Behavior analytic based virtual reality interventions to teach adaptive and functional skills for individuals diagnosed with autism: A systematic review

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Abstract

Virtual reality technologies hold promise for the therapy based on the science of applied behavior analysis as they can replicate real life environments and allow the user to role-play in a simulated environments. This literature review synthesizes the research base evaluating the effects of behavior analytic interventions delivered via virtual reality (VR) technology to teach adaptive and functional skills for individuals with autism.

Method: We conducted a systematic search in four databases followed by a reference search for those articles by the systematic database search. We also conducted a quality review using the *Evaluative Method for Evaluating and Determining Evidence-Based Practices in Autism* (Reichow, 2008).

Results: We identified 24 studies with a majority of the studies (*n* = 18; 75%) utilizing group experimental or quasi-experiment research design, and the remaining (*n* = 6; 25%) utilizing single-case research design. Of those studies, ten targeted vocational related skills, seven targeted functional behaviors (e.g., problem behavior treatment, hypersensitivity, phobias), four targeted safety skills (e.g., driving, airplane travel, pedestrian safety), two studies targeted general functional skills, and one targeted exercise engagement. Of the 24 studies, 12 met the quality criteria to be classified as “strong” or “adequate” and can offer evidence on the integration of VR technology into the practice of behavior analysis for teaching adaptive or functional skills**.**

Discussion: Taken as a whole, the three studies (Cox et al., 2017; Hu & Han, 2019; Wade et al., 2013) identified as “strong” quality studies were conducted by three different research teams, at three different locations, with 74 different participants and meet the qualifications to be considered a promising practice.

Introduction

Recent numbers from the Centers for Disease Control and Prevention (CDC) indicate that 1 in 44 children have autism spectrum disorder (ASD; Maenner et al., 2021). ASD is characterized by a range of strengths (e.g., attention to detail) and needs (e.g., social communication skills). The needs of those with ASD can best be supported through interventions, particularly those considered to be evidence-based practices. Evidence-based practices are interventions and teaching methods that are substantially supported through research to produce positive outcomes (Hume et al., 2021). One evidence-based practice aimed at improving socially valid behavioral concerns is applied behavior analysis (ABA). ABA is a branch of the science of behavior analysis which relies on assessment to inform individualized interventions designed to reduce or strengthen human behavior (Cooper et al., 2020). There is a strong body of evidence to demonstrate its use in supporting individuals with ASD (Leaf et al., 2020; Tiura et al., 2017). Evidence-based practices for individuals with ASD that are aligned with the principles of ABA include discrete trial training, functional communication training, prompting, and self-monitoring, to name a few (Hume et al., 2021). However, as our society shifts to a more technological world, there has been an increase in the use of technology-based interventions to support individuals with ASD (Thai & Roberts-Nathan, 2018).

Technology-aided instruction and intervention (TAII) is an evidence-based practice for individuals with ASD in which technology is the primary component of the intervention (Hume et al., 2021). This can include the use of more common technology, such as the use of computers or mobile device application, as well as more advanced technology, like virtual reality (VR) and augmented reality (AR), or robots. For example, in Rosenbloom et al. (2016), researchers investigated the effectiveness of using a commercially developed mobile device application, I-Connect (Wills & Mason, 2014), for self-monitoring in the general education classroom. The results of the study indicated strong outcomes for increasing on-task behavior and reducing disruptive behaviors, including good social validity from the participant and the teacher. In McMahon et al. (2015), the authors compared the use of Google Maps, a traditional map, and AR to teach navigation to unknown employment settings to post-secondary students with disabilities. Results of this study indicated that students were more successful (i.e., independent) when using AR. TAII has demonstrated to be effective at supporting a variety of needs (e.g., communication, academics, adaptive skills, etc.) for individuals with ASD from infancy to adulthood (Hume et al., 2021). Advanced technology, like VR, has become more accessible over the last decade, thus, increasing its popularity within our society.

VR is a three-dimensional, computer-generated visual experience that can replicate real life that the user can interact with (Clay et al., 2021; Lorenzo et al., 2016). It allows for different types of immersive experiences for the user: non-immersive (e.g., desktop display), semi-immersive (e.g., smart glasses), and immersive (e.g., head-mounted display; Di Natale et al., 2020). There are several advantages to the use of VR interventions for individuals with ASD, which align with the principles and dimensions of ABA. A clear benefit is its ability to emulate a real-world setting and offer experiences that cannot otherwise be captured through typical teaching methods like text (i.e., written instructions) or videos (Bailenson et al., 2008). VR allows for repeated practice of skills that may be difficult, or dangerous, to do in real life (e.g., safety skills; Karami et al., 2021). This is extremely advantageous for individuals with ASD as it may reduce the stress associated with learning adaptive and functional skills through more traditional means (Didehbani et al., 2016). It allows for individualization as the implementer can adapt the user's experience (e.g., appearance of the VR environment displayed, complexity of the task) to meet their specific needs (Bailenson et al., 2018). Reinforcement is given through real-time feedback and repetition, therefore, enhancing the learning quality (Clay et al., 2021; Kamari et al., 2021). Because VR can mimic the real-world, it promotes generalization. While this could be achieved using in-vivo teaching methods, it enables possibilities beyond face-to-face teaching. VR uniquely enables the tracking of a user's movements (Bailenson et al., 2008), which provides valuable information as to where the user responds, interprets, and interacts with the world (Lorenzo et al., 2018). Additionally, individuals with ASD have shown a strong preference for technology (Valencia et al., 2019), thus, increasing the social validity of this type of intervention.

Despite an increase in research regarding VR and ASD, there are a limited number of systemic literature reviews to further inform research and practice. A couple of reviews focus on technology-based interventions, which do include information regarding VR (e.g., Barton et al., 2017). However, these reviews may not have captured the extant literature on VR given this was not the focus; therefore, search terms encapsulating VR may not have been used. There are two existing reviews that are specific to use of VR as an intervention for people with ASD. Both Mesa-Gresa et al. (2018) and Lorenzo et al. (2019) provided understanding of this topic, with the focus of Lorenzo et al. (2019) being focused specifically on immersive VR. Together, these reviews analyzed 43 published articles from 1990-2018. While these reviews give researchers and practitioners an understanding of how VR has been used, neither of them assessed the rigor of the research using quality indicators (e.g., What Works Clearinghouse). This is an important consideration as synthesizing the literature and evaluating the effectiveness of interventions without consideration for the quality of the research (e.g., threats to internal validity) will not be helpful in informing practice (Kratchowill et al., 2013).

Often practitioners rely on systematic reviews to give them insight on a specific intervention or target behavior that is socially significant to a client or student they are working with. Therefore, more focused reviews may provide an easier way for them to access the research. Currently, to the authors' best knowledge, four focused reviews exist on VR for people with ASD. Three of these four reviews focus on social communication skills (Irish, 2013; Parsons & Mitchell, 2002; Vasquez et al., 2015) and one review focuses on the use of naturalistic interventions within the context of VR (Dechsling et al., 2021). A focus in these areas is not surprising given the diagnostic criteria for ASD relates to deficits in communication; however, individuals with ASD often have difficulty acquiring other skills as well. Additionally, neither of these reviews assessed the methodological rigor of the studies; therefore, it is unclear about the extent of the reliability of interpreting the outcomes of the included studies within their review. While there is a need to address the deficits of communication for those with ASD, it is also imperative to teach adaptive and functional skills in order to promote independence.

There is significant potential for VR to enable people with ASD to have meaningful opportunities to learn and generalize skills to their everyday life. The current review aims to (1) evaluate the current existing body of literature utilizing behavioral analytic interventions delivered using VR to target adaptive and functional skills for individuals with ASD, and (2) assess the methodological rigor of the literature to inform future research and practice for the use of VR when targeting adaptive and functional skills.

Method

Search Procedures

The researchers completed a systematic search of the following databases: *PsychINFO, Medline, Psychology and Behavioral Sciences Collection,* and *ERIC.* These searchers were conducted by combining a term to describe ASD (i.e., “Autis*,” “Developmental disab*,” “Asperger,” “ASD”) with a term to describe VR (“virtual reality”) and (“intervention”, “treatment”). The original search was conducted in September 2021 and yielded 191 articles after the removal of duplicates (see Figure 1 graphic results). Following the database searches, the third author did an initial screening of each article by their title and abstract and excluded articles that did not include the use of VR and ASD (n = 129). An additional search using Google Scholar was conducted to identify any additional articles. After excluding duplicates, a total of 34 articles were added to the total article list for application of the inclusion criteria. In total 67 articles were screened by their full text using the following inclusion and exclusion criteria and 50 were excluded with a total of 17 articles meeting inclusion criteria.

Next, an ancestral and forward search of the included articles was conducted. For the ancestral search, the references of the included articles were reviewed and extracted if titles contained any of the key search terms (provided above). For the forward search, Google Scholar was used to search the record of included articles by selecting the “cited by” button. Relevant articles citing the included article were reviewed for possible inclusion. All relevant articles were extracted from the ancestral and citation search into a Microsoft Excel™ spreadsheet. These articles then underwent the full inclusion review. The researchers conducted this iterative process and retrieved a total of 7 additional articles from the ancestral and forward search. The final number of articles included totaled 24 studies.

Inclusion and Exclusion Criteria

To be included in this review, articles had to meet the following criteria: (a) be peer-reviewed and published in English, (b) include at least one participant with an ASD, (c) implement a therapeutic intervention designed to establish/increase appropriate behavior or decrease interfering behaviors, (d) utilize an experimental design to evaluate the effects of the intervention on the target behaviors, (e) use a form of AR to facilitated the therapeutic intervention, and (f) provide quantitative data pertaining to the participant's acquisition of adaptive and functional target behaviors (e.g., teaching air travel behavior, treatment of phobia, learning pedestrian safety skills). Studies that did not collect data on an adaptive or functional target behavior or did not include a therapeutic intervention as the independent variable were excluded (e.g., social skills, communication skills). For example, Fitzgerald et al. (2018) conducted a study that evaluated the use of VR and video modeling to teach paper folding tasks (e.g., making a paper boat). However, this paper was excluded since although folding paper might have some functional and adaptive contexts, such as folding paper menus in the context of job skills, this was in the context of what could be viewed as an arts and craft activity, without a direct functional or adaptive context during the intervention. Additionally, the researchers included any study utilizing a quasi-experimental, group comparison experimental, or single-case experimental design. Studies evaluating the validity of AR interventions or participants' perspectives on using the technology were excluded. For example, McCleery et al. (2020) evaluated the usability and feasibility of an immersive VR program to teach police interaction skills for participants with autism but did not measure targeted skills gained from the intervention program, and thus was excluded from this review. Finally, any study that discussed the development of technologies or the architecture of the technologies but did not provide quantitative data on the effects of the intervention on the target dependent variables was excluded. For example, Trepagnier et al. (2005) discussed multiple computer-based and virtual environment technologies that are in development but did not utilize those technologies in an experiment. After application of the inclusion criteria, a total of 24 articles were included in this review.

Descriptive Synthesis

The raters coded each article by the following variables: (a) number of participants; (b) participants characteristics (age, gender, diagnosis); (c) dependent variable; (d) independent variable, (e) technology utilized (description of the AR technology); (f) experimental design; and (g) study outcomes. Raters coded the total number of participants including both the participants with ASD and without ASD. Raters provided a narrative description of the dependent variables, independent variables, and technology used. Raters coded the experimental design as either group experimental, quasi-experimental, or single-case experimental designs. Finally, raters coded the study outcomes according to how the author(s) reported the outcomes for the target dependent variable(s).

Quality Evaluation Method

Articles were group based on the experimental design (i.e., single-case research versus group experimental/quasi-experimental) to facilitate the quality evaluation. The two lead authors then evaluated each study according to corresponding rubric developed by Reichow et al. (2008) evaluative method single case or group-experimental research design. Reichow's evaluative method was chosen in comparison to other quality evaluative method (e.g., Center for Exceptional Children Standards) since it includes procedures to evaluate both single-case and group experimental research, evaluates internal and external validity, and was specifically developed for research specific to individuals with autism (Cook et al., 2015; Reichow, 2008). Additionally, Reichow's evaluative method has been well established in the literature to aid in the identification of practices that meets the standards to be classified as an evidence-based practice (EBP; Lynch et al., 2018; Reichow, 2011).

Interrater Reliability

Search and Inclusion Criteria. During the review for inclusion, two raters coded 100% of the articles (*n* = 74). To evaluate the reliability of the application of the inclusion and exclusion criteria, interrater reliability (IRR) was calculated using the percent agreement by dividing the total number of agreements by the total number of agreements plus disagreements and then multiplying by 100 to obtain a percentage. Agreement on inclusion was obtained on 89.19% of the studies (*n* = 66). Disagreements were reviewed and discussed by the raters until agreement was established for a final agreement of 100%.

Data Extraction. Two raters independently coded 50% of the included articles (*n* = 24). Each article was coded across three categories with a total of 36 items for which reliability was evaluated (i.e., 12 articles with three categories each). Agreement was established on 33 of the items. And IRR was calculated using the percentage of agreement by dividing the total number of items with agreement and by the total number of items and then multiplying by 100 to obtain a percentage. The initial IRR was 91.67%. Disagreements were reviewed by the raters and discussed for a final IRR of 100%. The final table was then evaluated for accuracy by the remaining authors to ensure accuracy of the table.

Quality Evaluation. Twelve studies of the 24 articles (50%) were independently reviewed by the two lead authors to establish IRR. The 12 articles included seven group experimental/quasi-experimental design studies and four single-case research studies. There were 12 indicators per article for a total of 24 items for which reliability was evaluated. Agreement was established on 21 of the 24 total items (88%). Disagreements were discussed by the authors until a consensus for a final IRR of 100%.

Results

The 24 articles included in this review were summarized by dependent variable, intervention components, behavioral components, and technology used. Table 1 provides the data summary of each study.

Participants. Across the 24 included studies there were a total of 882 participants (excluding the staff participants included in Smith et al., 2021a) with an approximate mean age of 19.77 (range = 4 to 29.4). The majority of the included participants were high to moderate functioning levels.

Dependent variables. Of the 24 studies, 41.67% (*n* = 10) taught vocational related skills. Specifically, nine of these studies (e.g., Burket et al., 2018; Genova et al., 2021; Smith et al., 2014) targeted job interview skills and one targeted general vocational skills (i.e., Bozgeyikil et at., 2017). Of the functional behaviors targeted, 29.17% (*n* = 7) of the studies focused on the treatment of problem behavior, such as the treatment of fears, phobias (e.g., Maskey et al., 2014; Maskey et al., 2019a; Meindl et al., 2019), or hypersensitivity (i.e., Johnston et al., 2020). Four (16.67%) studies focused on safety related skills, such as pedestrian safety (i.e., Dixon et al., 2019), driving skills (i.e., Cox et al., 2017; Wade et al., 2016), and transportation use (i.e., Miller et al., 2020; Simões et al., 2018). Two studies targeted general functioning skills, such as match to sample skills (i.e., Hu & Han, 2019) and understanding the context and characteristics of common objects (i.e., Wang & Reid, 2013). Lastly, only one study focused on increasing exercise engagement (i.e., McMahon et al., 2020).

Behavior analytic components embedded within VR. A combination of behavior analytic components, such as antecedent interventions, prompting, reinforcement, or corrective feedback, were utilized by all the included studies. For nine of the studies (37.5%) the VR system primarily provided the learning stimuli, prompts, and consequence variables (e.g., reinforcement or feedback) and although in some cases a researcher or therapist provided pre-training on the use of the VR system. For five of the studies (20.83%) a combination of the VR system and therapist implementation was used. For example, for most of the studies utilizing VR within the context of job interview training, the VR system was primarily used for practice interviews and additional instruction was provided by a therapist on related interview skills (e.g., Smith et al., 2021a; Strickland et al., 2013). Lastly, eight studies (33.33%) the VR system was utilized primarily for the learning stimuli needed for teaching the targeted skill with a therapist delivering instruction, prompting, and reinforcement. For example, Dixon et al. (2019) used the VR system within the context of pedestrian safety (visual and auditory stimuli) with a therapist delivering questions related to the safety of the situation (e.g., “Is there a moving car?”) and providing reinforcement for the participants responses.

VR Technology. All papers used software to create the virtual environments, but some used additional hardware displays and interfaces to increase the level of immersion. A non-immersive VR was the most commonly utilized configuration, which was used by 41.67% of the included studies (n = 10). This type of VR configuration is the least immersive and generally relied on a standard desktop sized computer monitor (i.e., size range) with basic inputs from the user (e.g., desktop keyboard or controller; Bamodu, & Ye, 2013). The second most utilized VR platform was a semi-immersive VR which was used by 33.33% (n = 8). This configuration relied on external equipment, such as sensors for interaction (e.g., XBOX Kinect, Leap Motion) and projectors or large screens to display the VR simulation (e.g., Blue Room advanced VRE) to create a sense of deeper immersion and interactivity within a VR simulation (Bamodu, & Ye, 2013). Lastly full immersive VR was used by 25% (n = 6) of the included studies. This set up entailed both the use of advanced VR technology (e.g., motion tracking, head mounted display, Oculus Touch controllers) with the use of software (e.g., Unity Game engine) to create the more advanced 3D VR environments (Bamodu, & Ye, 2013).

Quality Ratings and evaluation of evidence. There were 18 group experimental design studies and six single-case experimental design studies. Overall, the raters identified three (12.5%) of the studies as meeting criteria to be classified as “strong” and nine (37.5%) of the studies as meeting criteria to be classified as “adequate”. The remaining studies (12; 50%) did not meet criteria and cannot offer evidence towards the research question. Of the 18 group experimental design studies the raters classified two (.83%) as “strong”, six (25%) as “adequate” and ten (41.67%) as “weak”. Of the six single-case experimental design studies, the raters classified one (.42%) as “strong”, three (12.5%) as “adequate” and two (.83%) as “weak”.

Taken as a whole, the three studies (Cox et al., 2017; Hu & Han, 2019; Wade et al., 2013) identified as “strong” quality studies were conducted by three different research teams, at three different locations, with 74 different participants and meet the qualifications to be considered a promising practice.

Discussion

The primary aim of this review was to synthesize the literature based on the use of VR interventions for adaptive and functional behavior for individuals with autism. The secondary aim of this review was to evaluate the quality of the studies to help guide future research and practice applications. A total of 24 studies met the criteria of inclusion for this review. Of those studies, ten targeted vocational related skills, seven targeted functional behaviors (e.g., problem behavior treatment, hypersensitivity, phobias), four targeted safety skills (e.g., driving, airplane travel, pedestrian safety), two studies targeted general functional skills, and one targeted exercise engagement. In terms of quality ratings, only three of the studies met the three quality criteria for a classification of “strong”. This indicates a need for replication of both single case and group experimental design, as well as an increase in the rigor of quality design methodology. Further, since these studies did not incorporate full immersive VR, this also highlights an area of need for quality research design and replication.

This review highlights several benefits for the use of VR based interventions for individuals with autism. First, the ability to create environments conducive to safe practice for the development of safety skills, such as driving safety and pedestrian safety skills. In particular, VR environments can reduce the risks associated skill acquisition that might not be feasible in the real-world environments. For example, when practicing safely walking across the street in a VR environment, there are no real risk if the user does not wait for the crosswalk sign to signal as compared to the real environment, where an individual could be hit by a car.

Another potential benefit of VR based interventions are the ability to customize the user’s intervention based on their progress for skill acquisition, such as embedding prompts to help highlight the salient cues in the environment that should evoke a specific behavior response from the user. For example, Cox et al. (2017) included extra stimulus cues within the VR driving simulation based on user eye gaze to highlight driving hazards that should evoke driver attention and defensive driving maneuvers. This type of included component can potentially help ensure the VR interaction can individualize to the user, thus providing a more tailored intervention and user experience.

VR interventions can also allow for extra practice and a variety of exemplars to better promote generalization of skills (multiple exemplar training study). Further, VR can also easily allow for generalization to the natural environment since it allows for programming of the relevant stimuli that would occur within the natural environment (Stokes & Baer, 1977). For example, Miller et al. (2020) included programming for generalization within the sessions of the study. Specifically, this study conducted the last session of the study at the airport to provide a real-world rehearsal of the air travel skills targeted during the VR-based intervention. This study highlights the utility and efficacy of VR based interventions as well as the need to evaluate the transfer of skills to the “real” environment. However, given the lack of assessment of generalization to real-environments from the studies included in this review, more analysis is needed to evaluate the effects of generalization on VR-trained skills.

Lastly, some of the studies included in this review indicated the effectiveness of using lower cost VR systems, which may increase the feasibly of VR-based interventions within clinical applications. For example, Miller et al. (2020) used an iPhone X with Google Cardboard device to create a virtual air travel experience. And several studies used a commercially available internet software program (i.e., Molly Porter by SIMmerson Immersive Simulations) to provide mock interviews for developing interview skills (i.e., Genova et al., 2021; Humm et al., 2014; Smith et al., 2014; Smith et al., 2021a, 2021b; Ward & Esposito et al., 2018). Although low tech solutions may be readily available, research is still needed to help evaluate the costs and benefits of the various VR technology as it relates to skills being taught, the needs of the individual, and the programming of relevant environmental variables to help best promote generalization of skills to real world environments.

While the current research evaluated in this review indicates that VR is a conducive platform complementary for the integration of behavior analytic strategies to develop effective interventions, there are a few considerations worthy of discussion. First, only three studies met the criteria for a classification of “strong” quality standards. This indicates a need for further replication of VR-based interventions that focus on teaching functional and adaptive skills.

Second, there is a need for decision making frameworks to help inform practitioners and service providers which equipment options allow for individualization or what technology options best align to various characteristics and needs of the individuals we serve. For example, Simões et al. (2018) provided differentiation across the technology used. Specifically, four of the participants in the study did not use the VR head-mounted display due to vision impairments, however the desktop configuration was still conducive for those users to participate in the VR intervention. This highlights the need for clear decision-making framework for technology selected in VR-based interventions.

Third, there is a need for cross field collaboration to ensure that VR interventions have the programming capacity for individualization, systematic teaching procedures, and reinforcement contingencies that are transferable to the real environments. In many of the studies included in this review, therapist/researchers were still providing prompts and reinforcement rather than these elements being seamlessly incorporated into the VR system. This may indicate that there was a lack of collaboration across technology developers and behavior analysts. As such, future research should consider the benefits of cross-field collaboration to improve the quality and efficacy of VR-based interventions.

Finally, there is a need to evaluate other skills that fall within the domain of adaptive and functional behaviors, where VR could provide a better context for developing effective interventions. Given the few areas of safety skills addressed in the current literature, this seems like an obvious area that could benefit individuals who are working to develop these functional skills. For example, abduction prevention could be an area where VR base interventions might provide for more effective training, as compared to role playing or social stories-based interventions, since the virtual environment could include relevant signals with multiple exemplars and provide practice opportunities (e.g., Ledbetter-Cho et al., 2016).

Implication For Practice And Conclusion

For practitioners, it is important to highlight the use of EBPs when developing interventions for individuals with autism. Given the range of technology options for VR-based intervention, consideration of prerequisite skills for both the use of technology and the skill that is targeted within the intervention. Thus, assessment should be utilized to help guide the intervention plans. For example, if using VR goggles, it would be important to do some direct assessment to ensure the user has the necessary skills and that the VR experience is enjoyable and does not cause issues, such as motion sickness. Practitioners would also want to be sure that generalization of the skill is accounted for within the intervention and transfers easily to the real world. This may also require incorporating other stakeholders within the intervention phases to ensure the technology used is feasible for everyone involved. As VR technology continues to advance, research is needed to help provide a clear framework for collaboration and decision making to help progress and extend VR-based interventions.

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Declarations

We have no known conflict of interest to disclose.

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Tables

Table 1.

Descriptive Synthesis

Citation	Dependent Variable	Intervention	Behavioral Component	VR Technology
Bozgeyikil et al. (2017)	(1) Level scores measured via 6 vocational skills (2) Participant self-rated (tiredness, immersion, motion sickness, satisfaction, effective training, reasonable design, and accuracy) via a modified version of Loewenthal's core elements of the gaming experience questionnaire, (3) Follow-up data on the 6 vocational skills were collected via a survey by the job trainers and, (4) Social validity was collected via qualitative survey data.	The user completed six job training modules (cleaning, environmental awareness, loading, money management, shelving, social skills). Each module began with a tutorial provided by a virtual instruction to explained and show the user how to perform the task. This was then proceeded by two additional levels increasing in difficulty.	**Antecedent Component:** Module tutorial delivered by virtual instructor who provided verbal instructions and modeling of the skill without any distractors. Assistive prompts via VR. If user did not perform task within a minute, a prompt (verbal instructions, pictographs, and animations) was given. **Consequence Component:** Corrective feedback delivered in the form of pictures via VR, for example stating, "well done" or "collision".	**Fully Immersive VR:** VR2200 Head Mounted Display (HMD), an optical motion tracking system with 12 OptiTrack Flex:V100 cameras that track an area of 8ft by 8ft, a large 180∘ curved curtain screen, touch screen controls, tangible objects equipped with optical markers that can be tracked by the system in real time, and a remote control panel for the job trainers. The software was developed using the Unity game engine and run via a desktop computer.
Burke et al. (2018)	Interview skills measured using the Marino Interview Assessment Scale Measures	Intervention involved participants completing job interview coursework with the final 5 sessions dedicated to ViTA virtual interview. Participants completed four virtual interviews.	**Antecedent Component:** Staff provide instruction on interview strategies and equipment training for ViTA to user. **Consequence Component:** Corrective feedback delivered via VR system. **Other Component**: Role-play of interviews via the VR system	**Semi-immersive VR:** Virtual interactive training agent (ViTA) system. ViTA utilizes the Unity Game Engine as the sole core of the ViTA software. The ViTA lab utilizes 3 different cameras (a HD video camera to record interviews, a web camera used as a backup camera, and an XBOX GEN 1 KINECT camera system used to track facial expressions. The VR was delivered using a 60–70-inch Samsung HD flat-screen TV. A custom networked three PC server cabinet was used to run the ViTA software, camera system, and automatic backup and shutdown system.
Burke et al. (2021)	(1) Interview skills measured using the Marino interview assessment scale measures (2) Self-efficacy measured using the ViTA self-efficacy scale consisting of three subscales (strength, career decisions, and general).	Participants accessed multi-media interview skills content from their home computer and afterward completed a simulated online interview (ViTA system). Participants participated in four ViTA interview sessions, one initial	**Antecedent Component:** Staff provide instruction on interview strategies and equipment training for ViTA to user. **Consequence Components:** Corrective feedback delivered via VR system. **Other Component**: Role-play of interviews via the VR system.	**Non-immersive VR:** Virtual interactive training agent (ViTA) system. The apparatus consisted of a HD LCD monitor with the minimum equipment needed composing of a laptop (recommended) or another computer, 24″ HD LCD monitor or larger, feature cable, lapel microphone, wireless mouse and keyboard HDMI Cable or VGA, 3.5 mm multimedia speakers, 3.5 mm lapel microphone, wireless mouse,

		face-to-face interview, and one final face-to-face interview at completion of sessions (approximately 22 weeks).		and a wireless keyboard to allow for the remote operation of the Interview Scenario.
Cox et al., (2017)	(1) Driving-specific executive function abilities, (2) Tactical driving skills and (3) Eye tracking	Participants were randomized to either Routine Training (the state-specific department of motor vehicle training manual) Standard VRDST, Automated VRDST, or Eye Tracking VRDST. Standard VRDST: During each session, the trainer would first demonstrate the task to the participant, and then monitor participant performance while providing continual verbal feedback. The Automated VRDST: identical to Standard VRDST with the simulator's computerized voice provided real- time auditory feedback. Eye Tracking VRDST: similar to the Standard VRDST with the addition of feedback from the eye tracker (glasses) options that modelled exactly where the participant should look while driving. Once a segment was completed, the trainer and participant would review their performance.	**Antecedent Component:** In Standard condition, the trainer demonstrated first to participant. **Consequence Component:** Feedback (both corrective and positive vocal praise) was delivered via a trainer in Standard condition and feedback was delivered via VR in Automated conditions.	**Semi-immersive VR:** Driver Guidance System (DGS-78) VRDS is a realistic driver's cockpit with side and rear-view mirrors. The driver's view is projected onto a 2.44 m (8 ft) diameter, 210° curved screen. Eye-tracking glasses (Mobile Eye XG).
Dixon et al. (2018)	Percentage of correct response for safe street crossing.	Intervention entailed teaching safe street crossing (identifying whether it was safe to cross the road or not) in the natural environment. Training sessions	**Antecedent Component:** Flexible prompt fading was used by the therapist to teach the participants the approach responses for all three steps.	**Fully Immersive VR:** Oculus Rift (Version CV1) headset and sensors. The Oculus Rift was connected to a laptop. The immersive VR environment consisted of 360-degree videos of real streets from the participants' community. Videos were

		entailed showing a video clips of safe and unsafe crossing situations using immersive VR. Flexible prompting and fading procedures were used to teach the participant the responses (looking left and right, responding to “Is there a car moving?”, and responding to “Is it safe to cross?”).	**Consequence Component:** Reinforcement was provided by the therapist regardless of a correct or a prompted response, verbal praise was provided after each step, verbal praise or a token was provided at the end of each trial, and access to a preferred activity was provided after each session based on the participant’s preference.	recorded using a Samsung Gear 360 camera attached to a 4-ft. (1.2 m) monopod. A low-profile monopod was used to reduce visual distractions in the videos. The videos were hosted on YouTube.
Genova et al. (2021)	(1) Job interview skills measured via the Mock Interview Rating Scale, (2) Likelihood to be hired, (3) Interviewee performance measured via composite score, (4) Job interview self-efficacy and anxiety measured via self-report questionnaires.	Participants used the Virtual Reality Job Interview Training (VR-JIT) system with includes e-learning component to teach job interviewing skills (getting ready for the interview, being on time and acting professionally), as well as virtual practice interviews. Sessions consisted of three levels of difficultly. Participants practiced job interviews with a virtual interviewer.	**Consequence Component:** Three types of feedback were provided (1) real-time feedback through the use of a virtual “Job Coach” (non-verbal cues (thumbs up/down, clapping) after answering a question, (2) a quantitative performance-based score given upon the conclusion of each interview, (3) the interventionist reviewed the interview transcript with the participant to provide feedback on how they performed.	**Non-immersive VR:** VR-JIT system (developed by SIMmersion LLC) is a computerized job interview simulator delivered via the internet. Other equipment used not specified.
Hu & Han (2019)	(1) Percentage of correct matching responses, (2) Percentage of task engagement (physical attendance to the match-to-sample tasks), and (3) Social validity collected via teacher survey.	Discrete-trial teaching. The computer application randomly presented 15 out of the total 30 pairs of associated items. Each pair was presented as one trial at a time. After the software presented the pictures with verbal stimulus (directions) the participant was given 3s to respond using the Leap Motion controller. Th researcher provided prompting if a response did not occur following the 3s. The software	**Antecedent Component:** Each session began with attending skills and establishing rapport with the researcher. Pretraining for VR system utilized an errorless learning procedure by the researcher for basic operation. A visual cue serving as a prompt was delivered by the system if participant did not respond within 5s. **Consequence Component:** During the intervention reinforcement was delivered via VR (smiley face and an auditory reinforcing statement). Corrective feedback was provided if the student failed to	**Semi-immersive VR:** PC laptop and a Leap Motion controller. The match-to-sample software program was developed for the purpose of this study and not commercially available.

		provided feedback based on the accuracy of the response (e.g., corrective or praise).	respond correctly with the visual cue, the system would display a crying face with the auditory statement of 'Try again'.	
Humm et al. (2014)	(1) Role play skills scores, (2) Self-confidence measures, (3) Helpfulness, (4) Enjoyableness, and (5) Ease of used. Items 2-5 all measured via the Training Experience questionnaire.	Virtual job interview training program (Job Interview Training with Molly Porter) that includes user-driven elearning, an interactive job application, and practice interview simulation with a virtual interviewer.	**Consequence Component:** Feedback delivered via VR to reinforce appropriate demonstration of job interviewing skills.	**Semi-immersive VR:** Computer based VR System. VR-VIT with Molly Porter from SIMmersion PeopleSim™ technology.
Johnston et al. (2020)	(1) Anxiety measured via the Modified Smiley-Face Assessment Scale, and (2) Tracked participant interaction with target auditory stimuli.	The intervention was deviled using the VR game called SoundFields. During the sessions, participant engaged with a non-playable character who provides direction within the game (as a guide). Across the sessions, a spatial audio exposure hierarchy was programed into the VR environment.	**Consequence Component:** Positive reinforcement for interacting with aversive auditory stimuli and utilization of token economy within VR.	**Fully Immersive VR:** SoundFields is the prototype of an individual interactive virtual reality game. All visual stimuli were rendered using the Oculus Rift CV1 head mounted display (HMD). Head tracking was also achieved using the HMD, with motion tracking of participant position calculated by the Oculus Rift sensors. Player input was achieved using the Oculus Touch controllers. Audio was presented to the participant using Sennheiser HD-650 headphones.
Maskey et al. (2014)	(1) Anxiety symptoms measured the via Spence Children's Anxiety Scale-parent version and child version, (2) Target behaviors related to handling the situation that caused anxiety, and (3) Confidence rating scale (feelings thermometer).	A combination of CBT and gradual exposure in VR environments (Blue Room) were provided during the intervention. Each child had one assessment and preparation session at home where they were coached on techniques to use when experiencing anxiety (CBT). This was then followed by a VRE exposure sessions. For each participant the VRE scene was individualized based on their phobia).	**Antecedent Component:** Presession coaching was provided by a therapist for relaxation techniques in a relaxing VRE scene prior to the phobia treatment. Systematic desensitization/ extinction through graded exposure of Phobia. **Other Component:** Session debriefing with the therapist and family to discuss planning for real life exposure to their phobia.	**Semi-immersive VR:** Immersive technology 'Blue Room', an advanced computer generated VRE. The Blue Room uses audiovisual images projected onto the walls and ceilings of a 360-degree seamless screened room. iPad for therapist use to operate the graded exposure on the computer-generated scene.
Maskey et al. (2019a)	(1) Anxiety symptoms measured the via Spence Children's Anxiety Scale-parent version and child	A combination of CBT and gradual exposure in VR environments (computer delivered	**Antecedent Component:** Presession coaching was provided by a therapist for relaxation techniques in a relaxing	**Non-immersive VR:** For the VR software, a Third Eye Neurotech programmer was used. The computer monitor had a diagonal screen size of

	version, (2) Target behaviors related to handling the situation that caused anxiety, and (3) Confidence rating scale (feelings thermometer).	sessions) were provided during the intervention. Each child had one assessment and preparation session at home where they were coached on techniques to use when experiencing anxiety (CBT). This was followed by four VRE exposure sessions. For each participant the VRE scene was individualized based on their phobia).	VRE scene prior to the phobia treatment. Systematic desensitization/ extinction through graded exposure of Phobia. **Other Component:** Session debriefing with the therapist and family to discuss planning for real life exposure to their phobia.	24 in. with an attached soundbar with stereo speakers. iPad for therapist use to operate the graded exposure on the computer-generated scene.
Maskey et al. (2019b)	(1) Target behavior ratings measured via the recorded rating of change over time in the specific phobia, (2) Anxiety measured via the Spence Children's Anxiety Scale-parent version and child version, (3) Assessment of fear measured via the Fear Survey Schedule for Children—revised, and (4) increase in child's participation in a range of community activities measured via the Children's Assessment of Participation and Enjoyment.	A combination of CBT and gradual exposure in VR environments (Blue Room) were provided during the intervention. Each child had one assessment and preparation session at home where they were coached on techniques to use when experiencing anxiety (CBT). This was followed by a VRE exposure sessions. For each participant the VRE scene was individualized based on their phobia).	**Antecedent Component:** Presession coaching was provided by a therapist for relaxation techniques in a relaxing VRE scene prior to the phobia treatment. Systematic desensitization/ extinction through graded exposure of Phobia. **Other Component:** Session debriefing with the therapist and family to discuss planning for real life exposure to their phobia.	**Semi-immersive VR:** Immersive technology 'Blue Room', an advanced computer generated VRE. The Blue Room uses audiovisual images projected onto the walls and ceilings of a 360-degree seamless screened room. iPad for therapist use to operate the graded exposure on the computer-generated scene.
Maskey et al. (2019c)	(1) Anxiety measured via the Beck Anxiety Inventory and the Generalized Anxiety Disorder-7, (2) Depression measured via the Patient Health Questionnaire-9, (3) quality of life measured via the WHOQOLBREF, and (4) confidence measured via 6-point scale (feelings thermometer).	Intervention involved a combination of CBT and gradual exposure in virtual reality environments (Blue Room). Each participant had one assessment and A combination of CBT and gradual exposure in VR environments (Blue Room) were provided during the intervention. Each child had one assessment and preparation session at home where they were coached on	**Antecedent Component:** Presession coaching was provided by a therapist for relaxation techniques in a relaxing VRE scene prior to the phobia treatment. Systematic desensitization/ extinction through graded exposure of Phobia. **Other Component:** After the fourth sessions debriefing with the therapist, participant, and supporter was provided to discuss planning for real life exposure to their phobia.	**Semi-immersive VR:** Immersive technology 'Blue Room', an advanced computer generated VRE. The Blue Room uses audiovisual images projected onto the walls and ceilings of a 360-degree seamless screened room. iPad for therapist use to operate the graded exposure on the computer-generated scene.

		techniques to use when experiencing anxiety (CBT). This was followed by a VRE exposure sessions. For each participant the VRE scene was individualized based on their phobia.		
McMahon et al. (2020)	(1) Total amount of time participants engaged in exercise, (2) heart rate, and (3) calories burned.	Participants use a VR exercise game Virzoom where participants pedal a Stationary bike which corresponds to various games and scenarios in immersive VR.	**Antecedent Component:** Adult delivery of equipment instruction prior to VR. **Other Component:** Embedded reinforcement (presence of VR game) for interacting with exercise.	**Fully Immersive VR:** The VR exercise gaming platform used was the Virzoom exercise bike and the HTC VIVE VR goggles. Apple Smartwatch (Version 2), was used to measure the heart rate and the duration of the exercise.
Meindl et al. (2019)	Total steps achieved in the task analysis of a blood draw.	VR-based blood draw to provide exposure therapy. As the participant viewed the blood draw simulation, a therapist attempted to replicate the sensations in real time that should accompany the video.	**Antecedent Component:** Prior to the start of the session the therapist determined the target step in which the participant would earn reinforcement and informed the participant of the contingency. While viewing the video, the therapist counted to help the participant predict when he could move his arm and gain reinforcement. **Consequence Component:** The training involved a differential reinforcement of other behaviors procedure, in which, the participant was reinforced if no avoidance behavior occurred during a session. Edible reinforcement was provided by the therapist.	**Fully Immersive VR:** Virtual reality (VR) equipment consisted of a Tzumi Dream Vision VR Headset, an iPhone 6s to display the VR video, and an Insta360 One VR camera. A 360-degree video of a blood draw was developed using the Insta360 One VR camera equipped with two lenses that simultaneously record two 180-degree video images which combined to produce one 360-degree video.
Miller et al. (2020)	(1) Activity completion measured using a checkpoint completed during intervention assessing if the child attended to the duration of the VR checkpoint stimulation, (2) Travel ability measured using an air travel questionnaire.	VR-based air travel training module combined with traditional functional communication training based on an air travel experience. Individualized scripts for each child were delivered based on social stories. The final session was a real-world rehearsal.	**Antecedent Component:** Prior to the start of the session a 15-minute warm up activity was provided to help the child acclimate to the clinic. During the video a narrative script was provided to help the child attend to the VR simulation. **Consequence Component:** Reinforcement for functional communication responses	**Fully Immersive VR:** VR-based air travel training module delivered on an iPhone X with a Google Cardboard device.

			and prompting of replacement behaviors delivered by therapist.	
Simões et al. (2018)	(1) Action accuracy measured via the number of correct actions for the task, (2) Debriefing accuracy measured via the accuracy of the participants describing the process of riding the bus, (3) Task duration in minutes for each session, and (4) Anxiety level measured via electrodermal activity (EDA) variation during each session.	Participants were given a brief tutorial of game controls, then a task ranging in difficulty and complexity (taking one bus or two buses) for selecting a bus route and engaging in corresponding steps to reach the destination. At the end of every session the participant was asked to describe the process of riding a bus to the experimenter, but feedback was not provided.	**Antecedent Component:** Tutorial on game controls. **Consequence Components:** Feedback was provided by the VR system at the end of each task (scoring system evaluated the performance of the player on 2 different components: "Actions" and "Route"). A biofeedback system was implemented to adjust the environmental noises if needed.	**Semi-immersive VR:** The VR system was ran on a laptop computer (Windows 8.1, 16.0 GB RAM and an IntelCore i7 2.50 GHz processor). The head-mounted display used was Oculus Rift Development Kit 2, firmware version 2.12, and a gamepad was used for input. A bracelet for wireless EDA recording (Biopac Bionomadix BN-PPGED and MP150 amplifier).
Smith et al. (2014)	(1) Job interview skills rated on nine communication skills, and (2) Job interview self-confidence measure on seven-point Likert scale to answer 9 questions.	Intervention involved virtual reality job interview training which used strategies to target both job-relevant interview content and interviewee performance. .	**Antecedent Component:** User informed of instructional strategies regarding job interview process prior to virtual interview via coursework. Prompts delivered to user via use of a help button within the VR job interview system. **Consequence Component:** Corrective feedback utilized displaying scores on key dimensions of performance allowing review of audio and written transcripts color coded for 'strong,' 'neutral,' or 'needs improvement' interview responses.	**Non-immersive VR:** Computer-based VR job interview training (VR-JIT) is a computerized virtual reality training simulation that can be used as computer software or via the internet. SIMmersion's patented PeopleSIMTM technology is the main platform for the simulated interactions in VR-JIT.
Smith et al. (2021a)	(1) Acceptability outcomes measured via an adapted Treatment Acceptability Rating Form, (2) Adherence outcome measured via the recorded total number of completed virtual interviews, frequency of participants who progressed through systems levels, and total number of mins engaged with virtual interviewers, (3) Job	Self-guided e-learning materials and computer simulated job interview using virtual interviewers.	**Antecedent Component:** User informed of instructional strategies regarding job interview process prior to virtual interview via elearning coursework. **Consequence Component:** The VR system provided non-verbal cues and delivered prompts for relevant information, reinforcement (token economy), and corrective feedback.	**Non-immersive VR:** Computer-based VR via VIT-TAY software developed by SIMmersion LLC.

	interview skills measured via the Mock Interview Rating Scale, (4) Self-efficacy measured via self-reported scale, (5) Job interview anxiety measured via a modified version of the brief Personal Report of Public Speaking Apprehension, and (6) Vocational outcomes			
Smith et al. (2021b)	(1) Implementation outcomes measured via VR-JIT orientation acceptability, appropriateness, and expected implementation feasibility, (2) Effectiveness outcomes measured via vocational outcomes (employment)	Self-guided e-learning materials and computer simulated job interview using virtual interviewers.	**Antecedent Component:** User informed of instructional strategies regarding job interview process prior to virtual interview via elearning coursework. **Consequence Component:** The VR system provided non-verbal cues and delivered prompts for relevant information, reinforcement, and corrective feedback. **Other Component**: The system provides review of audio and written transcripts (color coded for 'strong,' 'neutral,' or 'needs improvement') interview responses. Token reward system	**Non-immersive VR:** Computer-based VR via VIT-TAY software developed by SIMmersion LLC.
Strickland et al. (2013)	Interview skills measured via the Interview Skills Rating Instrument	Self-guided e-learning materials and computer simulated job interview using virtual interviewers. Written instructions were issued to each participant (treatment group) directing them to review all seven website subsections and the participants would complete two simulated job interviews.	**Antecedent Component:** Systematic instruction delivered via multimedia employment training website. Embedded within most subsections were printable summaries, graphic organizers, worksheets, and visual reminder cues. **Consequence Component:** Participants received direct, positive feedback for areas of strength in practice interview and corrective feedback on areas of need via VR avatar assumed by the clinician.	**Non-immersive VR:** Computer based VR using website-based Venugen platform (http://www.venuegen.com/).

Wade et al. (2016)	Driving performance measured via median trial duration to assess task difficulty and proficiency in task completion and median number of trial failures per task (e.g., adherence to traffic laws, turning, merging, speed maintenance) pre- and posttests.	Using the VR driving module, participants completed a practice driving sessions for assigned driving tasks.	**Antecedent Component:** VR equipment and program pretraining by researcher. **Consequences Component:** Corrective feedback via VR in the form of object-highlighting and audio/text presentation. Positive reinforcement (token economy) was also provided contingent upon a successfully completed trial.	**Semi-immersive VR:** The VDM consists of both VR driving simulation software and a hardware driving interface that allow users to perform driving tasks in a controlled environment. A 3D model city was created via CityEngine and Autodesk Maya software, along with the Unity3D game to implement the VR driving application. The Tobii X120 remote eye-tracking device (www.tobii.com) was used to extract eye gaze data from participants.
Wang & Reid (2013)	(1) Contextual processing of objects measured using Virtual Reality Test of Contextual Processing of Objects an adaptation of the Object Integration test, (2) Executive functioning measured using the modified version of the Flexible Item Selection Task, (3) Visual attention, visual scanning, visuomotor inhibition measured using the Attention Sustained Subtest, and (4) behavioral changes measured using a final feedback questionnaire.	The VR training program provided lessons focused on one class of object characteristics: perceptual, spatial, or functional. The goal of each lesson was to teach the child to flexibly attend to object dimensions of that class. The VR program presented each set of 10 training items in a predictable sequence. Motion-capture VR technology allowed for the child to see themselves on the screen and indicate responses through gestures (grab and dragging objects across the screen).	**Antecedent Component:** A researcher provided one-on-one instruction within the virtual environment. Components of the training included verbal instruction, modeling, and prompting. **Consequence Component:** Researcher delivered reinforcement. Visual reinforcement and corrective feedback was built into the VR program (correct responses rewarded with a happy face, while incorrect responses were discouraged with a sad face).	**Non-immersive VR:** VR training programs and virtual tests were displayed on a 15-inch Acer TravelMate 8204 laptop computer. Motion-capture technology was incorporated using a tracking webcam (Logitech QuickCam Pro 9000) to capture and project the child's image and movements into the virtual environment. All software programs were programmed using Flash 8 with the programming language Actionscript 2.0. The programs were run using Macromedia Flash Player.
Ward & Esposito (2018)	(1) Self-efficacy measured via the General Self Efficacy Scale, (2) Self-confidence measured via the Interview Self Confidence Survey, (3) Progress Monitoring within VR-JIT, and (4) Student satisfaction.	Virtual job interview training program (Job Interview Training with Molly Porter) that includes user-driven elearning, an interactive job application, and practice interview simulation with a virtual interviewer.	**Antecedent Component:** VR equipment and program pretraining by researcher using direct instruction in group setting. **Consequence Component:** Feedback delivered via VR to reinforce appropriate demonstration of job interviewing skills.	**Non-immersive VR:** VR-JIT system (developed by SIMmersion LLC) is a computerized job interview simulator delivered via the internet. VR-JIT delivered with individual Google Chrome books equipped with headsets with microphones.

Table 2

Quality Indicator Ratings for Group Experimental and Quasi-experimental Research

	Bozgeyikil et al. (2017)	Burke et al. (2018)	Burke et al. (2021)	Cox et al. (2017)	Genova et al. (2012)	Humm et al. (2014)	Maskey et al. (2014)	Maskey et al. (2019a)	Maskey et al. (2019b)
Primary Indicators									
Participant information	U	A	A	H	U	A	H	H	H
Independent variable	H	H	H	H	H	H	A	H	H
Control condition	H	U	U	H	H	H	U	U	H
Dependent variable	U	H	H	H	H	H	U	U	U
Link Between Research Question and Data Analysis	A	H	H	H	H	H	H	H	H
Use of Statistical Tests	H	H	H	H	H	H	U	U	H
Secondary Indicators									
Random assignment	0	0	0	0	1	1	0	0	1
Interobserver agreement	1	0	0	1	1	1	1	1	1
Blind raters	1	1	0	1	1	0	1	1	1
Fidelity	0	1	0	0	1	1	0	0	0
Attrition	1	1	1	0	1	0	1	1	1
Generalization or maintenance	0	0	0	0	0	0	1	0	1
Effect size	1	1	1	1	1	1	0	0	1
Social validity	1	1	1	1	1	1	0	0	1

[1] Codes for quality ratings for primary indicators are as follows: H = high quality, A = acceptable, and U = unacceptable

[2] Codes for quality ratings for secondary indicators are as follows: 1 = criteria met, 0 = criteria not me

Table 2 (cont.)

Quality Indicator Ratings for Group Experimental and Quasi-experimental Research

	Maskey et al. (2019c)	Miller et al. (2020)	Simões et al. (2017)	Smith et al. (2014)	Smith et al. (2021a)	Smith et al. (2021b)	Strickland et al. (2013)	Wade et al. (2016)	Ward & Esposito (2018)
Primary Indicators									
Participant information	H	A	H	A	H	A	U	H	H
Independent variable	H	U	A	H	H	H	H	H	H
Control condition	U	U	H	H	H	H	A	H	U
Dependent variable	U	U	H	H	H	H	H	H	H
Link Between Research Question and Data Analysis	H	A	A	H	H	H	H	H	H
Use of Statistical Tests	H	U	A	H	H	H	H	H	H
Secondary Indicators									
Random assignment	0	0	0	1	0	1	1	1	0
Interobserver agreement	1	0	0	1	0	1	1	0	1
Blind raters	1	0	0	1	0	0	1	0	1
Fidelity	0	0	1	0	1	1	0	1	1
Attrition	1	1	1	1	0	1	1	1	1
Generalization or maintenance	1	1	0	0	1	1	0	0	0
Effect size	0	0	1	1	0	0	1	1	1
Social validity	0	1	1	1	1	1	1	0	1

[1] Codes for quality ratings for primary indicators are as follows: H = high quality, A = acceptable, and U = unacceptable

[2] Codes for quality ratings for secondary indicators are as follows: 1 = criteria met, 0 = criteria not me

Table 3

Quality Indicator Ratings for Single-case Research

	Dixon et al. (2017)	Hu & Han et al. (Year)	Johnston et al. (2020)	McMahon et al. (2020)	Meindl et al. (2019)	Wang & Reid (2013)
Primary Indicators						
Participant information	A	H	A	U	A	H
Independent variable	H	H	H	H	H	H
Dependent variable	H	H	A	H	H	A
Baseline	A	H	U	H	H	A
Visual analysis	H	H	U	H	A	A
Experimental control	H	H	H	H	H	H
Secondary Indicators						
Interobserver agreement	1	1	0	1	1	1
Kappa	0	0	0	0	0	1
Blind raters	0	0	1	0	0	1
Fidelity	0	0	0	1	1	1
Generalization or maintenance	1	1	0	0	1	0
Social validity	1	1	0	1	1	0

[1] Codes for quality ratings for primary indicators are as follows: H = high quality, A = acceptable, and U = unacceptable

[2] Codes for quality ratings for secondary indicators are as follows: 1 = criteria met, 0 = criteria not met