs ≥ 23. A nonconcurrent multiple baseline across participants design was used, with an embedded changing criterion for two participants. Daily step count was measured using pedometers that were worn sealed during baseline, and uncovered during intervention. During intervention, the children and parents selected their own step count goals and reinforcers for goal attainment. At the end of each day, parents informed their child of (1) their step count, (2) whether their goal was attained, and (3) whether the reinforcer was earned. For three participants, supplementary prompts in the form of daily phone calls from the researcher were included midway through the intervention. The phone calls involved the researcher reviewing their progression towards the daily step count goal and providing strategies to meet the goal. The results indicate an increase in mean step count from baseline during intervention for three of five participants, with the three participants receiving the supplementary prompts producing a further increase in step count. Results from a social validity questionnaire indicate that parents perceived the intervention to be enjoyable for themselves and their children, but that the intervention was effortful or very effortful to implement. Several issues, however, limit the study's conclusions. First, the parents and children selected their own goals by arbitrary means. For example, one parent-child dyad selected a mean daily step count of 9,000 as a goal, which was below the child's mean daily step count during baseline (9,796 steps). Another parent-child dyad selected a modest mean daily step count of 5,000 as a goal, which while quickly achieved, falls well short of PA guidelines. Second, the child's parents provided feedback and reinforcers without receiving training on the procedures. In addition, maintenance was assessed for two participants based on parent's judgment of whether their child engaged in appropriate levels of PA, rather than pedometric measurements of step count. Ek et al. (2016) offered no explanation regarding including subjective rather than objective assessments for the maintenance phase. Third, treatment fidelity was not assessed, making it unclear whether parents were implementing the contingencies accurately. Moreover, two of four parents indicated they implemented the procedure only 50%–75% of the time, and parents indicated that their children received the reward without meeting the step count goals somewhat often.

Poor treatment fidelity limits the validity of assessments regarding the outcomes of this study. Overall, further research is warranted to address this study’s limitations.

The aim of the present study was to address a gap in knowledge regarding effective interventions to increase PA levels of adolescents diagnosed with ASD. The study examined the effectiveness of a multicomponent intervention comprising progressive goal setting, self-monitoring, feedback, and reinforcement administered by a parent to increase whole-day step count. Several of the limitations in Ek et al. (2016) were addressed in this study, including providing systematic and progressive goals, behavioral skills training for parents or caregivers, and monitoring of treatment fidelity. Additionally, the study was conducted through telehealth, a cost-effective solution, and which has taken on a special significance in the current COVID-19 epidemic situation (Lindgren et al., 2016; Pollard et al., 2021).

Chapter II: Method

Participants and Settings

The researcher recruited three adolescents for this study through community outreach in Singapore. The inclusion criteria for participants were: being age 14–21, having an ASD diagnosis, having a sufficient vocal-verbal repertoire to follow rules, being ambulatory, answering “no” to all questions in the Physical Activity Readiness Questionnaire (PAR-Q, Thomas et al., 1992; see Appendix A) as assessed by the participant’s parent or guardian, informed consent from the parent or guardian (see Appendix B), and informed consent from the participant (see Appendix C). A parent or caregiver also had to be able to commit approximately 5 minutes daily to implement the study procedures. Two of the participants were siblings of Eurasian Chinese descent. Andy, the older brother, 19, had an ASD diagnosis. Charles, 16, had diagnoses of Asperger syndrome and attention deficit hyperactivity disorder. The parent of the adolescents implemented the study procedures. A third participant, Brandon, 19, had an ASD diagnosis and was of Chinese descent. Prior to acceptance into the study, the researcher conducted an interview with the parents to determine whether the participants met the inclusion criteria and to determine their availability to participate in the study.

The parents implemented the study in the participants’ daily environments throughout their waking hours. Goal setting, data collection, feedback delivery, and reinforcement delivery occurred in the participants’ homes. The researcher scheduled weekly check-ins every Sunday or Monday with the parents to discuss intervention progress and observe treatment fidelity via video call. On days when the parents were unavailable, they recorded a video of their procedural interactions with the participants and sent it to the researcher.

Materials

The participants wore Xiaomi Mi Band 5 fitness trackers during the study. The Mi Band 5 uses a three-axis accelerometer to measure step count. The Xiaomi Mi Band range of fitness trackers are affordable and have been demonstrated to produce reliable and valid measures of step count (Paradiso et al., 2020; Pino-Ortega et al., 2021; Xie et al., 2018). The Xiaomi Mi Band 5 has a 14–day battery-life, sufficient for the purposes of the study. Prior to commencing the study, the researcher verified fitness trackers functioned properly by walking 100 steps as measured with a mechanical click counter, and comparing the step count recorded on the fitness tracker and the click counter. The researcher conducted this procedure twice for each fitness tracker.

Similar to Kuhl et al. (2015), the researcher provided an activity diary (see Appendix D) containing data sheets tracking daily step count and daily step count goals to the participants. Participants recorded their daily step count data in the activity diary during the intervention phase of the study.

Response Measurement and Reliability

The dependent measure was the participants' daily step count, a permanent product measured and stored electronically by the fitness tracker. The parent accessed the data using smartphones with Bluetooth functionality by pairing a smartphone with each fitness tracker. Andy's and Brandon's fitness trackers were paired to their parent's smartphone while Charles' fitness tracker was paired to his own smartphone. Daily step count was defined as the cumulative measurement of steps in a day (i.e., a 24-hr period beginning at 12:00 am) as recorded by a fitness tracker worn on the participants' non-dominant wrist. A step was defined as a recorded unit of activity as determined through the fitness tracker's built-in accelerometer and proprietary algorithms for measuring steps. Each day's datum was only included if recorded activity on the fitness tracker met or exceeded eight hours for that day.

During scheduled daily check-ins, the parents retrieved step count data from the fitness tracker and sent a screenshot of the data to the researcher. During the intervention phase, the participants also recorded the data in their activity diary. During weekly check-ins, the researcher conducted an exact agreement analysis to assess self-monitoring integrity data by comparing step count data from the screenshots with the diary recordings. Exact agreement analysis was calculated as the percentage of total number of agreements divided by the total number of agreements plus disagreements. On occasion, the parents took the screenshot after the step counts were recorded in the activity diary and the screenshots thus reflected a higher number. In such instances, the data was considered to be in agreement. Self-monitoring integrity was 100% for both Andy and Charles (Brandon did not proceed to the intervention phase).

Parent Training and Treatment Integrity

Prior to starting the study, the researcher trained parents on implementing the procedure and collecting data using a behavioral skills training (BST; e.g., Miles & Wilder, 2009; Miltenberger et al., 2004; Sarokoff & Sturmey, 2004) package. The BST package comprised written and vocal instruction detailing the components of the procedure and data collection, modelling by the researcher, rehearsal with the parent, and feedback on the execution of each component of the procedure (see Appendix E).

As a whole-day intervention, assessments of treatment integrity involved unique challenges as the researcher could not directly observe intervention implementation throughout the day. For example, the parent might provide supplementary prompts for increasing PA levels throughout the day outside of observation time. Recognizing these challenges, the researcher made efforts to maximize treatment integrity (and assessment of treatment integrity) with the aid of technology.

First, the researcher set up an automated daily text reminder sent at 9:00 pm to parents to remind them to conduct the daily check-ins. Second, the researcher verified accuracy in goal-setting and recording of step count data from behavior products (i.e., recorded goals in the activity diary, screenshots of step count data). Parents sent a daily screenshot of the data, allowing the researcher to verify if the check-ins were occurring. Parents also filled the participants' step counts in a Google Sheets document (accessible to both parent and researcher) that automatically computed the step goal for the following week. Third, the researcher arranged to observe the check-ins on Sundays or Mondays through video calls or through video recordings, which was when procedural interactions (i.e., goal setting, retrieval and recording of step count data, feedback delivery, and reinforcement delivery) between the parents and participants co-occurred. The researcher assessed observed treatment integrity for parent's procedural interactions using a treatment integrity checklist (see Appendix F) for 14% of all days (i.e., every Sunday or Monday). Observed treatment integrity was calculated as the percentage by dividing correct steps by the total number of steps, multiplied by 100.

Experimental Design

A changing criterion design was used to progressively increase daily step count of both participants to a terminal criterion level. Phase changes were contingent on meeting step count goals, which were individually determined for each participant. Experimental control was demonstrated by instating withdrawals and varying phase lengths, and observing corresponding changes in step count (see Klein et al., 2017). In addition, a multiple-baseline across participants design was originally included to strengthen experimental control. Due to Brandon discontinuing participating in the study, only two participants remained and the multiple-baseline feature was dropped due to insufficient participants.

Social Validity

Following the completion of the study, the researcher administered social validity questionnaires (Appendices G and H) to the parent and participants to solicit their perspectives regarding the intervention. In keeping with recommendations, social validity questionnaires included questions regarding the social significance of the goals, acceptability of the procedures, and satisfaction with outcomes (Schwartz & Baer, 1991; Wolf, 1978). The questionnaire included 5-point rating scales and open-ended questions. In addition, the researcher conducted a post-study interview with Andy and Charles' parent to gather qualitative information through a series of open-ended questions regarding behavioral changes associated with participation in the study.

Procedure

General Procedure

The researcher conducted an initial video call meeting with the parents and participants in two segments. In the first segment with the parents, the researcher evaluated the eligibility for participation in the study according to the criteria described above and discussed and listed up to five potential rewards to be used as the reinforcer in the study. In the second segment, the participants joined in the meeting and selected a reward from the list to be used in the study. Andy and Charles selected 10 Singapore dollars (SGD; approximately 7.20 USD) reload of their Starbucks Card as the reinforcer. Brandon selected 20 SGD (approximately 14.40 USD) worth of departmental store gift vouchers as the reinforcer. To probe the participants' understanding of the intervention contingency, adapting from Valbuena et al. (2019), the researcher provided pictures of a fitness tracker screen displaying a step count number (ranging from 1,000 steps to 10,000 steps), and asked them to identify the step count number. The researcher then described an abbreviated intervention contingency:

> You have a step count goal of 5,000 steps. If you walk 5,000 or more steps in a day, you will get a tick. Let’s say you walked ___ steps in a day, will you get a tick? If you get five ticks in a week, will you earn your Starbucks reward? Let’s say you got ___ ticks in a week, will you earn your Starbucks reward?

The researcher required participants to answer both questions accurately three consecutive times respectively before commencing with the study. For Andy, the parent included additional visual prompts (i.e., activity diary with written goal and permutations of daily step counts and ticks) as his vocal-verbal repertoire was more limited. With the inclusion of the prompts, Andy was able to accurately answer the questions regarding the contingency. Brandon and Charles did not require any additional prompts.

The researcher conducted parent training in two further video call meetings—before commencing the study, and before commencing the intervention phase. Conducting the parent training immediately prior to each phase reduced the latency between training and implementation, thus increasing fidelity during implementation. During parent training, the researcher provided written and vocal instruction to the parents regarding the procedures and retrieval of the data from the fitness trackers, modelled and rehearsed the procedures, and provided feedback on the parents’ execution.

During the study, the parent issued participants a Xiaomi Mi Band 5 fitness tracker and instructed them to wear it on their non-dominant wrist during their waking hours every day throughout the study. A week, as defined in this study, ran from Sunday through Saturday. For Andy and Charles, this was changed to Monday through Sunday from Day 29, as the parent expressed that this was a more suitable arrangement. The parents assessed each day’s step count data between 9:00 pm that day and 12:00 pm the next day during daily check-ins. If the battery level of the fitness tracker fell below 20%, the parents reminded the participant to charge their fitness tracker.

Baseline

During baseline, the parents informed the participants they needed to wear the fitness tracker for a time period to calibrate the device and ensure its accuracy. The parents retrieved each day's step count data between 9:00 pm that day and 12:00 pm the next day and recorded it down. To ensure compliance with wearing of fitness trackers, the parents provided the selected reward at the end of the week if they wore their fitness trackers for a minimum of eight hours daily (i.e., all seven days) that week. The parents provided no further instructions, feedback, or consequences to the participants.

Goal Setting, Self-Monitoring, Feedback, and Reinforcement

After baseline, Brandon discontinued participation in the study as the parent and Brandon were both satisfied with his baseline mean daily step count. Andy and Charles were each assigned an individual daily step count goal, determined as an increase of 10% over their respective mean daily step count in the baseline phase, rounded to the next 100. For example, Andy averaged 7,600 steps a day during baseline and was assigned an initial goal of 8,400 daily steps. The parent also provided the participants with a written list of 10 potential ways to increase their step counts, incorporating some of their leisure activities (e.g., playing the drums for Charles). During daily check-ins, in addition to the parent retrieving step count data and sending it to the researcher, participants also recorded their step count in their activity diaries and gave themselves a tick upon goal attainment. The parent provided praise to the participants for goal attainment (e.g., "You hit your goal today. Great job!") during daily-check-ins and provide encouragement to the participants if they did not meet their goals (e.g., "You missed your goal today. It's ok, keep trying!").

The parent conducted a weekly performance evaluation each Sunday after 9:00 pm, or on the following Monday before 12:00 pm. If the participants met their goal on at least five days of that week (corresponding to five ticks in the activity diary), the parent provided praise and reloaded their Starbucks Card. The parent then assigned a new daily step count goal to the participants, determined as either (1) a 10% increase over the participant's mean daily step count in the previous phase, or (2) exceed the third-highest daily step count from the previous phase, whichever goal was higher and rounded to the next 100. This ensured participants who vastly exceed their goals in the previous phase were not limited by modest goal increments and progressed at a faster pace (see Kurti & Dallery, 2013). If the participants did not meet their goal on at least five days that week, the parent provided feedback and encouragement, and the step count goal remain unchanged for the next week. The terminal goal criterion was set as 14,000 daily steps, which represented the upper bound of the recommended range for adolescents aged 12–17 (Adams et al., 2013). While Andy was outside the age range in the guideline, the parent decided to extend this criterion level to him as she felt a higher daily step count would be beneficial to him.

Chapter III: Results

Step Count

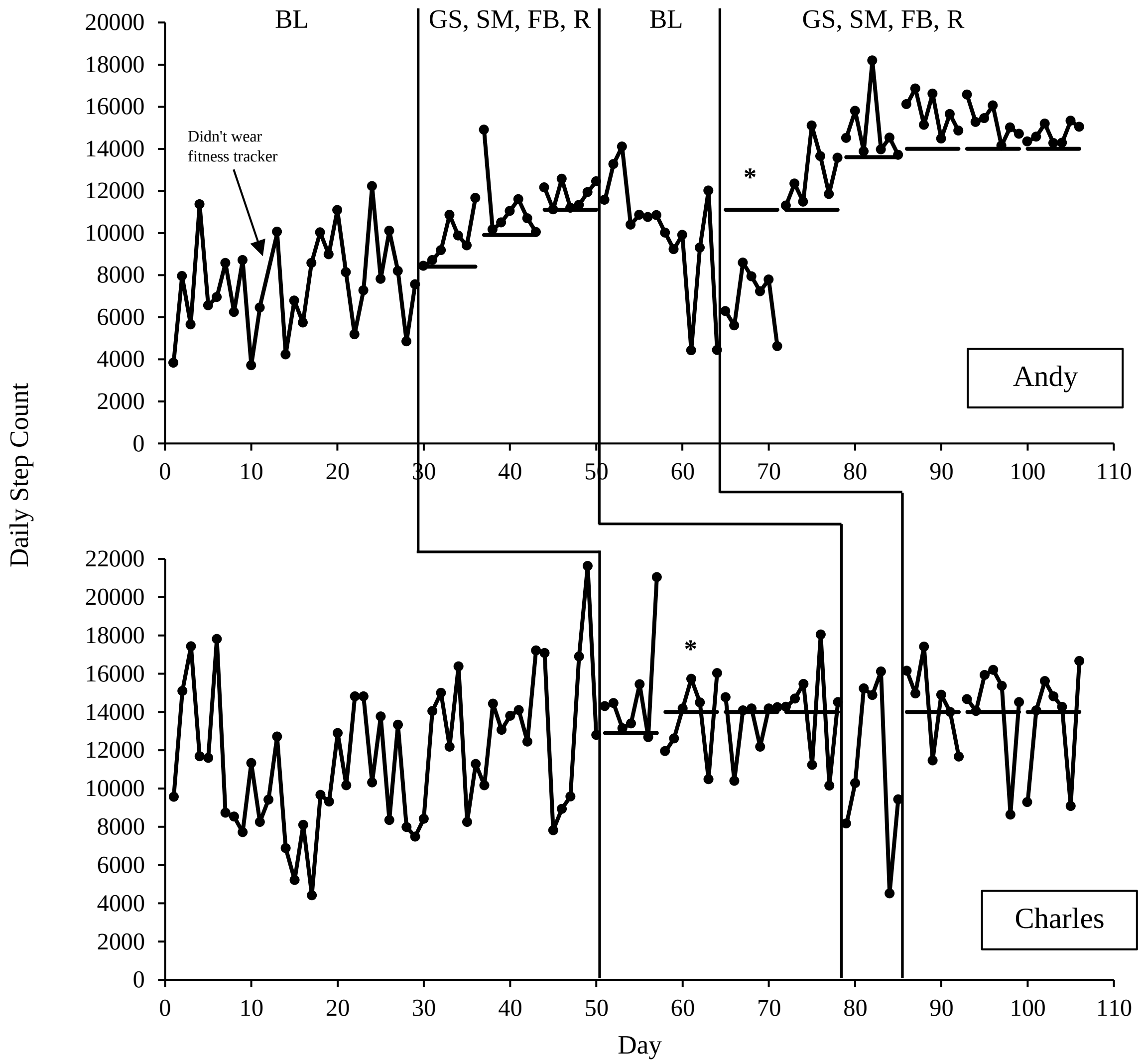
Brandon's mean daily step count was 12,484 steps during baseline (data not shown). The family decided that this was a sufficient level of PA, thus discontinuing participation in the study.

Figure 1 depicts the daily step counts of Andy and Charles. Due to the inherent variability in whole-day PA, the researcher also computed their mean daily step counts with one standard deviation error bars each week (see Figure 2) to facilitate visual analysis (Valbuena et al., 2017). During baseline, Andy's mean daily step count was 7,600 steps (*SD* = 2,265). He did not produce 14,000 or more steps on any day during baseline. In the last three weeks of the intervention phase, Andy's mean daily step count was 15,235 steps (*SD* = 815), a 100% improvement over his baseline levels. Andy also engaged in 14,000 or more daily steps on 100% of the days in the last three weeks, in comparison to 0% of the days during baseline. Charles' mean daily step count was 11,659 steps (*SD* = 3,650) during baseline. In the last three weeks of the intervention phase, Charles' mean daily step count was 13,988 steps (*SD* = 2,518), a 20% improvement over his baseline levels. Charles also produced 14,000 or more daily steps on 76% of the days, compared to 26% of the days during baseline.

During the intervention, both Andy and Charles' variance in daily steps also decreased, suggesting that the intervention had an effect of stabilizing steps produced (see Figure 2). Andy's variance in steps in the last three weeks of the intervention phase (*SD* = 815) was 64% lower than during baseline (*SD* = 2,265). Charles' variance in steps in the last three weeks of the intervention phase (*SD* = 2,518) was 31% lower than during baseline (*SD* = 3,650). Table 1 summarizes the mean daily step count and step goals for Andy and Charles for each week. Andy, Brandon, and Charles earned a respective total of 140 SGD, 80 SGD,

Figure 1

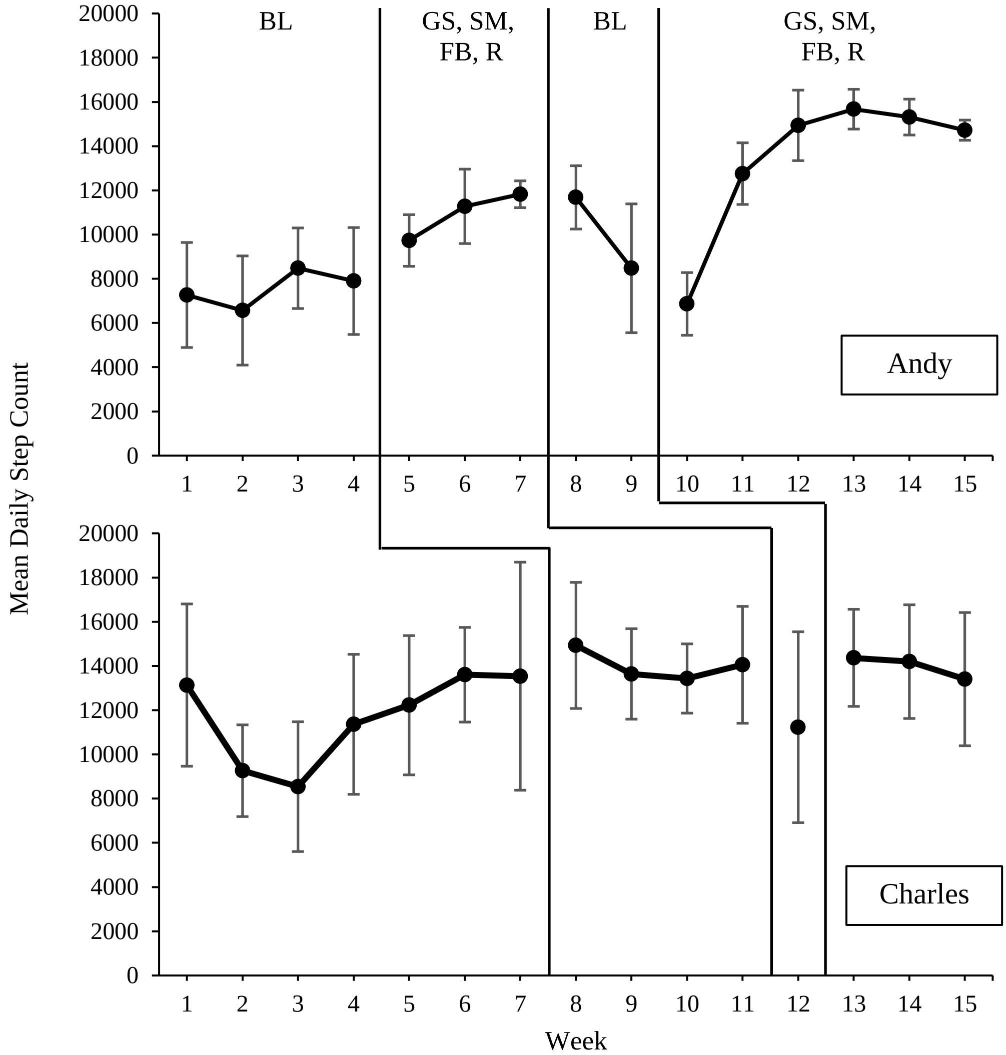
Daily Step Counts of Andy and Charles



Note. BL = baseline; GS, SM, FB, R = goal setting, self-monitoring, feedback, and reinforcement. The horizontal lines represent the participants' weekly intervention goals, to be met on at least five days each week. An asterisk denotes when the participant did not meet their goal on at least five days for that week. Note that the y-axis is scaled differently for Andy and Charles.

Figure 2

Mean Daily Step Counts Each Week of Andy and Charles



Note. BL = baseline; GS, SM, FB, R = goal setting, self-monitoring, feedback, and reinforcement. Error bars denote one standard deviation from the mean.

Table 1

Summary of Mean Daily Step Counts and Step Goals Each Week for Andy and Charles

Participant		Week							
		1	2	3	4	5	6	7	8
Andy	Mean daily step count (*SD*)	7,267 (2,375)	6,565 (2,469)	8,477 (1,823)	7,899 (2,418)	9,732 (1,167)	11,276 (1,683)	11,823 (607)	11,681 (1,432)
	Step goal	-	-	-	-	8,400	9,900	11,100	-
Charles	Mean daily step count (*SD*)	13,134 (3,670)	9,261 (2,075)	8,541 (2,936)	11,360 (3,166)	12,224 (3,150)	13,602 (2,140)	13,536 (5,157)	14,928 (2,852)
	Step goal	-	-	-	-	-	-	-	12,900
Participant		**Week**							
		9	10	11	12	13	14	15	`
Andy	Mean daily step count (*SD*)	8,474 (2,913)	6,863 (1,418)	12,756 (1,394)	14,938 (1,594)	15,671 (900)	15,314 (812)	14,720 (457)	
	Step goal	-	11,100	11,100	13,600	14,000	14,000	14,000	
Charles	Mean daily step count (*SD*)	13,639 (2,046)	13,432 (1,566)	14,050 (2,643)	11,229 (4,317)	14,366 (2,196)	14,195 (2,572)	13,403 (3,012)	
	Step goal	14,000	14,000	14,000	-	14,000	14,000	14,000	

Note. A dash indicates when no step goal was given for the week (i.e., during baseline or withdrawal phase).

and 140 SGD (approximately 101.40 USD, 58.00 USD, and 101.40 USD) through participation in the study (15 weeks for Andy and Charles, four weeks for Brandon).

During the withdrawal phase, Andy's mean daily step count was 10,077 steps (*SD* = 2,763), which was an increase of 32% from baseline, but lower than Andy's last weekly intervention goal before the withdrawal phase (11,100 steps). The increase in step count was partially attributed to a procedural error by the parent in the first week of the withdrawal phase, who had instructed Andy to continue filling in his activity diary. The parent reported Andy assumed he still had to hit a step goal, even though the parent had not given goals for that week. As the parent was away that week and uncontactable, the parent only rectified the procedural error the following week, during which Andy's mean daily step count decreased to 8,474 steps (*SD* = 2,913). During the withdrawal phase, Charles' mean daily step count was 11,229 steps (SD = 4,317).

In total, Andy and Charles' each missed their weekly intervention goals (i.e., meeting the step goal on at least five days of the week) once respectively. In both instances, the failure was partially attributed to a procedural error by the parent, who was one day late in conducting the weekly check-in, thus resulting in the participants receiving their goals one day late. In Andy's case, he missed his goals on the first two days of the week and forgot to put his fitness tracker on after charging on the third day. Having missed out on his reward for the week, he proceeded to miss his step goals the rest of the week. To prevent further similar occurrences, the researcher implemented a differentiated reinforcement contingency (van Haaren, 2017) for both participants. If a participant did not meet the current goal criterion on five or more days that week but met the immediately preceding goal criterion on five or more days, they would receive a smaller reward of 5 SGD (approximately 3.60 USD). For example, if the current goal criterion was 11,100 steps and the immediately preceding goal criterion was 9,900 steps, a participant who attained at least 9,900 steps but not 11,100 steps on five days would receive a 5 SGD reward rather than a 10 SGD reload of their Starbucks Card. If the current goal criterion was 14,000 steps (terminal goal criterion), the goal criterion for receiving the smaller reward was 12,600 steps (10% less than 14,000 steps). Neither participant failed to meet their weekly intervention goal subsequently and thus did not contact differentiated reinforcement.

Figure 3 depicts two examples of the participants' distribution of steps throughout the day as recorded by the fitness tracker. One critique of session-based PA interventions is that increases in PA are restricted to within the sessions themselves rather than throughout the day. A visual analysis of the daily step count data suggests distribution of steps were similar to those shown in Figure 3 and well-distributed throughout the day during the intervention for Andy and Charles. This indicates that they were engaging in more PA throughout the day rather than in concentrated bursts followed by long periods of sedentary behavior, in line with PA guidelines (WHO, 2020).

Treatment Integrity

Mean observed treatment integrity for Andy's and Charles' parent was 94%. Errors in treatment integrity wholly resulted from being late in conducting the check-in (i.e., after Monday 12:00 pm). Overall, the parent conducted the weekly check-ins on time for 60% of days. Observed treatment integrity for Brandon's parent was 100%. The researcher verified the conduct of daily check-ins through the daily screenshots of the participants' step counts sent by the parent. The researcher deduced the timeliness of the check-ins from the accompanying time stamp of each screenshot. In total, Andy's and Charles' parent conducted the daily check-in on time (before 12:00 pm of the next day) for 84% of days throughout the whole study. Brandon's parent conducted the daily check-in on time for 100% of days.

Figure 3

Sample Distribution of Steps for Andy and Charles

Note. Sample distribution of steps retrieved from Xiaomi Band 5. Top—Andy's distribution of steps on Day 91; bottom—Charles' distribution of steps on Day 62.

Social Validity

The social validity questionnaire results revealed both Andy and Charles and their parent perceived the intervention to be high in social validity (see Table 2). Andy and Charles' parent indicated that the goals were appropriate and valid, the intervention was easy to implement, appropriate with her current resources, not time-consuming to implement, and intervention outcomes were satisfactory. The parent also indicated she would like to continue implementing the intervention with Andy and Charles. Both Andy and Charles indicated they enjoyed participating in the study and would like to continue with the intervention. The parent indicated she might change the reward as it was a hassle for her to reload the Starbucks card as she had to go to the store. In the post-study interview conducted two weeks after the study's conclusion, the parent revealed she was still implementing the intervention procedures. The parent also observed that as a result of his participation in the intervention, Andy changed his daily routines to include more walking around the house and at the family's restaurant where he helps out at, and more frequent walks around the neighborhood. She did not observe any changes to Charles' routine.

Table 2

Summary of Social Validity Questionnaire Results

Parent	
Question	**Score**
The goals of the intervention were appropriate.	5
The goals of the intervention were valid.	5
The intervention was easy to implement.	5
The intervention was time-consuming to implement.	1
The intervention was appropriate with my current resources.	5
The outcomes of the intervention were satisfactory.	5
I would like to continue implementing this intervention with my child.	4
Participants	
Question	**Score**
I enjoyed participating in this study.	5
I want to participate in this study again.	5

Note. 1 = Strongly disagree; 5 = Strongly agree. Participants score reflects the mean score of Andy and Charles' responses.

Chapter IV: Discussion

The present study represents the first known attempt at increasing whole-day step count in adolescents diagnosed with ASD. In this study, a multicomponent intervention comprising progressive goal setting, self-monitoring, feedback, and reinforcement was implemented in full by the parents, with the researcher having no procedural interaction with the participants except during the initial meeting. The results of the study demonstrate the efficacy of the intervention, with both participants who progressed to the intervention phase reaching the 14,000 daily steps criterion level by the study's conclusion. In doing so, both participants met (and in Andy's case, exceeded) the PA guidelines (Adams et al., 2013; Tudor-Locke et al., 2011). Importantly, the participants' step counts were increased gradually, which was both easier to achieve (Klein et al. 2017), and from a participants' health standpoint, more desirable, reducing the risk of adverse events (WHO, 2020). In the last three weeks of the intervention, Andy's and Charles' mean daily step counts were 15,235 steps and 13,988 steps, representing an increase of 100% and 20% from their baselines, respectively. Variance in steps produced by Andy and Charles' also decreased as they progressed through the intervention, suggesting that the intervention had a secondary effect of stabilizing steps produced. This effect should be considered desirable as it aligns well with PA guidelines recommending producing consistent high levels of PA rather than having periods of high PA punctuated by periods of sedentary behaviors (WHO, 2020).

Andy's progress was particularly noteworthy for two reasons. First, he had not produced 14,000 steps on any day during preintervention baseline, and his increase of 100% in mean daily step count in the span of nine weeks (excluding two weeks implementing withdrawal) represents an impressive achievement. Second, Andy had a limited vocal-verbal repertoire, requiring supplementary visual prompts from the parent to accurately identify the intervention contingencies during the initial meeting. Andy's results revealed that, apart from missing his intervention goals for one week (likely due to a procedural error on the parent's part), he met his goal criteria on all days for the other weeks. Anecdotal report from the parent indicated he did not "like to lose", and not getting all the ticks "would feel like it's losing", suggesting an over-generalized intervention contingency, or that Andy's behavior was controlled by other sources of influence (e.g., self-generated rules). Nonetheless, Andy's success paves the path for further studies examining similar interventions with populations with similarly limited vocal-verbal repertoires and more sedentary populations.

Following Andy missing his weekly intervention goals every day of a week (Week 10), the researcher implemented a differentiated reinforcement contingency for both Andy and Charles to reduce the probability of similar occurrences. However, both participants met their intervention goals at least five days a week for the remainder of the study, and thus did not contact differentiated reinforcement. As such, the effectiveness of differentiated reinforcement cannot be concluded from this study. Differentiated reinforcement has been evaluated in the context of promoting skill acquisition (Cividini-Motta & Ahearn, 2013; Karsten & Carr, 2009), and reducing problem behavior (Athens & Vollmer, 2010). However, research on differentiated reinforcement remains scarce, and no study has evaluated the role of differentiated reinforcement on increasing response rates along multiple criterion levels. Setting multiple criterion levels with differentiated reinforcement would allow lower but still desirable response rates to contact reinforcement (albeit of a lower quality). This may act as a more effective shaping paradigm and avoids the participant giving up (i.e., collapse in response rates), which aligns with PA guidelines that doing some PA is better than doing none (WHO, 2020). Further studies should evaluate the effectiveness of differentiated reinforcement compared to single-strength reinforcement on increasing PA.

One unique feature of the study was the use of technology to achieve the study outcomes. Whole-day PA interventions have typically been difficult to implement as researchers were not able to continually measure behaviors or ensure adherence to procedures throughout the day. Advances in healthcare technology have allowed researchers to resolve the first issue, with accelerometers and pedometers providing valid measures of step count and allowing the possibility of whole-day interventions (e.g., Kuhl et al., 2015; Kurti & Dallery, 2013). In regard to the second issue, the researcher included automated features, including automated daily text reminders to prompt adherence and automated step goal computation to reduce response effort of the parent. In addition, the time stamps of the daily screenshots were used to assess if the daily check-ins were occurring in a timely fashion. Finally, the study was conducted through telehealth, which reduced costs (Lindgren et al., 2016), reduced response effort associated with scheduling in-person meetings, and which presents as a safe, viable alternative to in-person meetings (Pollard et al., 2021). The application of technology presents behavior analysts with new possibilities with regard to designing effective interventions and this study offers a glimpse of some of its potential applications.

Limitations

The study presents with several limitations. First, treatment integrity was modest for Andy’s and Charles’ parent, who conducted the weekly check-in on time for 60% of days and daily check-in on time for 84% of days. Scheduling weekly check-ins was also challenging, with the parent not responding to the researcher’s text messages on several occasions. During the initial meeting, the parent indicated she had a busy schedule and that she worked late hours, so these results were not completely unexpected. Lapses in treatment integrity directly affected the results on at least two occasions, with both Andy and Charles missing their weekly intervention goals once when the parent was one day late in giving them their goals. While Brandon’s parent was assiduous in conducting timely daily check-ins during baseline, the family ultimately discontinued participation in the study and continued treatment integrity during intervention cannot be inferred. The challenges of increasing and monitoring treatment integrity can be seen as a potential limitation of whole-day interventions in general.

Nonetheless, viewed in the context of the robust intervention results, one can conclude that whole-day interventions can be effective, even in the absence of high levels of treatment integrity. In fact, parent's anecdotal report suggested participants were self-initiating retrieving their step counts and sending screenshots to the parent (Charles), or asking the parent to retrieve their step counts (Andy). These self-management behaviors speak to high levels of social validity amongst participants and could have potentially offset the lower levels of treatment integrity by the parent. Self-management has been used in studies with neurotypical adults (Kurti & Dallery, 2013) and children (Kuhl et al., 2015). Future studies should examine the potential of self-management applied towards ASD populations. Further studies can examine having the parent administer goals and reinforcers, but with the participants self-managing all other aspects of the intervention (i.e., self-monitoring, self-feedback, and seeking reinforcement from parent upon goal attainment).

Second, due to time constraints, there was a lack of long-term outcome measures. While reported social validity amongst both parent and participants was high, a true measure of social validity is the maintenance of behavior change (of both parents and participants) long after the study has concluded (Kennedy, 2002). In the social validity questionnaire, both Andy and Charles, and their parent, expressed a desire to continue with the intervention procedures. The parent was also still implementing the intervention procedures at a two-week follow-up. Nevertheless, a six-month or one-year follow-up on whether they were still implementing the intervention procedures would be highly illuminating.

Third, all participants selected monetary-based rewards for this study. Both Andy and Charles selected a 10 SGD reload of their Starbucks Cards, and Brandon selected 20 SGD worth of departmental store gift vouchers. Andy and Charles both earned a total of 140 SGD equivalent in monetary-based rewards through their participation in the study (15 weeks), and Brandon earned a total of 80 SGD (four weeks) equivalent in monetary-based rewards. While this figure might appear high to some, it is important to note that these rewards were self-selected by the families (the researcher played no role in the selection process) and thus deemed acceptable to them. Nonetheless, it is unclear if the same intervention results can be attained without the use of monetary rewards. The use of monetary rewards might exclude some families without sufficient resources from implementing similar interventions. Future studies should explore the effectiveness of similar interventions using non-monetary rewards in increasing step count. Another potential area of exploration is reinforcement thinning after criterion-level PA has been established and its effect on the maintenance of PA (e.g., Kuhl et al., 2015).

Last, a common call-to-action regarding multicomponent interventions is to conduct a component analysis to determine the effectiveness of each component (e.g., Bassette et al., 2018; Kurti & Dallery, 2013; Valbuena et al., 2019). The researcher acknowledges that such analyses are important, but asserts that examining the effectiveness of well-established multicomponent packages in whole to new populations and contexts is equally important. For example, one need not re-examine each individual component of a BST package when applied to each new context (e.g., Miles & Wilder, 2009; Miltenberger et al., 2004; Sarokoff & Sturmey, 2004). The multicomponent intervention used in the present study involves readily integrated components, and is specifically designed to be easily implemented by most families with the further addition of automated components. If effectiveness and easy adoption by families is considered the end goal, one should consider the outcomes of this study highly successful. In fact, further studies should consider how adding more components (e.g., automated reward delivery) might further reduce barriers to adoption such that similar interventions can be adopted on a large (perhaps societal-wide) scale.

Conclusion

The present study demonstrated the effectiveness of a multicomponent intervention comprising progressive goal-setting, self-monitoring, feedback, and reinforcement in increasing whole-day step counts of adolescents diagnosed with ASD. From a public health perspective, the outcomes of the study are important in three ways. First, the results suggest that it is possible to progressively increase PA to recommended levels in a population more likely to have insufficient PA and associated health risks (Jones et al., 2017; McCoy & Morgan, 2020). One can view this study as a stepping stone for extending similar interventions to other at-risk populations. Second, the ease of implementation of the intervention procedures makes the intervention amenable to be implemented at scale, perhaps at a societal level. Further harnessing of technological aids has the potential to simplify the intervention further and increase its scalability. For example, a similar intervention (excluding progressive goal setting and feedback) has been implemented with success to increase step count at a societal level in Singapore (Yao et al., 2020). Last, the high social validity, particularly among the participants, increases the intervention’s acceptability to both stakeholders and target populations, making it more readily adoptable. Further research into similar interventions is warranted, with this line of research potentiating substantial improvements to the health of at-risk populations.

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Appendix A

Physical Activity Readiness Questionnaire

Your child's name: ____________________________

	Yes	No
1. Has your doctor ever said that your child has a heart condition and that you should only do physical activity recommended by a doctor?	☐	☐
2. Does your child experience chest pains during physical activity?	☐	☐
3. In the past month, has your child had chest pains when he/she was not doing physical activity?	☐	☐
4. Does your child lose his/her balance because of dizziness or does he/she ever lose consciousness?	☐	☐
5. Does your child have a bone or joint problem (for example, back, knee, or hip) that could be made worse by a change in his/her physical activity?	☐	☐
6. Is your doctor currently prescribing any medication for your child?	☐	☐
7. Do you know of any other reason why your child should not do physical activity?	☐	☐

Parent/guardian declaration

1. I affirm that I have answered the questions accurately and to the best of my knowledge.
2. If there are any changes in my child's condition, I will report it immediately to the researcher.

Your signature: _______________________________ Date: _____________________

Your name: __________________________________

Researcher's signature: _________________________ Date: _____________________

Researcher's name: ____________________________

Appendix B

Increasing Physical Activity in Adolescents Diagnosed with Autism Spectrum Disorders

Informed Consent (Parent/Guardian)

Your child is invited to participate in a research study examining increasing physical activity levels in adolescents diagnosed with autism spectrum disorders. This research is being conducted by Chin Yen Chai (the researcher) to satisfy the requirements of a Master's Degree in Applied Behavior Analysis at St. Cloud State University in Minnesota.

Background Information and Purpose

A procedure involving setting goals, self-monitoring, providing feedback, and providing incentives has previously been used to increase physical activity in various populations. The purpose of this study is to evaluate whether such a procedure, implemented by you or a suitable caregiver, can be used to increase the number of steps walked by your child toward a terminal goal of 10,000 steps daily. It is anticipated that your child will increase their daily physical activity level (i.e., the number of steps they take each day) during this study.

Procedures

The expected duration of the study is 16–20 weeks. During this study, your child will wear a fitness tracker that will be used to monitor their daily step count. Your child will be asked to wear the fitness tracker every day during their waking hours except during certain activities (e.g., swimming, bathing). The caregiver or yourself will be responsible for setting goals (e.g., walk 8,000 steps each day), retrieving and recording the step count data, providing feedback (e.g., praising your child for meeting their goal or encouraging them if they did not), and providing incentives for meeting goals. The researcher will be providing you with instructions and a brief training on how to implement the procedures.

Your family will NOT be responsible for lost or broken fitness trackers. However, there is a possibility that your child may not be able to continue the study if his/her fitness tracker is lost or broken due to a limited number of replacement fitness trackers.

Risks

There is a health risk associated with engaging in any form of physical activity, especially if your child has an existing medical condition. This study is evaluating a procedure to increase step count, which can primarily be achieved through light- (e.g., walking leisurely) to moderate-physical activity (e.g., walking briskly). To mitigate this risk, you will be required to complete the Physical Activity Readiness Questionnaire for your child before he/she is able to participate in the study. The researcher reserves the right to remove your child from the study at any point if there is reason to believe that participation will compromise his/her health or safety.

Benefits

Potential benefits for your child increasing his/her physical activity levels include improvements in psychological well-being, cognitive function, cardiorespiratory fitness, and bone and cardiometabolic health.

Confidentiality

Information obtained in connection with this study is confidential. No specific identifying information about your child will be revealed. The fitness tracker has an in-built GPS function, which will be disabled for the duration of the study. Additionally, the fitness tracker measures and records other biological data including heart rate data and sleep data. While the researcher might have access to this information in the course of the study, none of this data will be recorded and stored.

Research Results

At your request, the researcher will be happy to provide a summary of the research results when the study is completed. In addition, upon completion, the researcher’s thesis will be placed on file at St. Cloud State University's Learning Resources Center.

Contact Information

If you have questions, you may contact the researcher at **+65 9456 4973** or **yenchai.chin@go.stcloudstate.edu**. You may also contact the thesis advisor, Dr. Odessa Luna, at **+1 (320) 308 4167** or **odluna@stcloudstate.edu**. You will be given a copy of this form for your records.

Voluntary Participation/Withdrawal

Participation is entirely voluntary. If you decide to allow your child to participate, you are free to withdraw him/her at any time without penalty.

Acknowledgement of Informed Consent

1. I grant permission to have my child participate in the study conducted by Chin Yen Chai.
2. I give permission to have my child's daily step count be recorded using a fitness tracker.
3. I understand that confidentiality will be maintained and that my child's name will not be used in any manner while conducting the study or reporting the results of the study.
4. I further understand that I may withdraw my child from the study at any time without penalty.

Your signature: ______________________________ Date: ____________________

Your name: __________________________________

Researcher's signature: ________________________ Date: ____________________

Researcher's name: ____________________________

Appendix C

Physical Activity Levels in Young Adults

Informed Consent

I am doing a study called Project Starwalker to learn about how active young adults are. I need your help to understand how many steps young adults like you take every day.

This study will take around 16–20 weeks to complete. If you agree to be in my study, I will ask you to wear a special watch called a fitness tracker that lets me know how many steps you take every day. Your ________________ will be helping me take note of how many steps you take every day during the study. When you participate in my study, I will give you goals to walk a certain number of steps each day. You can receive rewards when you meet these goals. Other than your ________________ and myself, no one else will know how many steps you take each day if you choose not to tell them.

You can ask questions about the study at any time. You can also decide to stop participating in this study at any time by letting your ________________ know.

If you sign on this paper, it means that you have read this and that you want to be in this study. If you do not want to be in this study, don't sign on the paper. No one will feel unhappy if you decide you don't want to participate or change your mind later.

Your signature: ________________________________ Date: _____________________

Your name: ___________________________________

Researcher's signature: _________________________ Date: _____________________

Researcher's name: ____________________________

Appendix D

Project Starwalker Diary

Week: ______________	
Sunday Step Count Goal: Step Count:	**Goal met:**
Monday Step Count Goal: Step Count:	**Goal met:**
Tuesday Step Count Goal: Step Count:	**Goal met:**
Wednesday Step Count Goal: Step Count:	**Goal met:**
Thursday Step Count Goal: Step Count:	**Goal met:**
Friday Step Count Goal: Step Count:	**Goal met:**
Saturday Step Count Goal: Step Count:	**Goal met:**

Appendix E

Parent/Caregiver Training Data Sheet (Baseline)

Provide vocal-verbal instruction, written instruction, and modelling of the entire sequence before role-playing with parent/caregiver. Provide feedback upon incorrect response and, if necessary, modelling, and set up another role-play practice opportunity.

- **Mark '+' for correct response, '–' for incorrect response.**
- **Mastery criterion for each step is 2 consecutive '+'; mastery criterion of procedure is 2 consecutive '+' for entire sequence of 3 steps.**

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Parent/caregiver retrieves previous day's step count data from the fitness tracker and records it on data sheet										
2. Parent/caregiver checks fitness tracker battery levels and prompts participant to charge their fitness tracker if battery level falls below 20%										
3. Parent/caregiver provides individual access to preferred item or activity if participant wore fitness tracker every day of the week										

Parent/Caregiver Training Data Sheet (Intervention)

Provide vocal-verbal instruction, written instruction, and modelling of the entire sequence before role-playing with parent/caregiver. Provide feedback upon incorrect response and, if necessary, modelling, and set up another role-play practice opportunity.

- **Mark '+' for correct response, '–' for incorrect response.**
- **Mastery criterion for each step is 2 consecutive '+'; mastery criterion of procedure is 2 consecutive '+' for entire sequence of 6 steps.**

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Parent/caregiver retrieves step count data from the fitness tracker and record it on data sheet										
2. Parent/caregiver provides accurate feedback: - Praise for goal attainment - Encouragement for missing goals										
3. Parent/caregiver instructs and ensures participant fills in their step diary										
4. Parent/caregiver checks fitness tracker battery levels and prompts participant to charge their fitness tracker if battery level falls below 20%										
5. Parent/caregiver provides access to preferred item or activity on Sunday if participant met their goals on ≥ 5 days the previous week										
6. Parent/caregiver correctly assigns new step count goal on Sunday if participant met their goals on ≥ 5 days the previous week										

Appendix F

Treatment Integrity Checklist (Baseline)

Step	**Check if completed**
1. Parent/caregiver retrieves previous day's step count data from the fitness tracker and records it on data sheet before 12 noon	
2. Parent/caregiver checks fitness tracker battery levels and prompts participant to charge their fitness tracker if battery level falls below 20%	
3. Parent/caregiver provides individual access to preferred item or activity if participant wore fitness tracker every day of the week	
Total steps completed correctly	**/**

Treatment Integrity Checklist (Intervention)

Step	**Check if completed**
1. Parent/caregiver retrieves previous day's step count data from the fitness tracker and records it on data sheet before 12 noon	
2. Parent/caregiver provides accurate feedback: - Praise for goal attainment - Encouragement for missing goals	
3. Parent/caregiver instructs and ensures participant fills in their step diary	
4. Parent/caregiver checks fitness tracker battery levels and prompts participant to charge their fitness tracker if battery level falls below 20%	
5. Parent/caregiver provides access to preferred item or activity on Sunday if participant met their goals on ≥ 5 days the previous week	
6. Parent/caregiver correctly assigns new step count goal on Sunday if participant met their goals on ≥ 5 days the previous week	
Total steps completed correctly	**/**

Appendix G

Parent/Caregiver Social Validity Questionnaire

Please circle the response that best describes your experience with this research study.

1. The goals of the intervention were appropriate.

Strongly Disagree **1**	Disagree **2**	Neutral **3**	Agree **4**	Strongly Agree **5**

2. The goals of the intervention were valid.

Strongly Disagree **1**	Disagree **2**	Neutral **3**	Agree **4**	Strongly Agree **5**

3. The intervention was easy to implement.

Strongly Disagree **1**	Disagree **2**	Neutral **3**	Agree **4**	Strongly Agree **5**

4. The intervention was not too time-consuming to implement.

Strongly Disagree **1**	Disagree **2**	Neutral **3**	Agree **4**	Strongly Agree **5**

5. The intervention was appropriate with my current resources.

Strongly Disagree **1**	Disagree **2**	Neutral **3**	Agree **4**	Strongly Agree **5**

6. The intervention increased the physical activity levels of my child.

Strongly Disagree **1**	Disagree **2**	Neutral **3**	Agree **4**	Strongly Agree **5**

7. The outcomes of the intervention were satisfactory.

Strongly Disagree **1**	Disagree **2**	Neutral **3**	Agree **4**	Strongly Agree **5**

8. I would like to continue implementing this intervention with my child.

Strongly Disagree **1**	Disagree **2**	Neutral **3**	Agree **4**	Strongly Agree **5**

9. What issues/difficulties did you encounter (if any) when implementing the intervention?

10. What aspects of the intervention were helpful for you?

11. What aspects of the intervention were not helpful for you?

12. What changes would you make if you were to implement the intervention again?

Appendix H

Participant Social Validity Questionnaire

Please circle the response that best describes your experience with this research study.

1. I enjoyed participating in Project Starwalker.

Strongly Disagree **1**	Disagree **2**	Neutral **3**	Agree **4**	Strongly Agree **5**

2. I want to participate in Project Starwalker again.

Strongly Disagree **1**	Disagree **2**	Neutral **3**	Agree **4**	Strongly Agree **5**

3. What did you like about participating in Project Starwalker?

4. What did you not like about participating Project Starwalker?