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Effects of Digital Navigation Aids on Adults With Intellectual Disabilities: Comparison of Paper Map, Google Maps, and Augmented Reality

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Abstract

The purpose of this study was to compare the effects of three different navigation aids with students with intellectual disability. Participants included six college-aged students with intellectual disability who attended a postsecondary education program. An adapted alternating treatment design was used to compare a paper map, Google Maps on a mobile device, and an augmented reality navigation application. The results indicated that the augmented reality navigation application was functionally the most effective condition. Conclusions are discussed in the context of supporting people with intellectual disability by teaching navigation skills.

Keywords

augmented reality, navigation, intellectual disability, postsecondary education, mobile devices

Navigation, the ability to relocate from one place to another, is a critical skill for independent living and employment for people with disabilities (Dymond, 2011; LaGrow, Wiener, & LaDuke, 1990; Sohlberg, Fickas, Lemoncello, & Hung, 2009). To enjoy a high quality of life, people with intellectual disability (ID) may choose to visit the grocery store, meet with friends, use public transportation, or access community services. Navigation and independent travel skills reduce social isolation and promote relationships for people with ID. Navigation skills define one's mobility and independence and are vital for community inclusion for people with disabilities (Clark & Hirst, 1989).

The ability to effectively navigate supports desired outcomes for individuals with disabilities such as self-determination, employment, and community inclusion (Shogren et al., 2009). For example, it is often necessary to navigate systems such as public transportation in order to access many employment opportunities. One potential barrier to employment is finding a job within the scope of the person's navigational abilities. In most cities, there are various forms of transportation to the workplace, which may include buses, subways, and pedestrian walkways. People with ID can use digital navigation aids and other technological supports to navigate to a variety of locations (Brown, Shopland, Lewis, & Dattani-Pitt, 2005; Liu et al., 2008).

Postsecondary Education (PSE)

Changes in recent legislation, such as the Higher Education Opportunity Act of 2008 (HEOA, 2008), offer young people with ID access to more educational options than ever before. PSE programs offer unique college experiences to people with ID within inclusive college communities. Young adults with ID who participate in PSE are more likely to maintain employment and access community supports than peers with disabilities who do not attend PSE programs (Grigal & Hart, 2010). As of 2010, according to Grigal and Hart there were approximately 200 PSE programs specifically for people with ID in the United States.

Navigating safely across a college campus is a critical factor in determining the success of students in PSE environments (Going-to-College.org 2014; McMahon & Smith, 2012). Many young adults with ID have never had the opportunity to independently go to a store to make a purchase, walk to a nearby building, or even cross the street without assistance and supervision (Grigal & Hart, 2010). Instead, opportunities for practice

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are embedded in experiences such as community-based instruction (Welch, Nietupski, & Hamre-Nietupski, 1985). While beneficial, these experiences often lack authenticity and are not representative of independent community navigation.

The primary mode of transportation on college campuses and in most major metropolitan areas is pedestrian travel. Most college campuses are equipped with sidewalks and pedestrian pathways to allow access to campus buildings. For people with ID, utilizing traditional pedestrian venues can be overwhelming and disorienting. Whether traveling on foot, or using a wheelchair to travel, students with ID can benefit from a variety of interventions and technological tools to improve street-level navigation and orientation (Lancioni et al., 2010).

In a 2011 study, Mechling and Seid investigated the use of a handheld personal digital assistant (PDA) to teach young adults with ID to travel independently between locations. The intervention consisted of a PDA with auditory, picture, and video prompts that participants used as a self-prompting device. Participants self-selected the level and intensity of the prompt. For instance, if the picture prompt did not provide enough detail to make a navigation decision, participants could choose to add the auditory prompt to the picture. The video prompt was the most intensive support available. In addition to increased independent navigation with the use of the PDA, the participants in this study were also able to maintain results over time and self-adjust the level of the prompt as needed (Mechling & Seid, 2011).

As well as pedestrian travel, public transportation is an increasingly common mode of travel on college campuses and in communities. Davies, Stock, Holloway, and Wehmeyer (2010) evaluated a global positioning system (GPS) to support independent bus travel for adults with ID. This study compared the levels of independence between two groups of adults with ID. Individuals in the control group attempted to navigate the bus route with a commonly available bus schedule and map, while those in the treatment group used a GPS to follow a novel route. Data collection occurred at key decision points. At each point, participants made a decision related to arriving at the destination. Results indicated that 73% of participants in the treatment group signaled the driver at the appropriate stop and exited the bus at the predetermined destination, while only 8% of the control group were able to successfully travel independently (Davies, Stock, Holloway, & Wehmeyer, 2010).

An effective method for teaching navigation skills to users with ID is mobile learning. Mobile learning facilitates decision making, independent living, and acquiring employment-related skills for people with ID. Previous research demonstrates some of the benefits of mobile devices to support learning (Cihak, Kessler, & Alberto, 2008; Ferguson, Myles-Smith, & Hagiwara, 2005). Brown et al. (2011) incorporated simulated games on mobile devices to teach students with ID to navigate to new locations. The results indicated that the students generalized the navigation skills from simulation activities to new locations in the real-world context. As innovative mobile technology and applications (apps) become available, new research is needed to establish these benefits for people with ID.

Augmented Reality (AR)

While there is an existing body of research examining the use of mobile devices by individuals with ID (Mechling, 2011; Wehmeyer, Palmer, Smith, Davies, & Stock, 2008), there is limited research on AR as a tool for this population. AR is a new development in the area of mobile learning. AR is part of the mediated reality field, which involves the blending of physical and digital worlds (Dieker, Hynes, Hughes, & Smith, 2008). AR apps use the cameras on mobile devices to produce live views of the physical world and add information from digital sources, such as maps. This results in a live video display of a combination of video from the real world and relevant, context-appropriate information. This information can include text, video, and pictures. Digital information received at the individual's physical point of view offers opportunities to access prompts and directions when needed (Cobb & Sharkey, 2007).

Computer-generated graphic displays blended with views of the real world appeared as early as 1968, with large stationary computers and helmet-mounted video screens (Sutherland, 1968). Early AR implementations, such as using heads up displays to superimpose manufacturing instructions on assembly lines, were limited by the large, immobile, and expensive technology of the time period (Caudell & Mizell,1992). In 2002, AR portable navigation systems were 15-pound computer backpacks that required a helmet-mounted display system (Kalkusch et al., 2002). Ten years later, the rise of mobile operating platforms with open app development tools led to the creation of hundreds of AR apps available across several different devices.

AR mobile technologies apply digital information within the user's immediate environment (Becker, 2010). AR apps on mobile devices can add contextual or location-specific information based on GPS, compass, or processing information from scenes selected by the user. Navigation-related AR apps are marker less (i.e., they do not require printed or object-oriented markers) and provide the user with information using geo-location tools like GPS (Craig, 2013). Academic settings, such as museums, classrooms, and libraries, were used as sites for AR demonstration projects in previous research. At these sites, AR apps allowed learners to use mobile devices to explore objects and locations according to their level of interest (Pence, 2011).

Purpose of Current Study

Digital aids are available to improve travel and navigation skills for people with ID (Lancioni et al., 2010; Mechling & Seid, 2011). By teaching young adults with ID to (a) access the needed technology, (b) apply the knowledge needed to use the tool or app, (c) make a decision based on information obtained, and (d) utilize embedded digital supports, learners with disabilities can navigate independently in complex environments such as college campuses and large cities. The current study evaluated the use of three different navigation aids with people with ID. Specifically, we examined which of the navigation aids (printed map, Google Maps on a mobile device, or an AR navigation app) would have the greatest impact on improving navigation for six young adults with ID enrolled in a PSE program?

Method

Participants

Six college-age students with ID participated in this study (Jack, Sean, Candice, Derrick, Vera, and Miguel). All of the students were enrolled in a university PSE program for students with ID. Four of the participating students were males and two were female. The students met eligibility guidelines for admission to the PSE program. All of the students regularly traveled around campus for different classes, meals, and program activities with the support of program volunteers. At the start of this study, all of the students were unfamiliar with the university campus and in their first semester in the PSE program. The students had no previous experiences with navigation training. Since map and navigation skills require reading skills (e.g., Street names), reading scores are included in participant descriptions.

Jack. Jack was an 18-year-old student diagnosed with mild ID. His Wechsler Intelligence Scale for Children, 3rd. ed. (WISC-III) 1991 full-scale IQ was 60. Jack scored in the third-grade level equivalent on both reading decoding and comprehension skills when assessed using the Brigance Transition Skills Inventory (Brigance, 2010).

Sean. Sean was a 19-year-old student diagnosed with mild ID. His WISC-III full-scale IQ was 65. Sean scored in the sixth-grade level equivalent on reading decoding and the fourth-grade level equivalent on comprehension skills on the Brigance Transition Skills Inventory.

Candice. Candice was a 24-year-old student diagnosed with mild ID. Her WISC-III full-scale IQ was 48. When evaluated with the Brigance Transition Skills Inventory, Candice's reading decoding skills placed her in the third-grade level equivalent. Her reading comprehension skills placed her in the second-grade level.

Derrick. Derrick was a 23-year-old student diagnosed with moderate ID. His WISC-III full-scale IQ was 51. Derrick scored in the prekindergarten level for reading decoding and comprehension skills when assessed with the Brigance Transition Skills Inventory.

Vera. Vera was a 24-year-old student diagnosed with mild ID. Her WISC-III full-scale IQ was 65. Vera's reading decoding skills were assessed to be at the fifth-grade level equivalent and her comprehension skills were at the third-grade level equivalent using the Brigance Transition Skills Inventory.

Miguel. Miguel was an 18-year-old student diagnosed with an autism spectrum disorder and mild ID. His WISC-III full-scale IQ was 62. His Gilliam Autism Rating Scale (GARS) autism index score was 103, which indicated a very likely probability of autism. Miguel's reading decoding skills were at the seventh-grade level equivalent and comprehension was at the fourth-grade level when assessed with the Brigance Transition Skills Inventory.

Research Design

An adapted alternating treatment design (Gast & Ledford, 2010) was used to determine the efficacy of a paper map, Google Maps, and an AR navigation app to independently navigate to an unknown location. Sindelar, Rosenberg, and Wilson (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 adapted alternating treatments design allowed the lead investigator to evaluate the relation between each navigation treatment condition and correct navigational checks. Navigation aid treatments were randomly presented to reduce potential carryover effects. The more effective navigation aid treatment was defined as bifurcation of the data paths.

Setting and Materials

The setting for this study was a large public university campus. The campus provided many opportunities to navigate to unfamiliar locations. Students were required to walk along sidewalks, use crosswalks at major intersections, access greenways, and walk around inside buildings as they attended classes and go for meals and activities on campus. A typical week for the students included attending work-based internships and university courses as well as going to the student center for lunch and recreational activities. Students walked with program volunteers to participate in these activities, as they were unfamiliar with the campus.

During the paper map intervention condition, a printed-paper map of the campus, produced from Google.com, was used to support navigation skills. The standard map view was selected to make the map representations as consistent as possible across the three treatments and offered the most detail and reduced number of distractions compared to the other views available, such as the satellite view.

The second treatment involved using the Google Maps app on mobile devices. The devices used were iPads and iPhones connected to the university's WI-FI system, which provided an accurate estimation of the device's location. Location information was represented on the app by a blue dot for the best estimation of user's location on the map. The Google Maps app also displayed a pin for the target location and highlighted the best path to take. The campus' wireless network coverage allowed the devices to continuously update their location.

The third treatment involved an AR navigation app. The app used was Navigator Heads Up Display (Niftybrick, 2009). Navigator Heads Up Display uses location-based or "marker less" AR to determine both the user's location and the destination location. When the camera was pointed toward the horizon

Figure 1. Student view of augmented reality (AR) map.

or eye level, the map view was minimized and live view from the camera was displayed, augmented with the digital information for the target location including the location name and remaining distance in feet. The digital information appeared in the form of a hovering arrow that provided a visual path for the students to follow. This allowed the students to move the camera around to find the direction of the target location to determine which way to travel. If students lost track of the information arrow, they were able to readjust the camera angle until the arrow was relocated on the device screen. The AR navigation app displayed the mobile device's default map when the camera was pointed at the ground. This map included the dot marking the user's location and pin marking the target location, providing a view similar to Google Maps in the second condition. A sample screenshot of the student viewpoint is displayed in Figure 1.

Variables and Data Collection

The dependent variable was the percentage of independent direction checks indicated by each student. Independent directions check response was defined as a verbal or gesture response indicating the correct direction to move in order to reach the desired location without assistance. If the student verbalized and/or gestured incorrectly, then the researcher recorded "assisted" and verbally prompted and gestured the correct direction. The number of independent navigation decisions made by each student was divided by the total number of decisions possible to calculate a percentage of independence. Seven direction checks were probed during each navigation session. Data were recorded and collected at each direction check, which occurred at street crossings, crossroads for foot traffic, or other typical decision points to go left, right, or forward. Data were collected using event recording procedures.

Procedures

The researcher started each session by asking the student to verbalize the name of the destination location and to show the researcher on the map. Then, the researcher asked, "Do you know how to get there on your own?" to ensure that the destination was an unknown location and ensure that the students looked at the map. When a student indicated a location was known, a second location was chosen. While navigating to the location, the researcher asked the students to make direction checks regarding what direction they needed to go to reach their destination. The researcher asked, "What direction should you go now?" at seven different points while traveling to the location. If the student responded by indicating the correct direction either verbally or gestural independently, the researcher said "OK" and they continued to travel to the target destination. However, if the student response was incorrect, or the student did not respond after 4 s, the researcher provided verbal and gestural assistance according to the system of least prompts. In addition, jaywalking or taking a short cut through buildings were not accepted as independent or correct responses. When a building or other barriers (e.g., construction) were encountered, the researcher 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, the researcher recorded the response as independent. However, if the student's response was incorrect or unsafe, the researcher provided verbal and gestural assistance and recorded the student's response as assisted.

During each navigation session, each student was randomly assigned to one of the three treatments (a) paper map, (b) Google Map, or (c) AR map. Each of the treatments had the target destination preprogrammed and marked for the user. Each session required the students to navigate to a new, novel location. Locations were chosen based on distance from starting location (all under ½ mile) and novelty (they were unfamiliar locations to students). An acquisition criterion was defined as 100% independent direction checks for three consecutive sessions.

Pretraining

Pretraining was provided to ensure each student could independently access and use the mobile apps. Model lead test procedures (Adams & Engelmann, 1996) were used to instruct each student. First, the researcher modeled each step of a task analysis regarding how to access and use the mobile app. Next, the researcher led the student through each step of the task analysis for access and use. Contingent on performance of steps, the researcher provided verbal praise. Contingent on student errors, the researcher implemented the system of least prompts with a 4-s response time between prompt levels (Ault & Griffen, 2013). The system of least prompts included (a) verbalizing the step, (b) gesturing to the device, and (c) providing partial physical prompts by guiding the student's hand to complete the step. Last, the researchers assessed each student's performance of the skills necessary to access and operate the device (e.g., turn on the device, open the mobile app, use the mobile app, close the app, and turn off the device). The pretraining phase continued until each student could independently perform all steps of the task analysis for three consecutive trials.

Baseline. During baseline paper campus map navigation, students used only the paper map. The starting location and unknown location were marked on the paper map and the student was asked to navigate to the location. The researcher asked "what direction" and either said OK and continued to navigate to the target location or provided verbal and gestural assistance contingently. The baseline condition, the paper map, was continued as a condition of the adapted alternating treatment in order to allow for the demonstration of a functional relation between the independent and dependent variables. Baseline data were collected for three sessions and until a stable baseline with less than 20% variability was observed.

Paper campus map. After baseline was established, the paper campus map condition was continued as one of the three randomly presented interventions. The same procedures as baseline were implemented.

Google Maps. The Google Map was displayed on a mobile device (i.e., iPad or iPhone). The unknown location was preprogrammed. Location data were obtained using the wireless data connection on the device, which allowed the student to see their current location and the target destination. As in previous phases, the researcher asked what direction and either said OK and continued to navigate to the target location or provided verbal and gestural assistance contingently.

AR map. The Navigator Heads Up Display app was displayed on a mobile device (i.e., iPhone). Similar to the Google Map treatment, the unknown location was preprogrammed. Location data were obtained using the wireless data connection on the device, which allowed the student to see their current location and the target destination. Similar to previous phases, the researcher asked what direction and either said OK and continued to navigate to the target location or provided verbal and gestural assistance contingent on an incorrect direction check or no response following 4 s.

Interobserver Agreement and Treatment Integrity

The researcher and a trained graduate assistant independently and simultaneously collected interobserver agreement (IOA) and procedural reliability data. IOA data were collected during a minimum of 25% of paper map condition and each treatment condition for each participant. Observers independently and simultaneously recorded the number of independent direction responses. IOA was calculated by dividing the number of agreements of the participant responses by the number of agreements plus disagreements and multiplying by 100. Interobserver reliability was 95% for each participant across all phases.

Procedural reliability data also were collected during a minimum of 25% of all sessions for each treatment condition and for each participant. The researcher was required to provide students with the necessary materials (i.e., campus map, mobile device, app, and location preloaded), ask what direction, and provide verbal and gestural assistances contingent upon an incorrect response or no response following 4 s. The procedural agreement level was calculated by dividing the number of observed researcher's behaviors by the number of planned investigator's behaviors and multiplying by 100. The mean procedural reliability was 100% for all students across all conditions.

Table 1. Percentage of Independent Direct Checks Across Treatments and Students.

Student	Baseline	Paper Map	Google Maps	AR App
Jack	0.0	16	50	90.5
Sean	0.0	5.8	45.8	85.5
Candice	0.0	31.3	57	81.4
Derrick	0.0	2	26.7	75.6
Vera	0.0	5.8	51.4	94.2
Miguel	0.0	4.7	50	95
Average	0.0	10.9	46.8	87

Note. AR = augmented reality.

Results

During the paper map condition, all students required person-supported assistance to travel to an unknown campus location. Table 1 shows the overall means for each phase of the study. On average, the students' mean level of independent direction checks increased to 10.9%, 46.8%, and 87% for paper map, Google Map, and AR map, respectively. Overall, the most effective intervention was the AR treatment. All six students were able to navigate independently to unknown locations using the AR app. During Google Maps or paper map treatments, all students continued to require person-supported assistances to navigate to unknown locations.

Jack. Jack was unable to navigate to any location independently during the paper map condition (see Figure 2, top graph). The three treatments produced noticeable differences in independent navigation ability as demonstrated by 100% nonoverlapping data between the paper map conditions and treatment phases. The AR navigator was immediately more successful than the other treatments, with 90.5% navigation independence. Jack required no person-supported assistances during the last three AR sessions. Google Maps was the second most effective, with a mean of 50% independence. The paper map treatment was the least successful, with a mean of 16% independent direction checks. Although Jack's independence increased during Google Maps and paper map treatments, he continued to require person-supported assistance for all sessions under these conditions.

Sean. Sean did not navigate independently to any location during the paper map condition (see Figure 2, middle graph). However, he immediately increased navigation independence when introduced to AR map and Google Map conditions demonstrating 100% nonoverlapping data compared to the paper map condition levels. During AR, Sean independent navigation checks increased to a mean of 85.8% and he navigated with 100% independence during the last three AR sessions. During Google

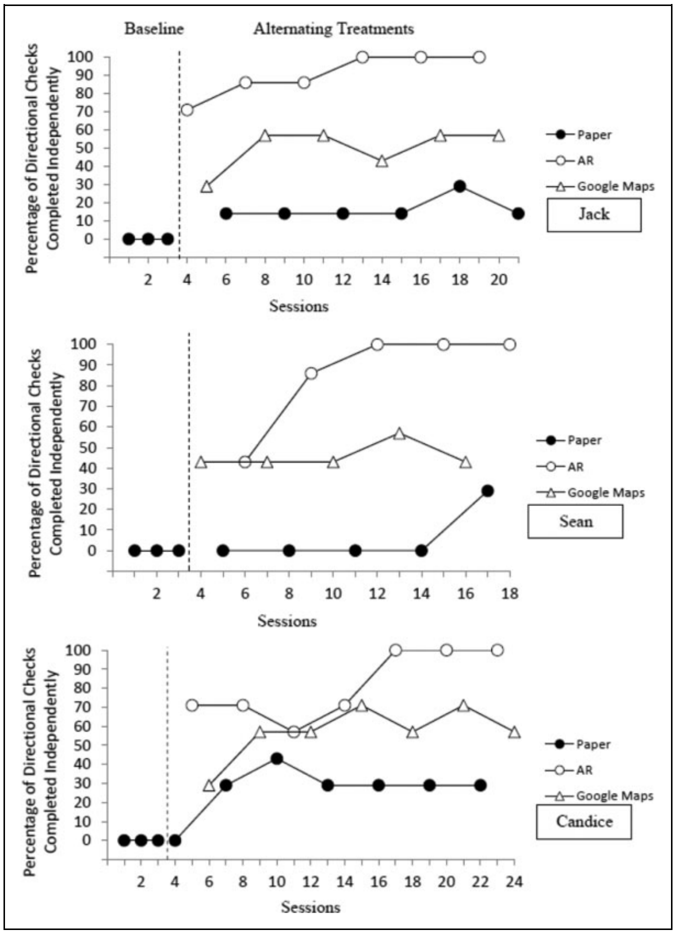

Figure 2. Students' percentage of independent direction checks across intervention conditions.

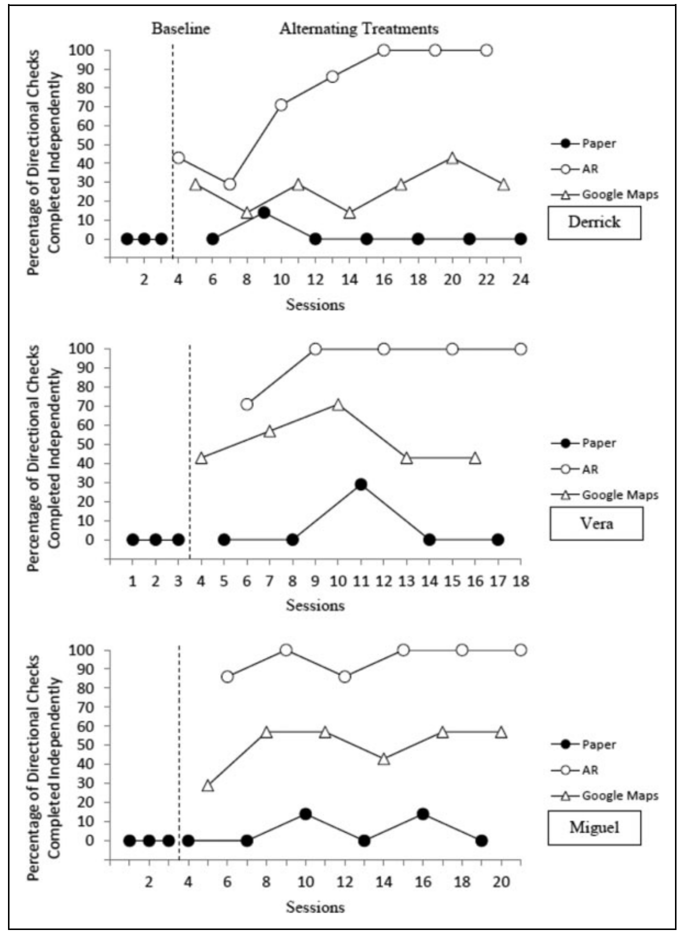

Figure 3. Students' percentage of independent direction checks across intervention conditions.

Maps, Sean's independent navigation checks also increased to a mean of 50%; however, he continued to require person-supported assistance in all sessions. During the paper map treatment, Sean continued to require person-supported assistance. His mean level of independent navigation checks was 5.8%, which corresponds to correctly indicating which direction to travel on two occasions.

Candice. Candice was unable to navigate independently to any unknown location during the paper map condition (see Figure 2, bottom graph). During AR, her mean level of independent navigation checks increased to 81.4% and she navigated with 100% independence during the last three sessions. Google Maps was the second most effective treatment, with a mean of 57% independence. However, she continued to require person-supported assistance for each session. During paper map, Candice navigation checks did improve to a mean of 31.3% although she was only able to correctly indicate which direction to travel on two of the seven checks per session consistently.

Derrick. Derrick required person-supported assistances to navigate independently during the paper map condition (see Figure 3, top graph). Derrick's greatest improvement occurred during the AR treatment. His mean level of independent direction checks was 75.6% and he required no person-supported assistance during the last three sessions. Person-supported assistance was needed during both Google Maps and paper map treatments. His mean levels of independent direction checks were 26.7% and 2% for Google Maps and paper map, respectively.

Vera. Vera was unable to travel independently to any unknown location (see Figure 3, middle graph). During AR, Vera immediately increased navigation independence when introduced to AR map and Google Map conditions, demonstrating 100% nonoverlapping data compared to the paper map condition levels. During AR, Vera's independent navigation checks increased to a mean of 94.2% and she navigated with 100% independence during the last three AR sessions. During Google Maps, Vera's independent navigation checks also increased to a mean of 51.4%; however, she continued to require person-supported assistance in all sessions. During the paper map treatment, Vera continued to require person-supported assistance. Her mean level of independent navigation checks was 5.8% or correctly indicating which direction to travel on two occasions.

Miguel. Miguel required assistance during all paper map sessions and was unable to travel to any locations independently (see Figure 3, bottom graph). However, he immediately increased navigation independence when introduced to AR map and Google Map conditions demonstrating 100% nonoverlapping data compared to paper map condition levels. During AR, Miguel's independent navigation checks increased to a mean of 95% and he navigated with 100% independence during the last three AR sessions. During Google Maps, Miguel's independent navigation checks also increased to a mean of 50%; however, he continued to require person-supported assistance in all sessions. During the paper map treatment, Miguel continued to require person-supported assistance. His mean level of independent navigation checks was 4.7% or correctly indicating which direction to travel on two occasions.

Social Validity. After each student had completed all alternating treatment sessions, he or she was asked to answer informal social validity questions regarding the use of the different strategies to navigate. *Which one of the navigation tools did you like best?*

All six students responded that they preferred the AR navigation condition. Interestingly, none of them ever mastered calling it "augmented reality." Sometimes they called it the name of the app, "Heads Up Navigator," but the most common way of describing it was "the one using the camera" (indicative of the live camera display view).

What made you like that navigation tool best? "It's much easier looking through the camera [AR] to see which way to go"; "I liked how easy seeing the pointer in the camera one [AR] was"; and "Using the camera [AR] I was able quickly be sure of which way to go."

Which tools would you like to use in your daily life?

"I want to put the camera navigator [Heads Up Navigator/AR condition] on my phone so I can use it when I get lost"; and "It would be easier to use the heads up one [Heads Up Navigator/AR condition] for walking to new places." Their responses demonstrate that the students had a strong preference for the AR Navigation app versus both the paper and Google Map App on the iOS device.

Discussion

The purpose of this study was to examine the effects of three different navigation aids (printed map, Google Maps on a mobile device, and an AR navigation app) for college students with ID to navigate a campus to an unknown location. All students independently navigated to unknown campus locations more effectively using the AR map compared to the Google Map and paper map conditions. Students benefited from the blending of real world and digital information in a meaningful way. Using Google Maps, students were able to navigate to unknown locations about half of the time. Most of the time, students required assistance to navigate when using the paper map. The large university campus provided students a real-world context to learn and apply navigation skills.

This study extended the research regarding navigation skills in several ways. First, it compared different navigational strategies. To fulfill the demand for evidence-based strategies, this study compared the effectiveness of different navigation aids. Paper maps and online maps, such as Google Maps, are common tools to help people navigate to unfamiliar locations. Students were more independent using either mobile learning apps compared to the paper map condition. One of the advantages of mobile learning is the shift away from a traditional learning environment that a student enters and then leaves. Mobile learning emphasizes the development of skills and tools to create a state where the learning environment follows the learner (Ogata & Yano, 2004). Mobile learning holds the potential to empower people with disabilities because of its ability to provide a learning environment that persists with them and follows them. As the students navigated campus, the AR treatment provided the supports necessary to travel independently to the correct locations.

Although Google Maps was successful about half of the time for the students, the mobile app using the technology of AR was much more effective. Cobb and Sharkey (2007) suggested that the blending of the real world and digital information allows users the opportunities to access prompts and information when needed. As students traveled to unknown campus locations, they benefited from using the camera view to get real-time visual prompts. The app used in this study displayed an onscreen marker for the students to follow. Additional onscreen information, such as the text that displayed the distance remaining to location, assured the students that they were traveling in the correct direction. As long as the distance to the location displayed was getting smaller, it indicated that they were getting closer to their final destination. The paper map and Google Map did not provide this level of assistance. Students benefit from knowing their precise location.

This study bypassed the student's need to generalize the skill by teaching the skill in vivo and applying digital information within the student's immediate environment. By using a navigation app with AR technology, the overlay of visual supports and digital information supported the student traveling to new places anytime and anywhere. The advantage of using mobile AR is that students with ID can access supports or prompts whenever and wherever needed without relying on another person. Brown et al. (2011) incorporated games on mobile devices to teach students with ID to navigate to new locations. Although the "practice mode" of the device was a realistic game simulation, the device "screen turns off while traveling between points of interest" (p. 16). They were required to generalize the information from the simulated practice. Melching and Seid (2011) imported auditory, picture, and video prompts in a mobile device to teach navigation skills, but the various prompts needed to be developed, customized, and uploaded into the device prior to navigating. One advantage of the AR technology used in this study is that it only requires that address be imputed into the app, thus removing the intervention development from some previous studies.

Multiple means of representation in the AR apps supported the diverse learning needs of the participating students. Students were observed using both the on-screen map and the AR view to make direction decisions. The flexible means of display included in the AR navigator allowed students to have context-relevant information that was the most useful to suit their needs at that moment.

In addition, the commercially available mobile devices used have the advantage of being inclusive and socially acceptable to individuals with disabilities because of the common, interactive nature of mobile devices in society. As an individual with a disability uses AR apps on their smart phone or tablet, they appear to be engaged in the common, real-world behavior of checking information on a smart phone or tablet. The popularity of mobile devices used increases the social validity of the product, since smartphones and tablets are used by many people, not just people with disabilities.

This study demonstrated the promise of AR for people with disabilities. The combination of real-world views combined with digital information can provide real-time prompts and supports to increase the independent living and community access skills. In this study, navigation information including location and distance was overlaid on top of the video view of the real world. This type of technology could easily be applied to many tasks other than navigation. This technology is becoming increasingly common as an advertising tool, but educators can adapt it to provide step-by-step instructions for tasks in the community, labeling of items to provide increased literacy practice, or to provide additional contextual information across a wide ranges of items and events.

Although the results of this study demonstrate promise for using AR to navigate independently, the findings should be interpreted with caution due to several limitations. One limitation of this study is that the maps may not work as a stand-alone tool to find locations in a large city that requires additional steps of locating a specific room within a multistory building. Both the Google Map and AR navigator use maps that are two-dimensional renderings of the world. Tasks like delivering items may require additional skills or adaptations of this technology. These additional skills and technology supports could scaffold on top of the AR intervention to support door-to-door delivery. A likely possibility is that additional new technologies will emerge to meet this need.

Another limitation of the AR navigator used in this study was the display of the target location in a line of sight or compass bearing. This often puts buildings, parking lots, roads without nearby crosswalks, and other obstacles in the path of the person navigating. However, the students readily realized where they needed to go and the safest route to get there. Students with more significant ID will need to be taught specific safety skills.

Although this study requires replication to verify its conclusions, emerging technology trends, like AR, provide potential new tools to support persons with ID to become more independent and self-determined. Additional research is needed to examine the use of AR to facilitate learning for children and adults of varying abilities. Prerequisite technological skills should be explored as well as the use of AR in K–12 settings. The AR app used in this study can provide new tools for enhancing self-determination, by allowing people with disabilities to access information in real time, based on their location or context. By learning to use these mobile device tools, they may increase their ability to live independently, to gain essential job skills, to learn new skills in searching for employment, and to increase their opportunities to participate fully in society.

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