ABSTRACT

MCDONALD, MITCHELL DEWAYNE. The Efficacy of Diminished Reality on Learning in Complex Environments. (Under the direction of Dr. Anne McLaughlin).

Objective: Classrooms are complex environments with an abundance of sensory information, including distraction. There is a growing need, in the classroom and other complex environments, for support with management of the information. We assessed the effect of Diminished Reality (DR) for attention and memory tasks within a socio-educational context. We also measured individual differences in cognitive abilities to explore relationships between attentional control and learning with DR support.

Background: DR allows the removal of sensory information from real-world environments. A literature review revealed a lack of experimental data supporting the use of DR in applied settings. Psychological theory supports the idea that diminishing distractions should reduce extraneous load and promote learning. However, the effects of removing distractions from the environment via technological means (e.g., DR) had not been tested.

Method: 150 participants were recruited from Mechanical Turk and participated in this research study. We assessed the effects of sensory mode (auditory/visual) and level of diminished reality support (high/low/none), on classroom learning, situational awareness, workload, and feelings of presence.

Results: The results of this study showed several significant associations between scores on a retention test, feelings of presence in the classroom, and Adult-ADHD scores. Higher performance on the Retention Test was seen in participants with lower ADHD scores. Higher presence was felt by participants with higher ADHD scores. Situational awareness (SA) bias, a subjective measure of confidence relative to accuracy of SA, held the strongest association with video conditions and modality of DR support. Only participants in the LAHV group showed confidence as the control group was the most underconfident of all groups. Data also showed participants in the Low Auditory DR support conditions were more confident compared to High Auditory DR support. Differences in performance on the retention task were observed when controlling for the effects of ADHD. Participants in the low Visual DR Support group scored lower than their peers in the high Visual DR Support group.

Conclusion: By diminishing what participants are able to see and hear, we may reduce their ability to be situationally aware of what is going on in their environment. Controlling for differences in attentional control, higher DR support allows for increased attention and focus on learning. Based on these results, in environments where situational awareness is not deemed critical, diminished reality may provide support to learning when focused on reducing visual distractions. Such aids should be able to improve attention and memory for events across situations beyond the classroom (e.g., open offices, public gatherings).

The Efficacy of Diminished Reality on Learning in Complex Environments

by
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BIOGRAPHY

Mitchell McDonald was born and raised in Houston, Texas. Upon graduating from high school, he was awarded an appointment to the United States Military Academy (USMA), West Point, NY. He played division 1 basketball and was awarded a Bachelor of Science degree in Engineering Psychology from WestPoint in 2011. Soon after, he was commissioned as a Second Lieutenant in the United States Army. After completing the Engineer Basic Officers Leadership Course Mitch deployed as a platoon leader to Afghanistan. After a successful deployment, he returned to the states to serve in several developmental positions (937th Clearance Company Executive Officer, 20th Engineer Battalion Assistant Operations Officer) before attending and successfully completing the Engineer Captains Career Course. While at the career course in 2016 he also pursued and was awarded a Master of Science in Engineering Management from the University of Missouri S&T. He then transitioned to Fort Polk, Louisiana where he would later assume command and successfully deploy and redeploy the 573rd Route Clearance Company (Combat) to Afghanistan. Enroute to Fort Polk, he attended and successfully completed the United States Army Ranger Course and Basic Airborne Course. Additional positions held include but are not limited to, 46th Engineer Battalion Assistant Operations Officer and the Fort Polk G3 Current Operations Officer. His successful career performance led to him being selected as an instructor at WestPoint. He began graduate school yet again at North Carolina State University pursuing a Master of Science in Human Factors and Applied Cognition under the direction of Dr. Anne McLaughlin. During this time assigned to the LACELab Mitch has gained experience in human factors research and completed several independent and collaborative research experiments including but not limited to a physiology of comfort, and diminished reality experiment. He currently resides in North Carolina as he completes his degree, preparing for his upcoming transition to New York to become an instructor in the Behavioral Sciences and Leadership department.

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I would like to thank all of the undergraduate assistants, my cohort, friends and colleagues in the Human Factors and Applied Cognition program, the LACELab and Dr. Anne McLaughlin.

DEDICATION

This thesis is dedicated to my NCSU family.

The ability to rely on the bonds and relationships developed during this assignment have allowed me to be successful in navigating the numerous obstacles encountered during this pandemic.

Specifically, Nina Ferreri, Braxton Hicks, Michael Wilkinson, the LACELab team, and especially Anne.

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Introduction

Complex environments (loud concerts, bustling streets, classrooms) are becoming even more complex due to the additional information offered through technology. For example, more information to be displayed through digital billboards and social media platforms, as well as the use of laptops in the classroom, phones vibrating in pockets, and numerous other technological distractions are competing for the attention of the user.

Saturating cognitive and sensory processing systems comes at a cost - fewer cognitive resources available to the learner. Cognitive load theory (CLT) provides a framework for classifying the kinds of loads that deplete the resources needed for learning (Sweller, 1988). Cognitive load is a function of the amount of information a learner attempts to process. In a complex environment, such as a classroom, a student is required to manage various streams (e.g. visual, auditory, haptic, olfactory) of information. A student must process relevant (classified as intrinsic and germane load in CLT) and irrelevant information (classified as extrinsic load) to understand and encode the course content from the instructor. When the combination of intrinsic, germane, and extrinsic load exceeds the capacity of the learner, learning will not occur. Reducing extrinsic load is the first target for increasing learning.

Some learners may be more able to utilize selective attention than others. Challenges with management of sensory information point to a lack of control of attentional resources. Individuals with sensory processing disorders find the task of selective attention challenging, especially in complex environments. As a result, the basic ability to direct attention to focus on a given task has now become a challenge for many. 5-16% of school age children are affected by disorders with sensory processing challenges including Sensory Processing Disorder (SPD), Autism Spectrum Disorder (ASD), and Attention-Deficit Hyperactivity Disorder (ADHD)

(Miller et al., 2017). Even for those without formal DSM-V diagnoses, attentional control and the ability to inhibit distraction decreases with advanced age (typically over age 65) (Persad et al, 2002; Tsang, 2013) and cell phones and other distractions in the classroom reduce learning (Fried, 2008; Lee, Kim, McDonough, Mendoza, & Kim, 2017).

Classification of Distractions

Pre-attentive cues. Although a distraction could be defined as any sensory information external to the task, the concept of pre-attentive cues is useful to describe some forms of distraction. Pre-attentive cues are those that grab attention before any processing can occur and are characterized by the speed in which the attentional system notices these cues and the difficulty the attentional system has in inhibiting them from grabbing attention (Treisman & Gelade, 1980). Examples include saliency (an attribute that differs from the rest of the environment, for example a bright red ball in a room full of grey balls), motion, and large, sudden changes in volume. It would be expected that any potential distractions that include pre-attentive cues would be the most likely to grab attention from the primary task of learning. Further, attending to pre-attentive cues is involuntary. Extremely well-learned stimuli can also gain pre-attentive properties, producing a “pop out” effect (Treisman, Vieira, & Hayes, 1992).

Multi-tasking. Multi-tasking often involves a combination of external cues and internal processes. For example, taking notes on a lecture requires listening to the lecture, deciding what information needs to be recorded, and recording it while the lecture proceeds and further information is attended to for future notes. There are often external cues, such as pauses made by the instructor or slide changes that help the learner to know when to switch from listening to writing, etc. There are internal cues, such as the learners’ own sense that enough information has been presented that a note should be taken. The distractions due to multitasking are often outside of the task. For example, a phone vibrating in a pocket or an instant message that appears on the screen would introduce multitasking that is not connected to the task.

Extrinsic load. Returning to CLT, extrinsic load is the load in a task that is outside what is needed for the task and does not support learning processes. For example, a difficult to use interface to an online learning system increases extrinsic load (using the interface) while trying to learn from the system. In this case and in many other types of examples, extrinsic load can be thought of as a type of multi-tasking. In all cases, extrinsic load is undesirable and should be minimized.

Auditory Dominance. The simultaneous processing of auditory and visual stimuli is essential and beneficial for optimal performance in everyday situations. For survival reasons, the brain is continually processing omnidirectional sounds whereas the visual system is subject to more constraints as visual processing requires retinal stimulation. Banbury et al. (2001) proposed that sound maintains obligatory access to memory even when attention is directed to another task, meaning that sound maintains a greater propensity to distract above and beyond that of visual stimuli.

In sum, there are many types of distractions to classroom learning. These distractions may not be equal in their effects nor in how they should be remediated.

Technological Innovations to Reduce Attentional Load

Augmented Reality. Augmented Reality (AR) has the capability to change the sensory information in the environment. For example, through the use of a head-mounted displays and smartphones, an individual is able to walk down a busy street corner and look in the direction of a restaurant and have 3-dimensional menu items and store ratings projected into their visual field (https://arvr.google.com/). In 2019, Forbes described a substantial demand for future business models to incorporate AR into the consumer experience (Naveen, 2016). Benefits such as content marketing, consumer personalization, and employee training have become the focus of retail. Thus, the goal of AR is to make more information accessible than is present in the non-augmented environments. Currently, AR is being used to increase efficiency and learning across a variety of domains, including construction, medicine, and education. Support exists for increased learning benefits with assembly tasks and medical training for anatomy (Behzadan, 2013; Ho et al., 2017; Ienaga et al.; 2016; Webster, 1996; Zokai et al, 2003). AR gives doctors new display technology to ease the cognitive load experienced during complex surgical procedures (Sielhorst et al., 2008).

Education benefits also exist as AR can now be brought into the classroom to add life to instructional information (Behzadan, 2013). In this study, researchers designed an AR book which, through an AR head mounted display, students were able to interact with virtual 3D objects mapped by AR markers from their AR book. In real time, students in a construction engineering class were able to see and manipulate 3D virtual engineering equipment from text they were studying, which was also being streamed live from a jobsite and broadcast onto the projector screen in their classroom. Students could interact as if they were on the jobsite, via motion sensors attached to their fingers, which was streaming construction jobsite activities. Taking contextual graphical information and presenting it in 3D form in real-time aids in capturing the attention of the students.

In sum, AR adds information to the environment. Although this can be in support of selective attention (for example, highlighting an important cue that would not be salient without the augmentation), the focus is often on providing more information. When well designed, this could create germane load, but when poorly designed, it creates extrinsic load or at the least, does not reduce load.

Diminished Reality. A new form of augmented reality subtracts sensory information from the environment: Diminished Reality (DR). In theory, DR provides a method to limit or eliminate the prevalence of distracting stimuli in an individual's environment in an effort to allow them to better focus on tasks. Kim et al., (2018) attempted to diminish a person from an image and, though image completion, replaced that region diminished with what the expected background would be. Although successful, this simplified use of a still image does not validate the use of DR in more complex environments. It has also been used to make games more fun. Sakai et. al (2018) employed DR technology in a gaming scenario to allow for a more immersive experience for players. In this instance all background stimuli were diminished so that the players could only see balls, lines and markers of a given color.

Although many studies using DR referenced its potential to reduce distraction, there are no behavioral studies of its effectiveness in doing so (Corlu, Ozdeslik, Yantac, & Fjeld, 2016; Yantaç, Çorlu, Fjeld, & Kunz, 2015). One study used a Wizard-of-Oz method to show a video conference with and without diminished distractions as though DR had been applied during the call (Yao, DeVincenzi, Pereira, & Ishii, 2013). They found a benefit in retention of material and experience of the video conference, but the study was small with a sample of 16 participants. Last, within DR research, there was a tendency to focus on the visual modality (Mori et al., 2017). However, distractions can be visual or auditory (Banbury et al, 2001).

Specific Aims

1. To understand the effect of DR level across both modalities, performance, presence, workload and situational awareness were compared between participants in high and low DR support for both modalities.
   a. Hypothesis 1: Retention test scores should increase as DR support increases.
   b. Hypothesis 2: Presence scores should decrease as DR support increases.
   c. Hypothesis 3: Workload scores should decrease as DR support increases.
   d. Hypothesis 4: Situational awareness should decrease as DR support increases.
2. To understand the effect of reduced performance attributed to modality, the same dependent measures were compared between participants in High-Auditory-DR and High Visual DR support.
   a. Hypothesis 5: Highly supportive Auditory DR should show more beneficial effects on the Retention Test than highly supportive Visual DR.
   b. Hypothesis 6: Presence scores should decrease more as Visual DR support increases, beyond the increase seen as Auditory DR support increases.
3. To understand the potential differential benefits of DR on persons with varying ADHD tendencies, individual differences in ADHD score will be used as a covariate with DR support level.
   a. Hypothesis 7: Those with higher ADHD or distractibility scores were expected to perform worse on the Retention Test.
   b. Hypothesis 8: The relationship between ADHD scores and Retention Test scores should be the strongest in the low DR support groups. ADHD should affect scores less in the high DR support groups.

Method

Participants

This study had a high technology failure rate and fairly high attrition rates. There were a total of *n* = 560 participants recruited online through Mechanical Turk. Nineteen of those did not consent to take the study after viewing the consent form. Twelve participants were excluded for blank participant names and 63 were excluded for being NCSU employees. There were 117 participants who completed the demographics and experiences survey but were not able to complete the distractibility study in Pavlovia. Another 63 completed the Pavlovia ability test but were not able to complete the study as they did not re-enter the Qualtrics survey. Seventy-six participants who reported completing the Distractibility measure were excluded from analysis because the system did not record their Distractibility Test scores. Issues with the linking of third party sites in addition to the challenges with accurate recording and saving of data within Pavlovia contributed to the high technology failure rate. A total of 210 continued to complete the measure of distractibility. Another 24 participants dropped out of the study either during or after watching the SDT lecture (experimental task). Three participants were excluded for hearing challenges. Six participants were excluded for having worse than 20/40 vision not correctable with contact lenses or corrective glasses because of our use of visual stimuli. These exclusion criteria were self-reported by the participant. Four participants who scored less than chance (i.e. 50% accuracy) on the Distractibility Task and Twenty-three who scored less than chance on the Retention Test (i.e. 25% accuracy) were excluded from all analyses. No participants were excluded solely for failing 2 or more out of the 3 attention check questions. Participants who missed two or more attention check questions may have been excluded for speeding through the study or not meeting other study requirements. Five participants were excluded for completing the study under 30minutes and five were excluded for spending over 90 minutes in the study. Expected time for completion was between 40-45minutes. A total of 150 participants provided complete data.

Table 1.
Characteristics of Participants in DR Study

Characteristics	Mean	SD	*n*	%
Gender				
Female	-	-	66	44.00
Male	-	-	83	53.30
Other	-	-	1	.70
Age	40.54	11.47	150	100
Individual Differences				
Adult-ADHD Score[1]	15.42	5.33	150	-
Distractibility Task[2]				
Accuracy[3]	91.74	10.88	145	-
Difference Score[4](ms)	.070	.14	145	-
Percent Increase[5]	13.11	15.27	145	-
ANT[6]				
Alerting[7] (ms)	-.026	.049	115	-
Orienting[8] (ms)	-.0086	.033	115	-
Executive Function[9] (ms)	-.12	.072	115	-
Race				
Asian	-	-	14	9.33
Black/African American	-	-	7	4.67
White/Caucasian	-	-	118	78.71
Native Hawaiian/Pacific Islander	-	-	1	0.67
Hispanic/Latino	-	-	7	4.67
American Indian/Alaska Native	-	-	1	0.67
Mixed	-	-	2	1.33
Interest[10]	3.73	1.12	149	-
Experience[11]	1.82	0.39	150	-

Note.
[1] Likert scale measure, e.g. “How often do you experience an event, 1 = ‘Never’ to 5 = ‘Very Often’”
[2]Forster & Lavie (2008)
[3] Accuracy score of Distractibility Task; participants excluded for below 50% accuracy.
[4] Measured as the difference in RT from when target was present without distractor, to when target was present with distractor.
[5] Measured as the percentage of increase in RT from when distractor was absent to when distractor was present.

Table 1 (continued).

[6]The Attention Network Test (ANT) was originally included in the study but eventually removed due to difficulties with the online testing system. The 115 participants who took it saw it as the last task in the study and thus we believe its removal for the subsequent participants did not affect their experience in the main part of the study.
[7] Measured by subtracting the difference in RT from when no cue was given to when center cue was presented.
[8] Measured by subtracting RT from when directional cue was given from when center cue was presented.
[9] Measured by subtracting congruent stimuli RT from incongruent stimuli RT.
[10]Likert measure of "Rate your interest in psychology and related topics. (1 - Low, 5 - High)"
[11]Measured in binary, as 0= "No experience with SDT" or 1="Have experience with SDT?"

Materials

Materials consisted of 1) the users preferred laptop or desktop system for demographics, virtual lecture, surveys, and ability test, 2) note taking material if desired, 3) a working set of headphones for listening to the virtual lecture and 4) the combined MTurk/Qualtrics/Pavlovia online websites.

Mechanical Turk, Qualtrics, and Pavlovia. We used Mechanical Turk and Qualtrics for management of participants and distributing the online study. Mechanical Turk provided access to a diverse sample population. The entirety of the study was managed through Qualtrics. The need for randomization of DR condition was also provided by the survey software. Participants were directed to a third-party platform, Pavlovia, to execute cognitive assessments which in turn redirected them back to Qualtrics to complete the study. Pavlovia was used for assessments as it is able to provide higher millisecond accuracy and display common cognitive tests (Sauter, Draschkow, & Mack, 2020). Participants were managed by their MTurk worker ID number to maintain anonymity but were also provided a unique 5digit validation code for compensation purposes. Upon entering Qualtrics, participants were required to enter their MTurk worker identification number. This allowed the researchers to link their information to MTurk accounts for troubleshooting and compensation.

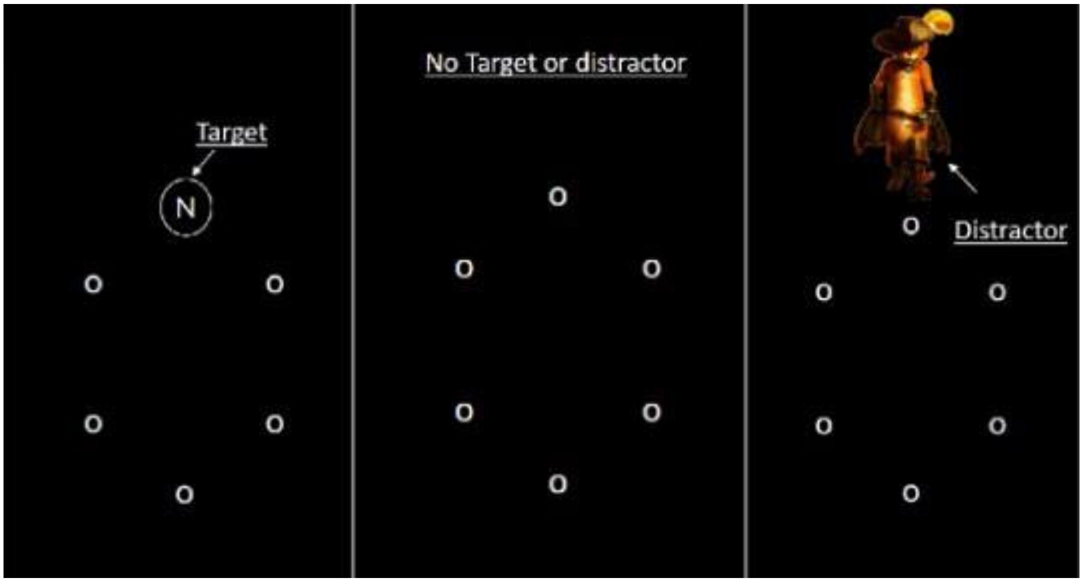
Measures

Adult-ADHD Assessment. A modified version of the Adult-ADHD Self-Report Scale Symptom Checklist was used to develop a measure relating to an individual's difficulty with attending to instruction (Hines, King, & Curry, 2012). The included six questions were found to be the most predictive of symptoms consistent with ADHD (Ustun et al, 2017). Participants responded to each question selecting whether they experienced the identified symptom from five options. (e.g. Never, Rarely, Sometimes, Often, Very Often). Scores on this assessment were scaled and participants who scored high on the ADHD aggregate score are said to exhibit more symptoms consistent with ADHD than those who scored low on the ADHD aggregate score. See Appendix A for Adult-ADHD assessment.

Distractibility Task. Task interruption by irrelevant information is a common issue that affects an individual's ability to learn in complex environments. The ability to ignore irrelevant information may directly relate to an individual's ability to focus and attend to relevant information in the environment. A cognitive measure of distractibility was used to assess participants ability to disregard clearly irrelevant information to the current task. This task displayed in Figure 1 assesses the interference effect of task irrelevant information (Forster & Lavie, 2008). Our measure was modified to only include the low load condition where target letters (i.e. N & X) were searched for in a letter grouping of O's. The Distractibility Task was developed in PsychoPy and administered online using Pavlovia. The measure included for analysis was the change in reaction time (RT) and the percentage difference in response time between trials that had a distractor and trials that did not have a distractor. A larger difference and higher percentage in RT indicated more distractibility.

Figure 1.

Modified Distractibility Measure with Low Load Condition.



Demographics & Experiences Survey. Age, gender, ethnicity, hearing deficits, and vision were collected. This survey also included participants' previous knowledge of the lecture topic and also interest with psychology topics.

Experimental Task

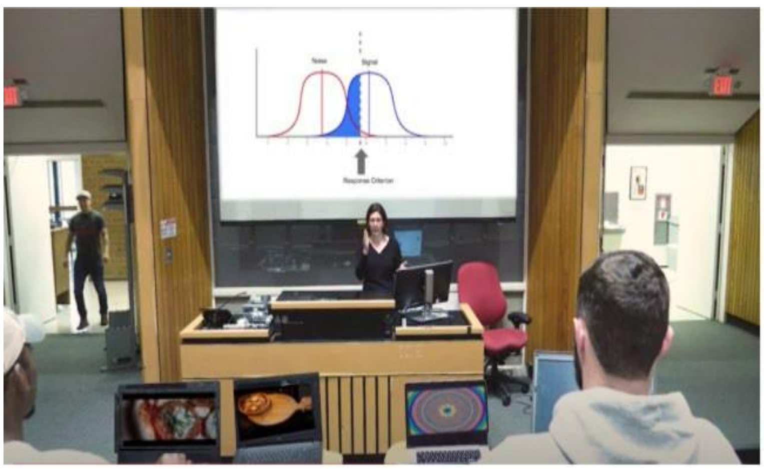
We developed a simulated classroom environment to allow for the manipulation of auditory and visual distraction. Participants watched a 9-minute lesson given on Signal Detection Theory. Taking notes was allowed and recommended to maintain ecological validity.

Virtual classroom. The setup of the classroom is shown in Figure 1. The instructional video was given in a classroom with auditorium style seating typically seen in classes with higher enrollment numbers (~200). This setting provided a complex environment where numerous auditory and visual stimuli could be presented to compete with the course content given by the instructor. (e.g. computer screens, cell phones,talking students, students walking around) At the front center of the classroom was a projector screen where the lecture slides were presented just above the professor. Four other laptops were displayed, offering sources of visual and auditory distractors throughout the study. The doors to the classroom remained open as another source of distraction.

Scenario. While the instructional video was presented, various forms of irrelevant stimuli were shown on the four laptops (Figure 2) in view of the participant, depending on treatment condition. Auditory and visual distractors are listed in Table 1. None of the distractor stimuli visually blocked the view of the professor or lecture slides. All auditory stimuli were presented at a safe level below 70dB, well below the authorized noise level for this task's duration (CDC/NIOSH, 2018).

Figure 2.

Setup of Diminished Reality Classroom



Note. View of the control condition. Moving images are visible on laptop screens, entering students are fully visible. Periphery of the scene contains full color and detail. All non-lecture sounds are at full volume.

Creating Stimuli Effects

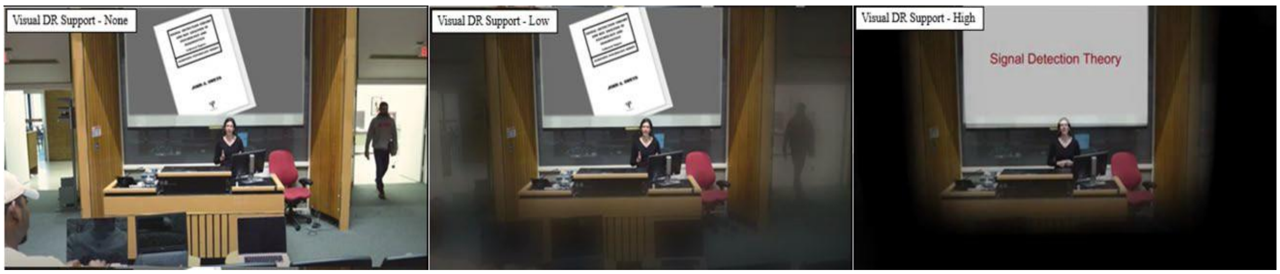
Adobe Premiere. In-person human subjects research was restricted during the data collection period of this study. To create the diminished reality environment under institutional IRB constraints it was necessary to artificially adjust auditory and visual stimuli inserted into the control video. Adobe Premiere video editing software was used to adjust auditory and visual stimuli of the original video and that of the artificially inserted stimuli used in the study. This robust video editing software was used to overlay sounds and visual effects and to create the distractions and the perceived diminished reality environment for the study. All motion graphics and visual effects needed in post-production were created through the Adobe After Effects add-on.

Auditory Stimuli. To maximize control of auditory stimuli all sounds were added to and normalized with the instructional video to create the control condition for this study. To reduce the number of auditory stimuli that participants were able to perceive in the low condition all auditory stimuli were reduced by 3dB from the control video. In the high DR condition, all auditory stimuli were reduced by 8dB from the control condition. Auditory distracting stimuli presented in this experiment consisted of items commonly heard within classroom environments. These are coughing/sneezing, classmate conversations, incoming calls, computer and keyboard clicks (Table 3).

Visual Stimuli. To establish the DR level in the presentation we decided to increase the level of opacity to prevent participants from being able to identify the underlying stimuli from the control video. To achieve the visual DR effect for the low condition reduction, an increase to 80% opacity was applied to the periphery of the video interface in a U-shaped pattern. The borders of this DR effect were feathered to allow for a smooth transition and to provide a level of realism in the presentation. For the high DR condition an increase to 100% opacity was incorporated to the periphery of the presentation maintaining the feathered transition between the DR and no DR segments of the video. Visual stimuli presented in the study consisted of motion of students seated, students departing/entering the classroom, and various videos being played on computer screens (4) within the participants field of view (Figure 3; Table 3).

Figure 3.

Virtual Classroom with Visual DR Support (None, Low, High).



Note. We artificially manipulated the level of DR applied to the classroom setting. Low visual DR corresponds to the equivalent of diminishing distracting stimuli with 80% opacity applied to a selected region of the video. The high visual DR diminished distracting stimuli will be created by increasing opacity to 100% for the selected region of the video. Low auditory DR will have distracting stimuli diminished to 3 dB below the normalization level of the control video while high DR auditory support will have distracting stimuli diminished to 8 dB below the normalization level of the control video.

Design

For this experiment we created five conditions using the design in Table 2. The between-participant independent variables were (1) Visual DR Support, a 3-level variable consisting of no DR support, low DR support, and high DR support, and (2) Auditory DR Support, a 3-level variable also consisting of no DR support, low DR support, and high DR support. This design was not a full factorial. No DR support (auditory or visual) served as a control condition. Low and High visual and Auditory DR support were fully crossed. Participants were randomly assigned to their condition via the Qualtrics Evenly Present Elements randomizer function. Excluding the control group, all other participants received some level of auditory and Visual DR support.

Dependent variables were Retention Test score, Presence score, Workload, and Situational Awareness bias score. Other measures included Adult-ADHD score, and Distractibility scores (change scores).

Table 2.

Study design matrix

	Low DR Visual	High DR Visual	No DR Support
Low DR Audio	X	X	-
High DR Audio	X	X	-
No DR Support	-	-	X (Control)

Table 3.

Distracting stimuli

Stimuli Presented	**Simulated DR Support**		
	Low	***High***	***None (control)***
Auditory	Reduced to 3dB Coughing/Sneezing Student conversations Phone Ringing Computer Video Keyboard typing	Reduced to 8 dB Coughing/Sneezing Student conversations Phone Ringing Computer Video Keyboard typing	Normalized - 0dB No DR Support
Visual	80% Opacity Effect Laptop (1) Video Laptop (2) Video Laptop (3) Video Student conversation Students entering/exiting	100% Opacity Effect Laptop (1) Video Laptop (2) Video Laptop (3) Video Student conversation Students entering/exiting	No Opacity Effect No DR Support

Procedure

This study was administered online to support established COVID-19 precautions through minimizing contact with participants. Participants were recruited through Amazon's Mechanical Turk platform. Once participants volunteered to be a part of the study through the MTurk website, they were given access to our Qualtrics study to begin the experiment. All participants acknowledged the study requirements and gave consent to proceed. Participants were also instructed to not multitask.

While headphones were instructed to be used for completion of this experiment, participants were still directed to take this study in a location free from external auditory and visual distraction. Demographics and the self-report and measure of Adult-ADHD were collected. Participants were directed to Pavlovia to complete the Distractibility Task and then back to Qualtrics to begin the experimental task. Participants watched a lecture video according to the random group assignment. At the completion of the lecture video, participants were given a questionnaire to assess their level of presence within the study. Participants were then administered the Retention Test. Following that, participants were given the situational awareness assessment. Next, participants were given the Adult-ADHD. Last, participants completed the NASA-TLX. Participants were redirected to Pavlovia to complete the second of two ability tests, the ANT task. At the conclusion of the ANT task, participants were redirected back to Qualtrics and received a validation code for MTurk compensation.

Measures Associated with Task

Presence Assessment. We used a modified version of the Slater, Usoh, and Steed (SUS) 6-question engagement survey to assess participant experience within the classroom domain (Appendix B). This assessment evaluated the experience of the simulated diminished reality environment and how well it replicated a natural experience (Usoh et al., 2000). Presence was measured on a 1 to 7 likert scale. Sample questions were formatted as follows: *Please rate your sense of being in the classroom, To what extent were there times during the experiment when the virtual environment was the reality for you?*

Retention Test. The Retention Test was a 13-item multiple forced choice Retention Test. The questions on this assessment focused on the participants' knowledge and retention of Signal Detection Theory as it was taught in the class lecture. Questions in this assessment were formatted to test participants' retention, recall, and comprehension on this information. See Appendix C for Retention Test questions.

Situational Awareness Probes. Post-study SA probes were used to assess situational awareness of the participants related to the SDT lecture. This survey consisted of 13 SA questions relating to what participants saw and heard during the SDT lecture. A modified Quantitative Analysis of Situational Awareness (QUASA) which combines objective queries of true/false and open-ended questions with subjective self-ratings of confidence levels of each response was used to develop metrics of situational awareness (McGuinness, 2004). Two measures were extracted, SA Accuracy which was the total number of correct answers and the SA Bias, which was the average confidence rating across all questions minus the proportion of correct SA probes. SA confidence levels were assessed on a continuous scale (e.g. 0%-100%). A positive bias score indicates a participant was overconfident. Negative bias score indicates underconfidence. SA bias was the measure used in analyses. SA probes are listed in Appendix D.

Subjective workload. The NASA Task Load Index (NASA-TLX) was used as a measure of subjective workload (Hart & Staveland, 1988). This measure contains subscales, such as mental workload, physical workload, and frustration. Since this study held no physical requirement, the physical workload segment was removed from the study. The assessment is scored by averaging the six ratings and then instructing them to prioritize pairs of the items (e.g., mental vs. physical) to establish a weight of importance for each item for the task. Administration takes about 5 minutes. The weightings are only collected once. This survey was administered after the experimental task. To ensure participants assessed their cognitive workload with respect to just the virtual lecture each measure was modified to fit. See Appendix E for modified NASA-TLX.

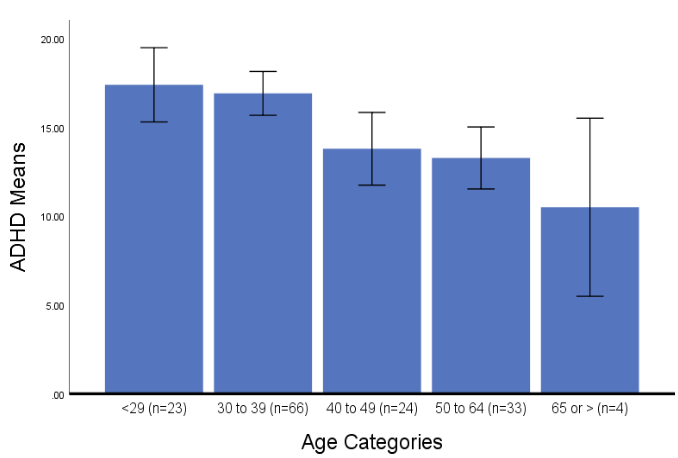
Results

Adult ADHD Analysis

A MANOVA was conducted to analyze the differences in ADHD scores across age groups (i.e. <29, 30-39, 40-49, 50-64, >64). Differences between age groups are expected according to population norms (Adler, Faraone, Sarocco, Atkins, & Khachatryan, 2019). Figure 4 shows there was a significant main effect for age group for our sample, $F(4,145) = 5.32$, $p < .001$, $\eta\eta^2 = .13$. *Post hoc* comparisons revealed that participants below the age of 29 scored significantly higher ($M = 17.39$, $SD = 4.86$) on the ADHD assessment than their counterparts between 50yrs to 64yrs old ($M = 13.27$, $SD = 4.38$). Participants ranging from 30yrs to 39 years old scored significantly higher ($M = 16.91$, $SD = 5.60$) than their counterparts between 50 years to 64 years old as well. An independent samples t-test was conducted to look at gender differences. No significant difference was seen across, $t(147) = -1.31$, $p = .19$.

Figure 4.

Distribution of Scores of Adult-ADHD Assessment



Correlations

The correlational analysis was performed across conditions (Table 4).

Table 4.

Correlations between Independent and Dependent Variables

	Retention	Presence	Adult-ADHD	Workload	SA Bias	Change in RT Distractibility	Interest	Experience
Retention Test	1							
Presence	-.29***	1						
Adult-ADHD	-.38***	.20*	1					
Workload	-.045	.27**	.12	1				
SA Bias	-.18*	.26**	.009	-.011	1			
Change in RT - Distractibility	.10	-.12	-.12	.056	.043	1		
Interest	-.22**	.39**	.18*	.14	.11	.040	1	
SDT Experience	.43**	-.42**	-.41**	-.009	-.10	.15	-.24**	1

Note. * $p < .05$. ** $p < .01$. *** $p < .001$

Results of the Pearson correlation analysis indicated several significant associations (Table 2). The level of presence a participant experienced during the virtual classroom lecture was significantly and negatively correlated with their performance on the Retention Test, $r(150) = -.29$, $p < .01$. As a higher score on presence indicated a stronger sense of reality with the experience, participants who felt a stronger sense of reality in the virtual lecture generally scored lower on the Retention Test. Scores on the Adult-ADHD survey also showed a significant negative association with performance on the Retention Test, $r(150) =-.38$, $p < .001$. This indicated that those who indicated higher ADHD tendencies scored lower on the Retention Test. The higher their performance the more accurate participants were in SA but the lower their bias was for SA $r(150) =-.18$, $p < .031$. Higher bias corresponds to overconfidence in their SA responses.

Presence scores also showed significant positive associations with Adult-ADHD scores, $r(150) = .20$, $p = .016$, and subjective workload, $r(150) = .27$, $p < .001$. Last, the data shows that participants with higher interest in psychology felt more presence in the study, $r(150) = .39$, $p < .001$. No significant correlations existed between other measures.

Multivariate Analysis (MANOVA) by Video Condition

To explain the relationship between treatment groups and performance, a MANOVA was conducted with the five conditions as the independent variable (control-no DR, Low Audio DR with Low Visual DR (LALV), Low Audio DR with High Visual DR (LAHV), High Audio DR with Low Visual DR (HALV), and High Audio DR with High Visual DR (HAHV)), and presence score, retention score, workload, situational awareness bias, and Adult-ADHD score as dependent variables. Results from the analysis revealed a significant main effect of video condition, $F(20,465) = 2.20$, $p < .002$, $\eta\eta^2 = .072$. Approximately 7% of variance in our model was explained by the DR condition groupings. The distribution or participants in each group is presented in Table X.

Table 5.

Distribution of participants in video condition

	Low DR Visual	High DR Visual	No DR Visual
Low DR Audio	31	34	-
High DR Audio	30	28	-
No DR Audio	-	-	27

Univariate Analyses

Retention Test Score. Results from the univariate analysis indicated that there was not a significant difference in retention for participants across the five conditions of diminished reality support, $F(4,145) = 2.29$, $p = .062$. Since we did not see a difference between Retention Test scores within these groups, our Hypothesis 1 was not supported.

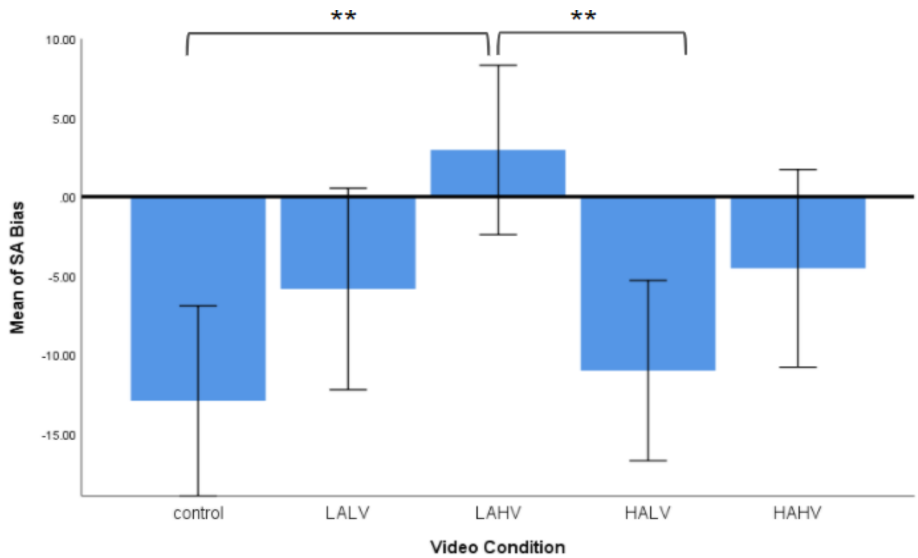
Presence Score. Results from the univariate analysis indicated that there was not a significant difference in presence for participants across the five levels of diminished reality support, $F(4,145) = .96$, $p = .422$. Hypothesis 2 stated that presence score would produce a negative correlation with DR support, however that finding was not supported.

Workload. Results from the one-way ANOVA indicated that there was not a significant difference in subjective workload for participants across the five levels of diminished reality support, $F(4,145) = .48$, $p = .731$. Hypothesis 3 was not supported as our findings suggested no relationship between workload and the condition groups.

Situational Awareness Bias Score. Significant differences existed within SA bias across video conditions, $F(4,145) = 4.95$, $p = .001$. A *post hoc* analysis with the Bonferroni correction applied revealed that the control group ($M = -12.92$, SD = 15.39), scored significantly *lower* than participants in the LAHV condition ($M = 2.96$, SD = 16.13). Participants in the LAHV condition also scored significantly *higher* than their counterparts in the HALV condition ($M = -11.00$, SD = 15.47). Thus only the LAHV group showed confidence and the control group was the most underconfident of all groups. Hypothesis 4 was not supported. Figure 4 displays the successive decrease in situational awareness bias from control to LALV to HAHV. The interaction of modality that occurs within the LAHV and HALV prevents us from accepting this hypothesis.

Figure 5.

Mean Scores on Situational Awareness Bias by Condition



Note. * $p < .05$. ** $p < .01$. A positive bias score implies over-confidence; a negative bias score implies under-confidence.

Multivariate Analysis (MANOVA) by Amount of DR Support

To explain the relationship between DR support levels (e.g. low and high) and performance, a MANOVA was conducted with Auditory and Visual DR support levels as the independent variables and presence score, retention score, workload, situational awareness bias, and Adult-ADHD score as dependent variables. Because this was a full factorial design, main effects of DR modality and interactions could be investigated. Results from the analysis revealed that while there was not a significant main effect of Auditory DR support level, $F(5,114) = .94$ $p = .47$, $\eta\eta^2 = .039$, there was a significant effect of Visual DR support level, $F(5,114) = 4.35$, $p < .01$, $\eta\eta^2 = .16$. The interaction effect between Auditory and Visual DR support levels was marginal, but not significant, $F(5,114) = 1.34$, $p = .25$, $\eta\eta^2 = .055$. Approximately 5% and 16% of variance in our dependent variables was explained by changes in Auditory DR support and

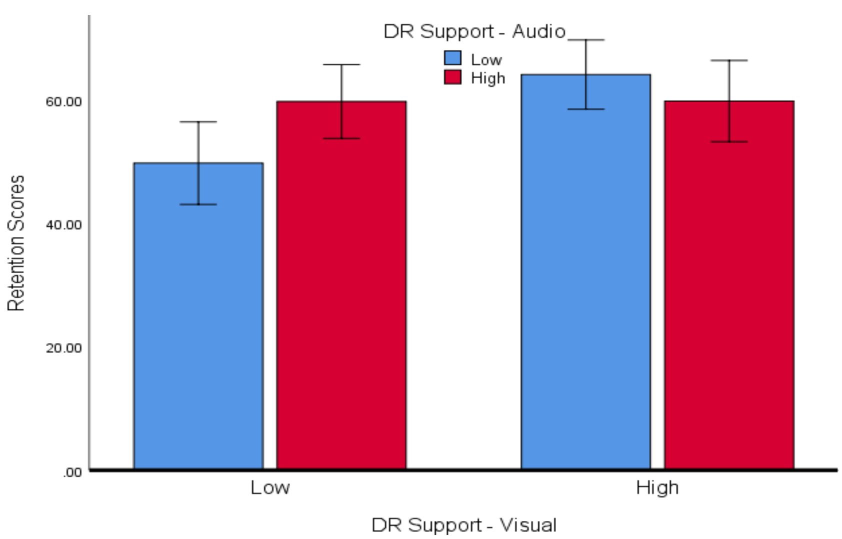
Visual DR support, respectively. The next step was to examine the univariate analyses for each dependent measure.

Univariate Analyses

Retention Test Score. Results from the univariate analysis indicated that there was not a significant difference in performance on the Retention Test for participants for Auditory DR support, $F(1,118) = .31$, $p = .57$, $\eta\eta^2 = .004$ nor Visual DR support, $F(1,118) =2.78$, $p = .098$, $\eta\eta^2 = .027$. The interaction effect showed significance, $F(1,118) =5.45$, $p = .021$, $\eta\eta^2 = .039$. This interaction (Figure 5) showed the significant difference in performance for the high Visual DR Support group who performed the best compared to the Low Visual DR Support group who scored the worst, both in the Low Auditory DR Support group condition. Hypothesis 5 was not supported as our findings suggested no significantly beneficial effect of participants in the Low Auditory DR, (M = -6.8, SD = 16.93) were more confident compared to High Auditory DR support Auditory DR Support.

Figure 6.

Results of MANOVA by DR Support on Retention Scores



Note. Scores range from 25 to 100 points. Scores less than 25 were excluded as less than chance.

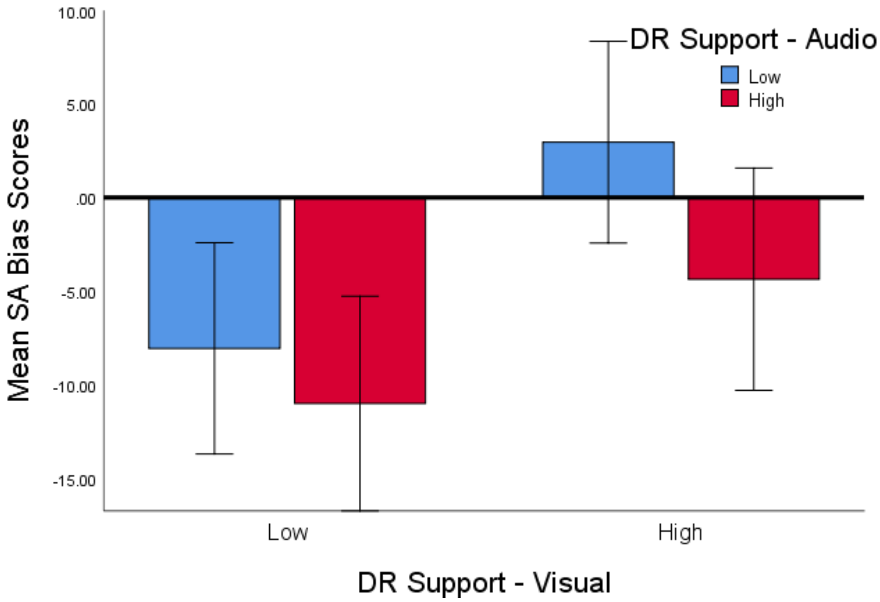
Workload. Results from the univariate analysis indicated that there was not a significant difference in workload reported by participants for Auditory DR support, *F*(1,119) = .30, *p* = .58, $\eta\eta^2$ = .007, nor Visual DR support, *F*(1,119) = .94, *p* = .33, $\eta\eta^2$ = .004. The interaction effect was not significant, *F*(1,119) =.71, *p* = .40, $\eta\eta^2$ = .003.

Presence Score. Results from the univariate analysis indicated that there was not a significant difference in presence reported by participants for Auditory DR support, *F*(1,119) = 1.50, *p* = .22, $\eta\eta^2$ = .013, nor Visual DR support, *F*(1,119) = .95, *p* = .33, $\eta\eta^2$ = .008. The interaction was not significant, *F*(1,119) =.25, *p* = .62, $\eta\eta^2$ = .002. Hypothesis 6 was not supported as our findings suggested no relationship between level of DR support and feelings of presence.

Situational Awareness Bias. Results from the univariate analysis (Figure 6) indicated that there was not a significant main effect in SA bias seen for Auditory DR support, *F*(1,119) = 3.08, *p* = .082, $\eta\eta^2$ = .026. A significant main effect for SA bias was seen for Low compared to High Visual DR support, *F*(1,119) = 9.47, $p < .01$. $\eta\eta^2$ = .074. This indicated that participants with High Visual DR support (*M* = -.35, SD = 16.05), were more overconfident in their beliefs about their own situational awareness compared to the Low-Visual-DR group (*M* = -9.51, SD = 15.94). The interaction effect was not significant, *F*(1,119) =.54, *p* = .46, $\eta\eta^2$ = .005.

Figure 7.

MANOVA results of DR Support and Situational Awareness Bias Interaction



Note. A positive bias score implied overconfidence; a negative bias score implied underconfidence.

Multivariate Analysis of Covariance (MANCOVA) Controlling for the Effect of Adult-ADHD

To explain the relationship between DR support levels (e.g. low and high) and performance, a multivariate ANCOVA (MANCOVA) was conducted with Auditory and Visual DR support levels as the independent variables and presence score, retention score, workload and situational awareness bias as dependent variables. In this analysis, the effect of Adult-ADHD was controlled for by including it as a covariate.

Results from the analysis revealed that while controlling for the effect of Adult-ADHD score, there was not a significant main effect of Auditory DR support level, $F(4,118) = 1.24$, $p = .30$, $\eta\eta^2 = .041$. Controlling for the effects of Adult-ADHD did result in a significant main effect of Visual DR support level, $F(4,118) = 5.52$, $p < .001$, $\eta\eta^2 = .16$. The interaction effect between Auditory and Visual DR support levels remained nonsignificant, $F(4,118) = 1.28$, $p =.28$, $\eta\eta^2 =$

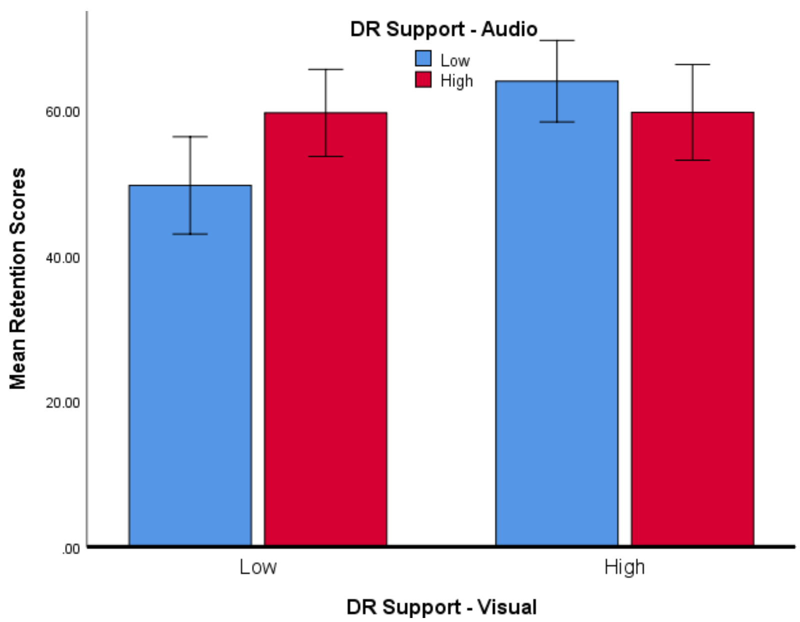
.043. Approximately 16% of variance in our model was explained by changes in Visual DR support when the effects of Adult-ADHD were controlled for.

Univariate Analyses

Retention Test Score. While controlling for the effects of Adult-ADHD on retention scores, the univariate analysis showed no significant effect for Auditory DR support $F(1,118) = .59$, $p = .45$, $\eta\eta^2 = .005$, but it did show a significant main effect for Visual DR support $F(1,118) = 5.18$, $p = .025$, $\eta\eta^2 = .042$. Participants in the low Visual-DR-Support group, ($M = 55.98$, SD = 17.39) scored lower than their peers in the high Visual-DR-Support group, ($M = 61.54$, SD = 18.40, Figure 8). The interaction was not significant, $F(1,118) = 3.78$, $p = .054$, $\eta\eta^2 = .031$. These results support Hypothesis 7 which proposed that those with higher ADHD were expected to perform worse on the retention test.

Figure 8.

MANCOVA results of DR Support and Retention Interaction; Adult-ADHD controlled



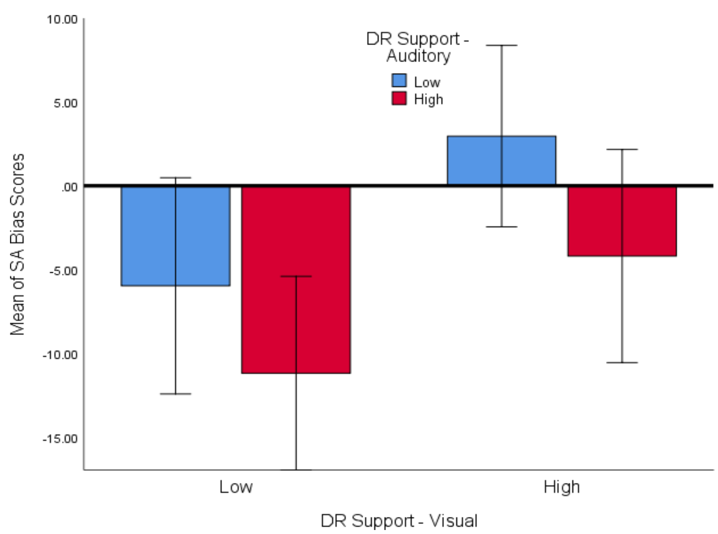
Workload. While controlling for the effects of Adult-ADHD, the univariate analysis did not reveal an effect for Auditory DR support $F(1,118) = .82$, $p = .37$, $\eta\eta^2 = .007$, Visual DR support, $F(1,118) = .61$, $p = .44$, $\eta\eta^2 = .005$, nor an interaction effect $F(1,118) = .22$, $p = .64$, $\eta\eta^2 = .002$.

Presence Score. While controlling for the effects of Adult-ADHD, the univariate analysis showed no effects for Auditory DR support $F(1,118) = 1.57$, $p = .21$, $\eta\eta^2 = .013$, Visual DR support, $F(1,118) = 1.29$, $p = .26$, $\eta\eta^2 = .011$, nor the interaction effect $F(1,118) = .10$, $p = .75$, $\eta\eta^2 = .001$.

Situational Awareness Bias Score. While controlling for the effects of Adult-ADHD, the univariate analysis showed no effect of Auditory DR support, $F(1,118) = 3.20$, $p = .076$, $\eta\eta^2 = .026$, but an effect of Visual DR support, $F(1,118) = 9.79$, $p = .002$, $\eta\eta^2 = .077$. No effect was seen in the interaction $F(1,118) = .46$, $p = .50$, $\eta\eta^2 = .004$. Figure 8 shows the effect for visual modality. Highly negative bias scores are experienced in the low Visual-DR-Support group compared to participants who were much more confident in the high Visual-DR-Support group.

Figure 9.

MANCOVA results of DR Support and Situational Awareness Bias Interaction; Adult-ADHD controlled



Note. A positive bias score implies overconfidence; a negative bias score implies underconfidence.

To test Hypothesis 8 we separated Retention Test scores by video condition and performed a correlation analysis with Adult-ADHD scores. The result showed us in which group was the relationship more strongly associated. The Pearson correlation coefficient was highest for those in the low Visual DR support group. However, it was not also strong in the control group, and thus Hypothesis 8 is only partially supported. Results from the analysis are presented in Table 6.

Table 6

Correlation analysis of ADHD and Retention by video condition

DR Support	*r*	*p*
Low Auditory DR	-.38	<.01
High Auditory VR	-.40	<.01
Low Visual DR	-.52	<.001
High Visual DR	-.28	.029
Control	-.34	.60

Note. H8 stated both Control and low Visual DR would have highest significance amongst all groups.

Discussion

The effects of removing distractions from the environment via technological means has not been tested before this point and this experiment provides a foundation for its efficacy. The primary aim of this study was to understand how varying levels of DR support would affect performance on a retention test, situational awareness, workload, and feelings of presence. With this experiment we identified several strong relationships between dependent variables and predictors: most notable were the significant correlations between retention test score and presence and between Adult-ADHD and situational awareness bias. Further exploring these relationships showed there significant differences between the randomly assigned DR condition groups. Univariate effects for this analysis showed that the significance in these relationships was driven by differences in situational awareness bias. This may be because a person's increased ability to perceive what is happening in the environment would take away from their ability to focus on the central task, paying attention to a lecture.

The distractibility ability test used for this study provided a measure of distraction for task performance (Forster & Lavie, 2008). This ability test, with the inclusion of an irrelevant distractor, closely mimics the effects of distracting stimuli experienced by students in a classroom. This interference in the way it was artificially created seems to only account for the effect of eye movement and does not fully consider the effect of shifting one’s attention. This may be the cause of the lack of correlation of this measure within this study. The validity of this measure may have been reduced by constraining the measure to the low load condition. Increasing the perceptual load of the task by incorporating letters that were similar to the target variables (e.g. M, H, K, Z, W) may have improved the reliability of this measure and the correlation of it to performance of the retention task.

Research shows that there are negative effects of learning and performance for those who exhibit ADHD symptoms. Our sample data showed 14% (n = 22) of our participants exhibited symptoms highly consistent with ADHD. This percentage is much higher than those of other published research (Adler et al., 2019; NIMH, 2017). One norm established from the ADHD scale is that there are significant differences across all age groups; however, our data did not show this (Adler et al., 2019). Nor did our sample reflect any gender differences in Adult-ADHD scores that are understood. Our findings did show that when controlling for ADHD scores, those who had low diminishment of the visual scene scored lower on the retention test compared to those with higher diminishment. This finding supports the relationship established from previous research. Differences in some of our findings may be due to the lack of appropriate distribution of participants across the specified age groups and gender. We do not suggest that our sample was fully representative of the population nor was it similarly distributed as previous research. The distribution of our data may not match that of the population due to the recruitment source used and unintended exclusion of certain demographics based on the participant population of MTurk and its associated technology requirements (e.g. Amazon account, computer access, internet access, desire to participate in online studies).

Previous research that has focused on learning challenges in distracting environments, typically due to the increase in technology in classrooms, found that student performance is negatively impacted by classroom distractions (Duncan, K., Hoekstra, A., Wilcox, B., 2012). Previous studies have also shown that students with lower attentional control ability are more likely to demonstrate academic problems and display learning disabilities (Barnett, 2017; Mayes, S., Calhoun., S., Crowell., E., 2000; Reid, 1999). We also found that a diagnosis of ADHD is not sufficient for special education support and as such most are educated in general education classrooms. Our results were surprising in that we found no difference in learning between the different conditions of DR support. This may be because our retention test was quite difficult, and most scores were relatively low. It may also be because, on a single computer screen it is easier for a participant to focus on a presentation and ignore other distractions that it would be if they were fully immersed in a virtual or real classroom.

Previous studies on the distracting effect of modality have shown the presence of auditory distractions to be most detrimental as visual signals are less alerting (Posner, M., Nissen, M., and Klein, R., 1976; Berti and Schröger 2001). In this study, we did not find this effect of auditory distractions. This may be because the decrease of 5dB in Auditory level was not significant enough to produce a noticeable change in the effect related to auditory distractions.

A similar study has been carried out using DR in an office setting to reduce visual distractions while on a conference call (Yao et al.2013). This study found that workers retained more relevant content when backgrounds were blurred compared to the traditional conference call without DR effects. This study also showed that the use of DR technology during the conference call was preferred by the employees. Recall that our recruited sample used was large (n=150); our study is unique in that it provided more robust results compared to the participants (n=16) used in the conference call study. Our study parallels the findings presented by Yao et al. that DR technology supports increased performance on retention tasks.

Previous research on presence and learning in virtual environments found a positive relationship between virtual presence and performance on learning tasks (Selzer, Gazcón, and Larrea, 2019). In our study, we did not find this effect of presence. This may be due to the varying environmental conditions in which our participants performed the online study. Some participants may not have been fully engaged on this task and having divided attention may have resulted in varying levels of presence felt by the participants. This may also be due to the lack of experimental control over screen resolution and the computer interface participants used.

Previous research on Situational awareness bias shows that participants who have lower confidence bias were found to have better performance (Sulistyawait and Chui, 2009). Our findings show that there is a strong negative relationship between the two. The data also showed that after controlling for ADHD scores, those who had low diminishment of the visual scene were more under confident with a lower situational awareness bias and also scored lower on the retention test. While those in the low Visual DR support group have more information presented in comparison to the high Visual DR support group, their information was more obscure which may have driven the lack of confidence in what they did see. For example, participants may have been able to identify that there were three figures moving within the virtual classroom but without detailed visual information afforded by the control condition, they were unable to determine if there were three separate students or just one very disruptive student. These findings tell us that by using DR technology, participants become less calibrated to what they understand from the environment. With our finding that increased DR support may improve learning a tradeoff is established between confidence in situational awareness and a person's need to eliminate distraction from the environment.

As a greater proportion of resources is allocated to processing, the person is assumed to experience increasing subjective workload (Hancock and Matthews, 2018). We proposed that perceived workload should be lower for participants with higher diminished reality support, as they would be exposed to less auditory and visual distractions in their environment. Our findings did not show the intended relationship between perceived workload and DR support. As a result of the study design there was a significant decay period between the virtual lecture and the administering of the NASA TLX. This decay period may have created some challenge in the accuracy of the retrospective assessment. Administering the NASA TLX after the lecture and retention test, instead of probing participants during, was the most optimal to prevent from interrupting the classroom lecture and negatively impacting their performance on the retention task.

An interesting dilemma in the use of DR technology is now presented. The use of DR may force users to choose between maintaining situational awareness and the reduction or elimination of task irrelevant information. The decision of when to use DR would then involve an assessment of potential risks and hazards that one might experience or be exposed to in their desired environment. Negative affect could be a byproduct of this analysis as it would require a user to acknowledge the negative aspects of this technology prior to its use. The use of DR in a given environment at this time would be conditional upon its utility.

Limitations and Future Directions

There are several aspects of this study that we would adjust and reconsider for future studies. Under COVID-19 precautions, this study was restricted to online data collection. As a result, we forfeited the ability to control the testing environment. Several problems may have affected the quality of the data as a direct result of this. Administering this study online mayhave created additional noise in the data if participants were able to be distracted by external auditory and visual stimuli. Although participants were instructed to only take this study in a quiet location free from distractions, participants may not have done so and may have adversely been subjected to unanticipated interruptions (e.g. dogs barking, cars, cell phone calls). The online testing platform also prevented us from ensuring no other tasks were being completed simultaneously.

The inability for the participants to interact with the instructor is another aspect of this study that reduces the ecological validity of the data. It is customary in learning environments to be able to ask clarification questions as needed and participants in this study were not afforded that. The recorded format was best suited for data collection under the COVID-19 restrictions.

Numerous participants gave positive responses about the flow of the study and the ease of transitioning to and from third party sites. However, there were also several participants who experienced challenges with the transition. Minimizing the movement between online sites would potentially reduce the stress participants experience. Additionally, with the movement between sites, the length of this study proved to be a challenge for some. This may have been a cause of the high rate of attrition experienced. Reducing the time commitment of participants in this study should improve response rate and the quality of the data in future experiments.

The recommendation for future studies is to minimize the effect of extraneous variables by conducting this study in a laboratory environment. Additionally, the data may be enriched by incorporating virtual reality using an Oculus Quest 2 or similar device. Allowing the participant to immerse themselves in the actual classroom environment may increase presence and their ability to focus.

The safety concerns that arise with the use of DR shines light on the adoption of this technology. Various models (e.g. Theory of Planned Behavior, Technology Acceptance Model) used to predict and explain the acceptance of technology consider an individual's attitude towards the technology a key component (Taherdoost, 2017). Trust of DR technology which may be secured through perceived usefulness and its ease of use should be assessed as a measure of effectiveness for future studies. This technology must prove to be useful within its designed context while also gaining the trust of the user.

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APPENDICES

Appendix A

ADHD Assessment

1. How often do you have trouble wrapping up the final details of a project, once the challenging parts have been done?

   Select one: Never, Rarely, Sometimes, Often, Very Often

2. How often do you have difficulty getting things in order when you have to do a task that requires organization?

   Select one: Never, Rarely, Sometimes, Often, Very Often

3. How often do you have problems remembering appointments or obligations?

   Select one: Never, Rarely, Sometimes, Often, Very Often

4. If you think the color of grass is green, select Sometimes. If you think the color of grass is red, select Never.

   Select one: Never, Rarely, Sometimes, Often, Very Often

5. When you have a task that requires a lot of thought, how often do you avoid or delay getting started?

   Select one: Never, Rarely, Sometimes, Often, Very Often

6. How often do you fidget or squirm with your hands or feet when you have to sit down for a long time?

   Select one: Never, Rarely, Sometimes, Often, Very Often

7. How often do you feel overly active and compelled to do things, like you were driven by a motor?

   Select one: Never, Rarely, Sometimes, Often, Very Often

*Item 4 is an attention check question and is not used as a part of the ADHD assessment.

Appendix B

Presence Questionnaire

1. Please rate your sense of being in the virtual classroom environment, on a scale of 1 to 7, where 7 represents your normal experience of being in a place.

2. To what extent were there times during the experience when the classroom environment was the reality for you?

3. When you think back to the experience, do you think of the virtual environment more as images that you saw or more as somewhere that you visited?

4. During the lecture, which was the strongest on the whole, your sense of being in the virtual environment or of being elsewhere?

5. Consider your memory of being in the virtual environment. How similar in terms of the structure of the memory is this to the structure of the memory of other places you have been today? By ‘structure of the memory’ consider things like the extent to which you have a visual memory of the virtual environment, whether that memory is in colour, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such structural elements.

6. During the time of your experience, did you often think to yourself that you were actually in the virtual classroom environment?

Appendix C

Retention Test

1. When was Signal Detection Theory first established?
   - WWI
   - WWII
   - Korean War
   - Vietnam War

2. Why was Signal Detection Theory initially developed/needed?
   - To analyze and support human radar detectors at detecting incoming enemy aircrafts or boats
   - To explain human error across many domains, beginning with the police force
   - To analyze and support WWI door gunners to be able to identify enemy targets in-flight
   - To explain misdiagnoses in radiology

3. What are the four possible decisions within Signal Detection Theory?
   - Hit, Try, Right, Wrong
   - Miss, Attempt, Hit, False alarm
   - Hit, Miss, Try, Fail
   - False alarm, Correct rejection, Hit, Miss

4. Which of these situations is a Correct Rejection?
   - Bob is the perfect match for Nancy on an online dating site, but she never responds to his first message
   - Andrea is told she should get a biopsy on a lump she found on body. Andrea thinks the lump is not actually an issue. She chooses not to get the biopsy. The lump did not turn out to be cancerous and disappeared later that month.
   - A TSA scanner notices what might be a water bottle in a bag, but lets it go through thinking it was empty. It turned out to be a pipe bomb.
   - A hiker and their dog see a snake on the path. They take a wide path around it, afraid of the snake being venomous. Later, it turns out it was just a harmless garter snake.

5. Within Signal Detection theory, if the signal is truly present the result may be either:
   - Hit or Miss
   - Miss or False Alarm
   - False Alarm or Correct Rejection
   - Correct Rejection or Hit

6. A large d' (d prime) is a sign of:
   - The difference between hits and misses
   - The level of confidence in the decision that was made
   - The small overlap between the signal and noise distribution
   - The probability of ending up with a hit when the signal is not present

7. What must first be done to calculate d prime?
    - Know the hit and false alarm rates
    - Standardize the distribution of correct rejections
    - Visualize the data with a ROC curve
    - Collect the number of misses and false alarms

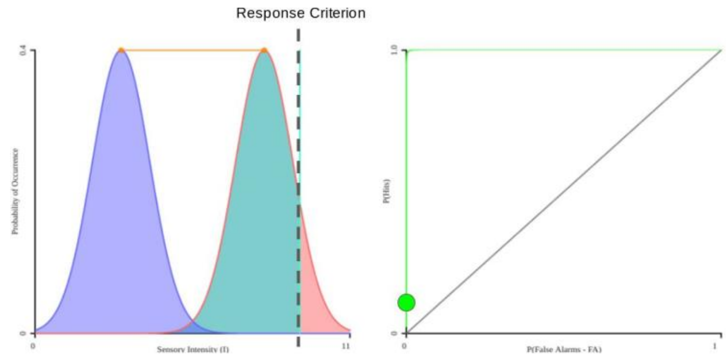
8. Response Criterion sets the definitive line of operator decision between the following:
    - Hits and Misses
    - Hits and CR
    - CR and False alarms
    - Hits and Misses & Correct Rejections and False Alarms

9. (attention check question) What is the color of grass? The fresh, uncut grass, not hay or leaves. Make sure to select red for this answer so that we know you are paying attention.
    - Green
    - Blue
    - Red
    - Purple

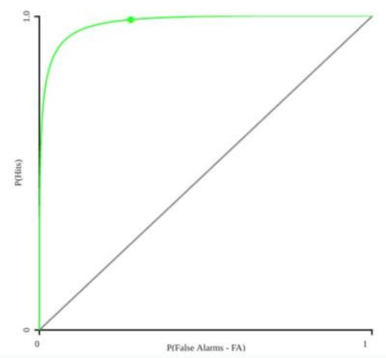
10. Which two of the four decisions are most commonly missed by humans who don't understand SDT?
    - False Alarm & Correct Rejection
    - Hits & Misses
    - Hits & Correct Rejections
    - Misses & Correct Rejections

11. Which one of the following careers was not mentioned in the video to support SDT?
    - Drone Operators
    - Police Training
    - TSA/Luggage scanner
    - Radar Operator

12. What is the best way to minimize the number of false alarms with SDT?
    - Have an extremely conservative response bias
    - Decrease your sensitivity index
    - Move your response criteria to the left to capture more hits
    - None of the above



13. Using the distributions and ROC curve above, which of the following is true:
    - The probability of a hit is small
    - The probability of a miss is small
    - The probability of a false alarm is high
    - The probability of a correct rejection is small



14. In the ROC curve above, the green dot indicates d prime. What conclusion can you reach about likely performance in a luggage screening task with this ROC?
    - You will capture virtually all threats, but will have a very high number of bags that get searched without reason.
    - You will miss a few threats, but most people don't have threats in their bags and they will pass through the line quickly, because they didn't get searched.
    - You will have a high number of correct rejections, because you can tell which bags most likely need to be searched to find the threats.
    - You will have many misses, where you let a bag through that contained a threat.

Appendix D

Situational Awareness Probes

1. Did any students walk into the classroom during the lecture?
    - Yes
    - No
2. Please rate your confidence in your answer above:
   (slider from 0-100, with labels at 0 for "not at all confident" to 100 "very confident")

3. There was student movement into the classroom during the lecture. How many students entered the classroom during the lecture?____#_____

4. Please rate your confidence in your answer above:
   (slider from 0-100, with labels at 0 for "not at all confident" to 100 "very confident")

5. Did any students walk out of the classroom during the lecture?
    - Yes
    - No

6. Please rate your confidence in your answer above:
   (slider from 0-100, with labels at 0 for "not at all confident" to 100 "very confident")

7. There was student movement out of the classroom during the lecture. How many students do you remember being in the classroom?____#_____

8. Please rate your confidence in your answer above:
   (slider from 0-100, with labels at 0 for "not at all confident" to 100 "very confident")

9. There may have been sounds you heard outside of the lecture itself in the classroom. Please list any sounds you heard.
   (allow list in textbox entry)

10. Did you hear a cell phone ring?
    - Yes
    - No
    -

11. Please rate your confidence in your answer above:
    (slider from 0-100, with labels at 0 for "not at all confident" to 100 "very confident")

12. Did you hear the fire alarm go off towards the end of the lecture?
    - Yes
    - No

13. Please rate your confidence in your answer above:
    (slider from 0-100, with labels at 0 for "not at all confident" to 100 "very confident")

14. Did you hear other students talking?
    - Yes
    - No

15. Please rate your confidence in your answer above:
    (slider from 0-100, with labels at 0 for "not at all confident" to 100 "very confident")

16. Did you hear other students typing?
    - Yes
    - No

17. Please rate your confidence in your answer above:
    (slider from 0-100, with labels at 0 for "not at all confident" to 100 "very confident")

18. Were any animals shown on the laptop screen's in the front rows during the lecture?
    - Yes
    - No

19. Please rate your confidence in your answer above:
    (slider from 0-100, with labels at 0 for "not at all confident" to 100 "very confident")

20. Were any food items shown on the computer screen during the lecture?
    - Yes
    - No

21. Please rate your confidence in your answer above:
    (slider from 0-100, with labels at 0 for "not at all confident" to 100 "very confident")

22. Did you see detailed colorful images on the laptops? (i.e. kaleidoscope effect, psychedelic)
    - Yes
    - No

23. Please rate your confidence in your answer above:
    (slider from 0-100, with labels at 0 for "not at all confident" to 100 "very confident")

24. Did you see a TV show or movie clip playing on a laptop screen in the front rows during the lecture?
    - Yes
    - No

25. Please rate your confidence in your answer above:
    (slider from 0-100, with labels at 0 for "not at all confident" to 100 "very confident")

Appendix E

NASA Task Load Index - modified

For the following questions, please rate your perception of how demanding learning the course content was. Concentrate on the understanding Signal Detection Theory in the virtual classroom when thinking about the workload.

Mental Demand
How mentally demanding was the virtual lecture on Signal Detection Theory? (e.g. thinking, deciding, remembering,)

Very Low Very High
O O O O O O O O O O

Temporal Demand
How hurried or rushed was the pace of the virtual lecture?

Very Low Very High
O O O O O O O O O O

Performance
How successful were you in paying attention to the lesson and ignoring the classroom distractions?

Very Low Very High
O O O O O O O O O O

Effort
How hard did you have to work to accomplish your perceived level of performance?

Very Low Very High
O O O O O O O O O O

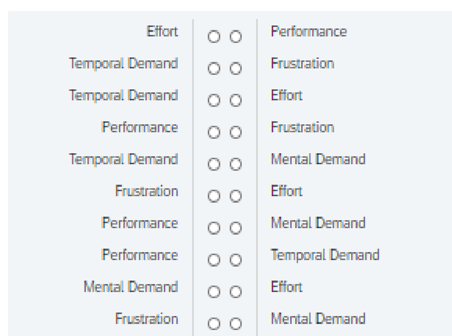
Frustration
How insecure, discouraged, irritated, stressed, and annoyed were you during the virtual lesson?

Very Low Very High
O O O O O O O O O O

NASA-TLX Weightings

For the following section, recall the scale descriptions:

Mental Demand - How mentally demanding was the task?
Temporal Demand - How hurried or rushed was the pace of the task?
Performance - How successful were you in accomplishing what you were asked to do?
Effort - How hard did you have to work to accomplish your level of performance?
Frustration - How insecure, discouraged, irritated, stressed, or annoyed were you?



Effort	O	O	Performance
Temporal Demand	O	O	Frustration
Temporal Demand	O	O	Effort
Performance	O	O	Frustration
Temporal Demand	O	O	Mental Demand
Frustration	O	O	Effort
Performance	O	O	Mental Demand
Performance	O	O	Temporal Demand
Mental Demand	O	O	Effort
Frustration	O	O	Mental Demand

Please select one in each pair of items that represents the more important contributor to workload for the task you performed in this experiment. Feel free to review the descriptions above as needed.

Appendix F

Demographics

What is your age?

Choose one...

Click here to edit choices

What is your gender?

Choose one...

What is your race/ethnicity?

- American Indian or Alaska Native
- Asian
- Black or African American
- Hispanic and Latino
- Native Hawaiian or Other Pacific Islander
- White
- Other

Do you have educational experience with Signal Detection Theory?

- Yes
- No

Select the most appropriate answer. (1 - Low, 5 - High)

	1	2	3	4	5
Rate your interest in psychology and related topics.	○	○	○	○	○

Display This Question:

If Do you currently suffer from hearing loss or have challenges with hearing? Yes Is Selected

You have confirmed that you have known challenges with hearing. Due to the nature of this study, we will not be able to collect you data as additional information would need to be collected that are beyond the scope of this study design.

Thank you for your time!

Condition: You have confirmed that you... Is Displayed. Skip To: End of Block.

Do you have vision worse than 20/40 that is not corrected by contact lenses or corrective glasses?

- Yes
- No

Display This Question:

If Do you have vision worse than 20/40 that is not corrected by contact lenses or corrective glasses? Yes Is Selected

You have confirmed that you have challenges with vision. Due to the nature of this study, we will not be able to collect you data as additional information would need to be collected that are beyond the scope of this study design.

Thank you for your time!