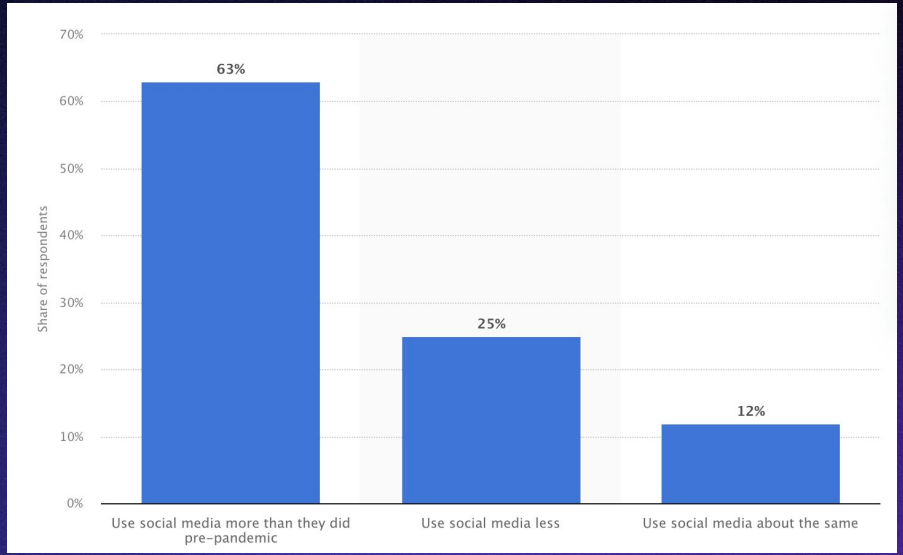
Digital Therapeutic for Executive Function in ADHD

Research Motivation

Importance of ADHD Medication

- **Globally increasing cases of ADHD diagnosis in infants and adolescents.**
- The **COVID-19 pandemic** led to a **rapid increase in exposure to digital devices and media**, which is linked to an **increase in ADHD prevalence.**



Increased usage of social media affected by pandemic (Statista)

Research Motivation

Importance of ADHD Medication

- **ADHD negatively affects learning, sleep, and relationships, among others.**
- **Early diagnosis and treatment are necessary.**

Table 2. Differences Between Children With and Without ADHD.

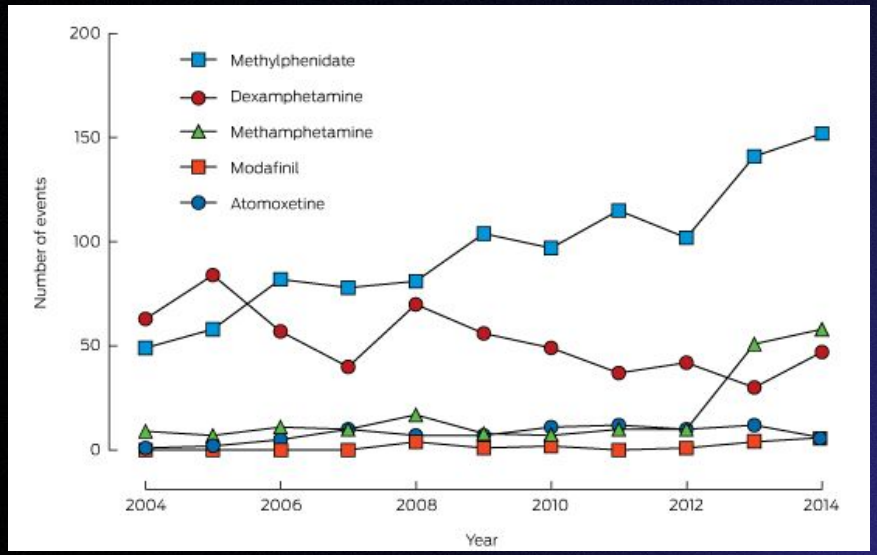
Variable	*t*-Value	*p*-Value	Cohen's *d*	ADHD *M*	ADHD *SD*	Non-ADHD *M*	Non-ADHD *SD*
COVID outcomes							
Breaking rules	−3.827*	<.001	−0.225	1.98	1.05	1.77	0.87
COVID worry	−1.393	.164	−0.082	2.29	1.14	2.20	1.04
Prepared for next school year	6.449*	<.001	0.380	2.97	0.95	3.34	0.95
Taking COVID seriously	−0.006	.995	<0.001	3.78	0.89	3.78	0.93
Trouble with remote learning	−6.510*	<.001	−0.56	2.84	1.26	2.17	1.10
COVID-elicited emotions	−4.70*	<.001	−0.341	1.61	.84	1.36	0.63
Sleep problems	5.472	<.001	0.524	11.04	2.34	12.21	2.09
COVID symptoms	4.41*	<.001	0.25	0.36	1.15	0.14	0.59
Self-quarantining	1.3	.092	0.10	0.02	0.14	0.01	0.11
Changed medical appts	4.87*	<.001	0.27	0.29	0.45	0.17	0.38
Pre-pandemic predictors							
Parental monitoring	4.432*	<.001	0.255	4.34	0.51	4.47	0.45
School involvement	4.997*	<.001	0.287	12.58	2.50	13.27	2.25
Positive school environment	3.376*	.001	0.194	19.90	2.95	20.43	2.54
Pandemic predictors							
Screen time (hours)	−0.679	.497	−0.040	4.84	3.08	4.72	2.99
Increased family conflict	−2.297*	.022	−0.133	2.48	1.20	2.32	1.15
Daily schedule	−1.503	.133	−0.089	3.40	1.17	3.29	1.16
Physical activity (time/day)	−6.47	.517	−0.041	1.43	1.55	1.37	1.50
Physical activity (days/week)	1.184	.237	0.070	3.13	2.10	3.28	2.02

*indicates significantly worse outcomes for ADHD sample.

Difference Between Children With and Without ADHD (ResearchGate)

Research Motivation

Disadvantages with current Drug Medication



Exposures of various ADHD Medications and the Number of Adverse Effects
(The Medical Journal of Australia)

A study of 71 children taking **Methylphenidate**:

- **Loss of appetite - 74.3%**
- **Irritability - 57.1%**
- **Insomnia - 47.2%**
- **3% of children expresses serious psychotics symptoms or mood disorders**
- **7.4 times higher risk of cardiac-related problems**
- **60% experienced an increase in frequency of side effect as drug dosage increased**

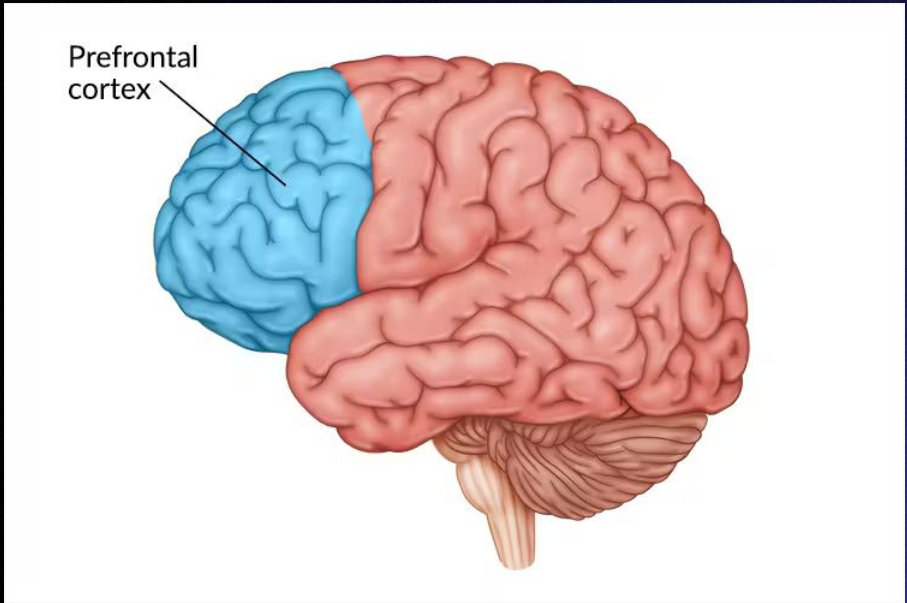
ADHD Digital Therapeutics

Endeavor Rx

- **Video-game–based Digital Therapeutic (DTx)**
- **Uses a Selective Stimulus Management Engine (SSME)** to stimulate and activate neural systems related to attention control
- SSME algorithm **adapts in real time based on the user's performance**

ADHD Digital Therapeutics

Mechanism



- SSEM promotes neuroplasticity as a therapeutic mechanism
- Strengthens connections between neurons
- Encourages the formation of new connections
- Enhanced prefrontal cortex efficiency → improved attention and focus

Key Aspects of ADHD DTx

1. **Impulse Control:**
   Delayed gratification and response inhibition training

2. **Attention / Focus:**
   Sustained attention tasks, selective attention stimuli, adaptive difficulty

3. **Memory:**
   Retaining and manipulating information, visual and auditory memory training, step-wise complexity increase

4. **Multitasking:**
   Performing simultaneous tasks, managing cognitive load

5. **Flow State Maintenance:**
   Balance between challenge and skill, clear goals and immediate feedback, personalized difficulty adjustment

Limitations

Limitations of existing ADHD games:

- Lack of personalized difficulty and flow state
- Insufficient immersive environment to maintain consistent engagement
- Prescription-only → limited accessibility

Our proposal:

- Use in-game log data to perform real-time ADHD screening

Proposed DTx System Overview

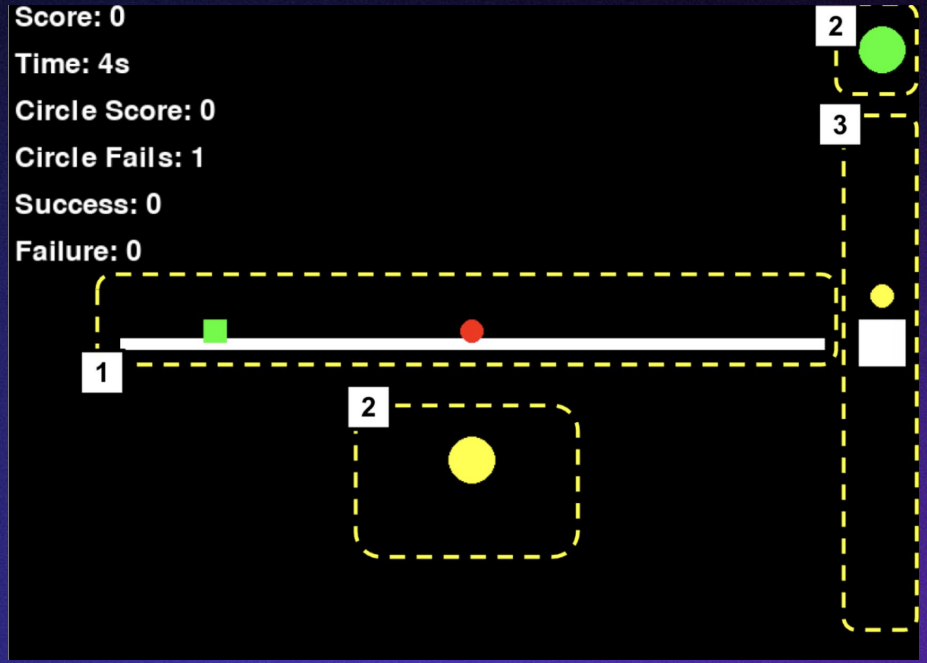
Improving Therapeutic Effect:

- **Real-time difficulty adjustment** → Maintains the **Flow State**
- Requiring **multiple simultaneous operations** → Enhances **multitasking ability**
- **Score acquisition method** → Improves **impulse control ability**
- **Memorizing and performing operations** → Enhances **working memory** and **concentration**

Proposed DTx System Overview

Adding ADHD Discrimination Function

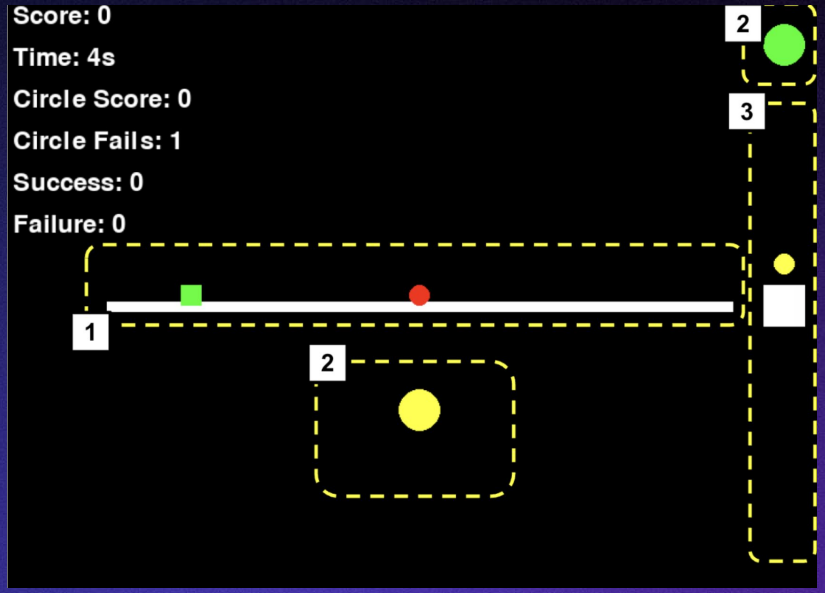
- **Game Play**
- **Log Collection** e.g. success_count, failure_count, score, score_circle
- **AI Model Analysis** → Determining the presence of ADHD



Overview of the game

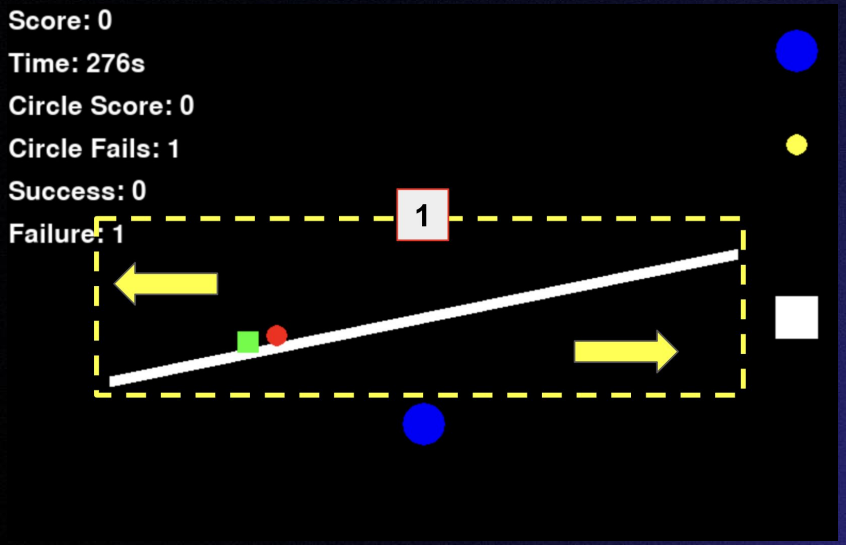
Proposed DTx System Overview

Area	Operation Method	Function
1	Tilt a white bar to collide a ball with a square	Enhances Working Memory and Concentration
2	Click when the two circles are the same color	Enhances Impulse Inhibition Ability
3	Click when a circle touches a square	Enhances Working Memory and Concentration



Overview of the game

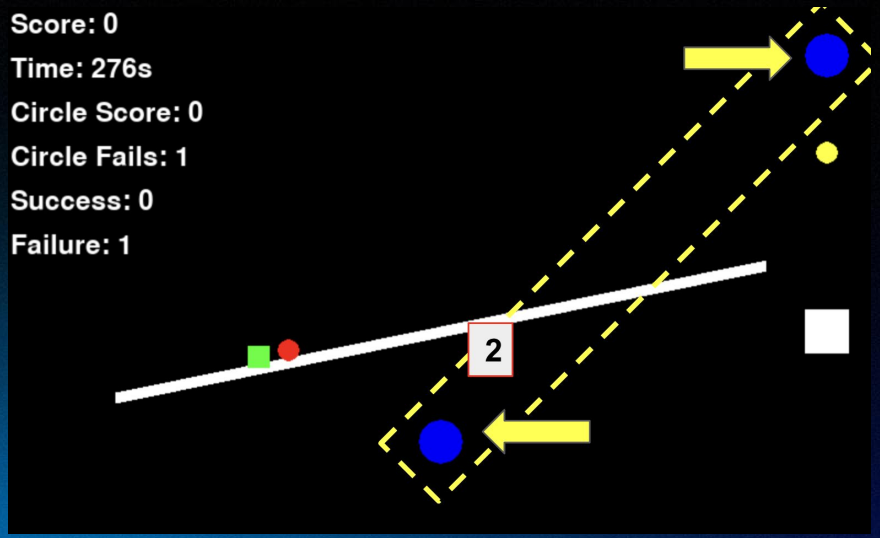
Proposed DTx System Overview



Area	Operation Method	Function
1	Tilt a white bar to collide a ball with a square	Enhances Working Memory and Concentration

Feature: Adjusting the tilt of the left and right bars (Gravity Implementation)

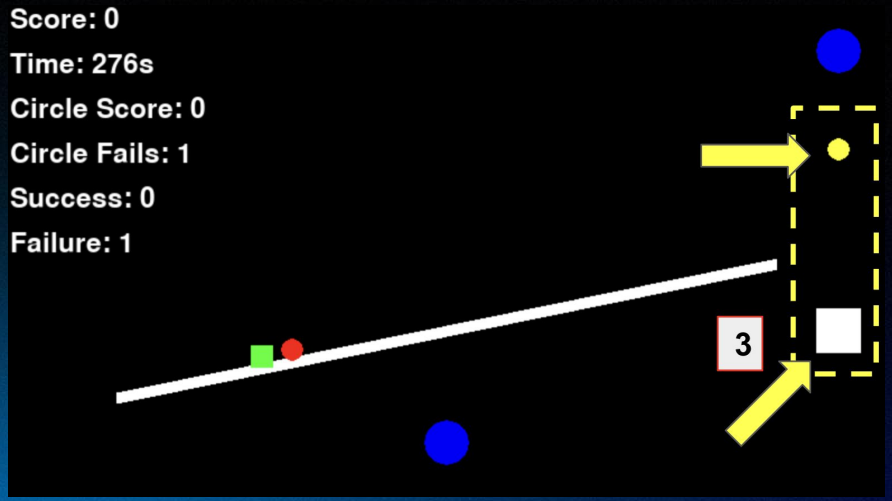
Proposed DTx System Overview



Area	Operation Method	Function
2	Click when the two circles are the same color	Enhances Impulse Inhibition Ability

Feature: Click when the colors are the same to earn points (The color changes randomly and continuously)

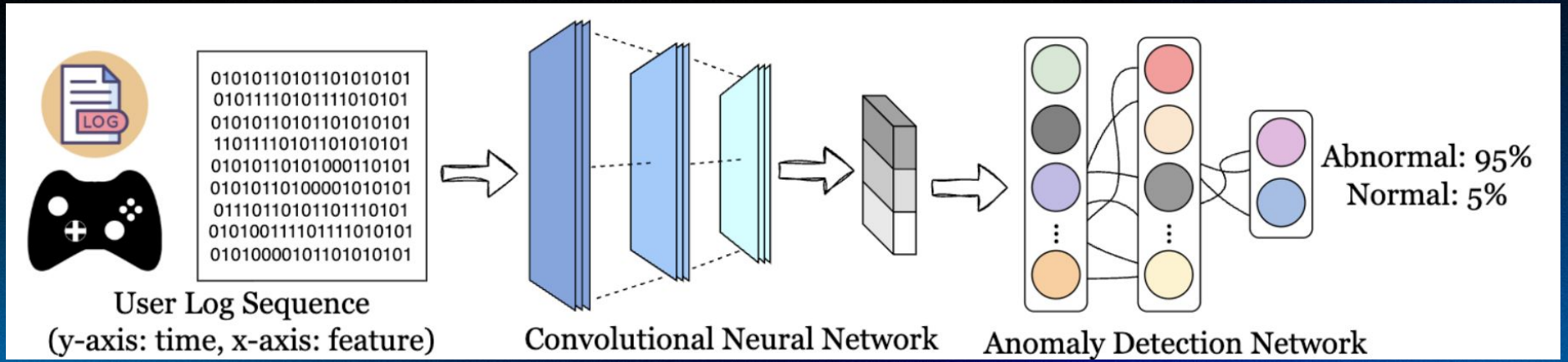
Proposed DTx System Overview



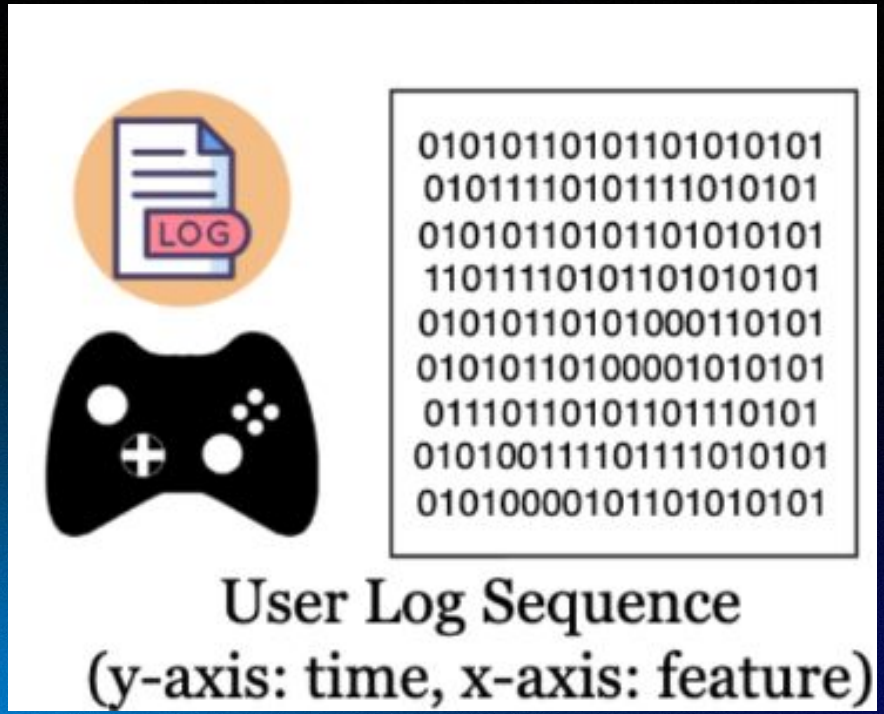
Area	Operation Method	Function
3	Click when a circle touches a square	Enhances Working Memory and Concentration

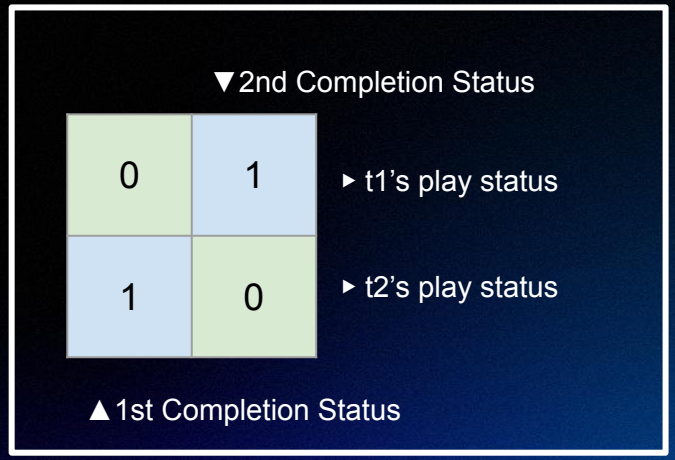
Feature: Press the button to get points when the yellow ball inside the square
(The drop cycle & speed is random each time)

Proposed DTx System Overview



Proposed DTx System Overview

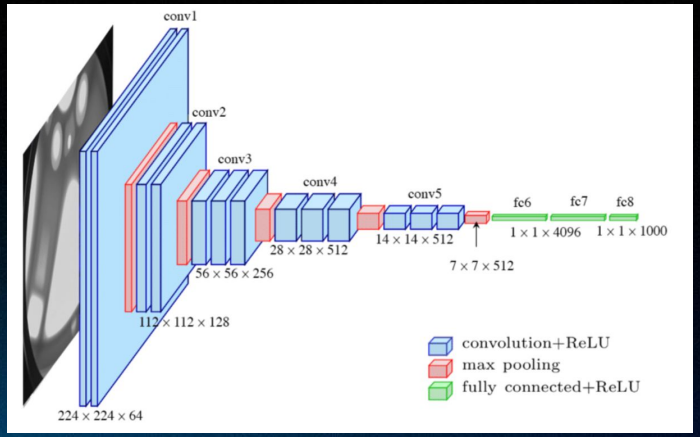


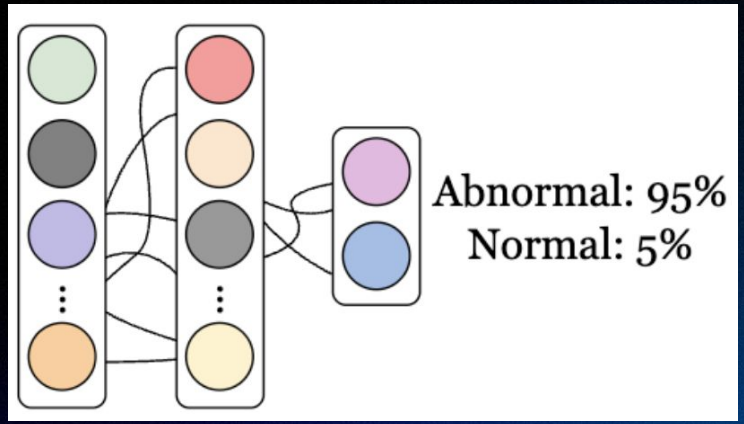


Input Data

- **X-axis:** Completion status of each task
- **Y-axis:** Converted to time-based vector

Proposed DTx System Overview





Model Structure

- **CNN Operations** → Feature Extraction
- **Fully Connected Layer** → Outputs ADHD Probability between 0 and 1

Optimization

- **Loss Function:** Binary Cross Entropy
- **Labeling w/ Anomaly Detection Network:** Abnormal / Normal group

Experimental Protocol

Test Group
(Treated with DTx)

Weekly testing of work ability (Memory, Impulse Control, Concentration)

Applied the proposed **DTx Treatment**

Repeated for 7 Weeks

Control Group
(Treated without DTx)

Weekly testing of work ability (Memory, Impulse Control, Concentration)

Test Configuration

Memory Test: Card Matching Game

Concentration Test: Shell Game (Thimblerig)

Impulse control Test: Click when colors of the shapes are same

Experimental Result Analysis (Memory)

Week	T1	T2	T3	C1	C2	C3
week-1	185	178	166	196	148	175
week-2	174	153	172	193	145	183
week-3	164	147	164	185	137	171
week-4	156	152	142	188	125	175
week-5	162	145	152	192	131	172
week-6	143	144	138	185	128	167
week-7	132	145	124	182	127	165

Table 1: Memory Ability Assessment Data

Subjects:

1. Test Group (T): 3 subjects exposed to the proposed DTx.
2. Control Group (C): 3 subjects not exposed to the therapeutic agent.

Experimental Period:

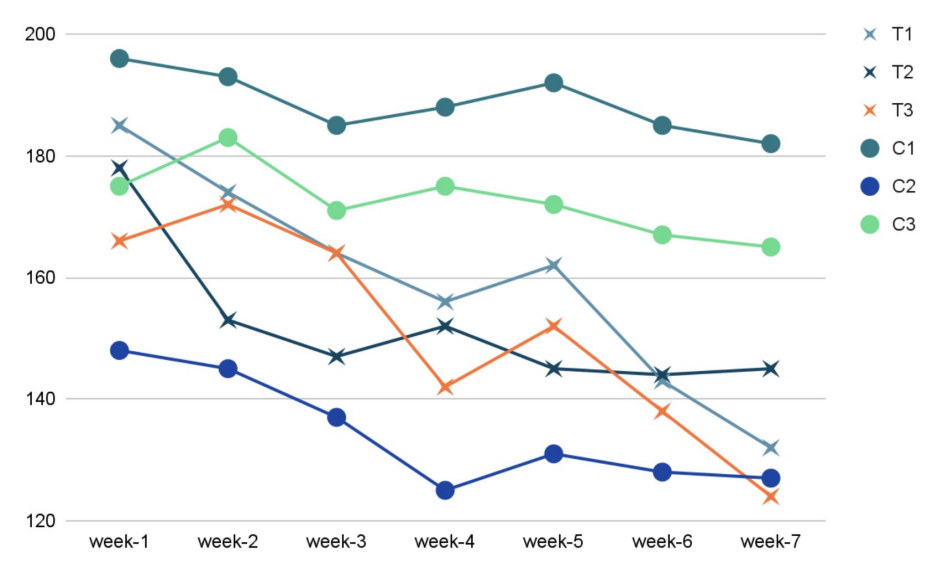
- Memory ability measured weekly from week 1 to week 7.

Evaluation Method:

- Completion time of the given task for each subject is recorded in seconds.

Experimental Result Analysis (Memory)

▼ In Seconds



- Test group average time: 42.67 seconds decrease
  24.2% improvement
- Control group average time: 15 seconds decrease
  8.67% improvements
- The test group's improvement is approximately **3 times greater.**

Experimental Result Analysis (Impulse Control)

Week	T1	T2	T3	C1	C2	C3
week-1	84	71	78	85	74	82
week-2	85	75	85	86	81	84
week-3	87	81	88	88	84	85
week-4	86	84	92	91	82	84
week-5	92	86	91	87	86	83
week-6	94	87	93	88	85	84
week-7	100	85	93	92	85	85

Table 2: Impulse Control Ability Assessment Data

Subjects:

1. Test Group (T): 3 subjects exposed to the proposed DTx.
2. Control Group (C): 3 subjects not exposed to the therapeutic agent.

Experimental Period:

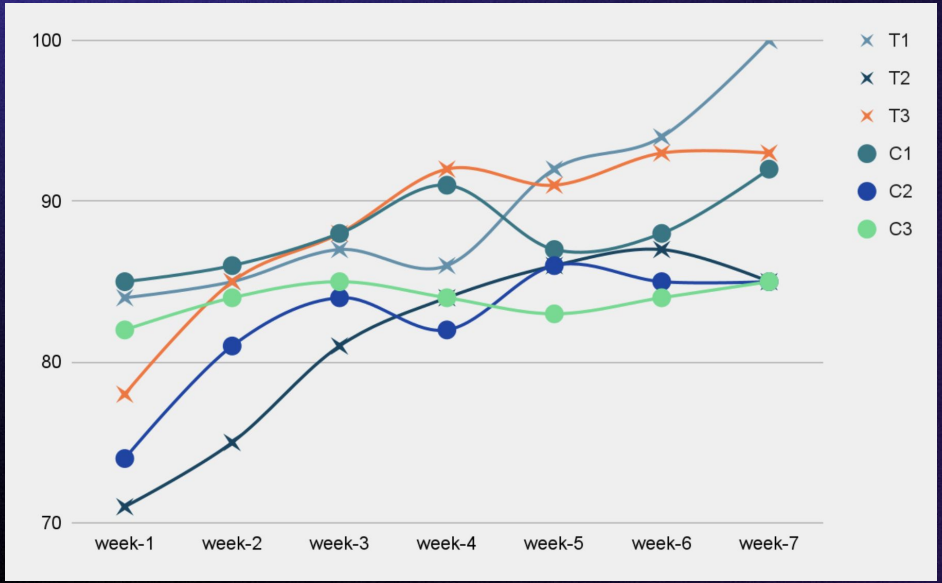
- Impulse control ability measured weekly from week 1 to week 7.

Evaluation Method:

- Accuracy (%) recorded through the impulse control test.

Experimental Result Analysis (Impulse Control)

▼ Accuracy



- **Test Group Average Accuracy: +15%p**
  18% improvement
- **Control Group Average Accuracy: +7%p**
  8% improvement
- Test Group's improvement margin was more than **2 times greater**.

Experimental Result Analysis (Concentration)

Week	T1	T2	T3	C1	C2	C3
week-1	54	62	57	52	58	49
week-2	60	62	71	53	55	55
week-3	72	65	73	55	57	57
week-4	74	67	75	54	61	54
week-5	71	69	74	57	63	55
week-6	72	71	76	61	67	56
week-7	73	74	76	62	68	59

Table 3: Concentration Ability Assessment Data

Subjects:

1. Test Group (T): 3 subjects exposed to the proposed DTx.
2. Control Group (C): 3 subjects not exposed to the therapeutic agent.

Experimental Period:

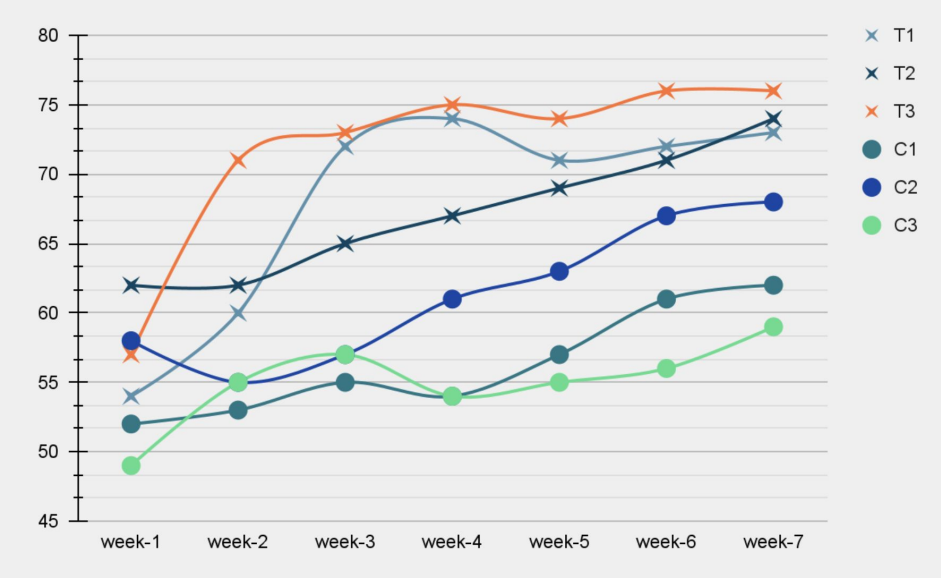
- Concentration ability measured weekly from week 1 to week 7.

Evaluation Method:

- Accuracy (%) recorded through the concentration test

Experimental Result Analysis (Concentration)

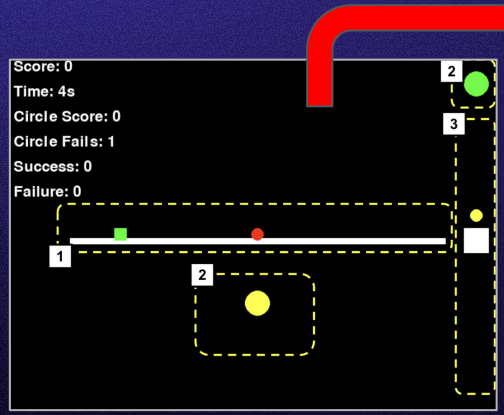
▼ Accuracy

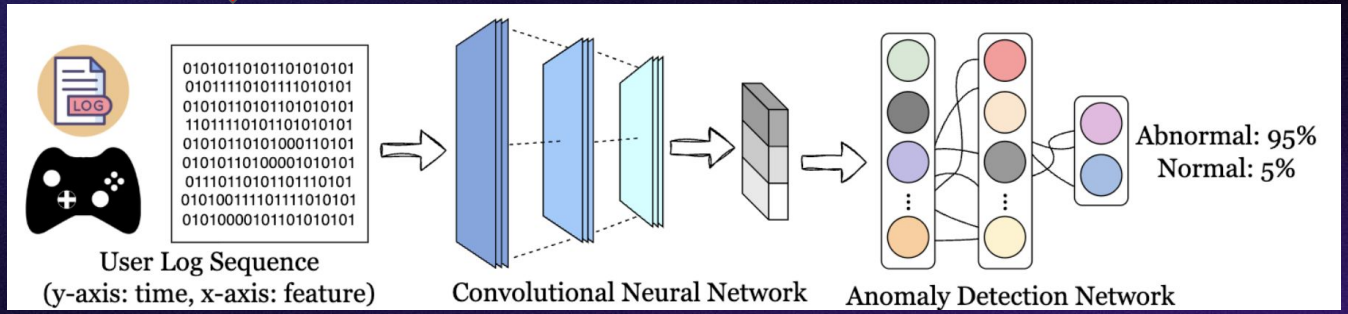


- **Test Group Average Accuracy: +15%p**
  127% improvement compared to baseline

- **Control Group Average Accuracy: +10%p**
  119% improvement compared to baseline

Experimental Result Analysis (ADHD Screening)

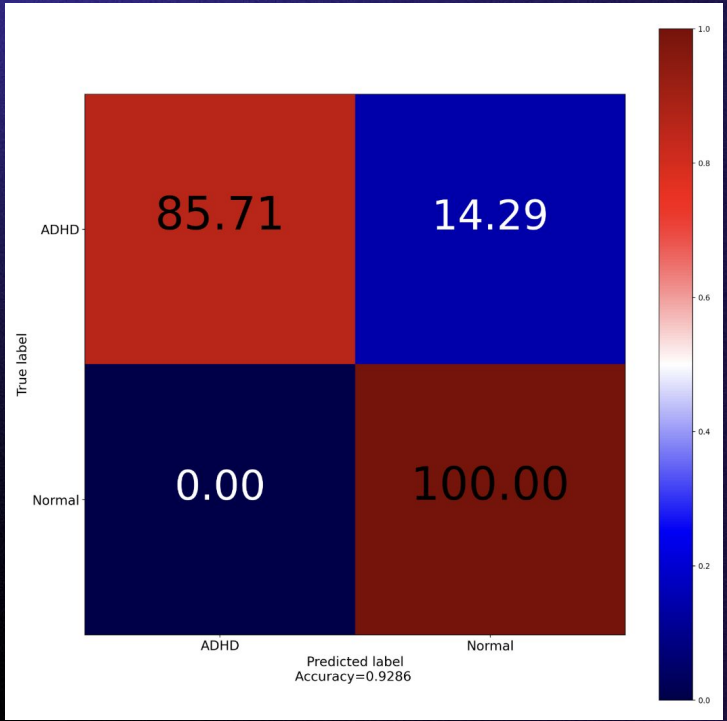




Experiment Description

- **User Logs** (Times & Features) Collected during gameplay
- **Logs** converted to a **2D Vector**
- Features extracted using **Convolutional Neural Network**
- ADHD likelihood calculated using an **Anomaly Detection Network**

Experimental Result Analysis (ADHD Screening)



Result Analysis

- Model Accuracy: **92.86%**
- ADHD Patient Discrimination: **85.71%**
- Normal Individual Discrimination: **100%**
- Misclassification Rate (Normal → ADHD): **0%**

Research Summary and Conclusions

Proposed Development:
A Digital Therapeutics (DTx) system designed for patients with Attention-Deficit/Hyperactivity Disorder (ADHD).

System Overview:

- **Input:** User gameplay logs
- **CNN model:** Extracts behavioral patterns and estimates probability for ADHD
- **Anomaly Detection Network:** Classifies normal vs. abnormal activity patterns
- **Output:** ADHD screening probability

Research Summary and Conclusions

Evaluation Results

1. The DTx intervention group showed measurable improvements in memory, impulse control, and attention compared to the control group

2. ADHD classification: **92.86% accuracy**, as confirmed by the confusion matrix

3. False Positive Rate: **14.92%**(no cases of normal– ADHD misclassification)

4. Model optimization utilized Binary Cross-Entropy Loss for enhanced precision

Future Implications/Recommendations

01 Increase sample size to strengthen statistical significance and improve generalizability.

02 Refine game mechanics to promote long-term user engagement

03 Integrate multimodal data (physiological, behavioral, and cognitive inputs) to further enhance model accuracy and reliability

Thank You