Grant Award N00014-18-1-2530

Stress **A**ugmentation with **I**mmersive **V**irtual **R**eality and **A**ugmented **R**eality **Tech**nologies (**SAIVAR-Tech**)

Final Research Performance Report

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SUBJECT: Final Report for N00014-18-1-2530
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This Grant is completed and ready to be closed. The final report follows.

Major Goals of Project:

Determine the stress-reducing capabilities of commercially available virtual, head-mounted immersive virtual, and augmented/mixed reality technologies.

Accomplishments:

1. It was determined that eight-hours of game training/ gameplay, distributed over three-weeks (Experiment 1), using head-mounted immersive virtual reality and mixed reality devices reduced self-focused attention measured by the Dundee State Stress Questionnaire.
    a. While not a direct measure of stress, self-focused attention potentially infers that state-dependent stress relating to internalized focus and potential rumination of thoughts (as measured by self-focused attention).
2. Likewise, eight-hours of distributed game training/ gameplay (Experiment 1) did result in significant cognitive performance gains in the domains of memory, attention, and potentially processing speed compared to pre-intervention/ baseline performance for participants using the head-mounted display immersive virtual reality (iVR) platform.
3. Additionally, preliminary results from our game training optimization study (Experiment 3) suggest that longer distributed gameplay periods, of up to 24-hours of training, may continue to maximize the cognitive performance benefits reported above.
4. Furthermore, our Coping with Stress and Social Distancing during the COVID-19 pandemic survey (Experiment 2), which was developed in order to continue to maintain performance progress during the pandemic, yielded a sample size of 691 respondents from across the United States.
    a. While analyses are still ongoing, preliminary investigations suggest that there was substantial emotional disruption (depression, anxiety, and fatigue) and stress related to the duration of social distancing during the pandemic.
    b. There were a number of lifestyle and demographic factors that were associated with individuals having poorer mood scores during the pandemic.
        i. For instance, worsening diet, tobacco use, changes in alcohol consumption and sleep were often associated with poorer mood scores/ great emotional disruption.
    c. Additionally, our results suggest that individuals reporting higher resilience were less likely to report these emotional disruptions.

Experiment 1.
Participants underwent pre-intervention, baseline neuropsychological assessments, using the NIH Toolbox, and self-report stress and stress reliance assessments using the Dundee State Stress Questionnaire and the Connor-Davidson Stress Resilience Scale. Participants were randomly assigned into one of four gaming conditions: non-intervention control (CTL), virtual reality (VR), immersive VR (iVR), and augmented or mixed reality (AR/MR). All participants underwent a baseline assessment, prior to the start of their game training/ gameplay sessions, followed by 8-hours of gaming over the course of 3 weeks (3-hours/week) with their assigned technology platform. Eighteen to 36-hours following their final training session, participants underwent a post-intervention assessment. Participants assigned to the CTL condition followed a similar baseline and post-assessment window but did not receive a gaming intervention. This group was included to determine the practice effects of repeated cognitive and neuropsychological assessments across a 3-week window. Neurocognitive (NIH Toolbox) and neuropsychological (NIH ToolBox, Beck Anxiety Inventory, Beck Depression Inventory, Connor-Davidson Resilience Scale, the Dundee Stress State Questionnaire [DSSQ]) assessments were used for both baseline and post-intervention assessments. Alternative versions of the cognitive assessment were used when available to minimize practice effects.

Experiment 2. Due to the COVID-19 pandemic, we halted all in-person recruitment for the safety of researchers and participants alike. However, due to the unique circumstances that the world is currently finding itself in, we developed an online survey to explore the effects of social distancing and to investigate whether social distancing

is affecting mental health in the general population. Additionally, we explored what activities individuals are adopting during this time, whether they participated in gaming, and if these activities are helped to combat stress. We hypothesize that the COVID-19 pandemic has created a unique opportunity similar to that our service members face while on deployment: physical removal from family and friends, increased levels of stress, and forced to adapt to foreign circumstances.

Six-hundred and ninety-one participants completed the survey from across the United States.

Experiment 3. Based on the preliminary results of *Experiment 1* we developed an additional protocol to explore the optimal training duration to maximize stress reduction and cognitive performance gains. Two participants were recruited and completed the study at the time the grant terminated. Participants completed 24-hours of game training with iVR and MR technologies. Cognitive assessments were conducted following every 4-hours of game training to determine the optimal training duration to maximize cognitive benefit.

Training Opportunities and Professional Development:

While this award did not specifically support professional development, the principal investigators (Drs. Glueck and/or Han) presented research findings at three conferences and during one grand rounds lecture given the Department of Neurology in the University of Kentucky:

1. 2021 Neuroscience Clinical Translational Research Symposium, October 2021; Lexington, KY
2. Kentucky Academy of Science, November 2021 Richmond, KY
3. International Neuropsychological Society Symposium, February 2022; New Orleans, LA
4. University of Kentucky, Neurology Grand Rounds, March 2022; Lexington, KY

Dissemination of Results:

Experiment 1: Exploring the effects of game training on cognition, stress and resilience. Forty-seven, healthy participants were recruited to participate in *Experiment 1*, and the neurocognitive results are illustrated in **Figure 1**. Baseline versus post-intervention cognitive performances and neuropsychological assessments were assessed using paired t-test. Following 8-hours of game training, participants in the iVR condition demonstrated significant improvement in the areas of memory (t = 3.59, p = 0.004, *d* = 0.70), with a mean age-corrected standard score (SS) increasing from 97.23 (*SD* = 9.30) during baseline to 103.62 (*SD* = 8.96). Additionally, there was a significant increase in the attention SS (t = 3.68, p = 0.004, *d* = 0.51) from baseline to post-intervention with the mean SS increasing from 91.69 (*SD* = 16.94) at baseline to 100.12 (*SD* = 16.30)

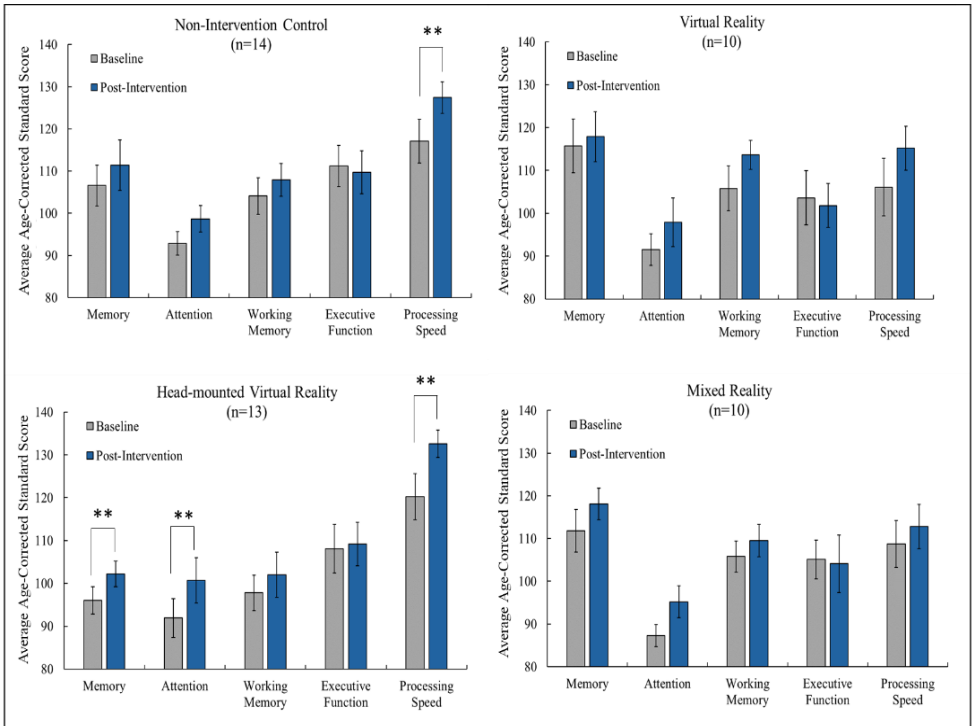

Figure 1. *Average age-corrected standard score (SS) of the neurocognitive assessments (collected via NIH toolbox) in a healthy population (N=47) prior to (baseline) and following (post-intervention) 8-hours of game play/training across four conditions:* ***a)*** *non-intervention control;* ***b)*** *virtual reality;* ***c)*** *head-mounted display virtual reality;* ***d)*** *mixed reality. Error bars are SEM. ** p≤ 0.005.*

during the post-intervention assessment for the iVR group. Finally, for the iVR group, there was a significant increase in the processing speed SS (t = 2.43, p = 0.005, *d* = 0.82) with the mean SS increasing from 115.31 (*SD* = 19.16) at baseline to 128.69 (*SD* = 13.27) during the post-intervention assessment. The CTL group demonstrated a significant increase in SS in processing speed (t = 3.55, p = 0.005, d = 0.78), with the mean SS increasing from 115.00 (SD = 17.82) at baseline to 127.00 (SD = 12.28) during the post-intervention assessment. All other baseline to post-intervention SS comparisons were not significant.

Results from the Dundee Stress State Questionnaire (DSSQ) are summarized in **Table 1**. Baseline versus post-intervention DSSQ domains were assessed using a paired t-test. Following 8-hours of game training, participants in the virtual reality condition demonstrated a significant increase in energetic arousal (t(9)=3.38, p=0.008, d=3.74), suggesting that participants in this condition experienced increased arousal and a great investment to engage in gameplay. Participants who completed their 8-hours of game training using the head-mount, immersive virtual reality demonstrated a number of significant changes following the intervention. There was a significant decrease in self-focused attention (*t*(12)=2.23, p=0.05, d=8.60), suggesting a decreased risk of thought rumination. Additionally, participants in the iVR condition demonstrated a significant increase in success motivation (*t*(12)=2.89, p=0.01, d=4.79), and a significant increase in total mood scores (*t*(12)=2.53, p=0.03, d=7.55), suggesting that an increased desire to perform well and a boost in overall mood. Furthermore, participants in the iVR condition also felt better about themselves after participating in the study, as indicated by a significant increase in the self-esteem measure (*t*(12)= 2.61, p=0.02, d=6.25). Likewise, participants who completed 8-hours of game training/ gameplay using the mixed reality headset, also demonstrated a significant decrease in self-focused attention (*t*(9)=3.86, p=0.05, d=8.60), suggesting, as with the iVR group, a reduced risk of ruminating thoughts. Finally, participants who did not engage in a gameplay intervention (the nonintervention control group) but completed the assessments at similar time points to the experimental groups (roughly 3-weeks following the baseline assessment) demonstrated a reduction in intrinsic motivation (*t*(13)=4.12, p< 0.001, d=2.44) as well as a significant decrease in task-irrelevant interference (*t*(13)=2.16, p=0.05, d=4.67), suggesting a decrease interest in taking the assessment without having

Group	Measure	Baseline M (SD)	Post-Intervention M (SD)	*t*	*p*	*d*
Control (**CTL**, n=14)	**Intrinsic Motivation**	**22.53 (3.62)**	**19.93 (5.08)**	**4.12**	**<0.001**	**2.44**
	Energetic Arousal	23.27 (3.83)	24.13 (5.07)	0.75		
	Task Irrelevant Interference	**15.07 (6.22)**	**12.47 (4.90)**	**2.16**	**0.05**	**4.67**
	Self-Focused Attn.	14.73 (7.26)	10.40 (6.24)	1.63		
	Success Motivation	13.27 (5.87)	11.60 (6.74)	1.32		
	Total Mood	71.87 (7.57)	71.80 (8.02)	0.03		
	Self Esteem	19.47 (6.53)	21.67 (6.86)	1.04		
Virtual Reality (**VR**, n=10)	Intrinsic Motivation	22.30 (2.63)	21.50 (3.78)	0.98		
	Energetic Arousal	**20.70 (4.32)**	**24.70 (4.08)**	**3.38**	**0.008**	**3.74**
	Task Irrelevant Interference	13.30 (3.37)	14.60 (7.66)	0.50		
	Self-Focused Attn.	13.90 (7.91)	9.10 (8.32)	2.10		
	Success Motivation	20.10 (5.38)	18.20 (5.57)	1.20		
	Total Mood	70.20 (5.27)	73.80 (6.05)	1.64		
	Self Esteem	19.20 (8.92)	21.50 (7.06)	1.10		
Head-mounted immersive VR (**iVR**, n=13)	Intrinsic Motivation	24.54 (1.85)	23.31(3.45)	1.29		
	Energetic Arousal	25.46 (3.93)	27.00 (2.45)	1.42		
	Task Irrelevant Interference	13.54 (5.21)	10.08 (2.87)	2.03		
	Self-Focused Attn.	**14.38 (7.56)**	**9.08 (6.65)**	**2.23**	**0.05**	**8.60**
	Success Motivation	**15.38 (4.48)**	**19.23 (4.48)**	**2.89**	**0.01**	**4.79**
	Total Mood	**71.23 (5.62)**	**76.54 (7.01)**	**2.53**	**0.03**	**7.55**
	Self Esteem	**19.08 (7.81)**	**23.62 (3.99)**	**2.61**	**0.02**	**6.25**
Mixed Reality (**MR**, n=10)	Intrinsic Motivation	24.22 (3.19)	23.11 (3.30)	1.49		
	Energetic Arousal	23.73 (3.98)	25.09 (3.81)	1.20		
	Task Irrelevant Interference	13.73 (4.27)	13.64 (4.18)	0.08		
	Self-Focused Attn.	**13.55 (3.59)**	**5.91 (6.04)**	**3.86**	**0.003**	**6.56**
	Success Motivation	16.64 (7.31)	19.64 (4.91)	1.89		
	Total Mood	70.91 (6.52)	75.45 (8.03)	2.02		
	Self Esteem	20.64 (5.77)	24.00 (4.10)	1.86		

Table 1. Average Dundee Stress State scores for baseline and post-intervention assessments. **Bold** text denotes significant t-test (*t*).

experienced a gaming intervention, and a reduction in distractibility. Therein, these results suggest that the control group was focused on the assessment but bored.

Current results reveal several potential mental health benefits to engaging in gameplay with advanced technology platforms. Participants who used the advanced and immersive technologies (iVR and mixed reality) demonstrated a significant reduction in self-focused attention, which can be associated with ruminating thought patterns. As the operational definition of stress carries multiple interpretations, the promising results relating to the reduction of self-focused attention, demonstrate that state-dependent stress relating to internalized focus and thought rumination is significantly reduced following iVR and mixed reality training/gameplay when compared to baseline. Furthermore, participants in iVR condition scored higher on overall mood and self-esteem following the intervention and were motivated to perform well in the study.

Experiment 2. Coping with Stress and Social Distancing during the COVID-19 pandemic survey. Six-hundred and ninety-one participants completed our Coping during the COVID-19 pandemic online survey between May 2020 and January 2021. The survey collected demographic information, such as age at the time of the survey, gender, race, location, education, etc, and included the Profile of Mood States questionnaire, The Connor-Davidson Resilience Scale, and the Beck Anxiety Inventory. Several linear regression analyses were conducted to investigate if age at the time of the survey, race, gender, resilience scores, and changes in lifestyle (exercise, alcohol use, tobacco use, diet, and sleep) predicted participants' POMS or Beck Anxiety scores.

First, we will examine the POMS Fatigue measure. Controlling for other variables in the model resilience scores, gender, tobacco use, diet change, and sleep were significant predictors for POMS fatigue scores (see **Table 2**). For every one-unit increase in resilience scores, fatigue is reduced by 0.18 points. Women reported fatigue scores that were higher than men. Tobacco users' fatigue scores were on average higher compared to non-tobacco users. Individuals who reported that their diets had worsened during the pandemic reported higher fatigue scores than those who reported that their diet had improved and higher fatigue scores than individuals reporting no change in their diets. Finally, individuals who reported that they were sleeping less during the pandemic reported higher fatigue than those reporting that their sleep had not changed (or individuals who reported that they were sleeping more. Individuals who reported no change in sleep reported lower fatigue levels than those reporting changes in sleep (increases or decreases).

Table 2
Impact of Lifestyle and Demographic Factors on Fatigue

Predictor		**b**	**t-value**	**p-value**
Age		-0.022	-1.22	0.224
Resiliency		-0.178	-10.36	<.001
Adjusted Means		**Mean**	**F-value**	**p-value**
Gender			4.98	0.026
	Female	14.22[a]		
	Male	12.70[b]		
Race			0.55	0.458
	White	13.76		
	Other	13.17		
Exercise Change			2.06	0.129
	Increase	14.15		
	Decrease	13.46		
	No Change	12.77		
Alcohol Change			2.33	0.099
	Increase	14.07		
	Decrease	13.57		

	No Change	12.75		
Tobacco Use			6.10	0.014
	Yes	14.55[a]		
	No	12.38[b]		
Diet Change			4.95	0.007
	Better Diet	12.54[a]		
	Worse Diet	14.84[b]		
	No Change	13.00[a]		
Sleep Change			29.89	<.001
	Sleeping Less	15.90[a]		
	Sleeping More	13.62[b]		
	No Change	10.87[c]		

Note. The relationship between the outcome and continuous predictors are presented as unstandardized regression coefficients. Adjusted means are presented for categorical predictors. Only groups whose omnibus test (F-test) was significant were examined for pairwise differences. Groups not sharing a superscript differ at $p < .05$

Next, we will examine the POMS Depression measure. Controlling for other variables in the model resilience scores, alcohol use, and sleep were significant predictors for POMS depression scores (see **Table 3**). For every one-unit increase in resilience scores, depression was reduced by 0.03 points. Individuals who reported a decrease in alcohol use, on average reported 0.24 point higher POMS depression scores than those who reported no change in alcohol use. Furthermore, individuals who reported that they were sleeping less during the pandemic reported higher depression scores than those reporting that their sleep had not changed or individuals who reported that they were sleeping more. Individuals who reported no change in sleep had lower depression POMS scores than those reporting changes in sleep (increases or decreases).

Table 3
Impact of Lifestyle and Demographic Factors on Depression

Predictor		**b**	**t-value**	**p-value**
Age		.002	0.78	0.44
Resiliency		-0.03	-14.15	<.001
Adjusted Means		**Mean**	**F-value**	**p-value**
Gender			0.04	0.83
	Female	2.63		
	Male	2.61		
Race			0.44	0.51
	White	2.59		
	Other	2.66		
Exercise Change			2.28	0.10
	Increase	2.72		
	Decrease	2.62		
	No Change	2.52		
Alcohol Change			3.29	0.04
	Increase	2.65		
	Decrease	2.73[a]		
	No Change	2.49[b]		
Tobacco Use			3.24	0.07
	Yes	2.73		
	No	2.51		

Diet Change			1.91	0.15
	Better Diet	2.54		
	Worse Diet	2.74		
	No Change	2.59		
Sleep Change			23.59	<.001
	Sleeping Less	2.88[a]		
	Sleeping More	2.70[a]		
	No Change	2.29[b]		

Note. The relationship between the outcome and continuous predictors are presented as unstandardized regression coefficients. Adjusted means are presented for categorical predictors. Only groups whose omnibus test (F-test) was significant were examined for pairwise differences. Groups not sharing a superscript differ at $p < .05$

For the POMS Anger measure, controlling for other variables in the model resilience scores and sleep were significant predictors for POMS anger scores (see **Table 4**). For every one-unit increase in resilience scores, anger was reduced by 0.03 points. Individuals who reported changes in the amount of sleep they were getting reported higher POMS anger scores.

Table 4
Impact of Lifestyle and Demographic Factors on Anger

Predictor	**b**	**t-value**	**p-value**
Age	.005	1.96	.052
Resiliency	-0.03	-9.92	<.001

Adjusted Means	**Mean**	**F-value**	**p-value**
Gender		0.26	0.69
Female	2.26		
Male	2.31		
Race		0.28	0.60
White	2.26		
Other	2.32		
Exercise Change		1.67	0.19
Increase	2.41		
Decrease	2.23		
No Change	2.23		
Alcohol Change		1.05	0.35
Increase	2.32		
Decrease	2.34		
No Change	2.21		
Tobacco Use		1.26	0.26
Yes	2.36		
No	2.22		
Diet Change		2.77	0.06
Better Diet	2.31		
Worse Diet	2.38		
No Change	2.17		
Sleep Change		17.38	<.001
Sleeping Less	2.53[a]		
Sleeping More	2.34[a]		
No Change	1.99[b]		

Note. The relationship between the outcome and continuous predictors are presented as unstandardized regression coefficients. Adjusted means are presented for categorical predictors. Only groups whose omnibus test (F-test) was significant were examined for pairwise differences. Groups not sharing a superscript differ at $p < .05$

For the POMS Tension scores, controlling for other variables in the model resilience scores, age, changes in exercise, alcohol use, diet, and sleep were significant predictors for POMS tension scores (see **Table 5**). For every one-unit increase in resilience scores, tension is reduced by 0.20 points. Similarly, for every one-year increase in age, tension decreased by 0.04 points. Individuals who reported an increase in exercise reported higher tension scores than individuals reporting decreases in exercise and no change in exercise. Whereas, individuals reporting no change in alcohol use reported lower tension scores than individuals reporting an increase in alcohol use. Furthermore, tobacco users reported higher tension scores than non-tobacco users. Additionally, individuals who reported that their diet had worsened during the pandemic reported higher tension scores than individuals reporting that their diet had improved or reported no change in their diet. Finally, individuals who reported that they were sleeping less during the pandemic reported higher tension scores than those reporting that their sleep had not changed or individuals who reported that they were sleeping more. Individuals who reported no change in sleep reported lower tension levels than those reporting changes in sleep (increases or decreases).

Table 5
Impact of Lifestyle and Demographic Factors on Tension

Predictor		**b**	**t-value**	**p-value**
Age		-0.04	-2.06	0.04
Resiliency		-0.20	-11.41	<.001
Adjusted Means		**Mean**	**F-value**	**p-value**
Gender			1.14	0.29
	Female	15.51		
	Male	14.76		
Race			0.93	0.33
	White	15.53		
	Other	14.74		
Exercise Change			3.30	0.04
	Increase	16.31[a]		
	Decrease	14.57[b]		
	No Change	14.53[b]		
Alcohol Change			3.73	0.02
	Increase	15.80[a]		
	Decrease	15.46		
	No Change	14.15[b]	6.56	0.01
Tobacco Use				
	Yes	16.29[a]		
	No	13.98[b]		
Diet Change			3.09	0.05
	Better Diet	14.56[a]		
	Worse Diet	16.23[b]		
	No Change	14.62[a]		
Sleep Change			26.03	<.001
	Sleeping Less	17.70[a]		
	Sleeping More	14.93[b]		
	No Change	12.77[c]		

Note. The relationship between the outcome and continuous predictors are presented as unstandardized regression coefficients. Adjusted means are presented for categorical predictors. Only groups whose omnibus test (F-test) was significant were examined for pairwise differences. Groups not sharing a superscript differ at $p < .05$

Next, we will examine the POMS Confusion measure. Controlling for other variables in the model age, resilience scores, changes in alcohol use, tobacco use, and sleep were significant predictors for POMS confusion scores (see **Table 6**). For every one-year increase in age, confusion was reduced by 0.03 points. For every one-unit increase in resilience scores, confusion was reduced by 0.16 points. Individuals who reported changes in alcohol use (increases or decreases) had higher confusion scores than those reporting no change in their alcohol use. Tobacco users reported higher confusion scores than non-tobacco users. Finally, individuals who reported that they were sleeping less during the pandemic reported higher confusion scores than those reporting that their sleep had not changed or individuals who reported that they were sleeping more. Individuals who reported no change in sleep reported lower confusion scores than those reporting changes in sleep (increases or decreases).

Table 6
Impact of Lifestyle and Demographic Factors on Confusion

Predictor		**b**	**t-value**	**p-value**
Age		-0.03	-2.10	0.04
Resiliency		-0.16	-12.56	<.001
Adjusted Means		**Mean**	**F-value**	**p-value**
Gender			0.92	0.34
	Female	11.84		
	Male	11.35		
Race			0.51	0.48
	White	11.39		
	Other	11.81		
Exercise Change			2.18	0.11
	Increase	12.22		
	Decrease	11.45		
	No Change	11.12		
Alcohol Change			5.02	.007
	Increase	11.72[a]		
	Decrease	12.38[a]		
	No Change	10.70[b]		
Tobacco Use			5.15	0.02
	Yes	12.34[a]		
	No	10.85[b]		
Diet Change			1.09	0.34
	Better Diet	11.22		
	Worse Diet	12.08		
	No Change	11.49		
Sleep Change			26.86	<.001
	Sleeping Less	13.18[a]		
	Sleeping More	11.91[b]		
	No Change	9.71[c]		

Note. The relationship between the outcome and continuous predictors are presented as unstandardized regression coefficients. Adjusted means are presented for categorical predictors. Only groups whose

omnibus test (F-test) was significant were examined for pairwise differences. Groups not sharing a superscript differ at $p < .05$

For the POMS Vigor measure, controlling for all other variables in the model age, resiliency, gender, using tobacco, and changes in exercise and sleep were significant predictors (see **Table 7**). For every one-year increase in age, vigor was increased by 0.05 points. For every one-unit increase in resilience scores, vigor was increased by 0.17 points. Females reported lower vigor scores than males. Individuals reporting decreases in exercise reported lower vigor scores than individuals reporting an increase in their exercise or no change in their exercise. Individuals reporting increases in exercise reported higher vigor scores than individuals reporting decreases in exercise or no change in exercise. Individuals reporting no change in their exercise reported higher vigor scores than those who reported decreases in exercise, but low vigor than those reporting that they increased their exercise during the pandemic. Finally, individuals who reported no change in sleep reported higher vigor scores than those reporting changes in sleep (increase or decrease).

Table 7

Impact of Lifestyle and Demographic Factors on Vigor

Predictor		**b**	**t-value**	**p-value**
Age		0.05	3.38	<.001
Resiliency		0.17	13.05	<.001
Adjusted Means		**Mean**	**F-value**	**p-value**
Gender			9.62	0.002
	Female	9.36[a]		
	Male	11.00[b]		
Race			0	0.95
	White	10.20		
	Other	10.15		
Exercise Change			7.46	<.001
	Increase	11.31[a]		
	Decrease	9.11[b]		
	No Change	10.11[c]		
Alcohol Change			0.47	0.62
	Increase	9.92		
	Decrease	10.22		
	No Change	10.40		
Tobacco Use			5.08	0.02
	Yes	9.41[a]		
	No	10.94[b]		
Diet Change			0.78	0.46
	Better Diet	10.35		
	Worse Diet	9.78		
	No Change	10.41		
Sleep Change			5.27	0.005
	Sleeping Less	9.60[a]		
	Sleeping More	9.86[a]		
	No Change	11.07[b]		

Note. The relationship between the outcome and continuous predictors are presented as unstandardized regression coefficients. Adjusted means are presented for categorical predictors. Only groups whose omnibus test (F-test) was significant were examined for pairwise differences. Groups not sharing a superscript differ at $p < .05$

The POMS Total Mood Disruption score is the cumulative total of fatigue, depression, anger, tension, and confusion scores minus the vigor score. For the POMS Total Mood Disruption Score, controlling for all other variables in the model, resiliency, tobacco use, and changes in alcohol use, diet, and sleep were significant predictors (see **Table 8**). For every one-unit increase in resilience scores, total mood disruption was decreased by 1.39 points. Individuals who reported an increase or decrease in their alcohol use reported higher mood disruption than those who reported no change in their alcohol use. Similarly, individuals who endorsed being tobacco users reported higher mood disruption than non-tobacco users. Individuals who reported that their diet had worsened during the pandemic had higher mood disruption scores than those who reported no diet change. Finally, individuals who reported that they were sleeping less during the pandemic reported higher confusion scores than those reporting that their sleep had not changed or individuals who reported that they were sleeping more. Individuals who reported no change in sleep reported lower confusion scores than those reporting changes in sleep (increases or decreases).

Table 8
Impact of Lifestyle and Demographic Factors on Total Mood Disruption

Predictor		**b**	**t-value**	**p-value**
Age		-0.11	-1.13	0.26
Resiliency		-1.39	.15.34	<.001
Adjusted Means		**Mean**	**F-value**	**p-value**
Gender			0.03	0.87
	Female	67.10[a]		
	Male	66.49[b]		
Race			0.53	0.47
	White	65.27		
	Other	68.31		
Exercise Change			2.10	0.12
	Increase	71.09[a]		
	Decrease	65.84		
	No Change	63.45[b]		
Alcohol Change			3.39	0.03
	Increase	68.35[a]		
	Decrease	70.43[a]		
	No Change	61.60[b]		
Tobacco Use			9.85	0.002
	Yes	74.05[a]		
	No	59.54[b]		
Diet Change			3.21	0.04
	Better Diet	64.26		
	Worse Diet	72.33[a]		
	No Change	63.78[b]		
Sleep Change			40.12	<.001
	Sleeping Less	87.79[a]		
	Sleeping More	67.52[b]		
	No Change	51.06[c]		

Note. The relationship between the outcome and continuous predictors are presented as unstandardized regression coefficients. Adjusted means are presented for categorical predictors. Only groups whose omnibus test (F-test) was significant were examined for pairwise differences. Groups not sharing a superscript differ at $p < .05$

Finally, we will examine the predictors for the Beck Anxiety measure. Controlling for all other variables in the model, resiliency, tobacco use, and changes in alcohol use and sleep were found to be significant predictors of anxiety. For every one-unit increase in resilience scores, total mood disruption was decreased by 0.03 points. Individuals who reported tobacco use had higher anxiety scores than non-tobacco users. Individuals who reported a decrease in alcohol use had higher anxiety scores than individuals reporting no change in alcohol use. Finally, individuals reporting an increase or decrease in their amount of sleep had higher anxiety scores than individuals reporting no change in sleep during the first 10 months of the COVID-19 pandemic.

Overall, the results suggest that there were some lifestyle and demographic factors associated with better affect scores during the COVID-19 pandemic. Individuals who had higher resiliency had better mood scores, and older age was more often associated with better affect scores, suggesting that age was protective. Furthermore, we saw that changes in sleep were associated with poorer affect scores, capturing the association of some negative affect disorders, such as depression, correlated with changes (an increase or decrease) in sleep. Worsening diet, and increased alcohol and tobacco consumption can also be viewed as negative coping mechanisms or self-medication for negative affect, and these analyses may be capturing the difficulties of the pandemic as our survey sample attempted to adjust to the related social distancing and restrictions. As with most survey data, one limitation of our data is that we did not have a baseline, pre-pandemic data and the results should be interpreted with caution and not be used to suggest causality.

Experiment 3: Game training optimization study.

Based on the promising preliminary results of Experiment 1 in 2019, we planned to further investigate whether increased game training would result in larger gains in cognitive performance. Two participants were recruited and completed their 8-9-week game training intervention. The results from these two participants are illustrated in **Figure 2**. Given the limited sample size, statistical analyses were not appropriate, however, visual inspection of the data demonstrated definite learning curves for both participants (regardless of the technology platform they trained on) for the attention and processing speed domains. These data suggest, that additional game training (3-4, 1-hr sessions each week over 8-9 weeks) with head-mounted iVR and mixed reality may yield continued cognitive improvement. However, given the limited sample size, more research is needed to further investigate whether more extensive game training is warranted to optimize cognitive outcomes.

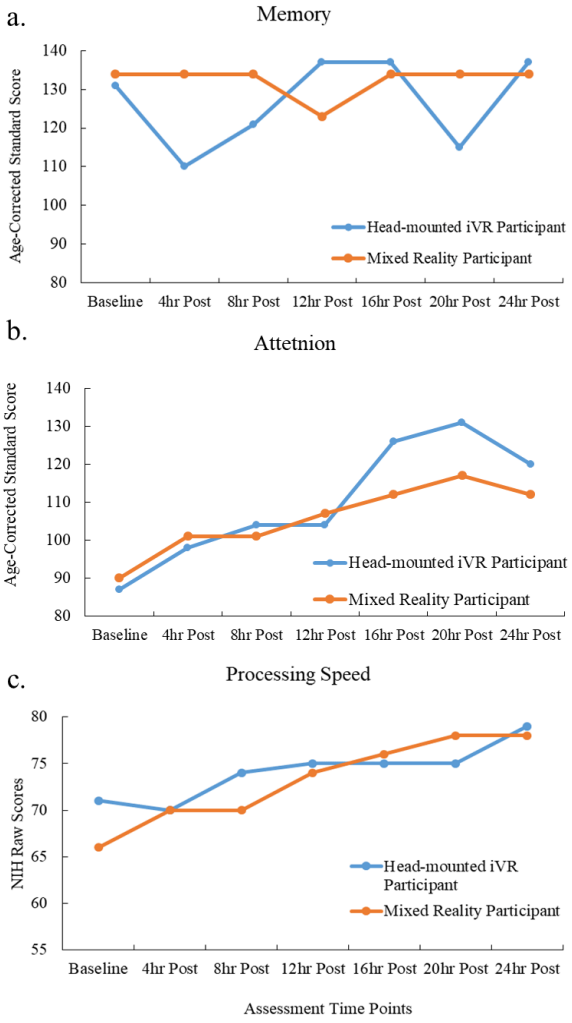

Figure 2. *Cognitive performance of two participants from the Optimal Training Study from the NIH Toolbox cognitive assessments for* ***a)*** *memory,* ***b)*** *attention, and* ***c)*** *processing speed.*

Recruitment barriers. Our first participant was recruited in Summer 2021, and completed 8-weeks of game training. However, despite continued recruitment efforts (renewed and increased advertising), we were not able to our second participant until February 2022. We attribute this reduced participant recruitment to the overall reduction in recruitment we and other labs at the University of Kentucky have been seeing. Whether this reduction is a direct result of health-related concerns with participating in research at a medical center during the COVID pandemic or whether a direct reflection of the public's mistrust of biomedical research in general is

unclear. However, recruitment was beginning to pick up and we had 3 potential participants interested in the study in May when we discovered the funding issue related to this grant had to halt recruitment and work on this project.

Participants:

Dr. Dong Y. Han was a co-principal investigator on this project. He contributed 1-month of effort during this reporting period.

Deliverables:

Currently, we have one manuscript under review from Experiment 1.

- Jenks K, Han D, **Glueck AC.** Game training with head-mounted immersive virtual reality improves cognitive performance. Games for Health Journal. Under review. Virtual Reality.

We are preparing 3 other manuscripts from the data collected in Experiment 2.

Conference presentations:

Last year, our team presented data supported by this grant four times at local, and international conferences:

- Gelnett GL, Han DY, **Glueck AC**. Gaming Makes You Smarter? Exploring the Effects of Virtual Reality. 2021 Neuroscience Clinical Translational Research Symposium; October 2021; Lexington, KY.
- **Glueck AC**, McLouth C, Han DY. Why do I feel so exhausted? Exploring factors that may contribute to fatigue levels during the COVID Pandemic. 2021 Neuroscience Clinical Translational Research Symposium; October 2021; Lexington, KY.
- Gelnett GL, Han DY, **Glueck AC**. Enhancing cognitive function through virtual reality training. Poster presented at: 2021 Kentucky Academy of Science; November 2021; Richmond, KY.
- **Glueck AC**, Han DY. Exploring the Effects of Virtual Reality Game Play on Cognitive Performance. Poster Presented at International Neuropsychological Society Symposium; February 2022; New Orleans, LA.

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14. ABSTRACT

Eight-hours of game training/ gameplay, distributed over three-weeks (Experiment 1), using head-mounted immersive virtual reality and mixed reality devices reduced self-focused attention measured by the Dundee State Stress Questionnaire.While not a direct measure of stress, self-focused attention potentially infers that state-dependent stress relating to internalized focus and potential rumination of thoughts (as measured by self-focused attention). Likewise, eight-hours of distributed game training/ gameplay (Experiment 1) did result in significant cognitive performance gains in the domains of memory, attention, and potentially processing speed compared to pre-intervention/ baseline performance for participants using the head-mounted display immersive virtual reality (iVR) platform. Additionally, preliminary results from our game training optimization study (Experiment 3) suggest that longer distributed gameplay periods, of up to 24-hours of training, may continue to maximize the cognitive performance benefits reported above. Furthermore, our Coping with Stress and Social Distancing during the COVID-19 pandemic survey (Experiment 2), which was developed in order to continue to maintain performance progress during the pandemic, yielded a sample size of 691 respondents from across the United States. Preliminary investigations suggest that there were substantial emotional disruption (depression, anxiety, and fatigue) and stress related to the duration of social distancing during the pandemic. There were a number of lifestyle and demographic factors that were associated with individuals having poorer mood scores during the pandemic. For instance, worsening diet, tobacco use, changes in alcohol consumption and sleep were often associated with poorer mood scores/ great emotional disruption. Additionally, our results suggest that individuals reporting higher resilience were less likely to report these emotional disruptions.

15. SUBJECT TERMS

Research in gaming training with immersive virtual reality, augmented/ mixed reality, stress resilience, cognitive performance

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