A Video Game to Teach Young Adults the Brain Basics of Addiction

Andrés Felipe Reyes
Brainwit Studios, Bogotá, Colombia

felipe@brainwitstudios.com

Abstract: While we struggle to find effective ways to prevent drug-related harm in young people all around the world, families and communities continue to get hurt. World-renowned experts on addiction believe if people understand its basics, they will make better decisions regarding drug use. Nonetheless, addiction happens in the brain, and the bases of brain function involved in addiction are quite complex. I asked whether young adults could learn with a video game some important basics of synaptic function in the brain related to addiction. My team and I developed 'You VS Drugs', a 3D video game beta which, through an adventure that takes place inside a synapse between two cells, explains some of the complex bases of brain function different drugs alter to produce their effects, including addiction. I ran an online questionnaire in which, as 340 young adults aged 18-25 viewed the video game content, answered five multiple-choice and two true-false questions which sought to measure their learning. Then, we ran a simulation with a thousand hypothetical participants who would answer the questionnaire at random. We found that, on average, participants had significantly greater performance on the questionnaire than the simulation group (p <.00001, r = .77). Also, the average of correct responses participants gave over the course of the video game (5.644) corresponds to a group performance of 80.63% in the questionnaire. Results show young adults understand complex bases of neurobiological function related to the effect of psychoactive substances and addiction while playing 'You VS Drugs', and they also highlight the potential video games have to teach complex subjects in an engaging way. If we want to reduce the misery drug addiction imposes on families in our societies, we should educate young people in any effective way possible.

Keywords: Addiction, Drugs, Brain, Education, Prevention, Video game

1. Introduction

Substance abuse remains a dire, persistent and pressing problem for many young adults (Lipari *et al.*, 2013), and the effects of this disorder not only impact them, but also their family and community (Lander, Howsare and Byrne, 2013). We also struggle to find effective ways to respond to problematic substance use in young people. Startling evidence comes from a review of systematic reviews that analyze the efficacy of various approaches to prevent, preemptively intervene, reduce harm and treat problematic substance use in youth (Stockings *et al.*, 2016). By classifying the treatments for dependence or substance use problems by effect, level of evidence and size of effect at three levels ('use', 'problematic use', and 'injury or harm´), the authors disentangle how approaches to intervene drug use differ according to age, level of substance use and socioenvironmental context. Unfortunately, the results are daunting: the review shows some effective measures to reduce alcohol and tobacco use are not available to target illicit drugs, and reveals the ineffectiveness of (a) social norms, (b) brief interventions to reduce substance use, and (c) prevention interventions which give information about substance use, the effects, and health risks. Also, there is little evidence of published work to prevent drug-related harm (Boden and Day, 2023).

However, after analyzing data for decades, scientists at the U.S. National Institute on Drug Abuse believe, "increased understanding of the basics of addiction will empower people to make informed choices in their own lives…" (NIDA, 2023). Although that statement seems a light in the darkness, it remains elusive how to implement such educational and preventive strategies so young people understand the basics of addiction since many of those fundamentals happen inside the brain in quite complex ways, and they are not only quite difficult to understand, but also take a long time to explain. So, how can we motivate a young audience which is not looking to actively study neuroscience to stay engaged long enough to master the fundamentals of addiction, and how different drugs have different effects on different parts of the brain? How can we explain all the relevant neurobiology in a simple way, so it becomes easier to understand?

To tackle these issues, since mid-2018 I have led a team which has been implementing an adventure saga inside the brain in the form of a video game, and we materialized a functional scenario during the Covid-19 pandemic. I then asked whether young adults could learn the basics of synaptic function with this first scenario. We are building a serious game saga that has peer-support at its core, where it hopes to be fun while building long-term engagement, mainly through intrinsic rewards (Staiano, 2014; Abdul Rahim and Thomas, 2017; Sardi, Idri and Fernández-Alemán, 2017). The novelty of our approach is to involve people within an adventure inside the brain: a story arc of friendship, loss and redemption. The objective was to measure whether the content of the video game was good enough to explain some neurobiological facts —particularly events which occur where cells communicate, called synapses— which psychoactive substances alter when they reach the brain.

2. Methods

Instruments and participants

The video game has a chibi cartoon-style, 3D graphic design of characters and settings, and it belongs to the action-adventure third-person genre for PC and mobile devices. It gives players a sense of fun at first glance. Friends and foes, level challenges, sounds, structures and objects are designed for players to explore, have fun, get surprised, fight and make decisions that test the players' knowledge (see Figure 1). The video game depicts the function of the working brain, mainly at the synaptic level, with educational and preventive intentions. As the story unfolds, the game introduces the function and possible fates of neurotransmitters between two cells. Although the detailed content of the events shown in the video game are beyond the scope of this article, the time comes when the player must use the provided information to answer seven questions mentioned in the evaluation block, described further below. According to the players' answers, the neurotransmitters take different paths which can lead them to continue with or without sustaining damage. Neurotransmitters can succeed in locating receptors, finding a way to activate them and return to their cell, wander around and/or face enzymes that can take away part of who they are and inactivate them.

Figure 1: Gameplay depiction of two acetylcholine neurotransmitters and the enzyme acetylcholinesterase in 'You VS Drugs'

Four hundred young adults volunteered to participate in the learning activity. Participants were recruited primarily through networks at different universities and degrees, and personal networks. Scientific literature suggests young adulthood spans ages 18 to 25, as it is when people develop psychological, cerebral and other biological ways which bridge the differences between adolescents and adults (Bonnie *et al.*, 2015; Higley, 2019). Although that range is somewhat strict and therefore leaves little room to represent variability within a population, I decided to invite people within that strict age range to remain consistent with data analysis across domains of research and policy (Bonnie *et al.*, 2015). Nonetheless, some people outside the age range showed up at the virtual learning sessions. To ensure data analysis within the proposed age range, the questionnaire asked participants to enter their age without any warning. For example, if someone outside the age range was curious about the topic, wanted to learn about it, or just wanted to see the video game, asking them to leave the session beforehand could make them lie about their age. At the same time, I had no reason to believe the results were going to differ significantly if I extended the age to encompass a wider range of individual variation, these people's data were excluded after they participated. In the end, only data from 340 participants aged 18-25 were analyzed.

The questionnaire was created using Google Docs forms. Although it was labeled 'Learning Activity: Psychoactive Substances' to make the game intention explicit, it was made clear no information about them was going to be presented. Solely they were going to see an audiovisual representation of basics of normal brain function that

are necessary to later understand how substances have different effects on the brain. The questionnaire consisted of three blocks: (i) disclaimers and instructions, (ii) general information and (iii) assessment.

In the first block, participants were reminded both in writing and reading the learning activity was not mandatory for them in any way. Since the sole objective was to see whether the content of the video game was appropriate to teach some basics of brain function to a young audience, the only thing they had to do was to pay attention to their screen at home, and when questions showed up, they had to answer them on the online form at that precise moment.

In the second block participants selected their age group and the socioeconomic stratum to which they belonged. The four age groups within the range of interest were 18-19, 20-21, 22-23, and 24-25. In Colombia there are six socioeconomic strata (Article 102, Law 142 of 1994), as follows: 1) low-low, 2) low, 3) medium-low, 4) medium, 5) medium-high, and 6) high.

The last block was devoted to measure the participants' responses related to seven introductory aspects of chemical communication between cells, such as a brain cell and a muscular cell. The content of the questions was related to: (1) the purpose of neurotransmitters, (2) how they produce their effect and where, (3) whether their goal/purpose is at risk if they meet others alike, or different ones, (4) what can happen when they reach the next cell, (5) the significance of *affinity* and (6) *activity* between neurotransmitters and a receptor, and (7) the main reasons neurotransmitters may fail to return to the cell they came from. Of the seven questions, five were multiple-choice single answer, and the two related to affinity and activity were true or false.

Steps were taken so that the questions discriminated who was really paying attention and learning, and who was just looking at the screen without paying much attention. As a general rule, relevant concepts mentioned once, but not evident in the non-linguistic audiovisual content, were evaluated. However, two exceptions seemed necessary: as questions (4) and (7) related to crucial aspects of synaptic function, they were depicted through non-linguistic audiovisual content, and were evaluated near the end of the game. Finally, wrong answers in the multiple-choice questions were semantically related to the game story, so the correct answers were not too obvious.

Procedure

Due to the Covid 19 pandemic, the learning activity was carried out through virtual platforms and presented to groups of young people between March 18, 2021 and March 2, 2022. The transmission of the video game content lasted around 80 minutes on average. As the game unfolded and the questions appeared on the screen, the participants answered them in real time through Google Forms. They were given one minute to do so from when they showed up. Feedback on the right answers was never given to the participants until the activity was finished.

After obtaining the data from the participants, a simulation was run in which scores were obtained from a thousand hypothetical participants who would answer the questionnaire at random, as would be done by people who ignore the basics of brain function shown in the video game. The simulation considered the number of possible answers to the seven questions. It did not matter that the number of simulations was greater than the number of study participants: the more simulations, the probability of obtaining a result by chance is better represented. Also, by analyzing probabilities data become more generalizable.

3. Results

I found, on average, participants had significantly greater performance on the questionnaire (M = 5.644) than the simulation group (M = 2.579; $t(677.14) = -31.417$, $p < .00001$, $r = .77$; Figure 2). Also, the average of correct responses participants gave over the course of the video game (5.644) corresponds to a group performance of 80.63%, while the average of correct responses in the simulation group (2.579) equals a group performance of 36.84%. I found no performance differences between different age groups, nor between participants from different socioeconomic strata.

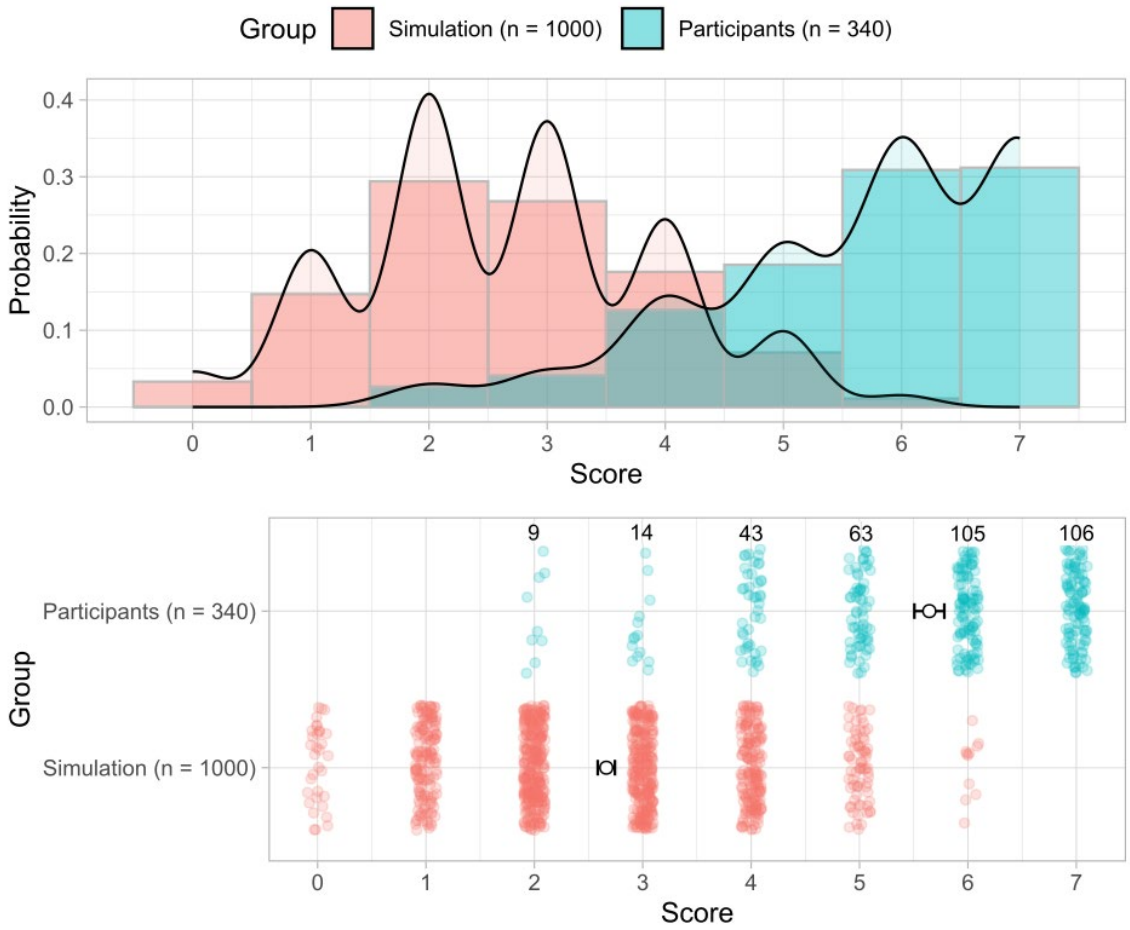

Figure 2: Above, solid lines represent the probability distribution of scores in each group, on top of the histogram with the score distribution. Below, the number of participants by score. The extent to which the scores of each group are significantly different can be appreciated. White dots represent the mean for each group and the 95% confidence intervals

4. Discussion

I found robust evidence young adults learn brain basics of synaptic function with the first scenario of the video game saga 'You VS Drugs'.

The findings are also novel because, to my knowledge, it is the first time the basics of brain function have been taught with a video game which shows the development of these events at the synaptic level. Furthermore, if it is true people will make better decisions in their own lives if they understand the basics of addiction, the results of this study are important for young people as substance use and its challenges are high among them (UNODC, 2018). I argue the features of 'You VS Drugs' are effective as learning tools.

A valid critique of the quantity and the way in which I selected the neurobiological aspects I evaluated can come from its objectivity/subjectivity. Why these seven aspects and not others, and why not more, or less? The way in which neuroscientists study the brain involves both different levels of its structure and mechanisms that generate changes in it (Figure 3). At the time of writing this article, I have already defined how to involve all thirteen levels and mechanisms in the video game saga, and eight of them are already implemented.

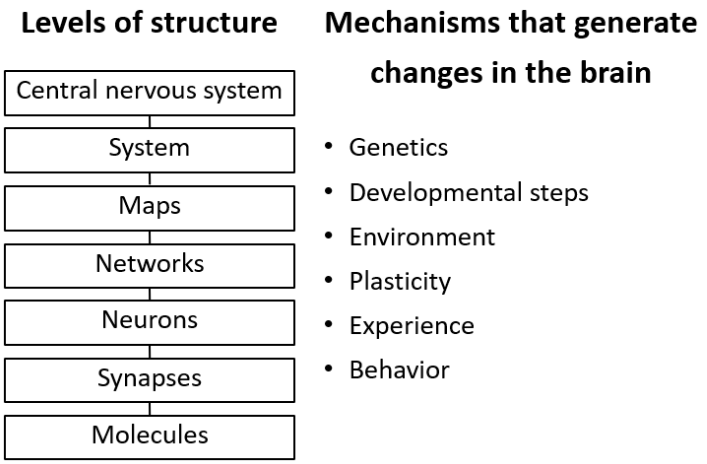

Figure 3: Different levels of brain structure and mechanisms. Taken from Wang (2010)

Now, the reasons by which I selected the aspects to evaluate are somewhat subjective is they are contingent on how explicit or implicit they become in the story one decides to tell. Mainly, the aspects in which one emphasizes should be the ones that are evaluated. However, in this case I decided to evaluate relevant concepts that are briefly mentioned but are not evident in the non-linguistic audiovisual content. Otherwise, I would be asking obvious concepts, and the questions would not fulfil the objective of discriminating who is really paying attention and learning, and who is only interested in playing. Another reason the aspects to evaluate were somewhat subjective was any story told depends on the one who tells it. In this case, after polishing a fictional story based on neurobiological events, I did my best to adapt it to the number of aspects I could evaluate without sacrificing the flow of the adventure. Of course, many more important neurobiological aspects that I did not evaluate emerge within the story arc both through language and audiovisual components, and I obviously welcome suggestions and critiques regarding the aspects I evaluated from anyone who plays the game.

It is also important to state details of the seven aspects measured may vary depending on the types of neurotransmitters and receptors, and there are other aspects which need to be shown before explaining the different effects of various substances in several parts of the brain. They will be explored in future updates of the video game saga. However, I decided to base the initial understanding of those aspects on the function of the neurotransmitter acetylcholine and its receptors due to (a) the story arc that I seek to tell throughout the whole saga; (b) that its action in muscles allowed me to give an introductory example of cellular communication before going into the neurobiological aspects of the brain, but at the same time (c) this neurotransmitter has a fundamental role in the brain's reward network, which is crucial for understanding the different ways in which different psychoactive substances have different effects in different brain structures, (d) promoting changes in active synapses, and (e) in how addiction can develop when using such substances (Grasing, 2016; Brzosko *et al.*, 2017; Galaj and Ranaldi, 2021). In addition, it is interesting the function of acetylcholine and its receptors constitute the basis of the story within the video game since they were also the first to be discovered by scientists, and therefore became the basis to study other types of neurotransmitters and receptors (López-Muñoz and Alamo, 2009; Changeux, 2020).

Finally, although the focus of the game is on brain function at the molecular level, there are important aspects of addiction which exist at psychological and sociological levels. However, such mechanisms are not independent on how our brain is built and how it works, which, in turn, interact with those mechanisms. There is a pervasive tendency to think about the levels of brain structure and these mechanisms as independent. Sometimes, this is expressed as “genes vs environment” approaches and positions, which manifest themselves into questions such as “is this caused by nature, or nurture?” In general, science left behind that sort of discussion long ago. As a striking example, world-renowned geneticists, psychologists and other professionals have warned, for decades now, against separating genes from environment when studying their influence in an organism because they *interact* so the environment regulates the manifestation of genes (Lewontin, 2002; Moore, 2002; Ridley, 2003). Therefore, they cannot be considered independently to explain behavior, and I invite the reader to take a look again at Figure 3 with that new perspective. In due time I will include the relevance of environmental factors of addiction within the video game, and I will encourage players to act in ways that involve neuropsychological executive functions and elements of the environment to train skills, which is more effective than regular strategies to prevent drug use, and mitigate its harm (Stockings *et al.*, 2016).

Future directions also include refining details of exciting story arcs that motivate players to continue learning for many more scenarios, and I should also measure learning in 12 and 13-year-old children and adolescents since they are already using psychoactive substances all over the world (Wang and Hoyte, 2018; Aly *et al.*, 2020; Molinaro *et al.*, 2020). Although conscious memory of meaning is highly flexible, (re)constructive and relational (Duff *et al.*, 2020), the educational purposes of video games in children and adolescents could be tested to a maximum if I include an evaluative phase of long-term learning in the study design.

The challenges the world impose on us demand we efficiently prepare for them. In the case of complex social and personal challenges it is crucial that we, as educators, creatively use layman's terms and strategies to prepare young people. In this study I found evidence that young adults learn the basics of synaptic function with the first scenario of the video game saga 'You VS Drugs'. If we want to reduce the misery drug addiction imposes on families in our societies, we should educate young people in any effective way possible.

Acknowledgements

I want to express my gratitude to Luis Fernando, Andrés Felipe, and Cristian Alejandro for helping me take this personal project to a product version people can test. To Pedro Javier, Sebastián Camilo, Santiago Gerardo, Brandon Steven, Óscar David, Jhon Jairo, John Fredy and Holman Leonardo, thank you very much for contributing at different stages of development. I also want to thank Juan David Leongómez for assisting me in illustrating the data in a more compelling way.

References

Abdul Rahim, M.I. and Thomas, R.H. (2017) 'Gamification of Medication Adherence in Epilepsy', *Seizure*, 52, pp. 11–14. Available at: https://doi.org/10.1016/j.seizure.2017.09.008.

Aly, S.M. *et al.* (2020) 'Substance abuse among children', *Archives de Pédiatrie*, 27(8), pp. 480–484. Available at: https://doi.org/10.1016/j.arcped.2020.09.006.

Boden, M. and Day, E. (2023) 'Illicit drug use in university students in the UK and Ireland: a PRISMA-guided scoping review', *Substance Abuse Treatment, Prevention, and Policy*, 18, p. 18. Available at: https://doi.org/10.1186/s13011-023-00526-1.

Bonnie, R.J. *et al.* (2015) 'Young Adults in the 21st Century', in *Investing in the Health and Well-Being of Young Adults*. National Academies Press (US). Available at: https://www.ncbi.nlm.nih.gov/books/NBK284782/ (Accessed: 26 April 2023).

Brzosko, Z. *et al.* (2017) 'Sequential neuromodulation of Hebbian plasticity offers mechanism for effective reward-based navigation', *eLife*, 6, p. e27756. Available at: https://doi.org/10.7554/eLife.27756.

Changeux, J.-P. (2020) 'Discovery of the First Neurotransmitter Receptor: The Acetylcholine Nicotinic Receptor', *Biomolecules*, 10(4), p. 547. Available at: https://doi.org/10.3390/biom10040547.

Duff, M.C. *et al.* (2020) 'Semantic Memory and the Hippocampus: Revisiting, Reaffirming, and Extending the Reach of Their Critical Relationship', *Frontiers in Human Neuroscience*, 13, p. 471. Available at: https://doi.org/10.3389/fnhum.2019.00471.

Galaj, E. and Ranaldi, R. (2021) 'Neurobiology of Reward-Related Learning', *Neuroscience & Biobehavioral Reviews*, 124. Available at: https://doi.org/10.1016/j.neubiorev.2021.02.007.

Grasing, K. (2016) 'A Threshold Model for Opposing Actions of Acetylcholine on Reward Behavior: Molecular Mechanisms and Implications for Treatment of Substance Abuse Disorders', *Behavioural brain research*, 312, pp. 148–162. Available at: https://doi.org/10.1016/j.bbr.2016.06.022.

Higley, E. (2019) 'Defining Young Adulthood', *DNP Qualifying Manuscripts* [Preprint]. Available at: https://repository.usfca.edu/dnp_qualifying/17.

Lander, L., Howsare, J. and Byrne, M. (2013) 'The impact of substance use disorders on families and children: from theory to practice', *Social Work in Public Health*, 28(3–4), pp. 194–205. Available at: https://doi.org/10.1080/19371918.2013.759005.

Lewontin, R. (2002) *The Triple Helix: Gene, Organism, and Environment*. Cambridge, MA: Harvard University Press.

Lipari, R.N. *et al.* (2013) 'A Day in the Life of Young Adults: Substance Use Facts', in *The CBHSQ Report*. Rockville (MD): Substance Abuse and Mental Health Services Administration (US). Available at: http://www.ncbi.nlm.nih.gov/books/NBK384660/ (Accessed: 27 April 2023).

López-Muñoz, F. and Alamo, C. (2009) 'Historical evolution of the neurotransmission concept', *Journal of Neural Transmission (Vienna, Austria: 1996)*, 116(5), pp. 515–533. Available at: https://doi.org/10.1007/s00702-009-0213-1.

Molinaro, S. *et al.* (2020) *ESPAD Report 2019*. Available at: https://doi.org/10.2810/877033.

Moore, D. (2002) *The Dependent Gene: The Fallacy of 'Nature vs. Nurture'*.

NIDA (2023) 'How Science Has Revolutionized the Understanding of Drug Addiction'. Available at: https://nida.nih.gov/research-topics/addiction-science/drugs-brain-behavior-science-of-addiction.

Ridley, M. (2003) *Nature via nurture: Genes, experience, and what makes us human*. New York, NY, US: HarperCollins Publishers (Nature via nurture: Genes, experience, and what makes us human), p. 326.

Sardi, L., Idri, A. and Fernández-Alemán, J.L. (2017) 'A systematic review of gamification in e-Health', *Journal of Biomedical Informatics*, 71, pp. 31–48. Available at: https://doi.org/10.1016/j.jbi.2017.05.011.

Staiano, A.E. (2014) '*Learning by Playing: Video Gaming in Education* —A Cheat Sheet for Games for Health Designers', *Games for Health Journal*, 3(5), pp. 319–321. Available at: https://doi.org/10.1089/g4h.2014.0069.

Stockings, E. *et al.* (2016) 'Prevention, early intervention, harm reduction, and treatment of substance use in young people', *The Lancet. Psychiatry*, 3(3), pp. 280–296. Available at: https://doi.org/10.1016/S2215-0366(16)00002-X.

Wang, G.S. and Hoyte, C. (2018) 'Common Substances of Abuse', *Pediatrics In Review*, 39(8), pp. 403–414. Available at: https://doi.org/10.1542/pir.2017-0267.

UNODC. (2018). United Nations Office on drugs and crime: World Drug Report. Drug Age. Available at: https://www.unodc.org/wdr2018.

Wang, S. (2010). Neuroscience of Everyday Life. (Trade Paperback). Teaching Company, LLC, T.H.E. ISBN-10 159803698x, ISBN-13 9781598036985.