Implementation of Live-Virtual-Constructive (LVC) Workplace Setting to Enhance Occupational Success among Young Adults with ADHD

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ABSTRACT

Educational impairments associated with attention-deficit/hyperactivity disorder (ADHD) have previously been researched. However, much less is known about occupational-related functional impairments that adversely impact young adults with ADHD. During high school and early-college years, this demographic is particularly vulnerable to frequent job changes, and these negative trends can have enduring detrimental career impacts. As young adults with ADHD transition to the workforce (e.g., either in entry-level jobs, often within the food service sector, or similar early-career occupations), it is important to understand intervention protocols that can serve as an effective support for reducing occupational impairment. To this end, we have developed the Live-Virtual-Constructive (LVC) **Laboratory Assessment of Behavior in Occupational Roles (LABOR)** analog workplace setting, designed to approximate a (*Live*) pizzeria Training environment with a (*Virtual*) simulated food delivery environment (alongside *Constructive* assets) endeavored upon a high-fidelity driving simulator. For this pilot examination, twenty young adults diagnosed with ADHD participated in an evaluation to promote improvements in occupational performance. Participants repeated the study on two visits held on separate days, and all study procedures were identical for both visits. Primary outcome measures included aspects of driving performance (e.g., speed, lane position, travel time) most relevant to our novel Modeling & Simulation (M&S) implementation.

ABOUT THE AUTHORS

Rachel Su Ann Lim is an Engineering Associate with The Stephen Still Institute for Sustainable Transportation and Logistics (SSISTL) at the University at Buffalo. She received her B.S and M.S. degrees from the Department of Biomedical Engineering at the University at Buffalo. Her research interests involve the novel application of Modeling & Simulation (M&S), and the Live-Virtual-Constructive (LVC) taxonomy for public health advancement and simulation analysis as a platform to extract features that encourage game-based training, simulation, and analysis.

Kevin F. Hulme, Ph.D., CSMP is a Program Manager of The Stephen Still Institute for Sustainable Transportation and Logistics (SSISTL) and the Director of the Motion Simulation Laboratory (MSL) at the University at Buffalo. His areas of research and teaching interests include the design, development, and deployment of experiential learning and game-based Simulation elements for next-generation Training and for human factors analyses.

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BACKGROUND AND MOTIVATION

Obtaining and maintaining a steady vocation is an essential measure of success and a primary source of social approval, and competitive employment contributes significantly to self-identity, self-esteem, and overall quality of life (Banaschewski, et al., 2018). These life skills are typically required during early adulthood, often when young adults are exposed to part-time employment for the very first time. For those afflicted with attention-deficit/hyperactivity disorder (ADHD), the process of employment sustenance is far more complex. ADHD is widely conceptualized as a chronic, neurodevelopmental disorder that is present early in childhood and persists into adolescence and young adulthood (American Academy of Pediatrics, 2011). Past studies have identified that adults with ADHD are often able to maintain a meaningful presence within the workforce with the help of interventions such as behavioral therapy (Fabiano et al., 2015) to improve functioning. Nonetheless, there remains little published research on *impairments due to ADHD*, and their associated impacts on overall occupational functioning (American Psychiatric Association, 2013), and workplace behavior is difficult to reliably assess within an uncontrolled work setting. As young adults with ADHD transition to the workforce, it is critically important to better understand interventions that can improve young adult knowledge transfer in a typical workplace setting and serve as an effective support for reducing occupational impairment. To accomplish this goal, we have developed the Live-Virtual-Constructive (LVC) Laboratory Assessment of Behavior in Occupational Roles (LABOR) analog workplace setting, designed to approximate a (*Live*) pizzeria Training environment, with a (*Virtual*) simulated food delivery component (alongside complementary *Constructive* assets) endeavored upon a high-fidelity driving simulator. Ultimately, this study aims to investigate the effectiveness of the LVC implementation by observing typical driving outcomes and human performance within a high-fidelity Simulator. For this examination, we recruited a small cohort (diagnosed with ADHD) who participated in our preliminary evaluation.

LITERATURE REVIEW – PROJECT RELEVANCE TO M&S

Many challenges presented by young adults with ADHD in occupational settings are not apparent via self-report, as individuals with ADHD are not reliable at reporting their own behavior (e.g., Sibley et al., 2012). For this reason, *analog settings* are commonly employed to mimic the types of environments within which young adults with ADHD commonly interact during daily life. Recent literature has demonstrated numerous such environments, including classroom (Fabiano et al., 2014), recreational (Pelham et al., 2014), and driving-based scenarios (Morris et al., 2014). Our primary motivation is to develop a novel M&S testing and experimentation environment that will serve as a suitable authentic workplace analog within which to observe young adult behaviors related to occupational functioning. Our innovative implementation manifests components of the ***Live-Virtual-Constructive (LVC)*** (e.g., DoD, 1998) simulation taxonomy to emulate an authentic workplace setting (i.e., in our case, the fictional "Bib's Pizzeria") for observation and measurement of occupational behaviors (and particularly those *related to driving*) among young adults. While commonly adopted for military and government training applications (e.g., McLean et al., 2012), the civilian LVC environment simulation described in this work is a unique mechanism by which to leverage emerging M&S technologies for the advancement of vocational preparation specifically intended for vulnerable demographic populations (e.g., young and inexperienced adult drivers with known cognitive deficiencies).

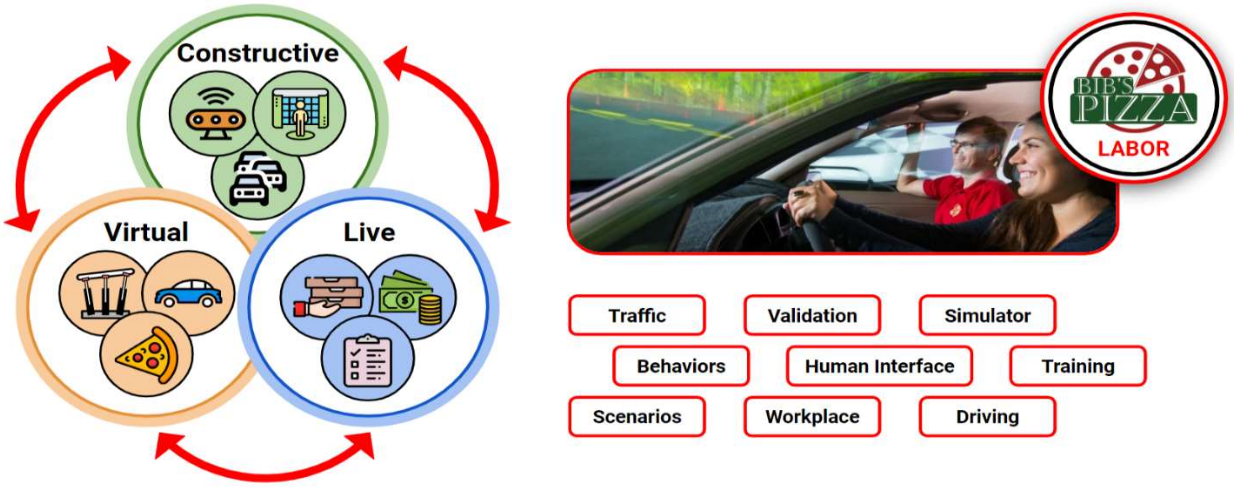


Figure 1: Notional Overview and Features/Benefits of work scope related to LVC

BROADER IMPACTS

The societal impacts of ADHD on adults in occupational settings can be far-reaching, regardless of professional sector (e.g., civilian, military, academia, industry, government). ADHD is thought to impact nearly 15% of young adults between the ages of 12 and 17 (Pastor et al., 2015), and adult prevalence has been recently estimated between 3 to 5%, worldwide (Fayyad et al., 2007). A recent summary (ADDA, 2015) found that adult workers with ADHD, on average, lose more than three weeks a year in workplace productivity. Most adults with ADHD agree that having the condition strongly affects various key capacities and discipline-specific skill sets related to their vocation, as summarized in Table 1. Disciplinary experts (Adamou et al., 2013) recently concluded that **future research should concentrate on further investigating occupational functioning in adults with ADHD, leading to a more informed understanding of possible barriers to employment and downstream approaches to address these problems.**

Table 1: Impacts of ADHD in skill sets required Occupational Settings

Skillset	Estimated Impact
ADHD symptoms strongly affect ability to stay on task: ***concentration***	70%
Feeling that one has to work ***harder*** than co-workers to accomplish similar work	65%
ADHD symptoms strongly affect ability to stay on task: ***concluding projects***	61%
ADHD symptoms strongly affect ability to stay on task: ***sitting still***	60%
ADHD symptoms strongly affect ability to stay on task: ***task organization***	59%
Impact on overall success/performance in the workplace setting	56%
Worry that ADHD symptoms affect opportunities for promotion	50%
Feeling that one has to work ***longer*** than co-workers to accomplish similar work	47%

TOPIC ALIGNMENT TO MODSIM WORLD PRIORITIES

The broad topic focus of this paper - leveraging M&S and LVC to observe, measure, and optimize "occupational success" - has profound relevance to the MODSIM World 2022 Conference Theme: "Building a Better Tomorrow", where establishing early vocational success is critical for achieving career sustenance and growth. Our novel implementation has timely relevance primarily to the domain of *healthcare*; to improve public health outcomes (e.g., as specifically related to driving), and LABOR has served as a *novel application of a first-of-its-kind LVC immersive environment*. Many recent analyses of analog settings emphasize office-based tasks similar to school seatwork (e.g., Wigal et al., 2010), and these are not consistent with the typical work environment most common for individuals with cognitive disabilities (e.g., ADHD), **where food preparation is the most common occupation following high school** (Newman et al., 2011). Therefore, there is a direct need to model, simulate, and analyze the impact of ADHD **on the type of setting most common for individuals with ADHD** entering the workforce. With this framework established and justified, we next present a concise overview of our primary study objectives.

PRIMARY STUDY OBJECTIVES

The primary objective of this work is to specify, design, and deploy a novel analog LVC workplace environment, which we refer to as: Laboratory Assessment of Behaviors in Occupational Roles (LABOR) - to determine preliminary efficacy. As discussed previously (e.g., see Table 1), ADHD can have profound detrimental impacts on workplace behavior, and particularly so for young adults who may be just entering the workforce for the first time. Therefore, by implementing LABOR's standardized tasks, we can evaluate the competence of an "employee" amidst multiple roles that are commonplace for entry-level employees. With this insight, we can better understand the type and intensity of functional problems within workplace settings with a terminal goal of reducing occupational impairment. Past literature (e.g., Fabiano et al., 2018; Gordon et al., 2019) related to this effort has focused on dissemination of occupational activities commonly performed "*on-site*" within the workplace (e.g., interview, job orientation, standard restaurant procedures, food-preparatory activities). Here, we present a notional overview of these (*Live*) training tasks, and focus on an accompanying **simulated (*Virtual/Constructive*) driving task**. A noteworthy novelty of LABOR is its hybrid atmosphere between which subjects participate and have interplay; they each experience a "Live" setting in the simulated workplace store; likewise, they encounter an environment with "Virtual/Constructive" characteristics to travel from store to delivery destination; after which they re-enter the "Live" environment to return to the workplace store. Refer to Figure 2 for a notional illustration of this distinctive feature-set.

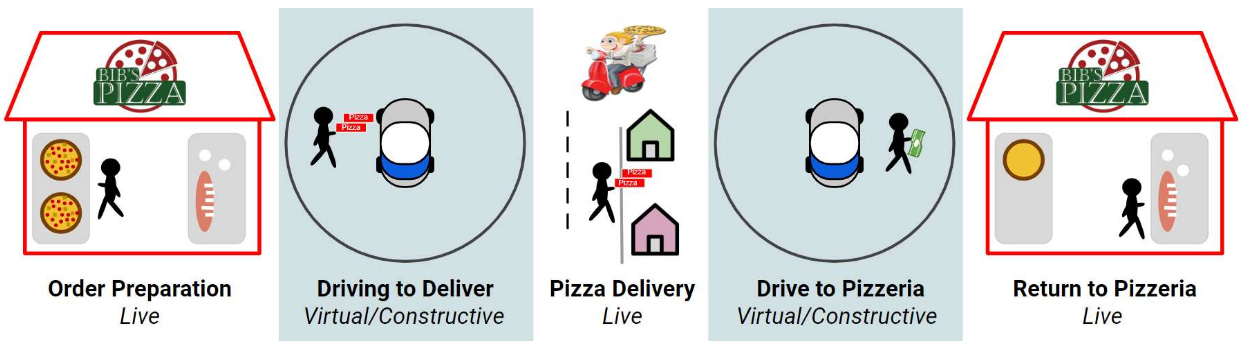


Figure 2: Participant interplay between (*Live*) and (*Virtual/Constructive*) aspects of simulated workplace

M&S FACILITIES AND LVC ENVIRONMENT

Hardware Infrastructure to Enable Modeling & Simulation (M&S)

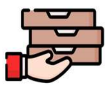
Our simRING simulator (see Figures 3 and 4) features a 360-degree, 16-foot diameter, 6' high screen that surrounds the vehicle and provides the driver with a full-fidelity depiction of traffic, landmarks, and roadway conditions. The system likewise features high-fidelity navigation controls, as well as a stereo sound system that emulates sounds heard inside and outside the vehicle during a typical driving excursion.

Figure 3: simRING (cabin view)

Figure 4: simRING (environment view)

LVC Adaptation to Workplace Environment
In our implementation, we embraced the LVC taxonomy for training and education that enabled the novel development of a simulated workplace setting within which to observe/monitor/assess occupational success among young adults. Refer to Table 2, which presents an overview of our innovative implementation. As shown, we fostered a ***Live*** setting by which participants could enact typical activities within a mock workplace. Likewise, a companion ***Virtual*** setting was implemented to enable participants to exit the (*Live*) training world seamlessly and enter a high-fidelity environment for pizza delivery activities. Finally, as a primary component of the (*Virtual*) world, realistic ***Constructive*** assets were instituted to comprise a high-fidelity traffic model, and with which LABOR participants interacted on their delivery excursions. **Note that in this implementation**, (*Virtual/Constructive*) components were used in tandem, such that the latter could not meaningfully function a training purpose without the former. Likewise, note that details regarding the physics-based representation of our driving simulator traffic models were described previously (Raghuwanshi, 2014). In the next section, we describe our experimental cohort and overall methodology.

Table 2: Innovations of LVS embedded within the LABOR framework

LVC Definition		LVC Implementation within the LABOR framework
	**Live:** A simulation involving real people operating real systems.	Physical workplace laboratory environment within which study participants executed common tasks associated with an occupational setting (e.g., interview, orientation/training, food preparation).
	**Virtual:** A simulation involving real people operating simulated systems.	Virtual workplace setting within which study participants executed common tasks associated with a food delivery (e.g., drive to/from pizza shop to/from delivery site, customer interactions)
	**Constructive:** A simulation involving simulated people operating simulated systems.	Realistic supplementary assets that comprise a primary companion segment of the Virtual environment, without which the human participant would be absent any compelling immersion.

METHODOLOGY

Here we present the overall methodology of the study. As we are investigating the viability of LVC for assessment of workplace behaviors in occupational settings, our environment closely mimics a selected workplace environment (e.g., food preparation/delivery) where many young adults (including those with ADHD) are commonly employed.

Experimental Cohort and Workplace Visit Details
Our experimental cohort consisted of a total of n=20 participants (16 male; 4 female). All participants were assessed an ADHD diagnosis as a prerequisite for study participation, and all recruited participants were between the ages 16 and 25. Further recruitment requirements during our screening process included: possession of a valid U.S. driver's license, no prior history of severe motion sickness (per self-report), and no current psychoactive medication for any other psychological disorder. Participants taking current medication for ADHD had to agree to not take their currently prescribed medicines on the day(s) of the study. Each participant had two identical "workdays" on separate visits with a time allocation of a three-hour block per visit.

Workplace Setup and LVC Implementation
A mock pizza place, called "Bib's Pizzeria" was crafted as the workplace of choice for the LVC laboratory session, using the LABOR analog workplace framework. This experimental arrangement was created to highlight the application of working memory, sustained attention, direction-following, and problem-solving from the participant; skills that are frequently deficient in individuals with ADHD. At the pizza place, a typical workday was structured based on (*Live*) job tasks that require critical skill sets. These included: filling out the application form for the job, a simulated job interview, the orientation session for the workplace (i.e., once the "employee" was officially "hired"), and a high-level description of job scope (e.g., an outline of food preparatory activities) to stage the completion of a delivery task. Then, the participants were exposed to a brief introduction to the driving simulator and afforded a 4-minute acclimation drive to become familiar with the (*Virtual/Constructive*) world, the dynamics of the moving vehicle, and the overall feel of the simulator controls (e.g., to adjust to steering and pedal sensitivity). Immediately after this practice exposure, the LABOR assessment included 40-minutes of (*Live*) tasks that are commonly associated with working in a pizza place: preparation of enclosed silverware napkin bundles; readying to-go bags with basic

napkin bundles and condiments; and folding pizza boxes. Next, participants were assigned a five-minute menu-search task consisting of totaling the prices for an assigned number of order items (per order slip). Upon completion, approximately 30-minutes of delivery preparation and (*Virtual/Constructive*) simulated driving delivery were assigned; more complete details are offered in the next subsection. At the conclusion of the visit, the participant completed post-session questionnaires and was debriefed on the overall experience.

Simulated Pizza Delivery Design

Once the participant collected all items for delivery, and entered the vehicle cabin of the driving simulator, they effectively exited the (*Live*) training world, and seamlessly entered the (*Virtual*) world. Refer back to Figure 2 for a notional reinforcement of this experimental novelty of our implementation. The delivery task was allocated to 20 total minutes to complete two successive residential deliveries originating from Bib's Pizzeria. The driver had to make deliveries to the locations demarcated on the map provided (i.e., "Delivery #1" and "Delivery #2"), and as depicted in Figure 5. Note that the residential environment is representative of actual locations and familiar landmarks that are adjacent to the North Campus of the University at Buffalo where the current study was conducted. This, we hoped, would nurture a sense of geographic familiarity among drivers in our experimental cohort. Notice, too, that the street names were augmented in an effort to enhance young driver engagement; local streets were renamed after popular (regional) roller coaster rides (e.g., *Cedar Creek, Valravn View, Maverick Mews*). This novelty, we hoped, would provoke a sense of adventure and discovery for these young adults to fully comply with the requested tasks.

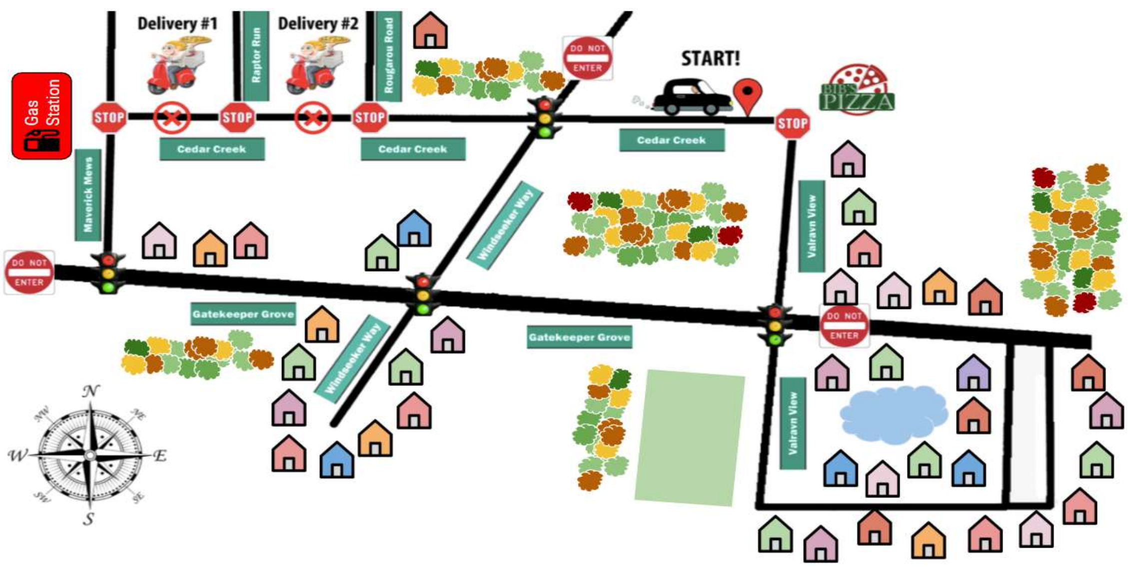


Figure 5: Pizza Delivery (residential) Map

Hard copies of this map were located in the (*Live*) pizza place for planning purposes, and a laminated version was also included inside the (*Virtual*) driving simulator. At each delivery site, the driver had to step out of the car (i.e., thereby exiting *Virtual*, and re-entering *Live*) to administer the order and complete the transaction to the delivery resident (i.e., served by a confederate actor from the LABOR research Team). After the food exchange and change-making activities (using simulated monetary resources), the driver returned to the car (i.e., exiting *Live*, and re-entering *Virtual*) to proceed to the second delivery site. There, the process repeated, and after the two deliveries, the driver had to return back to Bib's Pizzeria to complete the delivery tasks.

Lastly, note that our (*Virtual*) delivery environment was enhanced with (*Constructive*) assets that were developed and implemented based upon physics-based models and simulations. This Artificially Intelligent Traffic Model (AITM) was designed for civilian ground vehicle research applications and generates a fleet of autonomous and semi-intelligent vehicles with which our pizza delivery participant interacts within the (*Virtual*) LABOR environment. The behavior of the vehicles is based upon the principles of rigid body physics and real-time collision detection and incorporates a rule-base for: road-appropriate travel speed behavior, behavior at intersections (e.g., stop signs, streetlights), and interactions with other AI and human-driven vehicles on the virtual roads (i.e., lane changing, headway distance). These (*Constructive*) features are described more completely in (Raghuwanshi, 2014).

Measures
Quantitative driving performance measures were recorded by the driving simulator throughout each excursion at 30Hz. Key measures were selected specifically to observe overall compliance to conventional driving rules while performing a time-sensitive delivery task. The **travel time (*seconds*)** is defined as the time taken from the start of the delivery task from Bib's Pizzeria to complete both deliveries and the return trip to the pizzeria. The duration takes into account the car idling time when the driver gets out of the car to interact with the customer. The **travel speed (*mph*)** is decomposed into two components; the average speed is the mean speed from start to finish, while the maximum speed travelled is the fastest speed encountered throughout the drive. We also investigated the lateral **lane deviation (*feet*)** within a selected portion of the drive excursion. Lane deviation was calculated based on the observed digression from the median lane, and the street called "Cedar Creek" was selected (i.e., as this was where Delivery #1 and Delivery #2 were carried out; refer to Figure 5) to quantify the driver's digression. At the conclusion of the (*Virtual*) component of LABOR, and to determine any side effects relative to simulator adaptation syndrome (SAS) (Gálvez-García et al., 2017), the Motion Sickness Assessment Questionnaire (MSAQ) (Gianaros, 2001) was issued. The MSAQ assesses if, and to what severity, the experience had an adverse impact on the participant during the simulation, and is categorized into four symptoms; gastrointestinal, central, peripheral, and sopite-related, which are then tabulated into an overall score. In the next section, we present our preliminary results.

PRELIMINARY RESULTS AND DISCUSSION

In this section, we present the preliminary quantitative results from the driving simulator (i.e., *Virtual*) segment of our LVC implementation of our workplace analog (i.e., LABOR) to analyze and measure aspects of human performance amidst occupational functioning alongside observations from study-relevant self-report data. Our current presentation focuses on the core M&S and LVC novelties associated with our innovation, and to highlight preliminary tendencies observed in the collected data. A reminder that ***all results reported here are within-condition***, as all recruited subjects were pre-screened for ADHD. A similar study (i.e., Hulme et al., 2017; Fabiano et al., 2018) was performed previously that compared ADHD vs. "healthy" teens as controls. Noteworthy trends are described here; due to the relatively small sample size (n=20), statistically significant differences were not found (i.e., by way of independent sample T-tests, at alpha .05). Observed differences of these preliminary data are suggestive that significant characteristics may be identified with a larger sample, and with the implementation of scoring metrics that exhibit finer granularity.

Within the (*Virtual*) driving world, the posted speed limits ranged from 30 to 45 mph on the delivery excursion streets, and subjects were directed to "abide by the rules of the road" while participating in the environment tasks. However, no direction was offered during the experiment if these rules were being violated. In Figure 6, we plot the **maximum** travel speed (***measured in mph***) encountered during the experimental drives (*with standard deviation listed on the error bars*). Appropriately, the plot separates gender effects, and over the two visits, we observed slightly more aggressive overall behavior from the male members of the cohort, whose maximum speeds were (on average, and across all streets encountered) approximately 2 mph faster than their female counterparts. All young adults (both genders) with ADHD commonly demonstrate behaviors associated with impulsivity, but this is known to be more pronounced in males. It is well documented that young male drivers are more likely to get into car crashes than female drivers of the same age (IIHS, 2018). Young male drivers have been found to report significantly greater enjoyment in driving, and these "positive emotions" appear to support the notion that those who most enjoy risky driving behaviors are more likely to engage in them (Cordellieri et al., 2016).

Figure 7 presents a plot of overall time expended (***measured in seconds***) during the delivery tasks, again comparing gender effects. Note that each horizontal bar in the plot is decomposed into the LVC subtasks associated with the deliveries; that is, time spent driving (*Virtual/Constructive*) inside the car shown in green, and time expended performing the mock delivery and monetary exchange (*Live*) outside the car shown in orange. Interestingly, although maximum speeds were higher (on average; across the cohort) for males than females, overall drive excursions, and therefore average travel speeds were longer (on average; across the cohort) for males than females. We suggest that this could be due to the fact that males were driving faster (at the extremes), but overall -- were behaving more carelessly/recklessly than females -- and therefore, were less effective and efficient during the overall driving tasks. However, counting time expended within **both** the delivery time outside the vehicle (*Live*) **and** actual driving time within the vehicle (*Virtual/Constructive*) components, overall excursion durations (taken as a whole) were slightly longer for females than for males (by an average of 12.81 seconds, total clock time, or approximately 2.3%). This is indicative that males were much more rapid in their actions that occurred outside the vehicle during the (*Live*) delivery exchange. Again, due to small sample sizes - these general trends are not statistically significant - but nonetheless support the general notion that among young adults with ADHD, female behaviors tend to be more "inattentive", while males tend to behave in a more aggressive and "hyperactive" manner (Rucklidge, 2008). Overall, average speeds for the entire excursion (*Live*, and *Virtual/Constructive*) were practically comparable across genders. Similarly, drive paths/durations were largely ubiquitous across the entire cohort, and this was principally dictated by the geometric constraints imparted by the (*Virtual/Constructive*) World Map (see Figure 5).

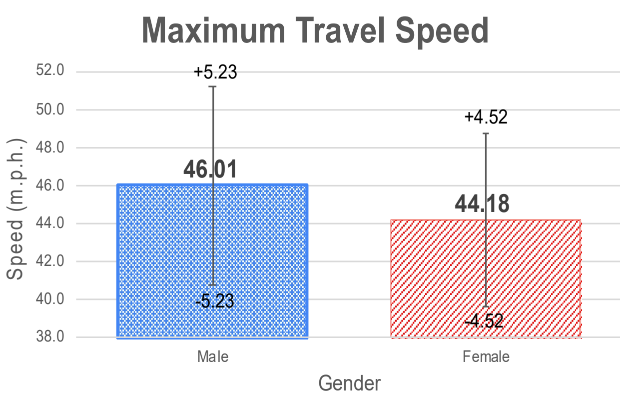


Figure 6: Maximum Travel Speed

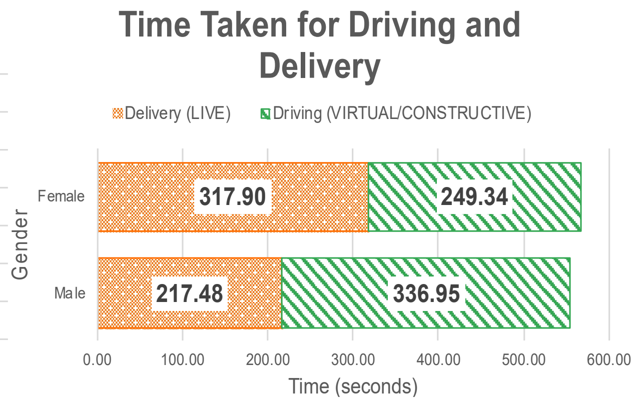


Figure 7: Delivery to Driving Ratio

Figure 8 presents an illustration of lateral lane deviation (***measured in feet***). Plotted here is the average lane deviation (again, comparing genders) for the linear segment of the delivery excursion that was encountered on the road named "Cedar Creek", (*with standard deviation listed on the error bars*). Recall that this was the focus street of the (*Virtual/Constructive*) workplace task upon which the two pizza deliveries were actually encountered (refer back to Figure 5). Reflective of the gender argument that has been emphasized thus far, average observed lateral lane deviations are slightly greater (and less consistent) for males (4.17') than females (3.23'). Note that deviation was measured from driving precisely at lane center, where the overall width of the entire street was 36', and the actual driving lane is 18' wide. Furthermore, note that these data are somewhat skewed to be excessive, as the "deviations" account for time during which drivers completed their mock delivery (i.e., exiting *Virtual*; and re-entering *Live*), for which many drivers (appropriately) staged this action by pulling over to the side of the road, which actually counted *against* their time-averaged lane deviation tally. Ultimately then, the cohort-averaged numbers reported in Figure 8 should be interpreted as general overall trends, and accordingly, LABOR participants should not be excessively penalized for the inherent flaws in our quantitative scoring procedures. These types of demerits within our "Gamification" methods are duly noted for future improvements to our LVC back-end framework.

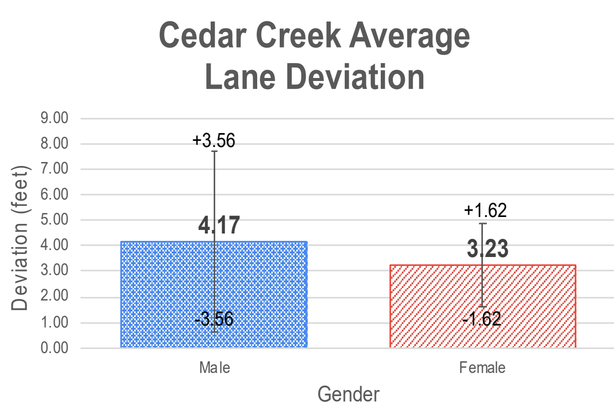


Figure 8 - Lateral Lane Deviation

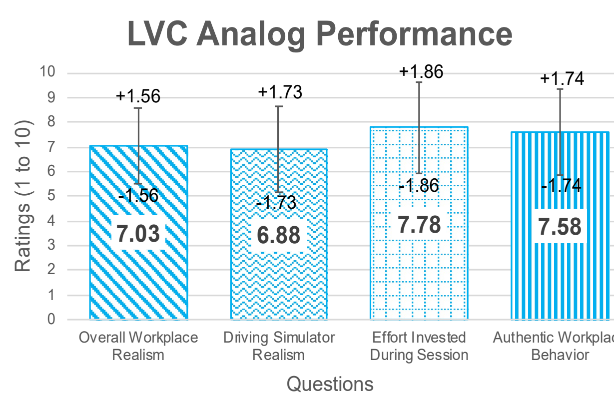


Figure 9: LVC Workplace (participant satisfaction)

Following the completion of the LVC laboratory tasks, participants were asked to rate their experiences for workplace (i.e., *Live*) authenticity on a 10-point Likert scale (*1 = Not at all realistic; to 10 = Very realistic*). The overall mean scores were observed as 7.03 (SD=1.56). When asked about the driving simulator (i.e., *Virtual/Constructive*) realism, the mean scores were observed as 6.88 (SD=1.73). The authors were disappointed with this rating but opine that the substandard rating is largely due to the quality of the graphics. Our robust simulations have been developed (in-house) using the OpenGL standard - but not representative of photorealistic "game quality" (e.g., Xbox or PlayStation). In a single, simplified question inspired by the NASA TLX (Hart and Staveland, 1988), participants were asked to rate their effort during the experience (*1 = No effort at all; to 10 = All my effort*), and the overall mean scores were observed as 7.78 (SD=1.86). Finally, participants were asked "To what degree was your behavior the same as it would be in a real workplace setting?" (*1 = Not at all the same; to 10 = Exactly the same*), and overall mean scores were observed as 7.58 (SD=1.74). These ratings are a notional indicator that the novel LVC environment implementation (and participant effort/behavior) reasonably approximated a workplace environment scenario. Figure 9 suitably illustrates these four primary rating categories (*with standard deviation listed on the error bars*). We accept this self-report as being "valid" as we emphasize that this data is in relation to the overall perception of realism of the environment and driving experience – and therefore not a self-report of actual driving performance, where those with ADHD often overestimate the positive merits of their own capabilities (e.g., Sibley et al., 2012).

Regarding symptoms related to the simulated driving experiences, Figure 10 offers an illustration of self-reported adverse symptoms from exposure to the driving experience, per the MSAQ. These data were averaged for all (n=20) participants across both of their visits to the LVC LABOR. As can be seen in the plot, visit-averaged severity symptoms were negligible (6) or minor (13) for all but one member of our study cohort. This outcome is expected; from past literature related to driving simulator implementations (e.g., Keshavarz et al., 2018) young adults tend to be more compliant with, and less averse to multi-sensory cues endeavored within a simulated environment. Finally, Figure 11 extends this analysis to greater detail, and decomposes MSAQ ratings into their subcomponent categories (reported as percentages) shown in yellow and includes an overall score (shown in blue). The highest rated symptoms (10.6%) were on the Peripheral scale (e.g., *which might include a participant feeling sweaty, warm, and/or clammy hands*), followed by Central- (8.8%), Gastrointestinal- (7.6%), and Sopite- (7.3%) related symptoms.

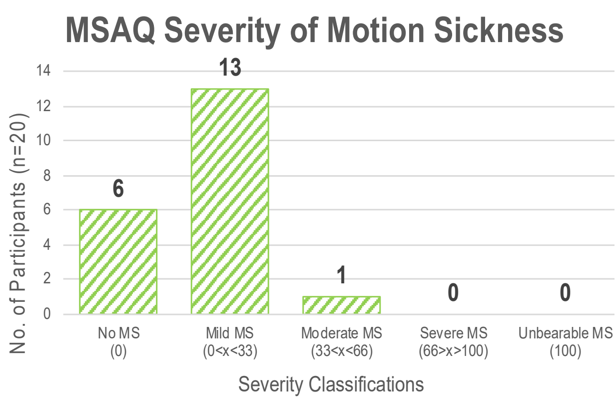


Figure 10: MSAQ (severity classifications)

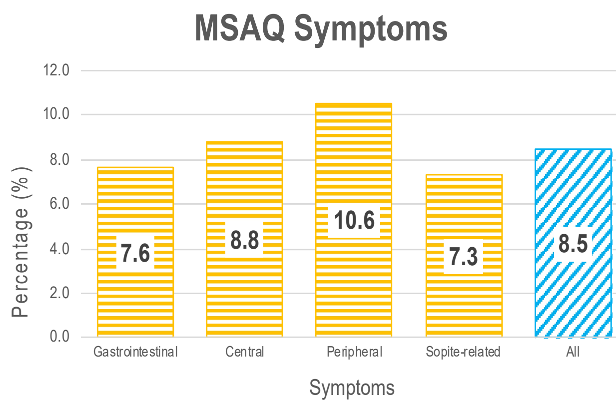


Figure 11: MSAQ (symptom decomposition)

CONCLUSIONS AND FUTURE WORK

In this paper, we have summarized the specification, design, development and successful pilot implementation of a Live-Virtual-Constructive (LVC) framework for observing young adults with ADHD within a comprehensive (simulated) analog workplace setting. To this end, we have developed and deployed the Laboratory Assessment of Behavior in Occupational Roles (LABOR) analog workplace setting, designed to approximate a (*Live*) pizzeria Training environment with a (*Virtual*) simulated food delivery environment (alongside *Constructive* assets) endeavored upon a high-fidelity driving simulator. The overarching goal was to innovate a novel mechanism - presently absent in current literature - by which to observe, measure, and analyze behavior within a controlled (laboratory) setting with the long-term aim of enhancing occupational success, particularly among young adults with ADHD. Our quantitative experimental findings have inherent limitations (i.e., primarily due to small sample size), yet are nonetheless demonstrative of the type of data that can be collected in such a novel M&S implementation. An executive summary of primary quantitative findings from our LVC deployment is as follows:

1) Conventional quantitative metrics were observed during the simulated driving tasks as a primary segment of measuring occupational functioning among teens with ADHD. These included maximum speed, overall delivery time (including *Live*, and *Virtual/Constructive* subcomponents of the task), and lateral lane deviation. Although results were not statistically significant, general trends were indicative that males with ADHD tend

to exhibit "positive emotions" associated with risky driving behaviors. Furthermore, observed performance suggested that males were prone to behave in a more aggressive and "***hyperactive***" manner, compared to females, who are generally less aggressive and more "***inattentive***".

2) Overall, participants seemed to enjoy the LVC workplace environment implementation, and appreciated its overall authenticity. Ratings ranged between 7 and 8 (on a 10-point Likert) for scoring categories associated with our LVC implementation, including: workplace and driving simulator realism, participant effort investment, and participant behaviors towards an authentic workplace analog. Driving simulator realism was the lowest-rated category due to absence of photorealistic, game-grade qualities for the visuals/graphics.
3) Maladaptation symptoms observed with relation to the simulated driving environment, assessed by way of self-report using the standardized MSAQ, ***were observed to be insignificant or very minor*** for almost the entire study cohort. Subcategory ratings were highest for the "Peripheral" category.

Forecasted future extensions of the LVC framework demonstrated here are numerous. Foremost, our quantitative metrics for rating driver performance in the *Virtual/Constructive* portion of LABOR require an expanded scope and finer granularity. Such features would allow us to rate and compare participants in a more refined manner, to better ascertain subtle nuances of driving performance. The authors likewise envision extensions of our evaluation framework to other application domains relevant to Education and Training. Most notably, we are currently engaged in novel implementations (e.g., Hulme et al., 2019) for post-secondary engineering education, leveraging "serious play" approaches for advanced education and training. To this end, gaming experiences that incorporate physics-based modeling and high-fidelity simulation effectively blend synthesis and analysis in a manner that empowers students to modify parameters - and observe downstream impacts – all in real-time.

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