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Augmented Reality as a Navigation Tool to Employment Opportunities for Postsecondary Education Students With Intellectual Disabilities and Autism

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Abstract

The purpose of this study was to examine the effects of location-based augmented reality navigation compared to Google Maps and paper maps as navigation aids for students with disabilities. The participants in this single subject study were three college students with intellectual disability and one college student with autism spectrum disorder. The study measured their ability to independently make navigation decisions in order to travel to unknown business locations in a city. All students attended a postsecondary education college-based program. Results indicated that students traveled more successfully using augmented reality compared to Google Maps and a paper map. Conclusions are discussed in the context of reducing barriers related to employment. (Keywords: augmented reality, intellectual disabilities, mobile devices, navigation, postsecondary education, transition)

Introduction

Unemployment levels of people with disabilities are much higher than the rate of unemployment in the general population. According to the National Longitudinal Transition Study (NLTS), the rate of employment for students with intellectual disabilities up to 8 years post high school is 38.8%, which is much lower than the similarly general population average of 66% (2011). Including additional postsecondary education programs and job training, 45.8% of students with intellectual disabilities engaged in employment or employment-related activities. The primary transition goal of secondary students with disabilities is to be employed (Cameto, Levine, & Wagner, 2004). Unfortunately, students with disabilities are significantly less likely to be employed than their peers without disabilities (Burge, Ouellette-Kuntz, & Lysaght, 2007; Newman et al., 2011). Employment is one of several factors that increase the quality of life for individuals with intellectual disabilities (ID; Schalock et al., 2002) and autism (García-Villamisar, Wehman, & Navarro, 2002), so it is critical for educators to find ways of helping these students minimize the barriers to their employment.

Barriers to Employment

There are several identified barriers to employment for students with intellectual disability (ID) and autism, including societal factors (Swain, 2004), limited transition options and training (Migliore, Mank, Grossi, & Rogan, 2007), limited availability of postsecondary education opportunities (Grigal, Hart, & Migliore, 2011), lack of knowledge (Folk, Yamamoto, & Stodden, 2012), and navigation/travel concerns (Rose, Saunders, Hensel, & Kroese, 2005). New technologies and innovative solutions using existing commercial technologies may provide individuals with ID and autism spectrum disorders (ASD) increased employment and navigation skills.

Mobile Devices for Students With Disabilities

Widely varied technologies have been used successfully to assist people with ID and ASD to navigate more independently including using mobile devices. Instructional technologies can be applied as assistive technologies to promote greater independence by enabling people with disabilities to perform tasks that they were formerly unable to accomplish. The proliferation of mobile devices in society led to the growing field of using these devices to learn new things commonly called mobile learning. Mobile learning emphasizes a movable learning environment rather than a static location (Ogata & Yano, 2004). Mobile learning tools have several advantages over stationary, traditional computer-based tools for navigation related tasks. In addition to portability, mobile devices frequently offer a variety of accessibility options for students with ID and ASD (McMahon & Smith, 2012). Wehmeyer, Palmer, Smith, Davies, and Stock (2008) conducted a meta-analysis of research on technologies used by people with disabilities, which identified several studies that support the effectiveness of mobile devices for teaching people with ID skills across many different academic and functional skills. Mobile devices have the potential to empower people with disabilities by providing a full range of supports readily available for the user in a socially acceptable platform.

Navigation for Students With Disabilities

Previous technology-based intervention research to teach navigation skills has demonstrated promise. Lancioni et al. (2010) conducted two studies using navigational technologies that provide both auditory and physical prompts (vibrating) to assist individuals with multiple disabilities and low vision or blindness in finding indoor routes. In the first study, the participants were wheelchair users, while the second study's participants were ambulatory. The system prompted the participants when they were approaching doorways and corridors. Both the participants who used wheelchairs and the participants who were able to walk successfully oriented themselves indoors using the mobile device prompting tools. In addition, Mechling and Seid (2011) used a commercially available handheld personal digital assistant (PDA) to provide picture, auditory, and video prompts for three young adults with ID to support independent navigation skills. The students could choose the prompts and how often they needed them based on their individual needs. Using the mobile device, the young adults with ID were able to increase their ability to find landmarks along a route and to reach independently their destination. However, since the intervention relied on video modeling, all materials for the students were created and downloaded in advance in order to navigate to a new location. Students were unable to travel to a location for which the video clips were not developed ahead of time. Davies, Holloway, and Wehmeyer (2010) also used commercially available mobile devices. The software was a custom-designed prototype with a global positioning system (GPS) to support independent bus travel for adults with ID. This study measured the independence of two groups of adults with ID. The intervention group ($n = 12$) used a GPS system to navigate independently to a new location, while the control group ($n = 11$) used a traditional paper map. The investigators collected data at specific decisions points. Decision points were defined as navigation points that required a decision regarding which way to turn (e.g., left, right, continue forward) and/or to access specific public transportation (e.g., bus). Using the handheld GPS, 73% of students with ID were able to navigate independently to a new location using public transportation; in the control group less than 10% of the students were able to get to the correct destination independently. Although the results support the successful use of independent navigation skills, the customization of the specialized prompting software used may limit greater usability compared to a commercially available product.

Augmented Reality for Location-Based Learning and Navigation

As described by Craig (2013), the defining characteristic of augmented reality (AR) is the addition of digital information within the physical world. In AR applications that use global positioning systems, (GPS) or other location tools (compass, accelerometer, etc.), individuals view digital media based on their location. This digital media can provide a variety of educational and independent living supports. Ten years ago, a portable AR navigation system required a 15-pound computer backpack that used a helmet-mounted display system (Kalkusch et al., 2002). Today using mobile devices as platforms, there are hundreds of AR applications addressing a wide range of needs including navigation.

Beckett and Shaffer (2005) used an augmented reality geographic information system (GIS) to teach urban planning skills for high school students in authentic professional practices. They concluded that the AR system represents a new technology that can teach students ecological concepts in a practical context, which can help to bridge the gap between indoor and outdoor learning environments. Etxeberria, Asensio, Vicent, and Cuenca (2012) reviewed the use of mobile devices to support location-based learning. The authors found that various technologies on mobile devices were implemented to support location-based context-relevant learning, navigation, and prompting at cultural tourism sites in Europe, including virtual reality, augmented reality, and geographic information system reference information that appears when an individual is near a particular set of GPS coordinates. Throughout Europe at cultural locations, these technologies are used to create formal scripted instructional experience, informal learning options, and optional supplementary information based on the needs and interests of the user.

While there is limited research on AR as a navigation tool for students with disabilities, there is research on the related technology of virtual reality that is relevant to this work. Virtual reality training and instructional activities for students with ID can transfer to new locations, which allows students to practice functional activities like navigating a grocery store or making a purchase in a low-stress, failure-free environment (Cobb & Sharkey, 2007). Hutcherson, Langone, Ayres, and Clees (2004) applied virtual simulations that provided prompts to assist students with ID to navigate large three-dimensional simulations of shopping experiences from a first-person point of view. Their results indicated that all of the students were able to generalize the lessons learned on the computer to the physical store.

Smith (2013) used a location-based AR application for college students with ID and ASD to improve navigation skills to unknown locations (not previously known to the participant) on a college campus. Participants in this ABAB design selected the target destination from a list of choices from within the application on the mobile device and then used the AR application to navigate independently to unknown locations. As students looked through the AR view, digital information was displayed, including an arrow showing the correct direction and text that indicated the amount of distance remaining to reach the destination. McMahon, Smith, Cihak, Wright, and Gibbons (in press) conducted a comparative study using paper map, Google maps on a mobile device, and an AR navigation tool for a similar group of students in a PSE program. The results indicated that students using the AR navigation app navigated more independently and the students preferred using the AR app.

Purpose: Navigating to Employment Opportunities

Augmented reality is a technology that may empower individuals with disabilities with new skills for independent navigation to locations not previously known to the individuals. One example that demonstrates the flexibility of using AR on mobile devices is the app Layar, which can function as an Internet browser for location-based information, like nearby job openings. When used, the AR app displays nearby businesses with open job opportunities based on the user's settings and location. A user choosing to display open jobs within a 5-mile radius is likely to have more search results compared to a user who only displays job results located within a 1-mile radius of their location. Adjusting the app search criteria allows the user to adjust the number of points of interest that are displayed in their mobile device, which is then used in addition to live video that was augmented by search apps for locating jobs.

The purpose of this study was to examine the effects of a location-based AR technology to teach college students with ID and ASD to navigate a city independently to local employment opportunities. While location-based AR could be used for many navigation related tasks, navigation to employment locations was selected because it aligned with the broader goals of the students' postsecondary education program. This study used an augmented reality app called Layar (2013) to view location-based navigation data on employment opportunities within walking distance of the individual with an intellectual disability. Due to the complex nature of navigation, appropriate technology should be selected to assist individuals with disabilities when navigating independently to new locations for employment opportunities in large cities, suburbs, and urban areas. By teaching young adults with ID or ASD to access the needed technology, apply the knowledge needed to use the tool or application, make a decision based on information obtained, and utilize embedded digital supports, AR navigation tools may help increase their ability of independent decision-making skills when navigating to unknown locations. The current study evaluated the use of three different navigation aids for people with ID. This study examined the following research questions.

1. What are the differential effects for college students with ID and ASD when using a printed map, Google Maps, and a location-based augmented reality navigation tool to navigate independently a city to unknown businesses locations?
2. Which navigation strategy do college students with ID and ASD report as being most helpful and socially acceptable?

Methods

Participants

Four college-age students participated in this study. All students attended a postsecondary education program (PSE) for college students with ID and ASD. This program was located at a large public university in the southeastern United States. Students participated in university audit courses, PSE courses, a work-based internship, and campus activities. Students participated in a course on digital literacy and regularly used mobile devices for educational and recreational activities. As part of their PSE program, students regularly and independently traveled to classes along familiar routes. Participants included one male and three female students. Pseudo names (Jamie, Catelyn, Jon, and Arya) were used to maintain confidentiality. All students received special education services under the ID category during their previous K–12 schooling. Two months before the start of this study all of the participants were administered selected tests from the Woodcock–Johnson III Normative Update Tests of Cognitive Abilities and Tests of Achievement (WJ-III; Woodcock, Schrank, Mather, & McGrew, 2007). Diagnostic and educational information including IQ, processing speed, and reading proficiency levels for each participant is displayed in Table 1.

Jamie. Jamie was a 21-year-old student diagnosed with autism. Jamie had an IQ of 63 based on results from the Wechsler Intelligence Scale for Children (WISC-III). His GARS autism index was 85 (Very Likely). Results from the Woodcock–Johnson III indicate compared to peers of his age, Jamie had very limited processing speed (SS = 34) and limited broad reading skills (SS = 74). Results from the Vineland Adaptive Behavior Scales (VABS) indicate mildly deficient adaptive

Table 1. Study 2 Participant Characteristics

Participant	Age	IQ	Adaptive IQ	Processing Speed	Broad Reading
Jamie	21	63 (WISC-III)	67	34	74
Catelyn	23	45 (SB-IV)	65	54	55
Jon	24	56 (RAIS)	73	49	71
Arya	20	64 (WISC-III)	72	50	77

Note. Wechsler Intelligence Scale for Children (WISC III), Wechsler (1991); Stanford Binet Fourth Edition (SB-IV), Thorndike, Hagen, and Sattler (1986); Reynolds Intellectual Assessment Scales (RAIS), Reynolds and Kamphaus (2003).

functioning (SS = 67). Jamie had moderate navigation skills and could independently travel to known locations but required assistance to travel new locations.

Catelyn. Catelyn was a 23-year-old student diagnosed with an ID. She had an IQ of 45 on the Stanford Binet Fourth Edition. Results from the WJ-III indicate compared to peers of her age, Catelyn had very limited processing speed (SS = 54) and negligible broad reading skills (SS = 54). Results from the Vineland Adaptive Behavior Scales (VABS) indicate mildly deficient adaptive functioning (SS = 65). Catelyn had limited navigations skills and required a mentor to travel to some known locations on campus depending on distance in her PSE program.

Jon. Jon was a 24-year-old student diagnosed with ID. He had an IQ of 56 as measured on the Reynolds Intellectual Assessment Scales (RAIS). Results from the WJ-III indicate compared to peers of his age, Jon had very limited processing speed (SS = 49) and very limited broad reading skills (SS = 50). Results from the Vineland Adaptive Behavior Scales (VABS) indicate borderline adaptive functioning (SS = 74). Jon had moderate navigations skills and frequently traveled independently to known locations on campus.

Arya. Arya was a 20-year-old student diagnosed with multiple disabilities, including ID. She had an IQ of 64 based on results from the WISC-III. Results from the Woodcock–Johnson III indicate compared to peers of her age, Arya had very limited processing speed (SS = 50) and limited broad reading skills (SS = 77). Results from the Vineland Adaptive Behavior Scales (VABS) indicate borderline adaptive functioning (SS = 72). Arya required a motorized scooter in order to travel between locations in her daily life. Arya had moderate navigations skills and frequently traveled independently to known locations on campus.

Settings. All phases of this study occurred in a community setting, specifically in a downtown area in a city of 150,000–250,000 people. Participants navigated city streets to locate businesses that offered potential employment opportunities. Starting and ending locales were within a 12- to 20-minute walking distance of one another. Starting and ending points were continuously changed in order for students to always attempt a new navigation experience.

Research Design

An adapted alternating treatments design (ATD; Sindelar, Rosenburg, & Wilson, 1985) was used to determine the efficacy of college students with ID and ASD to use a paper map, Google Maps, and the AR application to navigate correctly to an unknown business location. Sindelar et al. (1985) suggested that in adapted alternating treatment designs researchers can demonstrate functional control of the dependent variable by extending the baseline condition during intervention as a third condition. The baseline condition, the paper map, was continued as a third condition of the adapted alternating treatment in order to allow for the demonstration of a functional relation between the independent and dependent variables. The adapted alternating treatments design allowed the investigator to evaluate the relation between each navigation treatment condition and correct navigational checks. Navigation treatment conditions were presented randomly to reduce potential carryover effects. The more effective navigation aid treatment was defined as bifurcation of the data paths or if the student reported a preference using one application over another via the social validity questionnaire. Afterward, only the preferred navigation application continued to be assessed.

Treatment Conditions and Materials

Three treatment conditions were implemented to examine the effectiveness of each student's independent navigation skills including (a) paper map, (b) Google Map, and (c) augmented reality (AR). During the paper map treatment condition, a paper map of the city's downtown area was produced using Google maps. The paper map was 8.5 inches × 11 inches and printed in color. The map included major street names and the student's current location. Destinations were marked clearly with an X on the paper map for the students.

The Google Maps treatment condition used the Google Maps software application (Google, 2014). Students accessed the application from a mobile device provided by the researchers. The

Google Maps application displayed the student's current location as a blue dot and displayed a pin for the targeted business location. The lead investigator selected the target location. Google Maps also highlighted a route to the targeted business. The mobile devices used in this study were iPhones.

The AR treatment condition used the Layar mobile app (Layar, 2013). Layar is a free, widely available mobile application that works on multiple platforms including iOS and Android mobile devices. The specific devices used in this study were all iPhone 4s. Layar uses location-based augmented reality display to show selected content. There are thousands of potential channels of content called "geolayars." Users select content to view by subscribing to a particular topic's geolayer. This allows the app to function as a search engine for location-based information from the selected geolayer topics (e.g., employment opportunities) displayed according to the relative location of the user. This study used Layar to view employment postings from variety of geolayars, for example, TweetMyJobs. Layar's embedded visual prompts appeared as an icon of the employment location when viewed through the camera feature. The icon helps to inform the student's decision-making by "hovering" above the specific business destination. The prompts also include the distance to the location

Figure 1. Augmented reality view of location-based jobs information displayed for jobs within set distance of the user.

in miles. Like the Google Maps treatment, Layar uses a wireless Internet connection and other built-in tools on the mobile device to determine a user's location and orientation. In addition, the lead investigator selected the target location from the available nearby unknown business locations with employment opportunities. Figure 1 illustrates a participant's view when using AR to navigate.

Variables and Data Collection

The independent variable was the specific navigational condition: (a) paper map, (b) Google Map, and (c) augmented reality (AR). Each student participated in three navigational treatment conditions to assess the number of correct navigational checks to an unknown business location. Implementation of each treatment condition is described later, in the Procedures section.

The dependent variable was the percentage of correct independent navigation decisions during "navigation checks" while walking to a targeted unknown business location. Responses were marked as either *yes*, which was defined as independent correct responses, *no*, for incorrect responses, or *assisted*, for correct responses after assistance. Event recording procedures were used to record the number of correct navigation checks from the starting location to the business location. The number of correct independent responses was divided by the total number of navigation checks in order to produce a percentage of independent correct navigation decisions. Acquisition criterion was defined as 100% independent navigation checks for three consecutive sessions.

Navigation checks. Navigation checks occurred at common decision points (e.g., intersections, crosswalks), or after more than 2 min of walking without a navigation check. The investigator asked "Which direction do we go from this point?" during the navigation check. The investigator recorded the student's response as correct, incorrect, or assisted. Starting locations for the sessions were sufficiently far away that a minimum of seven navigation checks would occur. Students were allowed 30 s in order to use the selected independent variable condition (paper map, Google Map, AR app) to make their navigation decision. To support practical independent decision making, the investigators followed behind the students approximately 10 feet. This procedure supported the greatest level of possible independent navigation decision making while providing a responsible level of safety supervision as students navigated city streets.

Correct responses. A correct response was considered any response within 30 s that could directly and safely get the participant to the employment location. This included any verbal or gestural response indicating the accurate path to get direction (i.e., forward, left, or right) to get to the final destination without person-support assistances. If the response was questionable, the investigator used a general "rule of thumb" of a 45-degree arc for the "best" path. If the student indicated a path that fell within the correct 45-degree area of the 365 degrees possible, then the response was marked as correct. If the student correctly responded either verbally and/or gesturally, within 30 s, the investigator said, "ok" and they continued to travel to the business destination.

Incorrect and assisted responses. Incorrect responses were defined as responses that would not directly or safely get to the business location. Participants were allowed to get three incorrect responses before receiving assistance in order for each participant to have the opportunity to realize the navigation errors. This also prevented artificially inflated correct independent navigation checks, especially as the student was closer to the destination. Contingent on the third incorrect navigation check, the investigator then provided verbal and if necessary gestural assistance and recorded the navigation check as "assisted." Additionally, if students did not respond after 30 s, the investigator provided verbal and if necessary gestural assistances and they continued walking to the business destination.

In addition, "jaywalking" or taking a shortcut through buildings or alleys was not accepted as a correct response. If an obstacle or barrier (e.g., construction, sidewalk closure) was encountered, the investigator asked "What is the safest way to get there?" or "What is the best way to get there?" If the student self-corrected and indicated the correct direction without assistance within 4 s, the investigator recorded the response as “correct.” However, if the student’s response was incorrect or unsafe, the investigator provided verbal and gestural assistance and recorded the student’s responses as “assisted.” The number of correct independent navigation checks was divided by the total number of navigational checks in order to calculate a percentage of correct navigational checks, which was graphed for visual analysis.

General Procedures

During each navigation session, each student was randomly assigned using a spinner to one of the three treatment conditions. Each of the treatment conditions had the target destination selected (Google Maps and AR app) or marked (paper map) for the user. The investigator started the session by asking the students to verbalize the name of the target destination and to show the investigator on the map or mobile device. Then the investigator asked, “Have you ever been there before?” This ensured that the students looked at the map or device and that the destination was unknown. Each destination was estimated to require approximately 12 to 20 minutes of walking time to travel from the starting location, or using a motorized scooter, in the case of Arya. Both beginning location and destination varied every session, so students always experienced novel navigation activities.

Baseline. During baseline, students were given an unknown business location to travel to, navigating independently using a paper map. The location of the business destination was marked on the map, as well as the student’s current location. The investigator asked, “Have you ever been there before?” If the student responded “Yes” then a different business was selected until the student indicated that he or she had not been to a specific business. The investigator asked the students to verbalize the name of a business and to show the investigator the business location on the map. This ensured that the students looked at the map. Afterward, the investigator and student traveled to the business location. Each trial included at least seven different navigation decision points (e.g., crosswalks, intersections) where the investigator asked the student “which direction do we go from this point?” The investigator recorded the student’s responses and provided contingent assistance as noted earlier.

Pretraining phase. Pretraining was provided to each participate to ensure that they could independently access and use the two mobile applications (Google Map and Layar). Model-Lead-Test procedures (Adams & Engelmann, 1996) were used to instruct each participant. First, the investigator modeled each step of the task analysis regarding how to access and use the mobile application, then students practiced accessing and using the mobile apps with the investigator, and finally students were tested to examine whether they could independently access and use the mobile apps. During pretraining, all students demonstrated the ability to open both apps and view the selected destinations independently on three occasions.

Paper city map. During the paper map navigation condition, students continued to use the same paper map implemented during the baseline phase. This treatment was a continuation of the baseline. Similar to baseline, the job location was marked on the paper map and the student was asked to navigate to the location. Using the navigation check procedures, the student and investigator then traveled according to the decisions of the participant as they attempted to navigate to the business location. The investigator conducted periodic navigation checks (i.e., intersections, crosswalks, or after 2 minutes of walking without a navigation check) and provided verbal and gestural assistance contingently after three consecutive errors.

Google maps. The Google map was displayed on a mobile device using the iOS operating system (iPhone 4s). The app used location information obtained by the wireless data connection on the device, which allowed the student to see their current location and the target destination. The investigator selected the unknown business location and provided the mobile device to the student. Using the navigation check procedures, the student and investigator then traveled according to the decisions of the participant as they attempted to navigate to the business location. The investigator conducted periodic navigation checks (i.e., intersections, crosswalks, or after 2 minutes of walking without a navigation check) and provided verbal and gestural assistance contingently after three consecutive errors.

AR navigation. The AR application Layar was displayed on a mobile device using the iOS operating system (iPhone 4s). This app also used location information provided from the wireless data connection and used that information to provide the AR experience described in the materials section. Similar to the Google Map treatment, the investigator selected the unknown business location and provided the mobile device to the student. Using the navigation check procedures, the student and investigator then traveled according to the decisions of the participants as they attempted to navigate to the business location. The investigator conducted periodic navigation checks (i.e., intersections, crosswalks, or after 2 minutes of walking without a navigation check) and provided verbal and gestural assistance contingently after three consecutive errors.

Preference phase. The more effective navigation treatment condition was replicated during a preference phase. The more effective condition was defined as bifurcation of the data paths. In visual analysis, bifurcation is the separation in the data path of at least three consecutive points (Gast, 2010). If all conditions were determined to be equally effective, then the student's reported navigation preference via the social validity questionnaire would be replicated. Students navigated to three additional unknown businesses using the same procedures defined earlier.

Interobserver Agreement and Treatment Integrity

The lead investigator and a trained research assistant collected interobserver agreement (IOA) and procedural reliability data both independently and simultaneously. The research assistant was trained in the study procedures, independent and dependent variables, and data collection procedures. Interobserver agreement data were collected during a minimum of 25% of baseline and each intervention condition. Observers independently and simultaneously recorded the number of correct navigation checks. Interobserver agreement was calculated by dividing the number of agreements of the participant responses by the number of agreements plus disagreements and multiplying by 100. The overall IOA was 97% (range = 91%–100%). Jamie's treatment integrity ranged from 92% to 100% ($M = 98\%$), Catelyn's ranged from 91% to 100% ($M = 96\%$), Jon's ranged from 94% to 100% ($M = 98\%$), and Arya's ranged from 94% to 100% ($M = 96\%$).

Procedural reliability data also were collected during a minimum of 25% of all sessions for each treatment condition and for each participant. The investigator was required to provide participants with the necessary materials (i.e., paper map, mobile device, app, location preloaded), ask "Which direction do we go from this point?," and provide verbal and gestural assistances, contingent upon an incorrect response or no response following 4 s. A trained graduate assistant and doctoral student who were knowledgeable about the study, independent and dependent variables, and treatment condition instructional procedures observed the investigator implementation of treatment-condition procedures. The observer was provided with a task analysis of instructional procedures for the treatment conditions and recorded whether specific instructional procedures were observed. The procedural agreement level was calculated by dividing the number of observed investigator's behaviors by the number of planned investigator's behaviors and multiplying by 100. The overall mean treatment integrity was 100%.

Social Validity

Following the conclusion of the reimplementation phase, each participant was asked to complete a Likert survey created by the investigator to assess their opinions and acceptability of using the navigation tools. The question items were read aloud to the students. Each survey item used a Likert scale ranged from 1 (*strongly disagree*) to 5 (*strongly agree*) with the addition of "thumbs up" and "thumbs down" as indicators on the scale to support comprehension of the question. The social validity survey also included two open-ended social validity questions whose answers were scribed by the investigators.

Results

Baseline results for all of the participants indicated that they were not able to navigate independently to the unknown business locations. Visual analysis procedures for all of the participants revealed that the AR treatment condition was the more effective. A bifurcation was observed favoring AR. The continuation of the baseline condition, the paper map, as a condition of the alternating treatments demonstrated a functional relation between improved navigation independence and the two conditions using mobile devices. Between these two conditions, the AR condition was superior in terms of reaching the criteria of three successful 100% independent navigation attempts to potential employment opportunities.

Jamie

Jamie required assistance during all baseline sessions using the paper map to navigate to nearby possible job opportunities. His baseline average was 12.1% correct independent navigation checks. During the intervention phase, the three treatments produced noticeable differences navigating independently. Jamie's first session using the AR app was 75% independent navigation checks. In his second session using AR, his independent navigation increased to 100% independence and he achieved criteria after two more AR app sessions. Jamie's average navigation independence was 49.1% with Google Maps. His scores on the AR app remained at 100% while his scores remained approximately the same for the paper map and Google Map, both of which had an overall average of 50% or less. Of the three conditions, the paper map was the least successful with a mean of 13.8% correct navigation checks, which was effectively no improvement from baseline. During the preference phase, Jamie's navigation checks remained at 100% using the AR navigation treatment. Jamie's percentage of nonoverlapping data average using the more successful treatment (AR navigation) was 100%, which indicated a highly effective intervention (Scruggs & Mastropieri, 2001). Jamie's results are displayed in Figure 2.

Catelyn

Catelyn was unable to navigate to any location independently during baseline. Her baseline average was 11.5% correct independent navigation decisions. The AR app was immediately more successful than the other treatments, with 75% navigation independence. Catelyn achieved criteria of three consecutive sessions at 100% on her fifth session using the AR app. Visual analysis showed that the other two conditions remained fairly low and did not trend toward improvement. Google Maps was second most successful with a total of 45.75% independent navigation checks. The paper map was the least successful with an average of independent direction checks of 20.14%, a marginal improvement from baseline. During the preference phase her scores remained at 100% using the

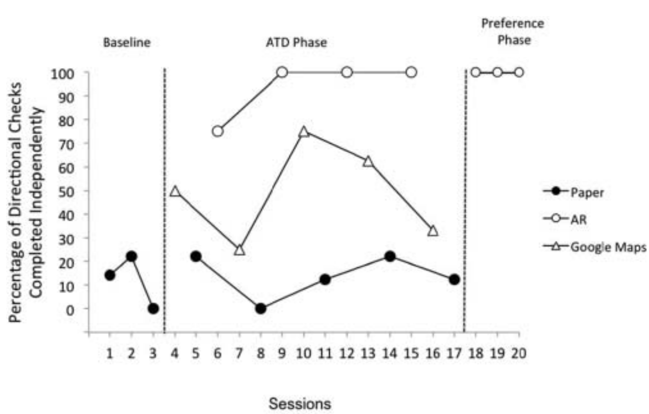

Figure 2. Jamie's percentage of independent navigation checks across paper map, augmented reality navigation, and Google Maps conditions.

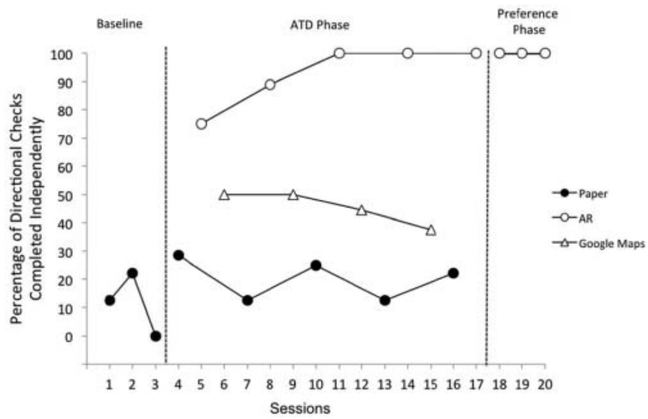

Figure 3. Catelyn's percentage of independent navigation checks across paper map, augmented reality navigation, and Google Maps conditions.

AR navigation treatment. Catelyn's percentage of nonoverlapping data average using the more successful treatment (AR navigation) was 100%, which indicated this was a highly effective intervention (Scruggs & Mastropieri, 2001). Catelyn's results are displayed in Figure 3.

Jon

Jon did not navigate independently to any location during baseline. His baseline average was 16.13% correct independent navigation decisions. The AR app was immediately more successful than the other treatments, with 75% navigation independence. Jon acquired 100% independence for three consecutive sessions on the fourth navigation session, indicating the preferred navigation aid for him was AR. Jon's mean level of independent navigation for Google Maps was 40.95%. The paper map was the least successful, with an average of independent direction checks of 20.47%, which was effectively unchanged from baseline. During the preference phase, his independence remained at 100% using the AR navigation treatment. Jon's percentage of nonoverlapping data average using the more successful treatment (AR navigation) was 100%, which indicates a highly effective intervention (Scruggs & Mastropieri, 2001). Jon's results are displayed in Figure 4.

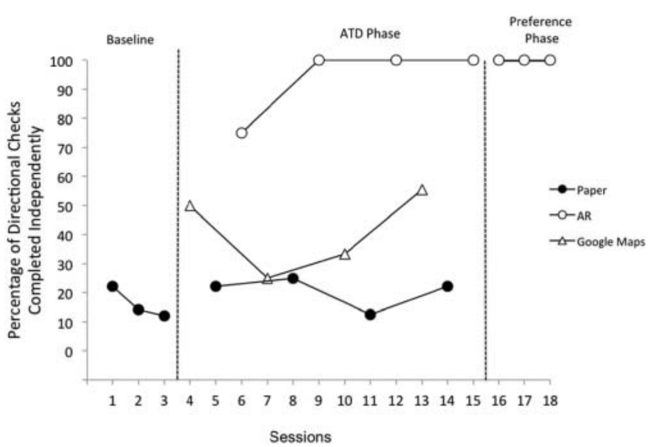

Figure 4. Jon's percentage of independent navigation checks across paper map, augmented reality navigation, and Google Maps conditions.

Arya

Arya was unable to travel independently to any unknown location during baseline using the paper map. Her baseline average was 13.6% correct independent navigation decisions. The AR app was immediately more successful than the other treatments with 85.7% navigation decisions. On her second session using the AR app, her independent navigation increased to 100% independence and she achieved criteria after two more AR navigator sessions. Using Google Maps, her mean was 31.4% independent correct navigation decision. During treatment, her scores remained approximately the same for the paper map and Google Map conditions, which had an overall average of less than 50% correct. The paper map was the least successful with an average of independent direction checks of 19%, which was effectively unchanged from baseline. During the preference phase, her independence remained at 100% using the AR app treatment. Arya's percentage of nonoverlapping data average using the more successful treatment (AR navigation) was 100%, which indicated this was a highly effective intervention (Scruggs & Mastropieri, 2001). Arya's results are displayed in Figure 5.

Social Validity Results

The social validity measure completed by the students after they completed the adapted alternating treatment design phase of the study indicated that all participants preferred to use the AR condition to navigate. The open-ended questions from the social validity survey also indicated that the participants enjoyed using the AR navigation tool over the Google Map and paper map navigation tools. Social validity results indicated all four students agreed or strongly agreed that they (a) think practicing the different apps helped to improve their navigation skills, (b) liked using both mobile devices (iPhone) apps better than the paper map, (c) liked the AR app best, (d) always found the place they were looking for using the AR app, and (e) recommend using their favorite navigation tool [AR] to a friend. Additionally, the open-ended questions from the social validity survey suggested that the participants enjoyed using the AR experience to learn new science vocabulary. Some specific responses to are shown in Table 2.

Discussion

The purpose of this research was to compare the effectiveness of three navigation tools (printed map, Google Maps on a mobile device, and AR navigation app on a mobile device) for college students with ID or ASD to navigate to unknown business locations. The three navigation conditions produced noticeable differences. All students made more independent navigation decisions using the AR navigation tool. Students also reached unknown designations without requiring

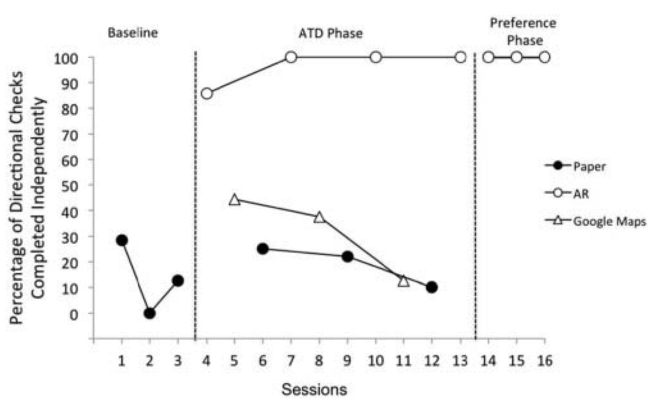

Figure 5. Arya's percentage of independent navigation checks across paper map, augmented reality navigation, and Google Maps conditions.

Table 2 Student Responses to Social Validity Questions

Social Validity Likert Questions	Likert Average
Practicing the different apps helped me to improve my navigation skills.	5
I liked using the mobile device (iPhone) better than the paper map.	5
I liked the Google Map best.	1
I like the AR app best.	5
I liked the Paper Map best.	1
I would use my favorite tool __________ again to help me navigate to new locations.	4.5
I would recommend using my favorite tool_________ to a friend.	4.5
I always found the place I was looking for using the Google map	2.5
I always found the place I was looking for using the AR app.	5

	Questions	
Student	Which did you like best the paper map, Google Map or the augmented reality app and why?	What would make your favorite tool better?
Arya	"The camera one [the AR condition] is more meaningful to me."	"Maybe if it talked and showed you the camera [live view] with the location"
Jon	"The AR one was best because all you had to do was look around you and see the thingy showing you the business [Location] and then you walked that way."	"I don't know how it could be better."
Jamie	"The AR one. It helped me to navigate to the places. It was easy."	"Having more places be in AR would make it better."
Catelyn	"AR. You look and check and then go that way."	–

person-supported assistance during AR. During printed maps and Google Maps use, students required person-supported assistance in all sessions. In addition, all students reported preferring AR to printed maps and Google Maps when navigating the city. The investigator chose to continue the baseline condition (paper map) as a condition to determine whether using the other treatments produced any effect on this skill and to allow it to function as an extended baseline for this alternating treatment design. Also, this extended baseline could indicate a functional relation between the mobile device and improved independent decision making depending on results (Sindelar et al., 1985). The results showed that the paper map did not improve the student navigation skills and demonstrated that a functional relation was established between the AR app and improved independent navigation decision making.

This study supported previous research on mobile devices to navigate independently to unknown locations for students with ID and ASD (McMahon et al., in press; Mechling & Seid, 2011; Smith, 2013). By providing context-relevant prompts, students were more likely to determine their current location and make decisions independently regarding what direction to continue to travel to ultimately reach the final destination. The mobile devices acted as a mobile prompting strategy that was accessible at anytime and anywhere the students needed a prompt. Second, this study supported the use of previous AR navigation studies (McMahon et al., in press; Smith, 2013). Students were more likely to make the correct navigation decisions compared to a printed map or Google Maps. All students reached criteria only during the AR navigation condition. The AR's ability to deliver digital information while viewing the physical world assisted the students more effectively in reaching their destination. Both Google Maps and paper maps required the students to interpret their positions on a two-dimensional map of the physical world and then extrapolate how to best proceed in the physical three-dimensional world. The AR experience allowed students to view context-relevant prompts in the physical world that effectively supported their decision-making needs in order to make correct navigation decisions.

This study also extended the navigation research literature in several ways. First, previous navigation AR research was conducted on a college campus (McMahon et al., in press; Mechling & Seid, 2011; Smith, 2013). This study demonstrated the use of AR in a large city. Students traveled on city sidewalks and had to adjust to city traffic and other pedestrians. While university campuses tend to be pedestrian friendly, the city streets presented additional challenges, including larger intersections, more traffic, and less familiarity. Second, the AR app used (i.e., Layar) identified business with job position openings. A major barrier of employment for people with ID and ASD is navigation and travel concerns (Rose et al., 2005). This study demonstrated a potential means to overcome this barrier. Third, the students indicated that using AR to navigate a city was highly socially acceptable. The improved independence and strong preference for the AR navigation tool suggest that students will be more likely to travel with confidence to businesses with employment opportunities available.

Limitations

Single-subject methodologies are effective for exploring new interventions in a controlled setting to demonstrate a functional relation, but they do have some inherent limitations. This study, like all single-subject research, examined a small population ($n = 4$). Additional studies will improve the ability to generalize these results by applying this intervention to different populations and additional settings, or replicating the study with a larger population. The AR experiences provided by the mobile app Layar are possible because of the app's ability to access databases of job opportunities that provide location information to this system. If the mobile device were not able to access the Internet then this would not be possible. Additionally, this study was conducted in an urban area with several nearby job postings viewable in AR using the employment "geolayars" in Layar such as TweetMyJobs. In a more rural area or an area without any job postings listed in these databases, business locations would be unavailable. Lastly, the investigator was always present with the participating students; therefore the students were never alone. This was designed purposefully to maximize safety. The results might have been different if the student were actually traveling alone.

Future Research

These results support the use of AR on mobile devices as an effective strategy to support the independent navigation of students with ID and ASD. Additional research can further explore the advantages and disadvantages of using location-based AR navigation tools for students with disabilities. Future studies applying this intervention to other navigation related tasks and across different student groups will determine if these results can be replicated and generalized to other populations. Future studies with positive outcomes may contribute to meeting the criteria established by Horner et al. (2005) to establish AR as an evidence-based practice for individuals with disabilities. Some possible examples for future research include applying the AR medium to other employment-related navigation tasks such as delivering packages, environmental monitoring in different locations, or conducting promotions across a city. Studies could examine using this technology for location-based learning opportunities to assist learners by providing instructional supports outside of the classroom. Another study could include "confederate" pedestrians who would observe the student for safety concerns while assessing their navigation skills.

Conclusion

Navigating to employment opportunities is only one of many factors involved in improving employment outcomes for students with ID and ASD. Using the AR medium as a tool, as described in this study, individuals with disabilities can systematically explore what job opportunities are available within their ability to navigate independently. The intuitive nature of digital content registered in the physical world allowed these participating students to demonstrate increased independent navigation.

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